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Electrifying Opera, Amplifying Agency

Designing a performer-controlled interactive audio system for opera singers

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Abstract

This artistic research project examines the artistic, technical, and pedagogical challenges of developing a performer-controlled interactive technology for real-time vocal processing of the operatic voice. As a classically trained singer-composer, I have explored ways to merge the compositional aspects of transforming electronic sound with the performative aspects of embodied singing.

I set out to design, develop, and test a prototype for an interactive vocal processing system using sampling and audio processing methods. The aim was to foreground and accommodate an unamplified operatic voice interacting with the room's acoustics and the extended disembodied voices of the same performer. The iterative prototyping explored the performer's relationship to the acoustic space, the relationship between the embodied acoustic voice and disembodied processed voice(s), and the relationship to memory and time.

One of the core challenges was to design a system that would accommodate mobility and allow interaction based on auditory and haptic cues rather than visual. In other words, a system allowing the singer to control their sonic output without standing behind a laptop. I wished to highlight and amplify the performer's agency with a system that would enable nuanced and variable vocal processing, be robust, teachable, and suitable for use in various settings: solo performances, various types and sizes of ensembles, and opera. This entailed mediating different needs, training, and working methods of both electronic music and opera practitioners.

One key finding was that even simple audio processing could achieve complex musical results. The audio processes used were primarily combinations of feedback and delay lines. However, performers could get complex musical results quickly through continuous gestural control and the ability to route signals to four channels. This complexity sometimes led to surprising results, eliciting improvisatory responses also from singers without musical improvisation experience.

The project has resulted in numerous vocal solo, chamber, and operatic performances in Norway, the Netherlands, Belgium, and the United States. Video documents of these works are found on Research Catalogue. The research contributes to developing emerging technologies for live electronic vocal processing in opera, developing the improvisational performance skills needed to engage with those technologies, and exploring alternatives for sound diffusion conducive to working with unamplified operatic voices.

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I would like to dedicate these research reflections to the memory of my friend and colleague Eric Phinney, leader of the Ethos Percussion Group, who passed away suddenly in 2023. His belief in this project was unwavering. He is very much missed.

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Introduction

Electrifying Opera, Amplifying Agency: Designing a performer-controlled interactive audio system for opera singers has been a transdisciplinary research project, spanning the fields of operatic performance practice, computer and electronic music, composition, sound design, and gestural control of human-computer interactive systems. As a composer and a classical singer I drew on multiple modalities to investigate and develop the possibilities for opera singers to augment their voices with performer-controlled interactive audio technology.

This research traces the development of real-time audio-processing environments that accommodate the operatic voice on its own terms. My ultimate goals were twofold: to identify a sound design that affords a balance between an unamplified, embodied operatic voice and its sampled, processed and disembodied voice(s), and to design an interactive audio processing system that facilitates mobility and allows performers to manipulate their own voice in real-time, independent of a visual interface. I wanted to create a performer-controlled interface that would enable nuanced and variable vocal processing, be robust, teachable, and suitable for use in a variety of settings: solo performances, chamber music and opera.

I started with the premise that I would work with the operatic voice as a self-amplified instrument that does not need sound reinforcement for the direct signal. Exploring the differences between operatic singing and electronic music required mediating between the analog and the digital, between the embodied and disembodied, and in general navigating the different needs, training, and working methods of practitioners in these two fields. Acknowledging opera as theater, with performers engaged in storytelling, no matter whether it is traditional, abstract or experimental, added a focus on meaning making beyond the sonic. During the course of my research I investigated multiple controllers, interactive designs and loudspeaker systems. With assistance from computer programmers Balint Laczko, Matthew Ostrowski and Simone Sacchi, I worked to develop a system that would allow a performer to sample and process their voice while relying solely on aural and haptic cues for the processing. The resulting performer-controlled audio processing system uses two wireless Genki Wave MIDI rings with 3-axis motion tracking technology and three switches on each ring to control a performance patch in Max/MSP, an audio processing software. The system is designed to be both partially controllable and partially unpredictable. It creates pseudo-randomized permutations of the singer´s voice and functions as a digital improvising partner for the singer, balancing between chaos and control, predictability and surprise. With a tip of the hat to Pauline Oliveros' Expanded Instrument System (EIS), I named the system the Expanded Vocal Improvising Instrument (EVII).

The design of the EVII puts the focus on process rather than product. Translating hand gestures into sonic processes brings an aspect of randomness and constant change to the musical results of the digital processing. Creating music "in the air", without the aid of keys, frets or a fingerboard, makes exact recall of positions next to impossible. The outer edges of a gestural position can be set, but the points in between those outer edges must be searched for. This has however been the most exciting part of the exploration as it has become a tool for music making that avoids two common pitfalls of conventional digital processing, that of being either too predictable or too randomized. Gestures and sound inputs can be repeated, and the sonic results can be similar, but they will never be exactly the same. The EVII elicits an improvisatory response by necessity. This fosters concentrated listening and presence for performers who use it.

Methods used in this practice-based research included workshops in vocal improvisation and in voice and technology, data mapping, experiential prototyping, sound design, signal processing and musical composition. Documentation of the research and the artistic results is in the form of written reflections, and video and audio recordings of performances. The final artistic application and outcome of this research is a series of works that have been created using the new performer-controlled interactive system. Between 2020 and 2023 I used the EVII in both solo and ensemble concerts, music for dance and film, and in two newly composed chamber operas. A collaboration with librettist/designer Julian Crouch and the Ethos Percussion Group, both based in New York City, formed the basis for one of the external teams committed to developing the opera *The Sailmaker´s Wife* with me (Norderval 2022). In the course of the research, the Japanese folktale[1] that this opera was based on became the inspiration for two separate but related works. The second of those works, *Crane Reflects on a Favor: An Eco-opera*, was premiered in Oslo, Norway on September 2, 2023 on the main stage of the Academy of Opera, as part of VoxLAB's VårFEST 2023 International Festival of New Works for Voice.

My original plan was to design and implement a performer-controlled audio interface in three short portions of *The Sailmaker's Wife*. In the end this research fellowship yielded much more than three sections in this acoustic opera. *The Sailmaker's Wife* has now expanded to be an operatic diptych with two independent chamber operas that can be presented either individually or together as a double bill. The EVII system has also been used to create music for film, for dance, and for solo, duo and chamber concerts. I and four other singers have performed with it in various public performances. My artistic results are the sum of all the works that came out of my practice-based research in 2020-2023.

Video documents of the artistic results and prototyping are housed on Research Catalogue: https://www.researchcatalogue.net/view/2222429/2222482

Aural Presentations of my research are found on the following page of the exposition: https://www.researchcatalogue.net/view/2222429/2247155

[1] *The Sailmaker´s Wife* is loosely based on the Japanese folktale *Tsuru no Ongaeshi* (Crane´s return of a favor). The folktale tells the story of a man's kindness to an injured crane who returns to him in human form and becomes his wife. To repay his kindness the crane-wife secretly plucks her own feathers to weave a magic fabric which brings her husband riches but makes her increasingly ill. Her gift is requested one time too often, her secret is ultimately betrayed, and she flies away. In Crouch´s libretto the tale is expanded and updated to a tale of industrial capitalist overreach questioning issues of balance and sustainability.

PART ONE – Research Questions, Motivation and Context

Research questions and limitations

The use of microphones and electronics is ubiquitous in many music genres. This is not the case in opera, which is still largely based on singing acoustically. The starting point of this research project was the question of whether I could design an interactive audio processing system for opera singers that allowed them to control their own vocal processing but not require amplification of their operatic singing. In other words, a system that would amplify the agency of the singer and meet the operatic voice on its own terms.

The primary questions driving this practice-based research were the following:

- What technical and aesthetic issues need to be addressed in order to design a real-time audio processing environment that accommodates the operatic voice on its own terms?

- Is it possible to create a performer-controlled interactive vocal processing system that takes into account opera singers' needs for physical mobility and an acoustic sound field suitable for the unamplified virtuosic voice?

My written reflections address additional artistic elements central to my research project.

- The context of my interest in electronics and opera
- The design of the interactive audio processing system and controller mapping
- My artistic challenges, choices and questions regarding sound design
- Aesthetic compositional choices in my opera
- Pedagogical issues and working methods

I do not outline the variety of extended acoustic vocal techniques that can be used in opera. This can be found in other sources and is beyond the scope of this research. Neither do I address the vast number of jazz and popular vocalists who use electronics to transform their voices. I do not focus on contemporary operas that use fixed media (sound or video) in their scores, or that require amplification of the singers. There are many examples in these categories, well worth studying, but I leave that to other scholars.

In this research project I have specifically focused on the question of how to create an environment that combines performer-controlled live electronics with unamplified operatic singing, observing what technological and aesthetic issues that endeavor presents. This does not mean that my definition of opera is solely music-dramatic works that refrain from using sound reinforcement for the singers. To the contrary. I have participated in and experienced many ground breaking operas that use sound reinforcement. I regard the use of the amplified voice to be an important addition to the field of opera, one that has yielded extremely valuable results and has expanded and changed performance practices within the genre. Contemporary opera, especially postoperatic works, make substantial artistic use of the possibilities that the disembodied voice offers (Novak 2015).

For this research project, however, I chose to focus specifically on the development of an audio processing environment that would combine the embodied voices of singers using operatic technique, without sound reinforcement, together with their disembodied mediated voices created through real-time sampling and diffused through loudspeakers, thus combining very old and very new techniques of projecting sound.

I believe this research will be beneficial to anyone working with interactive technology in an operatic context, to performer-composers working with or interested in gestural controllers, and to singers (particularly classically trained singers) who are interested in performing vocal works that include electronics. Some may be inspired to dive into the challenges of working with electronic audio processing for their own expression and will perhaps begin to compose. Singing teachers and those designing training programs for today's opera singers may also find this research helpful, particularly where there is an interest in performing and becoming fluent with contemporary opera.

About my methodology

My work with Pauline Oliveros over several decades has been central to my understanding of what it means to be an ear-oriented performing musician, performer-composer and teacher. From 1997 to 2000, after a rigorous university and conservatory training in both composition and voice, and years of freelance work as a classical singer, I studied the methods of Deep Listening that Pauline Oliveros had developed (Oliveros et al. 2010). Those three years of workshops, retreats and individual work with Oliveros changed my way of composing and making music. It led to my certification as a teacher of the practices of Deep Listening. I later performed and recorded with Oliveros and worked alongside her in Deep Listening workshops and retreats that I hired her to teach in Norway. Her influence has been enormous. The heightened sensory awareness that comes from trying to listen to "everything that is possible to hear" forms the basis of my aesthetics, my teaching, my composing and performing, and is core to my concept of presence. Listening has been at the core of my methodology in this research project (Buzzarté, Bickley, and Oliveros 2012).

Since it was important to me to design a system that could be used by others as well as myself, my reflections also have an educational component. My standpoint as a composer-performer led me to rely on experiential prototyping and embodied exploration of the various prototypes of the interface. The development of the technology and the development of the artistic product were and remain intertwined.

Personal background and motivation

I received a Bachelor of Music in both voice and music composition from the University of Washington in 1984, where I studied with Dr. Diane Thome, William O. Smith and Stuart Dempster. At that time, electronic composition entailed working in a studio with large synthesizers and patch bays, magnetic tape splicing and computer cards. I had a cursory introduction and only a few days in the studio during my studies. After graduating, composition took a back seat, and I focused on my continued education as a singer at the San Francisco Conservatory of Music, the Manhattan School of Music and the Santa Fe Opera apprentice program. I freelanced as a soprano soloist from the late 1980s onward specializing in baroque and contemporary music.

I was privileged over the years to work with leading American composer-performers such as Philip Glass, Steve Reich, Pauline Oliveros, Annea Lockwood, Sorrel Hays, Anne Le Baron, Eve Beglarian, David Lang, Tania Leon, Christian Wolff, George Crumb, Ned Rorem and many others. All the artists I performed and recorded for and with, were extremely important to my later development as a composer-performer.

The return to my own composer voice was developed through the Deep Listening work with Pauline Oliveros. Luckily, due to the digital revolution, audio processing gear had also become both more compact and more affordable. From 2000-2001 I learned to use the audio processing software Max/MSP. During artist residencies in 2002 at the Harvestworks Digital media studio and the Rensselaer Polytechnic Institute in New York, and at DIEM in Aarhus, Denmark, I developed a simple interactive patch for real time vocal sampling and audio processing in Max/MSP. It was inspired in part by Pauline Oliveros' Expanded Instrument System (EIS). With the help of Max/MSP programmers Stephan Moore and Holland Hopson, the patch was expanded and refined, and we prototyped a DIY MIDI glove to control certain parameters in the patch. The first prototype was cabled, but eventually with a DIEM custom-built radio sender and receiver it was modified to be wireless.

I used that MIDI glove for several projects including a collaborative opera commissioned by Den Anden Opera in Copenhagen: *I Sing the Body Electric* with Carl Unander-Scharin and Line Tjørnhøj. (Carl later created another opera of his own with the same name.) The limitations on what I was able to control with the MIDI glove and the physical awkwardness that accessing and maintaining certain parameters required, led me to eventually return to audio processing in the usual manner; standing or sitting behind the computer and engaging with tabletop controllers and/or foot pedals. In those early works for voice and electronics I encountered a number of challenges that I have now been able to explore deeply in this research project; challenges that are specific to combining live electronic audio processing with operatic work for the stage. Enormous technical advances over the last 15 years, especially in the field of sensors and data retrieval, have made this a particularly exciting field of research.

Early artistic influences

My earliest vocal influences were not opera but rather the singers in the folk music and protest song movements that blossomed in the 1960s. Odetta, Buffy Sainte Marie, Joan Baez and Bob Dylan were particularly inspiring to me. My first public performances, as the youngest member of an antiwar folk group in Seattle, were performances of their songs. Later as a high school student in Ontario, Canada, I auditioned for and was accepted into the Hamilton Philharmonic Orchestra Chorus. Again I was the youngest member. The thrill of singing with an orchestra was visceral and I set my sights on making a life in music. When I was accepted to both the composition and the vocal department at the University of Washington, I started my journey of lifelong learning and music-making. As a dedicated feminist and open lesbian, however, I was critical of much of the dramatic content in the operatic repertoire that I was expected to sing. Although I loved the music, the vast majority of the stories being told onstage from the mid 1980s through the millennial shift had little to do with my lived experiences or my values. After what I described to colleagues as "consciousness-raising myself out of a mainstream opera career", I focused primarily on experimental and multi-disciplinary work, and on collaborations with like-minded composers. My strongest influences were the performer-composers from the West Coast of the US, especially the multidisciplinary artists who had been associated with the San

Francisco Tape Music Center and the improvising scene in the Bay Area (Pauline Oliveros, Stuart Dempster, Rinde Eckert, Cathy Berberian) and later, my colleagues and collaborators from what Europeans refer to as the New York School.

Performing in the 1992 world tour of Philip Glass and Robert Wilson's *Einstein on the Beach* was a watershed moment. I was suddenly confronted with a very different model of what opera could be, both theatrically and musically. And I was immersed in music that used synthesizers and sound reinforcement for both singers and instrumentalists to great effect. Although I had specialized in new music, most of what I had performed before *Einstein on the Beach* was acoustic. I began to investigate other composers who worked with electronic sound.

In 1996, after a 1995-96 tour with the Netherlands Dance Theater 3 in Martha Clarke's *An Uncertain Hour*, I attended a music and gender conference in Sweden and was inspired to consider composing again. The opportunity came in 1997 at the Donna in Musica Festival in Italy when festival director Patricia Chiti commissioned me to write a piece for wind trio and voice. I quoted Hildegard von Bingen's writings and music in a work that explored the way that trauma can live on as physical memories in the body. In July 1999 I attended my first extended Deep Listening retreat with Pauline Oliveros, in Muerren, Switzerland. Hanna Hanni was another singer-composer at the retreat. We enjoyed improvising together and decided to continue collaborating after the workshop. I bought a Roland 808 and various stomp boxes for our piece *Warrum kuessen die Menschen?*, a multi-media piece with live video. That was the first piece I created that included both technology and improvisation.

In November 1999 I saw the software program Max/MSP demonstrated at the Conference on Small-Scale Opera and New Music-Theater (otherwise known as NewOp) hosted by Chants Libres, a small opera company in Montreal. It was described by Eric Salzman in the NY Times as "an informal collective of nontraditional creators and producers of offbeat music-and-theater collaborations with an emphasis on the in-between" (Salzman 1999). Among the nontraditional creators at NewOp that year was Pamela Z, who performed with her Bodysynth, a wearable controller designed by choreographer Chris Van Raalte and constructed by Ed Severinghaus (Mainsbridge 2022, 73). The Bodysynth used electromyographic (EMG) sensors - electrodes placed on the skin that measure the electrical activity of muscles - to control a Max/MSP patch that manipulated prerecorded soundfiles and Pamela´s live extended and operatic vocals. Meeting Pamela Z and others at NewOp and getting acquainted with these new tools was a pivotal and inspirational experience for me.

Max/MSP seemed infinitely more flexible than the off the shelf sampling and looping machines I had worked with in *Warrum kuessen die Menschen?*. It was not limited to the commercial conventions of beats and 4 second loops. Subsequently I was mentored by David Gamper, Pauline Oliveros' band partner in the Deep Listening Band. David let me try out the Deep Listening Band's Expanded Instrument System (EIS) - a set-up of foot pedals controlling Max/MSP patches, processing multiple delays and algorithms. David encouraged me to learn the program and he started me off with some simple patches. I then signed up for classes with Dafna Naphtali at the Harvestworks Digital Media Center in New York City. That was my road to working with the mediated voice.

My composing in the early aughts and teens focused primarily on improvised music, transdisciplinary work and music for dance, first with my duo partner trombonist Monique Buzzarté and later with my long-term collaborating partner, choreographer Jill Sigman. After

the terror attacks on September 11, 2001 in New York City, I felt compelled to address political issues in my music. My collaborative and multi-disciplinary works in subsequent years have taken on topics such as surveillance, civil rights, group think, torture, trash, and environmental sustainability in the face of the climate crisis.

I returned to the more traditional opera stage in 2016 with the production of my first full scale opera for six soloists, SATB chorus, electronic sound and a small chamber orchestra. The documentary opera *The Trials of Patricia Isasa* is based on the true story of Patricia Isasa, who survived torture during Argentina's dictatorship and fought for, and won, justice in the courts 33 years later. The opera was produced by Chants Libres and directed by Pauline Vaillancourt. Naomi Wallace wrote the libretto based on interviews between myself and Patricia. I composed the music and sang the lead role of Adult Patricia ("The Trials of Patricia Isasa" 2019).

Context

The challenge of using live electronics in opera

When I was composing *The Trials of Patricia Isasa*, Kaija Saariaho generously met with me in New York for a consultation while she was composer in residence for the New York Philharmonic. We talked, among other things, about the challenges of using electronic sound in opera. Kaija´s advice to me was to keep it very simple. Although she had written many chamber works that utilized live electronic processing, in her operas she chose not to use live electronics. She warned me that there were so many elements to deal with in opera that one would not have the time or resources necessary to make live electronic processing work. I heeded her advice and worked only with triggered electronic soundfiles in *The Trials of Patricia Isasa*. But the idea of finding a situation where one could explore the use of real-time audio processing in opera remained an intriguing challenge for me. The chance to investigate this issue arose with this PhD research project. Having experienced the differences between composing chamber works with live electronics and composing an opera with fixed media, I was eager to investigate the challenges specific to the integration of live electronic processing in opera. Focusing on developing an interface for performer-controlled live electronics took it one step further and made it all the more intriguing to me.

This research also continues an interest I have in creating and facilitating heightened aural perceptions in and of space, working with embodied presence, and incorporating improvisation into scores for ensembles

Two different worlds

There is an inherent tension between operatic singing and electronic music. This tension has largely to do with the role and type of sound reinforcement and sound design, and the architectural spaces that are designed for the two genres. In other words, the role of microphones and loudspeakers, and the role of acoustics.

Operatic technique focuses on developing a virtuosic voice of extended pitch and dynamic range able to project in large spaces and carry over large ensembles without the need for sound reinforcement. It is in effect a sound reinforcement technique in and of itself. Opera

singers learn to play to and with the acoustics of the space they are singing in. Recordings of opera, played through loudspeakers, can never substitute for the live performance where one experiences the power and presence of the live singer's voice reverberating in the space; where the effort that it takes to do what they do is palpable.

Electronic music on the other hand is both dependent on and created for loudspeakers. This has opened up the entire world of sound to composers. They are no longer dependent on singers and instrumentalists to perform their works, nor are they restricted to sounds that are humanly possible to create acoustically. With current technologies, composers of electronic music also have the ability, through the use of computers and speaker arrays, to digitally simulate different types of acoustics independent of the physical space. The performance spaces designed for acoustic singing and those designed for electronic music are therefor quite different.

In his doctoral thesis on the perception of musical space in electroacoustic music, Frank E. Henriksen explains

> In rooms with high ceilings, the first reflections to reach the listener are those which bounce off the walls. Reflections bouncing off the side walls lead to an experienced enhancement of the width of the sound field, and the result is a subjective sense of spaciousness generally regarded by music audiences as a desirable acoustic quality for concert halls. However, too much reverberation comes at the expense of clarity. Clarity is the ability to distinguish spectral and temporal detail in the musical sound. Electroacoustic music sometimes requires a higher degree of clarity in the performance space than the case is for instrumental music. One reason is that the often dry acoustics of the composition studio may entice the composer into implementing sonic detail that is dependent on a low- or non-reverberant listening environment in order to be heard. On a similar account, reverberation composed into a work in response to a dry composition environment may clash with the natural reverberation generated in the physical space and, in extreme cases, result in a spatially detailed work presenting itself as an undefined sound mass (Henriksen 2002, 73).

Composers of electronic music may prefer less reverberant spaces, but for opera singers, singing in a non-reverberant hall is much harder and much less satisfying. In a dry space, it feels as if we have lost half of our instrument. Although the acoustics of an opera house are designed for the unamplified singing voice, these same acoustics can present problems for electronic music. In addition to questions of reverberation times, there are difficulties with the physical design. The orchestra pit inhibits sight lines and audibility between orchestra and singers and creates a distinct spatialization of sound: the singers move about and sound from the stage in varying locations, the orchestra sounds from below in a fixed location. When electronic sound is used in opera productions it can create a strange aural disconnect if the electronic sound is coming from mounted speakers that don't blend well with either the orchestra or the singers. Despite these challenges I have been intrigued by the possibility of finding a way for these two worlds to co-exist.

Composer Hildegard Westerkamp, whose compositional practice was influenced by Pauline Oliveros and R. Murray Shafer, asserted in a keynote speech at Invisible Places 2017: "sound experienced, produced and received as a physical process can be an effective counterbalance to attempts by commerce and technology to transform it into product and commodity."

(Westerkamp n.d.). This foregrounding of physical process and context highlights the fact that sound always occurs as a vibration and an interaction in a specific acoustic setting, and that these vibrations and interactions do something significant, sometimes even radical, to both the sound-maker and the listener. As Nina Eidsheim so beautifully describes in her book *Sensing Sound*, live musical events, and especially vocal music-dramatic events are always a unique combination of aural, tactile, spatial, physical, material, and vibrational sensations (Eidsheim 2015).

One of the special things that audiences experience in opera is an unmitigated transmission of sonic vibrations from the singer's body to the listeners ears. Hearing a human voice soaring over other sounds in a large space, unassisted by amplification but audible, whether forte or pianissimo, can be tremendously moving. In this multi-modal artform, the singer is both a musician and an actor; a story teller. The singer's movements and spatial location are significant compositional and theatrical elements of the performance. The singer's body and hands have semantic value. Their movements are perceived in a theatrical context, rather than in a sound producing context, as with instrumentalists. The supporting actions of the singer convey emotional and storytelling elements. The opera singer's performance is indeed a combination of aural, tactile, spatial, physical, material, and vibrational sensations on a grand scale where none of these elements can be ignored.

In an interview in 2021 with Rhiannon Giddens on Aria Code in connection with the Metropolitan Opera 2021 production of his opera *Fire Shut up in my Bones,* composer Terence Blanchard spoke of how he had a "serious aversion" to opera up until the moment he was commissioned to compose one. Despite his father's love of opera, for Terence it had been just "a collection of recordings that I really didn't understand". The first time he saw an opera staged however, it changed his perspective and he fell in love with it. "When you see it live, that is something totally different, to understand how those voices project and to hear those orchestrations and to see the scenery, you know, - there is something that happens to you that I can't explain…" (The Greene Space at WNYC & WQXR 2021).

This research project deals with the unexplainable power of unamplified operatic singing and asks whether there is a way to join that with the magic of electronic audio processing that maintains the integrity of both. Additionally, it investigates the issues of performer-control of the mediated voice (and/or other electronic sounds) in an interactive audio processing environment. This upends the usual paradigm for vocal processing in electronic music, where the singer's voice is processed by a third party, (composer or sound engineer) and is out of the performer's control.

Vocalist-composers working with live electronic processing

There are a small but growing number of vocalist-composers who have been working with interactive technology and custom-built controllers with the goal to expand the options for vocal expression. This is the context that my artistic work is part of, and the context – both current and future – for this research.

A big challenge for any vocalist working with interactive controller systems is finding the type of controller that works well for live performance. Commercial controller systems for interactive music have been largely developed by and for instrumentalists who generally stand or sit in one location with their instrument. These developments started early in rock

and roll where stomp boxes were used to create different guitar effects, and joysticks and pitch bend wheels were added to synth keyboards. Pedal boards can work well for instrumentalists whose hands are otherwise engaged, but are not suitable for singers who want to move about the stage, and certainly not for opera singers who need to move as actors. Standing behind a computer and processing audio with a pedal board may be neutral in concert music situations, but it has limited performance value in opera.

I list here some of the singer-composers who perform with full body operatic style singing as at least one of their singing techniques in their work with live electronic processing. All of these artists work with custom built controllers.

Rome prize winner Pamela Z, perhaps the best known for combining extended vocals, bel canto and live vocal processing, has used multiple controllers over the years, from the Bodysynth that she used at NewOp, to her most recent systems incorporating motion sensors and ultrasound technology. Her current controller system includes a wireless sensor mounted on the back of one of her hands, and a separate stand-alone sensor. Z continues her explorations at concert venues and museums around the world ("Studio Residency: Pamela Z | MoMA" n.d.).

Dancer and vocalist Julie Wilson-Bokowiec performs with the Bodycoder, an interactive performance system relying on gestural manipulation of sound, developed in collaboration with Mark Bokowiec. It has gone through many iterations. Early versions featured flex sensors at the knee and elbow joints, and switches in a glove for triggering pre-recorded samples and visuals. (Jessop 2009) Mark and Julie Bokowiec have continued developing The Bodycoder for complex sound and image processing in immersive environments ("The Bodycoder System: A Wireless Sensor Suit for Real-Time Control and Manipulation of Sound and Images – ISEA Symposium Archives" n.d.).

Franziska Baumann uses the SensorGlove, a sophisticated custom-built midi glove and wearable controller using a variety of sensors that control both spatialization and vocal processing. Baumann started working on the design of her SensorGlove at STEIM (Studio for Electro-Instrumental Music) in Amsterdam in 2001 with Daniel Repond and has continued to develop it to the present day (Baumann 2023).

New York based vocalist-composer Dafna Naphtali designed an interactive system for controlling manipulations of her voice and robotic percussion instruments, using a hand held Wii controller, for her solo show *Robotica. Robotica* was specifically written for Eric Singer's "GuitarBot" and "ModBot" robots (Naphtali, Dafna 2010).

Alex Nowitz began developing both his stimmflieger (which uses two Wii remotes) and his Strophonium (two hand held controllers with multiple switches and sensors) through residencies at STEIM in Amsterdam in 2008 and 2010. He continued development during his Artistic Research Fellowship at Stockholm University of the Arts (Nowitz 2019). Nowitz now produces and curates the Designing Voices festival for exploratory vocal work in Berlin and performs with Franziska Baumann, Tone Åse and Sten Sandell as "Operadicals" (Nowitz n.d.).

Anne Hege uses tether controllers to process audio, mapped with the help of Rebekah Fiebrink's machine learning software, the Wekinator. In Anne Hege´s opera *The Furies: A Laptopera,* originally premiered by the Stanford Laptop Orchestra (SLOrk), a circular

controller rope is attached to six GameTrak Tether controllers connected to six laptops spaced evenly around a large circle. The tethers gather six axes of spatial information from the movements of the six performers operating them. The spatial data sent to the laptops controls the playback of samples and/or sound synthesis. Each player has a localized hemispherical speaker, and the sound is spatialized across the array. The live vocals of the performers are not amplified (Hege et al. 2021).

Carl Unander-Scharin has created controllers of various sizes, among them his tether installation, the Vocal Chorder and a hand held vocoder, The Throat. His doctoral research project Extending Opera focused on empowering opera singers through co-creation of works that used these controllers. Åsa and Carl Unander-Scharin, also develop opera works for machinery, puppets, and robots with disembodied voices for their company Opera Mecatronica (Unander-Scharin n.d.).

Elena Jessop designed the Vocal Augmentation and Manipulation Prosthesis (VAMP), a gesture-based glove controller for real-time vocal performance, as part of her MA research in 2009 for MIT's Opera of the Future research group. It was developed for use in a new opera by composer Ted Machover (Jessop 2009).

Inspired by Jessop's work, the British pop singer Imogen Heap and a team at the University of the West of England in Bristol designed the Mi.MU smart gloves (Mainsbridge 2022). The Mi.MU gloves contain multiple sensors and have a dedicated software interface. They are the only controllers of those I have listed here, that have been developed and marketed as a commercial product. All the other controller systems are custom-designed. With the exception of Imogen Heap, all of the above artists come from a classical or contemporary music tradition. Each of these performer-composer's patches are highly individual and have been developed over many hours and often many years. Anne Hege developed her controller system for an ensemble and Carl Unander-Scharin developed controllers for other singers as part of a doctoral research project. The other artists are the exclusive users of the custom-designed controllers they designed through practice-based research and experimentation. This is typical for the field of gestural control.

> Preparation in the studio involves physically experimenting with prototypes, refining movement vocabularies, assembling compositional elements, and calibrating responsiveness and dialog with the system (Mainsbridge 2022: 37).

Although all the artists I named use gestural controllers to trigger sound articulations in real time, most of their works are performed in positions nearby to the computer running the audio processing programs that they are controlling. Custom designed systems are not something one can give a sound engineer to operate for the first time in the soundcheck before a performance. Even if they were simply monitoring them, a sound engineer would need extra time to learn the specific program with its controllers and user interface. This adds an economic burden to freelance artists. Additionally, custom controllers and patches are vulnerable to crashes and glitches, especially when they are still in the development phase. So for a composer-performer working with custom-built controller systems, dependence on a visual interface to monitor their own live audio processing is the norm.

When working within a theatrical or performance genre, artists who work with interactive technology are confronted by various challenges: the relationship of the computers and audio hardware to the visual design of the show, whether the controllers should be cabled or

wireless and how that affects mobility and data transfer, how reliable and stable the data streams will be, the ease of set-up and use, and so forth. The work of all of the artists I mention above, and their examples of how to tackle technical challenges, informed my own work with the design of the Expanded Vocal Improvising Instrument. I took particular inspiration from Pamela Z for the types of gestural controllers she uses, some of which give her the possibility to move to various positions on stage or in the hall in her theater works. The manner in which she integrates sounds and visuals is also inspiring.

Regarding sound design, live interactive vocal processing and real-time sampling systems record vocal input with a microphone in order to use the voice as a sound source for the processing. Common practice for vocalists doing vocal processing has been to simultaneously amplify the voice and mix the amplified voice with the electronic sound, matching the vocal volume level to the volume of the electronic signal. In opera, however, this design prohibits both performers and the operagoer from experiencing one of the primary characteristics of the genre: the vibratory sensations of a human voice resonating an acoustic space without sound reinforcement. I was inspired to see that Elena Jessop, Anne Hege and Carl Unander-Scharin all focus on the acoustic, non-amplified voice for at least some of their work. It was helpful to see and listen to examples of their work.

PART TWO – Timeline, Methodology, Analysis of Artistic results

Video documents of the Artistic Results discussed in this section are found here:
https://www.researchcatalogue.net/view/2222429/2222482

Timeline of the research

My research fellowship began in Oct 2019. The bulk of the first year was devoted to researching potential controllers and updating my knowledge of processing systems and strategies for mapping. I tested prototypes first on myself and then with other individual singers. The libretto and dramaturgy for *The Sailmaker's Wife*, and initial music sketches were also developed that year. A New York workshop with Ethos Percussion Group and Julian Crouch in January 2020 resulted in the design of an early prototype for a potential interface and a video trailer for *The Sailmaker's Wife*. A presentation of my research at the International Conference on Live Interfaces March 9-11 in Trondheim was the last live event before the global pandemic shut-down. In spite of the restrictions imposed by the Covid-19 pandemic, through an intensive summer work session with my research assistant Balint Laczko, we successfully completed a working prototype for the performer-controlled interactive vocal processing system. I tested it in public at the VoxLAB VårFEST Festival of New Works for Voice in August 2020.

In October 2020 I led a workshop in vocal improvisation and working with interactive technology for opera students at the Academy of Opera, Oslo National Academy of Arts. I worked with the opera students for 10 days and we presented an open showing at the culmination of the workshop. The workshop included a comparison of various controllers, two different multichannel speaker systems, experiments with augmented instruments for sound diffusion, and the first design of a sound installation using suspended long string instruments. Unfortunately the Covid pandemic necessitated cancellations of all other planned workshops and travels that year, so a large part of the remaining second year was devoted to reading about the context and history of electronic and electro-acoustic music, and composing the music for *The Sailmaker's Wife*. Finally in late spring 2021 I was able to resume group rehearsals. In June 2021 I filmed an ensemble reading of excerpts from *The Sailmaker's Wife* and in August 2021 we performed a 25 minute section of the opera at VoxLAB´s VårFEST 2021 International Festival of New Works for Voice.

From September 2021 to June 2022 I was on exchange at the Institute of Sonology, Royal Conservatoire The Hague, Netherlands. This allowed a deep dive into audio technology, acoustics, sound design, electronic and computer music systems, and the refinement of my interface. I explored multiple speaker systems and strategies for spatialization, and tested my interface in ensemble performances in the Netherlands. I also performed duo concerts with jazz reed player Peter Van Bergen in Oslo and Tønsberg, Norway, in June 2022. I continued composing *The Sailmaker's Wife* and held a second development workshop with the Ethos percussion group in New York in July 2022. In August, co-teaching workshops in Trondheim and Oslo with Limpe Fuchs, the legendary German percussionist-composer and instrument-maker, allowed for further development of my long string instruments. I ended the academic year with a performance with Limpe Fuchs and ensemble at Kulturkirken Jakob and started the new schoolyear with a solo concert at Fotogalleriet, both in Oslo and both featuring the work with the EVII.

In October 2022 I gave a Keynote at the International Conference on the Performer-Composer at Orpheus Institute in Ghent, Belgium, and performed with other artists working with gestural controllers as part of the MuseumNacht festival at Studio Loos in The Hague, Netherlands. I cast the roles of the Captain and the Crane Wife for *The Sailmaker's Wife* and began rehearsals on the score and teaching the interface to my lead soprano. In the winter I worked with the Expanded Vocal Improvising Instrument (EVII) in New York recording material for a CD with Miguel Frasconi, and rehearsing for a live performance with Jill Sigman of her dance work *Re-seeding (Part 1:Self)* which premiered in New York, Feb 1, 2023. Returning to Oslo in February I gave a presentation of my research in a Women in Music Technology Seminar at the University of Oslo, Department of Musicology.

In March 2023 I got news that my lead soprano needed to withdraw from *The Sailmaker´s Wife* due to an opera apprenticeship contract she had received. Soon thereafter I received news that the Ethos Percussion Group's travel funding to Norway had been rejected. Although I had planned to present a concert reading of *The Sailmaker's Wife* for my final presentation, due to the loss of these performers, it became clear that I would not be able to do that. I decided to create a companion piece; Part Two of *The Sailmaker's Wife.* The resultant work, *Crane Reflects on a Favor*, explores themes from the folktale from the crane's point of view, features improvisations with the EVII as a primary element, and was developed for and with the improvising colleagues I had been working with. I composed the score using a combination of traditional notation, graphic notation, and text scores for structured improvisations. I divided the role of the crane into three parts and hired two new sopranos to learn the EVII and join me for the performance.

In the spring and summer of 2023 I held rehearsals and workshops in Oslo and The Hague, taught the interface and score to the two new soloists, and gathered the ensemble of instrumentalists. In June we held rehearsals on the Mainstage of the Oslo National Academy of Arts with the full ensemble, and started work on staging and scenography. August 24 to Sep 1 was the final production rehearsal period for the September 2, 2023 premiere of *Crane Reflects on a Favor – an Eco-opera* produced by VoxLAB for the VårFEST 2023 International Festival of New Works For Voice.

Methodology

The methodology in this project has been to develop the technology and the artistic project in a way that is intertwined. This has opened artistic insights and new expressions. I chose to work in multiple formats and genres (solo, ensemble, works for dance and film, and opera) because I felt each one posed new challenges. The work developing the technology began with an investigation into controllers and mapping, and continued with an investigation of spaces and speakers after the basic system had been established.

In the first year I used a practice-based methodology to explore the affordances of various controllers and interactive systems. I tested a variety of controllers: the LEAP motion controller, the HotHand MIDI ring, the Xbee, the Genki Wave Ring, Mari Kimura´s MUGIC motion sensor, stretch controllers, and touch and trigger based controllers. I decided to use two Genki Wave Rings as gestural controllers for the project as they were the most flexible (with both continuous controllers and switches). The MUGIC was extremely stable and gave the most reliable data. I chose that as an optional second controller for spatialization. I will continue to develop the spatialization components to better integrate these two aspects.

Similarly, I tried many different speaker set-ups during an exchange year at the Institute of Sonology in The Hague. I will elaborate on both of these investigations in Part Three.

When I started this research project, I expected I would build a new interface to do real-time sampling and trigger vocal effects using various digital signal processing plugins (DSP plugins). Several designs of simple interactive patches in Max/MSP and Ableton LIVE were tested in the beginning with a HotHand wireless midi-ring motion sensor, and with trigger based controllers. An important turning point came when I decided that instead of designing new processing patches, I would explore which wireless gestural controllers I could add to my existing main performance processing patch. Ultimately that choice yielded the most interesting artistic results. To integrate the motion sensor controllers with my main performance patch, I had to decide which parameters I wanted to control with the gestural controller. My interest in designing a system that was not dependent on a visual interface imposed certain limitations. Since there were a limited number of switches and continuous controllers on the Genki Wave Rings, I pared down the processing parameters to what I felt were the bare necessities needed to make music with this system.

As mentioned earlier, my main performance patch was inspired by the Expanded Instrument System (EIS) that Pauline Oliveros developed out of her experiments in the early 1960s with magnetic tape recorders. Like other composers experimenting with electronic music at that time Oliveros used reel-to-reel tape recorders to create extremely long tape loops, and played with the effects of recording and playing back at varying speeds. In the 1980´s, Oliveros´ analog version of EIS consisted of a series of daisy-chained Lexicon delay and effects units that were controlled via foot pedals by multiple performers. When the MIDI-based software program Max expanded to Max/MSP, which included signal processing capabilities, David Gamper, Pauline's bandmate in the Deep Listening Band, created patches that duplicated the functions of the Lexicons, and transformed the analog EIS to a digital version in Max/MSP. David gave me a simple patch when I was starting out that enabled multiple variable delays using either pitch shift or time stretch and time compression. Variable delay and feedback with time stretch and time compression were the parameters that I ultimately decided were most important for this current research.

The wireless Genki Wave Rings were mapped to control a limited number of parameters on my main processing patch, with a focus on real-time sampling of multiple, nonsynchronous, variable length loops in three delay-feedback channels. It is capable of complex layering with the gestural controllers due to the mapping of the two main parameters – delay and feedback – to trajectories that continuously impact each other: simultaneous Roll and Tilt. These simple audio processing functions yielded surprisingly varied and nuanced results due to the complex interactions of the gestural controller.

Creating the Expanded Vocal Improvising Instrument (EVII)

My work with this new performer-controller gestural system has challenged me to think differently about my electro-acoustic composition process. The computer in this system functions as both an effects unit and an improvising partner. It requires its own way of composing. I set up structures indicating parameters and sound input, and then I observe how they unfold sonically. The controller interface allows the performer to sense a physical connection to the mediated vocals and processed sound. Working with the rings becomes an embodied form of gestural listening and sounding.

Many have referred to performances with the EVII as seeming “theremin-like” since the performer is “playing the air”. Others use the term “conjuring”. They can see there is a connection between gesture and sound transformation. The fact that the audience can see, hear and follow the trajectory of the vocal processing brings a sense of action-sound connection into the picture. It allows the audience to experience the performer’s compositional and improvisational practice. The action-sound connection is interesting in this context since both electronic music and singing are generally missing that connection. In singing the action-sound connection is hidden since a singer’s sound producing actions are internal. Only the supporting actions - breath, mouth position, movement of the lips - are visible. In electronic music sounds can be entirely decoupled from the actions that produce them. The action-sound connection with the midi rings in this context affords a sense of familiarity, and yet it is also ambiguous, since the same gestures can produce wildly different results.

Sometimes I refer to the EVII as a vocal avatar, or vocal prosthesis – a vocal extension that can explore the acoustic space in a way that I cannot on my own. Another strong association is that of weaving a fabric using a single strand of voice to weave patterns in accumulating layers of time. A third association is that with my disembodied vocals I can create a soundbed or orchestration, or a cloned choir, to accompany me.

A common response from other performers is that working with the EVII is like working with a time machine. Since sample times can be extremely long, performers have often been surprised by the return of sonic material that they had forgotten having produced.

Artistic themes that surfaced out of the practice with the interface were:

- Control – what can be controlled, and what cannot?
- What and how much can be set? Or repeated?
- How do we recognize a piece?
- What constitutes a piece?
- Composition vs improvisation: which is which?
- Memory and structural choice making – considering past, present, future simultaneously
- Perception – which sonic elements are highlighted through my choice of interface design, instrumentation and/or processing strategies?
- Aesthetics – how am I using the operatic voice in this iteration of electro-acoustic music?
- Presence – performance presence and sonic presence in the space

The gestural controller and interface that has resulted from this research is designed for performers with improvisatory skills, or those willing to spend the time to learn them. It works best with open scores that are able to accommodate the rhythmic, motivic and timbral variations that can be created with the interface and its gestural controllers. Since the audio processing is based on real-time sampling and delays, it can be either sound-based or note-based, depending on the sound sources being sampled. My attention is often drawn to pitch relationships in my surroundings. Part of my interest in combining the acoustic voice with electronic sound comes from my practice of recording site specific vocal improvisations with machines and other ambient electronic sounds in our environment. I enjoy the opportunity to focus other people´s ears to ambient sounds that might otherwise be overlooked, by singing

acoustically in a manner that engages musically with those ambient sounds. I am in these cases combining and bridging note-based music with sound-based music.

An interesting characteristic of the interface is that the time-stretch and time-compression parameters can function like algorithms for transforming note-based motivic material to either shorter motivic elements, or vastly sped up ornamentations, or stretched out spectral elements, depending on how the controllers are used. This allows me to apply both note-based and sound-based compositional strategies to my improvisations.

Heightened awareness to ambient sound is important to me and is one of the key reasons I chose in this project not to amplify the voice. In my final piece – *Crane Reflects on a Favor* - I chose to work with musical sounds and instrumentation that traversed the gap between acoustic and electronic sound. A combination of traditional notation, graphic notation and text-based scores enabled heightened listening in the performers. The scores also enabled a process of ensemble-based devising, suited for short workshop periods. That turned out to be essential. Due largely to the pandemic, short workshop periods of a few days at a time was all I could manage to arrange with performers during the entire course of the research fellowship.

Mapping data

I started with a limited knowledge of mapping strategies, and limited awareness of the multitude and types of controllers available. Consultations with Seth Cluett (Columbia University), Mari Kimura (Juilliard and UC Irvine) and Alexander Refsum Jensenius (University of Oslo) helped me to get started with basic information about controllers, mapping and live processing. An early consultation and a subsequent workshop with Marije Baalman in the first year of my fellowship made me aware of the complexities of mapping data.

My initial plan was to observe opera singers´ gestures while singing and see if there was a way to link typical gestures to the mapping strategy for data processing. But I quickly understood that in order to decide what functions I wanted to control, I needed to experiment with the controllers myself first. I needed to experience how it felt physically to control particular parameters with the mappings I was choosing. The mapping strategies determined everything, and they were changed multiple times in the first year. I observed how working with the interface impacted the experience of combining my acoustic embodied voice with my electronic disembodied voice(s) and I made a note of which mappings aided memory of those choices. I had to design the mapping in a way that was not confusing and that enabled me to remember the processes I was creating. One approach that I found particularly helpful was to group similar types of processing on the same ring. Otherwise it was easy to mix up left and right.

Sound design

I was aware that a primary challenge with my approach would be finding strategies for combining the disembodied voices (electronic sound diffused through loudspeakers) with the acoustic singing and balancing both within the acoustic sound field of the space. I thought I might need to determine which microphones might best work with opera singers, or what loudspeaker set-ups would give the best balance. Instead I learned how our ears perceive the characteristics of space through acoustic sound. Spatial volume, types of material in the

space, distance and direction of the sound source in the space, the speed and force of the energy used to interact with materials in the space, are all understood instantly by what we hear. And all of these characteristics give meaning to the sound. Space and spatialization are implicit but often unarticulated expressive elements in opera, articulated visually by directors, but not thought about as much aurally.

As mentioned earlier, two very different approaches to a performance space presents a large challenge. I will elaborate on this in Part Three in the discussion of technology and sound design.

Performing with the EVII

What fascinated me in the course of working with the Expanded Vocal Improvising Instrument in numerous performances was that it enabled me to play with time and the perception of time, and explore memory, which is of course always distorted when you try to retrieve it. I felt as though I could easily conjure transformations of energy through listening and sounding, and give space to the voice for expression of intense emotions within abstraction. I also experienced how working with the interface subverted the usual hierarchies in the music business. In my role as a performer- composer with the interface, I combined the roles of creator, performer, conductor, and sound technician. This in turn could be seen to challenge and upend gender stereotypes, for example, the characterization of singing as feminine and technology as masculine.

As a creator interested in vocal music theater, the monophonic voice can only go so far. The multi-vocal voice opens possibilities for story-telling, harmonic complexity, counterpoint and timbral variation and energy transformation. I invite the reader to follow my journey through my written analysis and video documentation of selected works.

Analysis of Artistic Results

This research has been practice-based and has resulted in multiple artistic works exploring different facets of the investigation. In this section I describe some of the pivotal works. Video documentation of the works discussed in this section can be found here: https://www.researchcatalogue.net/view/2222429/2222482

ICLI (March 9-11, 2020)

In the beginning of March 2020, a few months into my research fellowship and immediately before the pandemic lockdown, I gave a colloquial talk about my research at the International Conference on Live Interfaces (ICLI) in Trondheim, Norway. As part of my presentation, I demonstrated a wireless HotHand MIDI motion sensor controlling a simple Max/MSP patch that looped my voice at varying lengths determined by gestural control. It was my “proof of concept” and my initial attempt to perform away from the screen. The most interesting part was discovering the implicit working method assumptions at the conference; the mixing board was assumed to be the only sound source necessary for the documentation of the conference. None of the room sound from the hall itself was recorded. A result of which only the processed sounds from my demonstration in the hall were recorded, and my acoustic singing in the space – my direct signal - was missing from the final video documentation.

This was my first observation of a significant gap between working methods and assumptions in the electronic music world and the world of opera.

Seeing singer composer Tone Aase perform with a Genki Wave Ring at that same conference, inspired me to order and try out that controller. In addition to a 3 axis motion sensor (similar to the HotHand) the Genki had 3 buttons on the ring. That turned out to be crucial in the design of the system I ended up with by the end of my first year of the research fellowship. Three years later Tone and I performed on a joint concert at Sentralen in Oslo, each with our own ways of using the Genki Wave Rings.

Flying Blind
Sentralen, Oslo, August 28, 2020

Flying Blind was the first public performance using the wireless Genki Wave controllers. In the initial phase of the research, together with my research assistant Balint Laczko, I had tested several types of controllers and tried various types of Max/MSP patches. After an intensive summer session with Balint and with invited guests who tested both the HotHand and the Genki gestural controllers, I settled on the Genki rings. And instead of working with the custom Max/MSP patches we had first designed and tested, I decided to try to map the Genki Wave Ring to parameters in my main performance patch. That was a turning point. We developed a prototype that I continued to work with for the remainder of the research period, gradually expanding the processing functions over time.

My goal with *Flying Blind* was to test whether I could do an extended performance without relying on any visual cues from the computer screen for the processing. I also wanted to test the range of the controllers while I moved in the space. The Genki rings connect via Bluetooth, which is known to be unstable, but for this occasion they stayed connected even up to over 50 meters, as long as the line to the computer was not blocked by columns or walls.

I started the piece acoustically in order to let the public focus on my solo voice resonating this particular acoustic space. As a former bank and a large space with marble surfaces, it is quite reverberant, with good acoustics for the unamplified voice. Starting acoustically focused the audience´s listening to what was happening in the space we were all occupying. I used hemispherical speakers for the sound diffusion of my processed vocal samples – a pair on my left and right and a pair placed in the middle of the audience in front of me.

My text score specified to explore the venue´s acoustic properties with my voice, to proceed to processing sibilants in a way that evoked wind, demonstrate to the audience that I was controlling the processing, resume vocal pitched material, respond to the results of the processing, and, after traversing the hall, end with a recap of the sibilant sounds. I used feedback as a primary way to extend and let go of the samples, but I also used gestural control to clear the buffers and a trigger to initiate or bypass audio input. I had learned in the early part of the research that designing numerous ways to create rests, or “turn off” the sound, was one of the most important aspects of the design.

In a video discussion with singer composer Franziska Baumann after the performance I described the mapping for Flying Blind:

I am using three different delay feedback lines. And each of those delay feedback lines has the ability to go from a very short delay to a very long delay, usually from about eighty milliseconds to a minute, but it could be even longer or shorter. On my left hand, the roll function of the gyroscope is mapped to delay. If I am in a palm down position, it is the shortest delay, and if I am in a palm-up position, it is the most extended delay. Any slight motion gets a significant change. The delay changes are scaled to eighth notes within a tempo. So it might be jumping from 500 milliseconds to a thousand milliseconds, or a different amount, depending on the BPM. But still, slight movements have a big change. I scaled it logarithmically so that the first part of the roll takes more of a movement to make a modification because those changes between, let's say, 80 milliseconds and 200 milliseconds are so audible. Once you get to the longer delays, we do not recognize the changes in delay length as much.

The interesting thing about the long delay is that I can start sampling a very long phrase and then choose to go to a very short delay, but the long delay is still there as long as the feedback is still up. That´s where I get the image of folded time. I can bring back some element of that long sampled phrase much later in the piece. And if I want to go back to the long delay, I can search it out, but of course, it has changed because my hand motions go all through these different delay times. That search of what I did in the past, getting changed when I am pulling up the memory, is interesting to me philosophically. That very, very simple mapping becomes much more complicated because the patch is listening all the time, and you get all these coincidental overlays and foldings.

The continuous controller is also mapped so that if I am at a hundred percent feedback, it does not take audio input, which is a safety bypass. If I find something that I like, that I want to have the possibility to do a solo over, then I can put the feedback at a hundred percent and do my solo without sampling that solo. […] *And I can even keep that on a hundred per cent and move to another feedback-delay channel. The gyroscope's pitch function with my arm all the way up is feedback at one hundred per cent. If I let my arm all the way down, I let go of the feedback.*

FB: I saw this gesture also on your right hand.
KN: Yes, with this gesture in the right hand, I empty all the buffers. It is fun to play with two different ways of creating a structural pause: letting all the feedback down, and clearing the buffers.

On the right hand, I can choose which delay line I am sending to, and those delay lines are routed to particular speakers. The right hand functions are like a menu object. The only use of the continuous controllers on the right hand is the gesture to clear the buffers.

Numerous people described seeing *Flying Blind* as an experience of seeing me conjure and/or physically mould the sound. Some asked about my gestures, which I had purposely exaggerated in order to make it very clear that I was controlling the sound. I wished to emphasize the sense of visibly letting the sound go, playfully bringing it back, offering it to the public, or listening to it myself, intimately. The piece has remained a good way to introduce people to my processing and my research.

Performing *Flying Blind* with the Genki Wave Rings, I felt much freer than I had felt with my previous gestural controller, the DIY MIDI glove. It felt like I was searching for the sounds with tai-chi like calm slow gestures, touching the edges, and shaping the sound with my hands. In my improvisatory vocal processing I experience a double focus. One part of me is in the flow the music making, and one part is keeping track of my choices and strategizing about how to structure the improvisation. Physicalizing the process helped to unify this double focus.

I have described *Flying Blind* at length since the basic structure of the performance patch and the mapping strategies remained stable in the subsequent versions of the prototype. Although the patch was modified over the next two years to increase parameter controls, those new parameters did not change the fundamental structure of the mapping. Of course, each change of mapping and each new parameter added, meant spending time to learn new physical movements and to unlearn previous movements. Unlearning old strategies typically took longer than learning new strategies.

Island – Renewable Rikers

Video Dance by Jill Sigman
Music by Kristin Norderval, created in October 2020, video launched 2022
Produced by jill sigman/thinkdance
Rishauna Zumberg – movement and video footage
Irene Hsi – movement and video footage

Jill Sigman created this online dance project in response to community efforts to close the notoriously violent Rikers jail on Rikers island in New York City. *Renewable Rikers* is an environmental justice project that proposes to convert the island to a source of renewable energy for neighboring communities. *Renewable* is a series of video dances metabolically reflecting on the future of Rikers Island after the Rikers jail is closed. The music for the video dance was created with the long string instruments and the EVII interface.

Although in the summer of 2020 it seemed that perhaps the pandemic would last only a few months, during the academic year 2020-2021 we experienced multiple repeated lockdowns. The resultant cancelations both in spring 2020 and during the subsequent academic year created havoc with live performance. It was a year of fits and starts and many projects had to transfer to the digital space. Including Renewable, which had been scheduled as a live event in New York on Earth Day in 2020. It was canceled and the process went online.

In Oslo in October 2020 I held a workshop with students from the Opera Academy at the Oslo National Academy of Arts. The time in the theater allowed me to research responses to two different speaker set-ups and to a sound installation consisting of augmented instruments - a zither and taffel piano with transducers mounted on their soundboards and multiple piano wires threaded through plywood amplified with contact mics, suspended from the lighting bridges and weighted with theater weights. My long piano string installation was inspired by the Long String Instrument of Ellen Fullman.

I used the augmented instruments as resonators of both acoustic and electronic sounds, and the long string instruments as sound sources for improvisation with the students. Visually and structurally the long string instruments had a relation to the most ancient types of looms – warp weighted looms – and thus they were connected to the subject of weaving in *The*

Sailmaker's Wife. Sonically they occupied a liminal space between acoustic and electronic. The fundamental tones of these very long piano strings are out of the range of human hearing, but the harmonic sounds and variations that we do hear and perceive are similar to spectral music.

Working on my own with the instruments in the sound installation also gave me the opportunity to test the Genki Wave Rings for vocal processing while engaging in other activities and types of gestures. (Bowing and plucking the strings.) I filmed a series of improvisations on the long string instruments, and later edited one of them to create the soundscore for *Island*, one of the videos for choreographer Jill Sigman´s *Renewable* series.

Creating the music for *Island*, I bowed and hit the long piano strings and theater weights, and processed my voice with the EVII. I chose vocal motives that stayed within a single tonal area and, since I had less direct control of my hand motions, I emphasized the harmonic overtone series in order to accommodate whatever sampling, delays and layering would accrue from my movements. The space I was in was extremely resonant, with a very high ceiling. This was an enormous contrast to the small rooms that the dancers were moving in, filming their improvisations alone in their covid isolation. The contrasts between the small spaces in the visual frames and the large space evident in the audio were I think effective in expressing the alienation and the isolation of both the dancers during COVID and the prisoners still at Rikers. This piece influenced how I composed the vocal sections for *The Sailmaker's Wife* that included both processing and playing the long string instruments.

Excerpts from *The Sailmaker's Wife*

SALT, Oslo, August 26, 2021 / VoxLAB VårFEST 2021

Kristin Norderval – composer, voice, laptop
Silje Aker Johnsen – soprano, live processing with the EVII
Halvor F. Melien - baritone
Sigrun Rogstad Gomnæs - percussion
Rob Waring - percussion

This concert reading of excerpts from *The Sailmaker's Wife* was my first opportunity to try out the EVII in a public concert with another performer processing her voice with the Genki Wave Rings. The performance went well in spite of a very challenging sound environment. The venue was not particularly well suited to quiet music, as it was not sound insulated. A significant amount of sound bled through from the street and from the other stages on the grounds.

The performance consisted of 25 minutes of excerpts that had been developed and revised during two intensive work periods – the first development workshop in New York in January 2020 when I was still testing the HotHand as a controller, and subsequent rehearsals and a workshop reading with the Oslo performers in the spring of 2021 with the long string instruments, the Genki MIDI rings and the mappings to my main performance patch. Covid had brought about multiple shut-downs during the winter of 2020-2021 but in April 2021 I was finally able to try out my sketches for soprano and percussion with Silje Aker Johnsen and percussionist Jennifer Torrence. Silje experienced some frustrations with the rings, especially with the tendency of the processing to default to more fragmented samples and shorter delays if not counteracted by controlling longer sampling lengths and delays with

slow, calm movements. The style of improvising that Silje excels in that emphasizes quick contrasts and short sounds compounded the tendency of the processing to default to more fragmented samples and short delays.

It took some time to get comfortable sampling with longer delays and trusting that the interface was indeed working. Fifteen seconds is considered long for a delay. My longest delays are over a minute. It can strain both trust and patience to wait that long for a sample to return. In my score for *The Sailmaker's Wife* I stipulate in one section that the singer should bow the long string instruments in various ways while processing with the Genki rings simultaneously. This was complicated. It was difficult to physically manipulate both rings while bowing. I suggested in rehearsal that Silje use only one ring – the continuous controller for delay and feedback. I controlled her audio input and routing with the other ring. We kept this strategy for the performance at SALT in August.

Silje was very creative in her improvisations on the long string instrument She discovered that one could produce a "wail" by bowing under the hooks of the loom weights. That became one of the signature sounds for the Crane-Wife. Her delicate vocal phrasings perfectly captured the frailty and vulnerability of the character of the Crane Wife. I chose a sonic palette that accommodated a blend of acoustic and electronic elements to match that delicacy. I used the long string instruments, bowed vibes, bowed piano strings, and a small modular synth diffused through an augmented zither.

Norderval / Van Bergen Duo

Galleri Galleberg, Tønsberg, Norway, June 26, 2022

Kristin Norderval – voice, live processing with the EVII
Peter Van Bergen – reeds, live processing with the Mi.MU glove

In September 2021, I began my exchange year in Den Haag, and attended the one year course at the Institute of Sonology. I was also granted an Artist Residency at Studio Loos during this time. The residency at Studio Loos was particularly important for this research project as it was the location for multiple trials and performances that investigated different aspects of the controllers and sound system. It was also a site for numerous other artists all of whom added important perspectives to this work. The renowned jazz wind player Peter Van Bergen, director of Studio Loos, was both supportive and insightful.

Almost two years after I had test-run the first prototype and after my exchange year in Den Haag, I had the privilege to play with Peter Van Bergen. While in Den Haag I had tested possibilities for spatializing with a MUGIC motion controller, but I had not yet added either this nor the desired additional processing parameters of optional pitch shift or spectral freeze to my patch. (That would come within the next months.) But my tests had allowed me to experiment musically and think more broadly about the processing options, especially in regards to playing with other improvisers.

Peter was using the Mi.MU glove designed by Imogen Heap and her team to process his acoustic Contrabass clarinet, soprano sax and other instruments in Max. I proposed that we play a duo concert combining our two ways of processing, both of us controlling separate Max patches. In this duo concert in Tønsberg, Norway, I alternated between acoustic singing,

vocal processing with the MIDI rings without viewing the computer screen, and processing prerecorded soundfiles seated behind my laptop with the screen in view.

It was useful for me to compare these three strategies in terms of my sense of embodiment and freedom of expression. Singing acoustically, with no processing, I could concentrate 100% on the room, my collaborator and the public, and I was free to make quick musical changes of any kind (melodic, harmonic, rhythmic, timbral, etc.) within the limits of my monophonic instrument. Singing with vocal processing, my concentration was divided between the room, my collaborator, my vocal choices, and my processing – which required both making and remembering choices regarding routing, considering the relationship of what I was adding to the processing, of how it returned (or might return) as the mediated vocals, and how I would further interact with what I was getting back. When sonic layering resulted in chordal material I could use that to define a harmonic structure within the improvisation. This in turn affected how I related to musical time, and changes over time, i.e. how I chose to change those structures over the course of the improvisation.

My sense was that navigating with the processed sonic material was a bit like navigating with a boat – it is not as easy to make quick changes melodically and harmonically with processing as it is with acoustic singing, because the material "sticks". Although the mapping allows multiple for ways to pause the material, the channels are not set up to be cleared individually. The gestural control that clears the buffer, clears all 3 simultaneously. To clear an individual channel I need to route the signal to that channel, set the delay to the minimum and the feedback to 0%. The sampled material in that channel will then disappear. But this is a slower process than clearing all the buffers at once. I noticed my strategy for quick changes became a that of quick scrubs to touch and let go of small units of material.

When I sat behind the computer to process prerecorded soundfiles, I felt the most disconnected from the public, although still very focused on my collaborator. At that point I was primarily strategizing about what I could add next and how I could support Peter´s improvisation. I felt that my role was more of an accompanist in this section. The screen took a significant amount of my concentration and I felt less physically present.

A note on the special context of this concert. It was part of the Nonfigurative Music series that Håkon Lie curates, and was scheduled for June 26, 2022, which was also the day for the LGBTQ Pride Parade in Oslo. Early that morning there was a mass shooting outside of the London Pub, one of the gay bars in Oslo. Two people were killed and 21 wounded, and the Pride parade was officially cancelled. The horror and fear was palpable. People were talking about gathering anyway in mourning and solidarity. I was conflicted about driving to Tønsberg as I would have liked to join friends and colleagues in Oslo that afternoon, but I didn't want to cancel the concert either. I decided to begin the concert with a spoken introduction and to dedicate the concert to the victims of the shooting and their loved ones. I started with an a capella vocal prayer of mourning, and gratitude for resistance and resilience. It continued on a somber note when Peter van Bergen joined me. He and I were both processing our monophonic instruments with our different controllers and interfaces. My vocals were also occasionally processed in Peter´s patch and the quiet mediated and transformed vocals in his electronic sounds hovered like eerie ghosts in the space.

After the concert a woman came up to thank us for the concert. She told me she had been disappointed that the Pride Parade in Oslo was cancelled that day as she had been planning to go. She said it was a bit lonely to be gay in the countryside. But through the concert and my

introduction of myself as an elder lesbian who has be out since age 19, and has seen homophobia ebb and flow at different times in different places, she didn't feel alone after all. I was very moved to hear that.

AnimariAnimate by Limpe Fuchs – excerpt: final quartet
Kulturkirken Jakob, Oslo, August 25, 2022

Limpe Fuchs – composer-improviser, percussionist, instrument-maker
Kristin Norderval – voice, live processing with the EVII, hemispherical speakers
Viktor Bomstad – electric guitar
Mirsaeed Hosseiny Paneh – santoor
Georgia May Anta - dancer

In the second year of my research fellowship, inspired by warp weighted looms, I had experimented with suspending long piano wires from a lighting bridge and weighting them just above the floor with metal theater weights. The piano wires were threaded through thin plywood rectangles at the top, on which contact mics were mounted. The contact mics were plugged into a small mixer and a guitar amp that sat on the lighting bridge. This gave me an electro-acoustic instrument to use in my workshop with the opera students; one on which no-one was an expert, so the bar was sufficiently low to overcome insecurities about improvising with it. Bowing, plucking, and hitting the strings and the weights produced interesting sounds and harmonic overtones with which the singers could improvise acoustically. This design was used in the subsequent reading and performance of excerpts from *The Sailmaker's Wife* the following summer, this time with cylindrical metal loom weights instead of theater weights. The sounds of these long string instruments became integral to the character of the Crane Wife.

In 2021, during my exchange year in The Hague, I discovered the phenomenal work of percussionist-composer Limpe Fuchs, and her custom-built Double Pendulum instruments: long piano strings suspended from brass rimmed frame drums and weighted with long solid bronze cylinders. The double pendulum design creates unusual sonic effects since both the movements of the suspended frame drum resonator and the movements of suspended brass cylinder affect the vibrations of the piano string. They are acoustic instruments, but they often sound electronic due to the effect of the double pendulums on the harmonic spectrum. I was enthralled and inspired by Limpe´s designs of these double pendulum piano wire instruments, and they influenced the next iteration of my own long string instruments.

After traveling to Munich to meet and hear Limpe Fuchs in a retrospective concert, I invited her to come to Norway to give two workshops with me – one for adult artists in Trondheim, and one for young performers in Oslo. I was thrilled when she agreed and in August 2022 I was privileged to teach two workshops with Limpe, and improvise and perform with her. Through close contact with her pendulum instruments, I understood that with the correct resonators one could achieve an amplitude strong enough to make contact mics unnecessary. That influenced the final design for the long string instruments that I would ultimately use in my opera *Crane Reflects on a Favor*.

Limpe Fuchs was also invited to be a guest artist at the VoxLAB VårFEST 2022 festival. Her program for the festival consisted primarily of solo works, but also included an introduction with the young performers from the Oslo workshop and a structured quartet improvisation

with me and two of the other workshop teachers - Mirsaeed Hosseiny Paneh on santoor and Viktor Bomstad on electric guitar.

This quartet performance was the first opportunity for me to try out my interface in a larger ensemble. I was curious to see how the processing possibilities would balance in an ensemble with three other improvisers. The challenges I experienced with the quartet were (as before) the somewhat limited ability to change sonic material quickly, and the challenge of balancing the volume of the mediated vocals to both my acoustic vocals and to three other instrumentalists in a resonant environment. (Jakob Kulturkirke). I asked the others to let me lead initially so that the audience would hear the vocal processing clearly at the beginning of the improvisation. My experience was that it often took a little while for the public to understand that the movements of my hands and arms controlled the audio processing of my vocals in real-time. It helped to begin in a way that highlighted that fact. Regarding the volume balance, although the hemispherical speakers gave me the vocal timbre I wanted for the mediated voices, the digital amplifier that I used was not quite powerful enough for the size of the room.

Re-seeding (Part 1: Self) - jill sigman/thinkdance
Crossroads by Pioneers Go East Collective at 14/ Y, New York, Feb 1, 2023

Choreographer and Performer: Jill Sigman
Composer and Performer: Kristin Norderval
Witnesses: Dani Cole, Vida Landron, Heather Robles, Anisah Sabur
Cups by Jill Sigman, Amy Schnitzer, HK Dunston, Susan Bluestone, Kate Alley, Hoyon Kim. All Other Ceramics by Jill Sigman

Re-Seeding is a multi-modal project that explores choreographer Jill Sigman´s relationship to the land as a granddaughter of immigrant Jewish refugees, and a non-indigenous person born in Brooklyn on occupied Lenape homeland. *Re-Seeding* asks: “How can I live on this land with respect and bring about healing?” The work has multiple parts. Jill asked me to create the music and perform with her in the first part.

In *Re-seeding (Part 1: Self)* Sigman worked with ceramic casts of her own body parts. In creating the music for Part 1, I wanted to use these same objects as sound sources (the ceramic casts and the paper they were wrapped in) and explore the interactions between them, my processing and my voice. Through multiple rehearsals we explored the sound world of these objects and created an overall structure for the 30 minute piece, allowing the objects to sound acoustically before and after being processed. The addition of spectral freeze to my processing parameters added an important sonic pivot point between the processing of the objects and the processing of my voice.

It was interesting in this piece to resume my familiar position behind the computer where I had contact with the screen and the mousepad again. One thing that surprised me was that the Genki Wave Rings remained my primary method of controlling the audio processing even though I had access to my earlier methods. In the performance, although I remained stationary, the processing advantages that the gestural controllers gave were numerous: increased speed of changes, ability to control multiple parameters, and increased visual interest for the public. I was conscious of the additional choices the rings afforded with the control of both feedback and delay simultaneously, and the ease of movements controlling

quick changes from minimum to maximum values on both of those parameters. With the Genki rings I was able to engage the public more with visual aspects of my processing, especially at the beginning when I processed the sound of a large ball of paper. Standing in front of the laptop, I was also able to trigger some parameters that were not mapped to the rings.

One of those parameters was the option of continuous randomization of delays within an individual channel. I found that engaging an automated continuous randomization of delay was useful when moving from one delay-feedback channel to a second one. Rather than remaining fixed on the last delay time registered in the channel I left, (as it is with the controller mapping), I manually triggered a continuous randomization function which kept that channel "alive", constantly transforming, even when data from the ring was no longer activating it. I may add that parameter to the mapping in the future.

The ability to closely monitor and adjust the input volume levels with the mouse, allowed me to experiment more with processing feedback of the room tones. In the current controller mapping, input levels need to set beforehand and are not changeable with the midi rings. The volume of output levels can be controlled with the rings, but it is difficult to achieve a nuanced control. Gestural control is cruder than gently moving faders on a mixer. I tend to limit my use of volume control with the rings to quick fadeouts at the end of a piece.

I used the theater´s stereo PA for diffusion of the electronic sound and was dependent on the audio technician to balance the volume with my acoustic voice. For my aesthetics, the volume of the electronic sound was a little bit too loud in comparison with my acoustic singing.

Crane Reflects on a Favor: an Eco-opera

Part Two of *The Sailmaker's Wife*
Oslo National Academy of Art, Main Stage, Sep 2, 2023
VoxLAB VårFEST 2023

Concept and text: Kristin Norderval
Music: Kristin Norderval, developed with the ensemble
Director: Jill Sigman
Lighting: Kaja Lund
Costumes: Jill Sigman, Lydia May Hann
Ensemble:

- Rosanna Vibe - Live backstrap weaving
- Flora Ångman - Soprano
- Viktoria Nikolova - Soprano
- Kristin Norderval - Soprano
- Viktor Bomstad - Electric Guitar
- Miguel Frasconi - Glass instruments & modular synth
- Peter Van Bergen - Contrabass clarinet
- Rob Waring - Percussion

Crane Reflects on a Favor is Part Two of the operatic diptych *The Sailmaker's Wife*. Both parts of the diptych are loosely based on the Japanese folktale *Tsuru no Ongaeshi* (Crane's return of a favor) about a crane who pulls feathers from her body to weave a magic fabric in

gratitude for being helped to survive. The first part of the diptych is from the Sailmaker's point of view; the second is from the Crane's point of view.

Crane Reflects on a Favor is a post-operatic allegory; a dream-like sonic performance installation, sung in three parts by three women, each representing one of the stages of the crane's response to her offering: first as a gift given freely, then as one given in response to pleading, and finally, one extracted after demands of ownership. A fourth woman weaves at a warp weighted backstrap loom. She, like the others, is another personification of the Crane Wife. In this final work I attempted to pull together my experiences working with the interface on my own and with other instrumentalists and singers. My goal was to create a sound design, instrumentation and staging where both the electronic sounds and the acoustic sounds could co-exist in the real life acoustic sound field of the theater we were performing in.

I worked with the liminal zones between electronic and acoustic. The staging focused on a physical spatialization of the instrumentalists and singers. The long string instruments were now acoustic, not amplified with contact mics like before. Their sounds were still similar to electronic sounds. The tam tam, resonated with a super ball mallet, and the bowed cymbals, have complex harmonic spectrums. They blend well with the electronic sounds. Adding acoustic vocal delays (hummed or sung) to the electronic delays was another strategy and it also worked well. It was difficult at times to tell which delays were acoustic and which were electronic.

The subharmonics of the Contrabass clarinet, and the sine-like tones of rubbed wine-glasses were also well suited to the electro-acoustic sound world, and using an eBow for long tones on the electric guitar blended with the acoustic glass. I used localized monitors for both the electric guitar and the modular synths. Miguel Frasconi, who played glass instruments and modular synths in the piece commented: "I like it that *everything* sounds acoustic". He related how he always tries to use localized speakers when performing with Joan La Barbara and their ensemble Nextworks.

In this piece I also aimed to bridge the ensemble practice of the earlier works with the theatrical world of postopera, the term Jelena Novak uses to describe new operas and music dramatic works that display postmodern characteristics and aesthetics. I felt the story was an apt parable for our time of climate crisis. Cranes are over 10 million years old and are related to the dinosaurs whose bones are the fossils in the fossil fuels we extract for wealth and power. That power, however, is simultaneously creating our own demise by destroying the body that sustains us. My goal with C*rane Reflects on a Favor* was to create a sonic space for us to collectively mourn.

I wanted the sound installation and the sound design for the opera to create a hybrid electro-acoustic sonic environment. The work with Limpe Fuchs and her double pendulum long string instruments had inspired me to try to create acoustic versions of the long piano string instruments I had tested in the fall of 2020. Together with instrument maker Jon Halvor Bjørnseth we built and tested 10 different resonators that would allow the long strings to be heard without amplification (without using the contact mics of the earlier versions). Seven of the designs were chosen for *Crane Reflects on a Favor*, based on their timbre, amplitude and visual suitability for the scenography. I felt that the eerie sounds of these long string instruments were an excellent bridge between the acoustic and electronic instruments used in the piece.

For the June rehearsal period I used four Genelec speakers mounted on the lighting bridges above the audience. My concept was to create webs of vocal sound that would hang over the audience. It was a challenge to integrate this with the sound from the stage. It was harder for the instrumentalists and singers to hear the mediated voices when they were not nearby. The space was bifurcated and the singers´ reported that their attention was split. The instrumentalists asked for monitors at the beginning, but when we began improvisations focusing only on the long piano strings and the vocal processing, they listened more carefully and got used to the sounds of the mediated vocals in the hall. They then modulated their own levels accordingly in subsequent rehearsals.

The singers sometimes pulled back vocally when processing, especially if the levels were not well balanced. Their vocal volume levels were sometimes in opposite proportion to the speakers; if the volume of the mediated vocals was too high, then they would sing more quietly. But if the mediated vocals were too quiet they also sang more quietly, in order to hear the mediated vocals. The trick was to get an ideal balance between the acoustic and electronic voices. We discussed the need to strategize when the volumes of sounds being sampled were radically different. One strategy was to route sampled quiet sounds to a dedicated delay-feedback channel, and to use another channel for louder sounds. That way the input level could be adjusted at the mixing board for the quiet sounds without risking the distortion or imbalance of sudden louder vocal signals elsewhere in the same loop. We had the safety of a limiter as well, but the goal was to be aware of how to circumvent the need for that.

When things went “wrong” with the rings, the singers became very concentrated while trying to figure out how to respond to or “fix” the problem. They were generally most present when working with the rings, but had more vocal freedom when they were singing acoustic solos and not processing the voice. Then there were no worries about levels or what they might get back in the mediated vocals.

After the workshop I expanded the multichannel system to six speakers. The two extra speakers were placed above the stage at the proscenium. That achieved a better integration with the stage sound. In August 2023, with the help of Balint Laczko, my patch was expanded to incorporate Ircam’s multichannel system SPAT, which gave more flexibility to position sources and a more diffuse sound. Balint and I experimented with both vector-based (VBAP) and distance-based (DBAP) diffusion algorithms. I chose to work with the DBAP for a more diffuse sound, even though it made it more difficult to hear distinct point sources.

PART THREE – Reflection and Discussion

Mapping and Prototyping

Video examples discussed in this section are found here:
https://www.researchcatalogue.net/view/2222429/2247120

I have been working with various types of audio technology since 2000, and I have learned the basics of most of the software that I have used. But I am not a computer programmer. When I wish to create work with a new type of human machine interactivity, I choose to work with professional programmers to help design the interface and ensure that the complex coding works as intended. The Max/MSP programmers who assisted me in this research project on designing a performer-controlled wireless gestural vocal processing interface were my research assistant, composer and computer programmer Balint Laczko, and the NY-based composer and Max/MSP programmer Matthew Ostrowski. Others who assisted with helpful commentary and patch developments were Cathy van Eck, Johan van Kreij and Simone Sacchi in Den Haag. New York based sound engineer Bill Siegmund helped set up and check the routing in my Metric Halo audio interface.

In this section on the technology and design of the EVII, I am writing as a composer-performer who uses technology to execute my vision. Not as a computer programmer nor as an acoustician. I outline in this chapter my subjective experience of how the mapping and design choices for the Human Machine Interaction in the system impact the creative choice making regarding timing and musical structure, and how the design calls for the performer's ability to pivot between predictable results and surprises. I then outline my exploration of various acoustic spaces and loudspeaker systems.

I spent the first year of my research fellowship investigating design and mapping strategies for creating a performer-controlled interactive vocal processing performance system that would be not be dependent on a visual interface and would allow for mobility. In this first part of the chapter I will present the design and implementation strategies that I chose, again using specific works as examples of the prototyping. In the second part of the chapter I will describe my investigations of space and loudspeakers, primarily undertaken during my exchange at The Institute of Sonology in Den Haag.

Experiential prototyping

The first experiments in the design and development of a performer-controlled wireless vocal processing interface involved using a wireless HotHand MIDI ring to control Max/MSP patches that Balint Laczko created for sampling and looping into a single channel. The mapping strategy was one to one: roll was mapped to control of the length of the sample. Tilt controlled the percentage of feedback. Samples could be overdubbed, and layered with either synchronous or nonsynchronous samples of varying lengths. Changing lengths resulted in pitch shift as the delay times were altered. Specific gestural positions triggered muting (audio off). During early prototyping sessions with Helena Schuback, it became clear that we desperately needed an "off" trigger – a way to create rests and not get caught in incessant loops. Balint created a patch in Max/MSP to recognize a particular gesture to trigger an audio input mute. I used the HotHand and Balint's Max/MSP patch in my first workshop with the Ethos Percussion Group and dancer Heloise Gold. We experimented with control of her

vocals as well as of prerecorded soundfiles. The HotHand was also the interface that I used in my colloquial presentation in Trondheim in March 2020.

Choosing a controller

Following the initial work with the HotHand, we experimented with other controllers, searching for those that allowed the performer to easily control functions without relying on a visual interface. Trigger based controllers were quickly eliminated since I decided that I wanted to work with wearable controllers not hardware, and I wanted to have the flexibility of one or more continuous controllers. We tested several gestural continuous controllers in addition to the HotHand MIDI ring: the LEAP controller, the MUGIC microcontroller, the Xbee, and the Genki Wave MIDI ring. I considered the possibility of testing Imogen Heap´s Mi.MU MIDI glove as well, but the price was prohibitive and the hi-tech visual design was a hindrance for this particular project. It was however very helpful to look at the mapping template of the Glover software, which can be configured to work with other controllers, and with which we experimented on the LEAP controller since they both recognized hand positions. (Fist, pointing finger, etc.) I tested all the controllers primarily on myself, but also with other singers and performers. The LEAP controller was eliminated due to the short distances necessary to maintain connection with the laptop. It did not meet the mobility or distance requirements for the project. The three controllers that I considered as real possibilities were all wearable sensors: Mari Kimura´s MUGIC microcontroller (which I could mount in a sleeve or armband), the HotHand, and the Genki Wave MIDI ring. I settled on working with two Genki Wave Rings as they were the most flexible. Although the MUGIC sensor was a far superior motion sensor that sent stable 360 degree motion data instead of 180 degrees as both the Genki and HotHand did, I chose the Genki nonetheless due to its compact design and combination of 3-axis continuous controllers and 3 switches on the rings. This combination provided more flexible mapping options than the Xbee, HotHand and MUGIC controllers, all of which offered 3-axis motion data, but did not have built-in switches. The MUGIC was implemented at a later stage in the research specifically for spatialization.

Mapping the processing functions

The next step after choosing which type of controller to use, was experimenting to see what kind of data the controllers gave, what they felt like, and how stable the connections were to the laptop, especially regarding distance from the computer. And I needed to decide which audio processing options I wanted to control with the wireless sensor. Once I had made the decision to work with my existing performance patch, this was mostly a task of elimination, figuring out which functions I was willing to give up and which functions were essential. It was a process of trial and error, paring down parameters and mapping them to gestures and haptics that felt clear, worked theatrically and could be easily taught.

It became quickly apparent that very simple, basic processing features would be most effective. I chose to work with three separate feedback and delay lines, but no other processing at that time. The default for the delay lines was delay without pitch-shift, since the integrity of the vocal timbre of the performer was important in this particular project. Which meant that varying delays were working with time compression and time stretch. Most people

are now aware of a similar function in video chats; the slowing down of signals that results in voices that are stretched out sonically, or the speeding up of the conversation when the faster signal reappears. This assisted me in explaining the time stretch and time compression function when teaching others.

The ability to create pauses and silences (through audio mutes, volume control, bypassing feedback and clearing the buffers) were crucial functions for creating musical complexity. The ability to alternate processing between at least two buffers, and to layer independent nonsynchronous variable length loops, also significantly increased the possibilities for making musically interesting choices. Ultimately we settled on a mapping that routed the vocal signal to one of three individual delay-feedback channels corresponding one-to-one to the three buttons on the Genki midi rings. That provided a convenient haptic device and memory aide for switching from one channel to the next.

Mapping strategy from *Flying Blind* (August 2020 to present)

Since the controller mapping and hardware set-up for *Flying Blind* set the foundation for the rest of the research period, I will look more closely at this piece in regards to the technology and design of my interface and the mapping of my controller data.

The hardware setup for *Flying Blind* was a MacBook laptop running Max/MSP software; an audio interface (Metric Halo 2882); a wireless headset and sender/receiver (Sennheiser); 2 wireless Genki Wave MIDI rings; and 4 hemispherical speakers (Isobel audio Alto hemispheres).

Flying Blind's processing environment consisted of a Max patch that mapped data from the two wireless Genki MIDI controller rings to control real-time vocal sampling and processing through three delay-feedback lines. The vocal audio feed was sent through a wireless headset, but the acoustic voice, although sampled was not otherwise amplified or fed into the audio mix. It was an interactive system for a multivocal solo voice: a combination of the unmediated operatic voice and the mediated vocals functioning as an independent instrument processed in real-time.

Once we had decided to use the Genki midi rings, I started work on the concept and score for *Flying Blind*. Each Genki ring sends midi signals from a 3-axis continuous controller; (roll, pitch and yaw). The three switches (buttons) were programmed to distinguish between trigger, hold-press and double click, affording 9 menu options. The three delay/feedback lines were diffused to three different speaker arrays (L and R speakers and a pair of speakers acting as a third center unit). I used my hemispherical speakers as I felt they gave the best acoustic balance between the mediated vocal signals and the acoustic voice in the performance space. Balint Laczko designed the mapping interface in Max that routed the midi signals from the rings to my processing patch.

The delay-feedback channels and speaker routings were mapped to the 3 buttons on the right-hand ring. With my right palm facing upwards and fingers pointing away from my body, the buttons on the ring could be perceived in a right, center, left array. Stage right, center and stage left speakers were chosen by triggering the right, center and left buttons with my thumb. With my right palm facing my chest, fingers pointing horizontally to the left, the buttons are in a top, middle, bottom array. That corresponds to the top, middle and bottom delay-feedback channels on the computer screen. These mirrored positions helped me to

remember where the signal was going, and which sounds or phrases I had sampled into each channel. The mapping allowed for a pseudo haptic sense of the routing.

There is one challenge, however, with the buttons on the Genki Wave Rings. They are closely spaced and the middle button is sometimes hard to feel. It might have been more easily identified had there been a ridge or bump on the middle button. With practice it became easier, but there were still moments that I needed to look at the ring to check if I had the right button. Viewing the video documentation of *Flying Blind* afterwards, I could see that this broke my communication with the audience and changed my performance presence.

In addition to routing to the 3 delay-lines and their dedicated speakers, the buttons on the right-hand ring also controlled audio input (on/off), and whether to process feedback and delay simultaneously (the default) or separately (by choosing either only feedback or only delay). The buttons on the left-hand ring were mapped to two volume controls: one that could fade out and fade back up again, and a second that would lock at the end of a fadeout. This feature was added to ensure there would be no unplanned sounds at the end of a piece.

I had initially experimented with using the left hand buttons to change presets of pre-recorded soundfiles, and using the continuous controllers to scrub through the files and change the lengths of the samples. I was unsatisfied with the musical results however. Scrubbing the pre-recorded soundfiles gave neither sufficient control nor enough variability for my purposes. I decided to focus solely on the real-time sampling and processing of vocal signals, and to explore processing of soundfiles at a later date. It remains an aspect to be further explored.

I chose to map delay and feedback to the continuous controllers on the left-hand ring. Pitch (wrist up/wrist down) was mapped to feedback. Pointing to the ceiling was 100% feedback, an infinite loop; to the floor was 0% feedback. Roll (rolling the wrist from palm down to palm up) was mapped to delay. Palm down was the shortest delay and palm up, the longest. Delays and feedback in each channel were independent. Even though these were one-to-one mappings, since each movement in one direction affected the other they function as cross-coupled mappings, creating more complexity (Hunt et al. 2002) and thereby more interest for both the listener and the performer.

The delay range was preset differently in each channel, with minimums from a few milliseconds to maximums of several minutes. In *Flying Blind* the shortest delay in one of the channels was 85 milliseconds and the longest delay was a minute and 15 seconds. The large range of delay times, and the possibility to shift from very short to very long almost instantaneously, or conversely very slowly and gradually - allowed for a kind of folding and unfolding of time and memory, with the long and short delays creating unpredictable overlapping structures. Controlling the percentage of feedback in the three separate delay lines offered the possibility to layer or to let go of audio signals and to revisit sonic events recorded earlier. At 100% feedback the audio feed was bypassed. This was both a safety mechanism and a mechanism to create opportunities for acoustic vocal solos. Soloing over a built- up accompaniment during an audio bypass, was when I felt the most free to sing in my full operatic voice as I was not worried about the possibility of a distorted signal coming back in the loop.

Testing the interface

The setup that we designed for *Flying Blind* was tested in group workshops with opera students at the Academy of Opera in Oslo (October 2020) and with individual opera singers and other classically trained singers in one-on-one sessions from the summer and fall of 2020. Individual trials with dancers and instrumentalists in July 2020 also provided useful feedback. The first public trial run of the system was my solo performance of *Flying Blind* at Sentralen in Oslo on Aug 28, 2020 in connection with the VoxLAB VårFEST 2020 festival.

The design remained relatively stable for the remainder of the research period. Modifications and additions to controller functionality since 2020 added an optional delay-with-pitch-shift parameter, spectral freeze in a 4th channel, and spatialization possibilities on the spectral freeze channel.

Relational time versus Quantifiable Time

After we had created the first prototype, I discovered that the mapping strategies I had chosen for my two hands corresponded to two different ways of conceiving of and interacting with time and numerical information.

The data from the continuous controllers on my left hand is mapped to delay lengths - the time it takes for a sampled signal to sound - and to feedback percentage - the number of times that a sample would be sounded and/or repeated, from 1 time (the delayed signal) at 0%, to an infinite loop at 100%. Since it is impossible to recall exact positions in space with the gestural controller, the left hand must search for the position of samples recorded earlier, or for interesting layerings that have accumulated. This is an understanding of time as relational, flexible and approximate.

The switches on the right hand ring control distinct functions: audio on/off, routing from one delay channel to the next, locking the feedback or the delay settings, etc. It is akin to a menu object and the choices need to be made at precise times. This is an understanding of time as quantifiable, sequential and/or digital. In this system I can guess at approximately what I will find with my left hand, but I cannot be precise. My right hand however makes sequencing and menu choices that must be precise.

Perceptions of the processing

When working with the Expanded Vocal Improvising Instrument (EVII), performers would often need to “search” for sound samples that were sampled into a long delay. Slow searches create a tai-chi like motion of the left hand. The searches for previously sampled material can produce unpredictable details; new sonic artefacts emerge, converging past and present. The resultant patterns, chords, and timbres elicit new vocal responses in the improvisation, creating a continuous spiral. Like any investigation of memory, the search itself changes one´s relation to the past events. Several of the performers who tried out the system

commented that it felt like a kind of “time travel”. Needing to respond to “whatever they get” also keeps the singer present, embodied and aware. It necessitates concentration.

The difference between triggering and continuous control has been the most important aspect to clarify when teaching the system to other singers . With continuous control of both feedback and delay happening simultaneously as a default, complex time relations take place, and practice is needed to get comfortable with that. I observed that when teaching the use of the Expanded Vocal Improvising Instrument (EVII) to other singers, working first with the continuous controller set to control only delay, and then only feedback, speeded the process of learning the interface.

Using the Genki Wave Rings as gestural controllers for the EVII created a more embodied relationship to the sonic manipulations in my patch than using stationary MIDI controllers with faders and knobs. I found I could modify the controller movements in expressive ways. I could raise or roll my entire arm, or raise only a finger and roll only from the wrist. The control of the data remained the same, but the impression given by my movements could be entirely different. How I chose to move, whether with large or small gestures, became part of my expression in a piece.

So far, the data from the right hand ring’s continuous controllers has only been used for one particular gestural control. Quick movement of the right hand in an up-down hand flick is mapped to clear all the buffers. This gesture requires both speed and force; which makes it a very recognizable gesture and easily understood. It is the only gesture that has a one-on-one mapping. But even this can be unstable since the clear buffers function only works if the velocity is sufficient in both directions. Sometimes in performance it took me several “flicks” to clear the buffers. That too can be expressive!

Control of two other parameters was eventually added to the EVII: a trigger for an optional pitchshift function, and a trigger for spectral freeze. The spectral freeze was based on a patch that Simone Sacchi designed. In my performance patch it is mapped to its own independent audio input, which enables two ways to use it: doubling it with a delay line, or using it on its own when audio input for the delays is turned off. This has been useful for crossfading or clearing the buffers while the spectral freeze provides a sonic layer for musical transitions.

Examples related to interface design

Video examples discussed in this section are found here:
https://www.researchcatalogue.net/view/2222429/2247120

MuseumNacht concert, Studio Loos, Den Haag, NL, October 10, 2022

Kristin Norderval - Voice, live vocal processing with the EVII
Jan Bas Bollen - Leap motion controller, video
Peter Van Bergen - Contrabass clarinet, Mi.MU Glove

On a MuseumNacht concert at Studio Loos Oct 10, 2022, I used the optional pitch shift on the vocal processing for the first time in public, controlling it with the left hand Genki Wave ring. In general I prefer to use vocal delays with time compression and time stretch rather

than pitch shift, since pitch shifting vocals can easily sound like either cartoon voices or horror movie characters. But where the delay change is large and extremely fast, the result is machine-like and the original vocal sample is not recognizable. Since the Genki rings enable large and fast changes, I felt this might be a good strategy for improvising with other musicians who work with electronic sounds where the rate of change is fast. I tested it out on the MuseumNacht concert in my solo piece *TimeWrap* (the pitch shifting can be heard at 5´20") and in two ensemble pieces. In the trio with Jan-Bas Bollen and Peter Van Bergen, each of us were processing sound with different gestural controllers. Jan-Bas was using the LEAP motion controller to control both audio and video, and Peter Van Bergen was using the Mi.Mu glove to process audio signals in Max/MSP. I was happy with the extra musical choice-making that the pitch shift enabled. It took some time though to get used to a new menu option on the left hand instead of the right.

Norwalk-3 Improvisation with Miguel Frasconi, December 29, 2022 NYC

Duo improvisation recorded in Norwalk, CT, USA, Dec 29, 2022.
Kristin Norderval - voice & gesture-controlled laptop (EVII)
Miguel Frasconi - glass & analog electronics

Norwalk 3 begins with Miguel Frasconi improvising with glass shards. After a minute I enter acoustically, seemingly not processing my voice for about a minute, since I chose to sample into a delay with the volume down. Bringing the volume up later reveals the surprise. In Norwalk 3 I also experimented with recording quite long samples, in order to create longer harmonic and contrapuntal structures. I used the minimum delay times on the delay-feedback channels to create a counterpoint of recurring short rhythmic delays. Choosing the minimum position of the roll, one can keep the delay time constant without "locking" the delay in place. The minimum delay presets in each channel are the only delay times that one can reliably access without fail with the continuous controller. All other delay times are approximate.

Current state of the EVII

In a rehearsal and prototyping workshop with Amanda Schoofs and the Ethos Percussion Group in July 2022, I tested both the Genki Wave Rings and the MUGIC motion sensor which had been mapped to control spectral freeze, based on a Max/MSP patch that Simone Sacchi had provided to me. I was happy to add another type of processing to the sonic palette, but adding another physical object to the interface for the performer to handle presented challenges. I ultimately decided to re-map the Genki Wave Ring in order to access the spectral freeze on the left hand ring. The MUGIC is currently mapped only to a spatialization parameter, and it only spatializes the signals in the spectral freeze channel. Compositionally, and as a memory aide, I have found it helps to maintain point sources for the signals from the 3 delay channels. If the signals from those channels are spatialized it is easy to forget which delay line has what previously sampled material, and therefor harder to make strategic compositional choices. In listening sessions Balint Laczko commented that this set-up also makes it easier for the listener to follow the improvisational structure and process.

When I began performing with the interface and sending documentation to colleagues, I got requests from other performer-composers to describe my mapping. One of my replies to performer-composer-improviser Norman Lowry, describes the current status of my interface.

Regarding my mapping:
My audio processing is fairly simple.
Basically just working with feedback and delay, … the default is no pitch shift, and the randomized functions are not automatically happening in the patch.

I have one channel for spectral freeze, and 3 delay-feedback lines set up that use timestretch and time compression when changing speed through delay changes (rather than pitch shift.). I can choose pitch shift as an option if I want however.

Continuous controllers on the rings control feedback, delay, and the speed of the spectral freeze drone. The buttons control routing & change functions.

The complexity comes with the fact that the continuous controllers on my left hand are defaulted to control both feedback and delay at the same time.
Roll = delays from 85 ms to over a minute, and Pitch = feedback from 0 - 100% .
At 100% my audio-in function is disabled to prevent uncontrollable feedback, but that also means I can choose to keep something going and do solos over it, or record only bits and pieces of my singing by lowering my hand just enough to get audio in again. The two ways to create rests or let my material go are 1. Letting go of the feedback, 2. Clearing the buffers, which is done with a gesture (measuring velocity) .

I can also choose to freeze the delay and just work with feedback, in which case it gets the more traditional discreet time looping function, but I prefer in general to work with a continuously changing delay and continuously changing feedback simultaneously, as that gives me surprises that I then have to respond to in real-time. It layers the sampling in unpredictable ways, especially with quick changes between the really long delay and the really short delay. The continuously changing delays are like a weighted random: I cant set precise times, I can only aim for approximate times, listen carefully and work with what I get. So instead of using David Gamper's strategy of randomly changing values within the Max patch, my movements themselves create the randomness. And the interface becomes an improvising partner in that way. :)

The buttons on the rings are used like a menu, for routing from one channel to the next, choosing audio on/off, choosing temporary pitch-shift, choosing to lock the delay time, moving to the spectral freeze, etc. The routing, and remembering where I am (!) becomes a great part of the complexity. :) I got assistance in the Max programming from Balint Laczko and Matt Ostrowski. They were both great at helping me figure out what would work to create the mappings I wanted. It was basically a long process of physical trial and error to find out what could work gesturally and what I could remember without looking at a visual interface.

Space and Speakers

Works discussed in relation to space and speakers are found here:
https://www.researchcatalogue.net/view/2222429/2222430

Spatializing test with Pablo Gastaldello, binaural recording – (both using Genki rings)
FuturePast - Studio Loos, Den Haag – voice, live processing, augmented piano
This Time Now – Royal Conservatoire concert hall – Iko 3D speaker, spatialized singers
Place, Manner, Time – concert with Mar Pino-Charlez, Anja Hertenberger, Gerriet Sharma
Queering Time – concert with guest dancer Maria Lothe at Fotogalleriet, Oslo, Norway

The missing dramaturgy of spatiality

Composers working with electronic music and classical opera singers approach space very differently. There are implicit, unarticulated understandings within these two groups that conflict with each other. I will try to elaborate on this question of spatialization as one of the important sonic elements of the operatic art form.

While my experiments in the first two years of my artistic research project focused on designing a performer-controlled system in Max/MSP, during my 2021-22 exchange year at the Institute of Sonology in Den Haag, I focused on learning about sound itself. I caught up on developments in electronic and computer audio processing techniques, experimented with spatialization, and tested several types of loudspeakers (micro to macro). I wanted to examine how different types of speakers and different performance spaces and acoustics might affect my performance and other singers performing with my interface. I tested my interface with transducers in augmented instruments, with a custom-made rotating "Leslee" speaker, the Bloomline Omniwave, the IKO 3D icosahedron speaker, my hemispherical speakers, Genelec and Meyers speakers in quad and multi-speaker arrays, a metallic coil speaker glove, and several portable Bluetooth speakers.

At the Royal Conservatoire The Hague I observed the lectures for composers working with electronic sound and master classes for the singers in the vocal department. I was pleased to see that the vocal department's study plan included several classes on collaboration between singers and composers. There was an openness to working with new material and with technology. I proposed a 3-day workshop on vocal processing, which the vocal department agreed to. Berlin-based composer Gerriet Sharma co-taught the workshop with me. We were able to observe the relationships between opera singers and the spaces they perform in and how the sound design and acoustics in performance spaces suitable for classically trained singers impact the balance between acoustic and electronic sound. It was fascinating to compare Gerriet's 20 sided IKO 3D speaker, my hemispherical speakers and a quad set-up of Meyers speakers. The Meyers were excellent for the electronic signals but the balance between the acoustic singers and the electronic sound was best when we used either the hemisphericals or the IKO. I created exercises for the singers to build awareness of sound reflections in the room, and they enjoyed improvising combining their physical spatialization with the spatialization of the electronic sound from the IKO.

Effects of distance & amplitude in physical space

In the fall 2021, I listened to John Chowning's lecture "The History of FM Synthesis" given at Knobcon in 2019. At 35 minutes into the video, Chowning describes the difference between diminuendos that occur due to increasing distance between the sound and the listener versus diminuendos that occur due to decrease in energy or force applied:

> *A sound that's projected in distance loses energy but the spectrum remains largely the same. However a sound which is decreased in loudness – subjective space – its physical representation is a loss of the high frequency energy and a shift of the centroid […] towards the lower harmonics.* (35.15 – 36.00)

Chowning then plays an example of a marimba sound decreasing in loudness due to increasing distance and the same marimba sound decreasing in loudness in a stationary position due to diminishing force applied to create the vibration. It was very clear how sonically different these two examples were, and how easily detected. He next demonstrated how sound also communicates not only distance, but also effort, through the sum of the reflections. Explaining that when clapping at a certain force

> *…the sound goes direct to [the listener's] ears, but it also reflects off all the surfaces. The sum of those reflections is reverberation. […] Now what if I clap at the same distance but only one quarter of the effort? […] The direct signal that is left goes direct to his ears. The reverberant signal is scaled by the same amount because the energy in the room decreases. Whereas if [the listener] goes to the back of the room and I clap at the initial force, he gets the spectrum as if it were close, but the overall intensity is decreased. The same amount of reverberation is in the room.*

This was a revelatory moment for me. My immediate thought was "This is what opera singers work with!" Opera singers understand the acoustic space implicitly and we work intuitively and expressively with the sonic effects that different spaces create. These become expressive parameters. We are also trained to be aware of and be able to control the differences between a diminuendo created due to decreasing energy versus a diminuendo due to increasing distance between ourselves and the public. There is an enormous expressive and semantic difference between the diminuendo in a long messa di voce sung by a singer standing in one spot, and the diminuendo of a sustained high note sung by a singer who exits the stage and is still heard offstage. The relationship to the space becomes a story-bearing element. At 42.33 Chowning continues:

> *Reverberation revealed the distance of a sound most noticeably when there was a change in frequency in the sound such as portamento or vibrato because of the phase complexity from the feedback paths – that is, when the direct signal was easily distinguished from the reverberant signal.*

This is extremely relevant to opera. The type of signal from an opera singer – where both vibrato and portamento are ubiquitous – easily distinguishes the opera singer's direct signal from the reverberant signal. The reverberant signals reveal distance and effort; both important elements in opera. Proximal distance and spatialization relate narrative and theatrical information. The goal of keeping the high frequency energies in the spectrum of the voice, and the effort that it takes to resonate those high frequencies is central to the artform. Not only does vocal effort convey emotional states and expressive information, but a singer's

ability to keep the vocal tone consistent (the spectrum constant) is a large part of their training and determines the evaluation of expertise by both fans and professionals in the field. Singers are known and identified by their timbre; the specific and unique sound of their particular instrument, and their particular manner of conveying emotional information, as Mary Mainsbridge points out.

> The pitch, pace and time of the voice conveys emotional cues linked to personal identity, relationship dynamics and worldly status. Each individual has a unique voiceprint, distinguished by the pattern, rhythm and sound of their vocal expression (Mainsbridge 2022, 68).

Chowning's lecture clarified for me that the main challenges when trying to combine operatic singing and live electronics is to define the desired characteristics of an acoustic space that is suitable for both the operatic voice and electronic sounds, and to design a sound system that functions in that space and creates a balance between the acoustic and electronic sounds.

A current working assumption in sound design is that the voice in electro-acoustic works always needs to be amplified and diffused through a loudspeaker system in order to join the unified sound field of the electronic signals. It has become a standard practice to close-mike both singers and instrumentalists when they are performing pieces that include electronic sound. Although many composers also choose to amplify the singers in their operas to mitigate the problem of balance with the electronic signals, amplification adds other potential problems to opera: loss of spatialization, loss of full vocal dynamic range, distortion of vocal timbre and distortion in the higher ranges. The extreme dynamic and register range of the operatic voice presents challenges even to the most sophisticated sound engineers using top of the line microphones and loudspeakers.

So what if we turned that on its head? In urban environments we are surrounded by electronic signals of all kinds. If the ringing of cell phones and the whir of ventilation systems can be heard by the audience at a classical concert hall where an orchestra is playing, why should we not be able to diffuse electronic music soundfiles in that same hall in a manner that interacts with both the acoustic sound field of the concert venue and the acoustic instruments?

Chowning's lecture led me to recall that close-miking of an entire ensemble was not always standard practice. Many of the works that I heard in the 1980's (some of which I performed) were for electronic sound and unamplified instruments and/or voices. The first piece for voice and computer sound that I learned and performed was *Levadi* by Diane Thome, one of my undergraduate composition teachers. It was scored for unamplified voice and fixed media played on stereo speakers. (*Levadi* was later recorded by soprano Montserrat Alavedra, my voice professor at the University of Washington.) The combination of unamplified voice or instruments and electronic sound was not unusual at the time. Other works by Thome, early vocal works by Nono, Cage, and Judith Shatin for unamplified voice and tape come to mind. But that practice of mixing unamplified acoustic instruments and voices with electronic sound seemed to change by the end of the 90's. Perhaps this was due, as Raviv Ganchrow speculated in a conversation we had in March 2022, to the development in the mid-90s of high quality miniature microphone headsets that replaced standing and handheld microphones.

One of the companies developing miniature microphones - DPA - was founded in 1992. The DPA 4060 and 4061 miniature microphones came on the market in 1995 and quickly became

one of the industry standards on Broadway in New York, and soon after in classical settings as well. Other companies soon followed and now there are numerous miniature microphones of excellent quality.

My first introduction to the DPA was in March 2004 in a co-created opera for Den Anden Opera in Copenhagen with Line Tjørnhoj and Carl Unander-Scharin. Following that experience I added a DPA headset to my own set-up. It enabled me to use a wider spectrum of sampled material, but I continued my practice of maintaining my direct vocal signal unamplified and only diffusing my mediated vocals and/or prerecorded soundfiles through loudspeakers.

Because of my interest in maintaining a balance between my direct unamplified voice reverberating in the space and the electronic sounds in the same space, I was drawn to work with the omnidirectional hemispherical speakers designed by Perry Cook, Dan Trueman and others on the team at Princeton. Hemispherical speakers are designed to radiate sound in a manner that imitates the properties of acoustic instruments. Hearing these speakers used in concert by composer and bass player Curtis Bahn early in the aughts, was in fact one of the inspirations that got me started with realtime-sampling and processing of my voice. I experienced that performance as one where both the acoustic and electronic signals could be clearly heard interacting with the acoustics of the performance space, and I knew that was how I wanted to work. [2] After listening to Chowning's Knobcon lecture I was convinced that my choice to keep the direct vocal signal unamplified may not be simply my particular personal preference. It may also be a key to one of the main challenges to incorporating live electronics in opera.

Sound reinforcement of the operatic voice is challenging in a way that goes beyond breaking with the tradition of unamplified singing. Not only are opera singers already self-amplified, but with the staging we are also self-spatialized. In fact one could say that opera is the only classical musical genre that is consistently spatialized. The spatialization – (staging) - is not only significant as a theatrical parameter; it is significant as a sonic parameter. There are audible sonic differences between singing directly to the public, singing upstage with the back to the audience, hiding behind a piece of scenery or under a coat, or sobbing into another character's arms. If the singer's voice is diffused through loudspeakers all those expressive elements of proximal space are lost. We lose significant narrative information. It even often becomes difficult to identify which singers are singing.

Trevor Wishart's description in Audible Design of how humans can distinguish two separate acoustic sources even if they are playing or singing in unison, is relevant here.

> When we hear two sounds at the same time certain properties of the aural stream allow us to differentiate them. Even when we hear two violinists playing in unison, we are aware that we are hearing two violins and not a single instrument producing the same sound stream. At least two important factors in our perception permit us to differentiate the two sources. Firstly , the micro fluctuations of the spectral components from one of the sources will be precisely in step with one another but

[2] An example of one of my earlier electro-acoustic works for unamplified voice and instruments with electronic sound diffused through hemispherical speakers, can be heard here: https://www.therestisnoise.com/2014/02/kristin-norderval.html

> generally out of step with those of the other source. So in the continuation we can aurally separate the sources. Secondly, the onset of the two events will be slightly out of synchronization no matter how accurately they are played. Thus we can aurally separate the two sources in the onset moments.
>
> If we now precisely align the onsets of two (or more) sounds to the nearest sample (onset synchronization) our ability to separate the sources at onset is removed. The instantaneous percept is one of a single source. (Wishart 1994, 47)

With sound reinforcement, singers often sing differently, less full-bodied, with less vibrato, and expending less effort. Diminished effort means a diminishing of the high frequency spectrum - that spectrum which most defines and identifies each individual singer.[3] Microphones and speakers add their own spectral footprint to the mix. Even the slightest variations in a singer's timbre are perceived by listeners. Of course some composers specifically request a different type of singing when the singers are amplified, which is fine as a conscious choice. That is a different story.

Illusions of space vs. awareness of space

In "Creating Sonic Spaces: An Interview with Natasha Barrett" published in Computer Music Journal 2006, composer Natasha Barrett speaks with Felipe Otondo about the creation of works with either Ambisonics or Wave Field Synthesis as a "three dimensional impression of space" and the creation of "a sound field that mimics the properties of our real acoustic sound field." She describes composers working with electronic sound and spatialization as creating "spatial mimicry" of a real acoustic sound field.

> To capture or encode the spatial information in the first place, we have two choices: either we can attempt to capture the real sound field via recording, such as by using a Soundfield microphone, or we can synthesize the spatial information using the math of either ambisonics or wavefield synthesis (Otondo 2007, 12).

In my practice I have been exploring singing "with" electronic sound in a common acoustic sound field. When I transform my voice through sampling and processing to an electronic signal diffused through loudspeakers, I am also singing "with" my mediated voice. From me, but not me. I am also singing "with" the real acoustic sound field of the venue.

Operatic voice training is geared to developing the ability to reinforce the signal in one's vocal tract, as well as to respond to the acoustics of whatever hall or performance location one is performing in. Classical and operatic singers are trained to work with the real acoustic sound field of the venue. We modify how we sing to resonate in a particular acoustic space; Tempi, timbre and projection all change depending on the acoustic properties of the space. The space itself also conveys semantic, emotional and theatrical information.

> As is known from real-world experience, little or no reverberation indicates that the sound is located near by, while a great amount of reverberation leads to a diffuse

[3] It would be difficult to identify whether the singer was Dawn Upshaw or Birgit Nilsson according to their transients – unvoiced or voiced consonants - whereas identifying a High C sung by Birgit Nilsson versus Dawn Upshaw is extremely easy due to the recognizable quality of their spectral voiceprint.

> sound field of largely indirect sound, which informs us that the sound source is located far away. Reverberation also tells the listener that the sound is excited in an enclosed space, and a spontaneous image regarding type, size and acoustical properties of this space is formed (Henriksen 2002, 39).

In “Spaces Speak, Are you listening? Experiencing Aural Architecture” Barry Blesser and Linda-Ruth Salter explain:

> … as a rule, vision both decodes size as length, width and height, and organizes distance by the way objects obscure one another or change their relative size. In contrast, hearing decodes size as the global metric of volume because sound permeates air as a fluid, flowing around objects and into crevices. We cannot see volume, but we can hear it. Aurally we sense the volume of a large space by its long reverberation time and the volume of a small space by its sharp frequency resonances. Visually, we can sense volume only by mentally multiplying the three dimensions of space (Blesser and Salter 2009, 21).

In conversation with composer Cathy Van Eck in 2022, she described her usual mode of listening to electronic music over speakers as “inward”. She said the loudspeakers form a closed space for her similar to headphones. As she spoke she motioned with her hands over her head as if being covered with a dome or a large bubble. In contrast, she said that when I sang acoustically in one of my multi-vocal processing works, it was as if I was throwing the sound, bouncing it off the walls. It made her aware of listening to the actual place we were in. She was with me in the real world, and had questions about what was happening when my unamplified voice was being directed at various parts of the room, and my mediated vocals appeared in speakers on the other side of the room from where I was standing physically. Awareness of the outer world was amplified. She commented that in this case her listening was directed “outward”.

Choreographer Sally Dean also commented after listening to me sing with my live audio processing system in a multi-channel surround system in the main theater at KHIO February 2022, that my singing allowed her to perceive the properties of the specific place we were all inhabiting. She elaborated:

> *When you sing acoustically I get a sense of where I am. I am getting to know this place we are in through your sound. The place is coming to life; an environment – or atmosphere - is being made. I am not thinking about the distance between the speakers. It is not so much about space as about this place. When it feels like it is working I feel embodied and in the place. I am not attending to locations or spots, but the whole place is resonating and I am resonating with it. I hear that one sound is coming here, and another there, but it is more about the whole.*

The dramaturgy of dynamic space

In “Space in electroacoustic music-composition… ” Frank E. Henriksen draws on the work and concepts of anthropologist Edward T. Hall, summarizing Hall’s categories of space as Fixed-feature space (architecture), Semi-fixed feature (movable objects) and Dynamic space (interpersonal distance). Hall coined the term “Proxemics” for "the study of man's perception and use of space” and categorized dynamic space into four distance zones: Intimate, Personal,

Social and Public. Each category is characterized by particular distances, voice levels, and types of communication. (Harper et. al. 1978: 247-48; Hall 1990b: 116-25) At *Intimate* distances - from body contact to about 0.5 meters - the voice level is very quiet and communication is confidential. At *Personal* distances - from about 0.5 m to 1.25 m. (the distance at which people can touch each other if they reach out) - the voice level is moderate and the communication is personal. At *Social* distances - from 1.25 m to 3.5 m – voice level is a little louder, communication is non-personal and may be audible for others to hear. At *Public* distances - from 3.5 m and up - the communication is addressed to a group. The voice needs to be raised or amplified and the subtleties in a normal speaking voice are lessened (Henriksen 2002, 113).

Opera performance operates in a setting of public distance, but the theater of opera engages with all 4 distance zones: performing (at a public distance) intimate, personal, social and public interactions. The subtleties of normal spoken voice and language that change according to these 4 distance zones, are expressed through musical subtleties rather than spoken inflection. This juxtaposition of different distance zones allows us to collectively experience intensely personal and/or powerful interactions at a safe distance. Interestingly, amplifying the voice, also allows a juxtaposition of different distance zones. With amplification we can hear intimate whispering even in a large public venue. It can create a surreal effect when a disembodied voice is being heard in an intimate way in a large space, but since the intimate disembodied voice is diffused through a speaker system that can also create a form of distancing and safety. For the composer of either electronic music or opera, being aware of the effects of distance and nearness, and various ways to creatively mix distance zones is important.

> The articulation of distance and nearness is an important aspect of spatio-musical structure that needs particular attention in diffusion. This is especially true when dealing with works which play with psychological space and personal distance. It can be problematic to transfer successfully to the concert hall a composition in which spatial intimacy plays an important role. Although sound material such as whispering and other close-up recordings may indicate a certain proximity to the sound source, the size of the concert hail and the physical distance to the loudspeakers may contradict such an indication (Henriksen 2002, 103).

Frank Henriksen also makes a distinction between *Extrinsic space* - which is focused on the sounds *in* space and the spatial relationships *among* sounds - and *Intrinsic space* - which is focused on the spatial characteristics of the sounds themselves. He points out that Time-stretching techniques can direct attention towards the sound's intrinsic space by making their inner spectral components become much more apparent, while pitch based compositions are more likely oriented to extrinsic space (Henriksen 2002).

With the EVII, I sense the shortest delays like effects on my voice, changing the timbre of the voice. (Intrinsic space.) Drawing a sound out with time-stretch through small gradual increases in the delay times can also be perceived as an effect as it morphs the quality of the sound; an exploration of intrinsic spatial qualities. The interaction between time and space also affects compositional structure. My longest delays feel like compositional structural elements. I can create a bass line that can be repeated, or a long melody that I can either repeat, or draw from to create motivic elements or quick ornaments. (Extrinsic space.)

Explaining the acoustic phenomena behind this, Henriksen writes:

> Because the reflected sound waves travel different distances, they arrive at the listener's position at different times. Reflections that arrive within 20 ms of the direct sound are perceived as part of the original sound wave, and will therefore directly influence the spectral quality of the sound. Reflections travelling within 50 ms to the listener's position are heard as reverberation, whereas intervals longer than 50 ms result in discrete echoes (Henriksen 2002).

I explore the places I sing in. With the EVII, I can move in the space to explore it acoustically, and send my mediated vocals out to loudspeakers to explore the space in a way that I cannot using only my embodied voice. This has allowed me to listen to and experience spaces in a different way. I have placed speakers high up over the audience, and on the floor in the middle of the audience, and at the outer edges surrounding the audience, and even had performers and audience members move small speakers physically through the locale. All those differences have given me different information about the space and different possibilities to play with it. When I used micro-speakers, portable Bluetooth speakers or the metallic coil glove speakers for example, I or others moved through the audience, engaging them to be more physically involved with the performance and aware of the space we inhabit together.

Examples related to space and speakers

Video documentation of these works can be found here:
https://www.researchcatalogue.net/view/2222429/2222430

Spatializing experiments with Pablo Gastaldello

Kristin Norderval - Voice, vocal processing with Genki Wave Rings in Max/MSP
Pablo Gastaldello - spatializing with Genki Wave Rings in Ableton, Meyers surround

(Recorded with binaural microphones. Please listen on headphones)

While in Den Haag I discovered that Pablo Gastaldello, a Master's student at the Royal Conservatoire The Hague, was also using Genki Wave Rings to control sound processing, in his case for spatialization of sound in a multichannel environment. Conversations with Pablo led to a series of shared experiments in joint spatializing and processing with Genki Wave Rings.

It was interesting to explore strategies with Pablo for spatialization in different contexts and different acoustic spaces. Our collaboration gave us each an opportunity to explore ways to integrate sound spatialization in situations when both processed and acoustic sound sources are used together. Pablo was intrigued by my insistence on avoiding the use of microphones to amplify my voice. We observed that when my acoustic voice and my processed vocals were sonically similar, it made the spatialized movement of the processed signals more difficult to perceive. One of Pablo's strategies in that case was to create a control on the distance parameter of sound sources, to enable greater dynamic contrasts between the processed sound signals and the acoustic voice. My strategies were either to lean into the similarity and explore the nuances in the chorusing, or to play with contrasting percussive sounds that could be more easily perceived. In listening back what stands out to me is the

clear difference between my acoustic voice reverberating in the actual space of the room, which was fairly dry, and Pablo creating a different sense of space with my processed vocals through his use of digital reverberation.

We also observed that through the physical movements of our processing, we could intuitively sense the directions the music was headed, and thus the gestural processing became a communication between us, not just a Human-Machine Interaction. I made note of the fact that Pablo also needed an "off" trigger. In his case the necessary "off" was an activation/deactivation trigger that allowed him to pause the reception of data from the Genki Wave Ring if he needed to interact with his track pad or other hardware.

***Future Past* - Studio Loos, Den Haag, NL, December 13, 2021**
Part of ABUNDANCE: LOOS Presents Eleven Days of Diversity to The Hague!

Kristin Norderval – Voice, augmented piano, audio processing with the EVII

In *Future Past* I wanted to explore the sonic features of an augmented piano; a piano used to diffuse electronic sound through a transducer mounted on the soundboard. This built on my experiments with augmented instruments during the workshop for opera students in Oslo the previous year. My experiments with space in this piece had to do with both the acoustic sound field of Studio Loos, and the reverberant space within grand piano itself.

Future Past was created for a friend whose brother was dying; he was in the last stage of battling cancer, and was sleeping a lot. I wanted to explore issues of balance, chance, and other-worldliness. The sounds that I could get by diffusing my mediated vocals through the transducer in the piano sound board gave me the timbre I was looking for. It functioned as a filter, dampening lower frequencies. It sounded like a small distant voice, stuck in a small reverberant space. A combination of chance and skill determined whether I could balance a wooden pin on the strings. Or not.

***This Time Now* – for vocal quartet and electronic processing,**
Royal Conservatoire The Hague Concert Hall, Amare, Den Haag, NL, May 2022

Kristin Norderval - Voice, vocal processing with the EVII, hemispherical speakers
Gerriet K. Sharma - Live electronics, with the IKO 3D speaker
Mar Pino-Charlez - Soprano
Joao E. Silva - Baritone
Meie Oei - Soprano (offstage)

At the end of a 3-day workshop with student singers from the vocal department at the Royal Conservatoire The Hague, and student composers from the Institute of Sonology, I presented a piece created for and with three of the vocal students in the classical concert hall. After an opening of electronic sounds from Gerriet Sharma diffused through his 20-sided IKO 3D loudspeaker followed by a short solo from me that led into vocal processing, my score called for the other singers to begin singing from the upper balcony surrounding the hall, and to continue singing while they walked slowly towards and down the stairs to join me onstage for

the end of the piece. I processed my vocals in my hemispherical speakers, and Gerriet Sharma processed and spatialized prerecorded sound (both vocal and non-vocal). I was curious how the balance would be between my acoustic vocals, my mediated vocals in the hemis, the electronic spatialized sounds from the IKO, and the singers singing acoustically and self-spatializing in the hall. Members of the public reported that it took them awhile to realize that there were live singers entering the sonic field. I took that as an indication that we had achieved a good level of balance.

***Place, Manner, Time* – Studio Loos, Den Haag, NL, May 7, 2022**
https://www.loosdenhaag.com/agenda/place-manner-time-by-kristin-norderval

Kristin Norderval - Voice, live electronics, wireless controllers
Gerriet K. Sharma - Live electronics, IKO 3D speaker
Anja Hertenberger - Performance, Interactive textiles/coil speakers
Mar Pino-Charlez - Voice, wireless controllers

Place, Manner, Time was a concert of works developed to resonate the space of Studio Loos with the acoustic voice and through multiple speakers including the IKO 3D speaker, hemispherical speakers, and specially designed micro-speakers created from metallic thread coils.

I invited Berlin-based composer Gerriet K. Sharma to join me, along with interactive textile artist Anja Hertenberger, and the young Spanish opera singer, Mar Pino-Charlez. Anja Hertenberger had developed a way to receive and diffuse my mediated vocals wirelessly by creating small metallic thread embroidered coil speakers and attaching tiny Bluetooth receivers. She literally held my voice(s) in the palm of her hand, and presented them to listeners one by one. Exploring the use of a portable Bose SoundLink Micro Bluetooth speaker, soprano Mar Pino-Charlez and I also traded holding each other's mediated vocals in our hands. We explored changes in timbre as we placed the speaker to reflect off of various material surfaces: the wall, our bodies, a glass cup.

On the same concert Gerriet Sharma diffused sound through his IKO 3D Audio Speaker by IEM & Sonible: a 20-sided compact speaker system based on Higher Order Ambisonics (HOA). The IKO offered a very different way of working with spatialized sound. Using complex algorithms that work with phase and delay times, the IKO is able to send focused sound beams in any direction. Using wall and ceiling reflections to establish a distinct sound space in any location, it can produce high quality immersive sound even in small spaces. Working with the IKO felt very much like an inverse hemispherical speaker. The immersive sound was easy to sing with. Even at high volumes it felt like there was space for the acoustic voice.

Queering Time
Kristin Norderval and Maria Lothe, Fotogalleriet, Oslo, September 17, 2022

Kristin Norderval – Voice, live vocal processing with the EVII, hemispherical speakers
Maria Lothe – Dancer

During Oslo Art Weekend in 2022, Fotogalleriet presented me in concert in connection with their project "Queer Icons". I performed the concert *Queering Time* with guest dancer Maria Lothe. The "Queer Icons" project marked the 50th anniversary of the decriminalization of homosexuality in Norway through an exhibition, a book, and a series of events produced by Fotogalleriet in Oslo. Featuring photographs by Fin Serck-Hanssen and writings by Bjørn Hatterud and Caroline Ugelstad Elnæs, "Queer Icons" depicted leading figures from the queer environment in Norway who were born before 1970 and who fought against discriminatory structures in Norwegian culture and society. Antonio Cataldo, Artistic Director of Fotogalleriet, was curator of the "Queer Icons" exhibition. My concert was produced by program curators Håkon Lillegraven and Miki Gebrelul for Fotogalleriet.

The gallery space at Fotogalleriet has a low ceiling but is quite reverberant with many reflective surfaces. I used my hemispherical speakers in a quad set up and I moved into various spaces in the gallery to explore variations in the acoustic sound field and reflections. This included moving into and singing from a separate room beside the main gallery.

In this concert I explored strategies for three separate improvisations with the EVII. The video excerpt on Research Catalogue exhibits the strategy of structuring quiet sounds into longer samples, using time stretch and spectral freeze to draw out the spectral characteristics of those sounds and create drones and other sonic material over which I layered an intimate solo.

Working with a vocal drone created through delays and time stretching or through spectral freeze, means also working with the contrasts between acoustic sound and electronic sound regarding variability. There is a constant variability in any sustained acoustic sound, even if to our ears it sounds like a sound without change. The micro fluctuations are precisely what make us recognize a sound as acoustic, or a voice as human. As Trevor Wishart reminds us in Audible Design:

> Apart from grain-duration sounds, once a sound has been initiated it must continue to evolve in some way. Only contrived synthetic sounds remain stable in every respect (Wishart, 1994, 48).

Human singers are not able to achieve an exact replication of a periodic signal acoustically. On the other hand, exact replication of a periodic signal is a primary element in electronic music. Some of the singers I worked with referred to their sampled voices as robotic or "dead". They could clearly hear that the disembodied looped voices were electronic, not acoustic. One way to keep the signal alive is by adding new source material. Another is to program constant random changes. The gestural mapping in the interface creates a constant fluctuation of the signal through a double pendulum principle. This adds the variability that keeps our ears attuned.

CONCLUSIONS

The goal of designing an interactive audio processing system that would meet the operatic voice on its own terms was the starting point of this research project. It arose from my curiosity as to whether some of the gaps between opera and electronic music could be bridged by creating a wireless performer-controlled vocal processing system for opera singers.

Refinements and technological advances for sensors and controllers have progressed amazingly quickly in the last few years. When MIDI-based software systems were replaced by digital signal processing systems at the turn of the millennium the interest in gestural controllers for real-time sound processing blossomed. Two decades later there are now many new developments manifesting. Three important new books on performing with gestural controllers appeared in the last two years alone. In 2022 Marije Baalman summarized her decades of experience building and designing interactive systems in her book *Composing Interactions: An Artist's Guide to Building Expressive Interactive Systems* (Baalman 2022) and Mary Mainsbridge published *Body as Instrument: Performing with Gestural Systems in Live Electronic Music* (Mainsbridge 2022).

In early 2023 Franziska Baumann's book *Embodied Human-Computer Interaction in Vocal Music Performance* was published (Baumann 2023). I was honored to have my work with the EVII in *Flying Blind* profiled in Franziska Baumann's book. Baumann outlines different conceptual approaches that gestural performers take in their work with embodied and mediated voices. Discussing her own work with her SensorGlove developed at STEIM, together with the work of Alex Nowitz, Pamela Z, Atau Tanaka, and myself, Baumann summarizes and categorizes different strategies for working with gestural systems and embodied human-computer interaction in performance.

Mary Mainsbridge also focuses on artists' subjective experiences regarding their gestural performance practices. She describes in first person narratives how experiential design strategies are used by practicing artists across genres to develop gestural systems that mirror their movement habits, preferences, and skills. Using the body-as-instrument metaphor she analyzes the relationships between performers, their bodies and their self-designed instruments. Mainsbridge points as well to the suitability of gestural controllers for vocalists:

> The close relationship between voice and movement in verbal communication, as well as vocal performance, has made gestural interfaces for voice one of the most attractive and compelling subsets of gestural performance. From early pioneers, Michel Waisvisz and Laetitia Sonami, to Elena Jessop, Donna Hewitt and Imogen Heap, vocalists across genres are embracing gestural control of digital audio effects, sample triggering and looping. Gestural systems are ideally suited to vocal processing as they allow the performer to maintain eye contact with the audience while manipulating the timbre of the voice. Vocalists are able to harness their ancillary and expressive motions to augment and enhance a vocal performance (Mainsbridge 2022, 69).

In *Postopera: reinventing the voice-body* Jelena Novak examines how contemporary composers have been using the amplified and mediated voice in opera in innovative ways (Novak 2015). And yet, with all this recent interest a large gap remains between the creators of new opera and those who are trained to sing it. During the course of this research I witnessed recurring tensions due to a significant interest in voice and technology from

composers at the Norwegian Academy of Music and reticence from the singers at the Academy of Opera toward amplification. The fact that I was designing a system that did not require amplification made it more acceptable as a way of engaging with technology, but only marginally so. I was often surprised at the resistance I encountered from some of the young opera students I worked with, students who have grown up with electronic music of all kinds. I came to see that familiarity with electronic music does not necessarily translate to comfort working with it in practice. Even though vocalists who work with gestural controllers may be a compelling subset of gestural performers (Mainsbridge 2022), working with the electronically mediated voice is still seldom sought out by opera singers.

I understand on the one hand that the time and effort it takes to build ones instrument as an opera singer leaves little time for creating and learning the new technology necessary for gestural performance. Most of the artists working with interactive vocal processing have developed custom-built systems over long periods in research contexts or for specific projects. The lack of standardized systems and cross-purpose applications presents a challenge to those new to the field. Other challenges are the relative instability of much of the technology in development. The Bluetooth wireless technology that the Genki Wave Rings rely on for example, is not yet stable enough to be trusted in a large opera house where everything must function properly and reliably for every show. During rehearsals for *Crane Reflects on a Favor* we needed on occasion to reconnect the Genki rings from the computer at the soundboard when the Bluetooth signals had disconnected, due to either distance or interference from other Bluetooth applications. Working with the Genki Wave Rings in the EVII met the requirements for mobility, but since they are still vulnerable to losing signals over longer distances, concert performances where one can maneuver back to the laptop if necessary, are still safer than staged works.

Since gestural instruments designed for specific projects are not easily accessible to others, and one needs a tolerance for instability, it is perhaps not surprising that the strongest interest in this artistic research on augmenting the operatic voice with gestural controllers has come primarily from other designers of interactive systems: other gestural performers, both instrumentalists and vocalists, but not necessarily opera singers. In the last decades there has been a significant increase of interest in stretching the boundaries of opera, not so much from those in established opera houses or educational institutions but from composers and producers interested in expanding performance possibilities in opera and from adventurous performers wishing to explore new ways of creating work: artists on the border between rigor and risk, tradition and innovation.

Unfortunately, the field of opera as a whole still focuses primarily on an extremely limited historical portion of the operatic repertoire. As I write my conclusions in this reflection, the 2023 Queen Sonja Singing Competition has begun. A look at the repertoire that 39 opera singers from around the globe are presenting reminds me of the enduring and enormous gap not only between opera and electronic music, but between opera and contemporary music of any kind. In the Queen Sonja Singing Competition, each singer presents 10 selections in different styles and periods for the jury to choose among: six operatic arias and four art songs. Out of a total of 390 works, only six were by living composers and all of these were art songs. Among the opera selections there was not one work by a living composer. Diversity was also almost non-existent. The works of one Black female composer, two Mexican male composers, and five White female composers were represented, most of these historical, and all art songs, with the exception of one aria by Mexican composer Daniel Catan.

Despite the fact that small scale opera and hybrid operas are a fast growing trend, especially after the pandemic years where digital work was the only available outlet for performance, most mainstream educational institutions are still only teaching old and outdated repertoire. A pedagogy that emphasizes total control and getting it "right", makes it hard for students to willingly enter a playful approach to improvising and exploring new sonic possibilities where getting it "wrong" might lead to interesting sonic results. The young singers who did dare to work in this new way, commented that it was liberating not to have to always sound "pretty".

The EVII has expanded my understanding of my improvisational strategies and it has expanded how I teach vocal improvisation. Among improvisers, being in the here and now is all important. Although I composed specific musical material for *Crane Reflects on a Favor*, I also left numerous portions open for improvisations with the EVII. In an improvisation, whether structured or free, in order to make spontaneous musical choices in response to what is happening musically one can't be set on a pre-determined plan. Through this research project I have come to think of and explain the "here and now" as literally space and time. Giving my focused attention to where I am, to the properties and conditions of the place that my collaborators and I are in and listening intently to what is happening here at this moment, I can be fully present. If I recall what happened a moment ago, or a minute ago, then that past event is also in the here and now. If I change the parameters so that the sonic artifacts transform in future iterations, this imagination in my mind, whether focused on an extremely short length of time ahead or a very long one, is also in the now. This is essentially what my interface is doing as well: listening to everything, reintroducing past events at variable lengths of time, and setting the time at which present events will be brought back in the future in transformed and altered versions.

Since the EVII frees the performer to move, embodied and disembodied voices can work together in a different way in the space, exploring the ways that the reverberations in that space function, exploring the resonance of the room, exploring the space through time, exploring relationships with other performers and with the audience. Working gesturally with the EVII has opened a new way of mediating between embodied vocals and electronically mediated vocals. Not only does it add a distinct physical presence and visual element to performances but it adds aleatoric elements that require improvisatory response. It extends the practice of "comprovisation", thinking structurally to be aware of past, present and future simultaneously while being prepared to spontaneously change direction if the sonic material calls for that.

The unmediated operatic voice is a monophonic audio signal. Through real-time sampling live vocal feeds can be transformed to fixed media, creating sonic objects that can be manipulated and processed to create multiphonic, multi-timbral compositions and improvisations. With the EVII the sounds created by processing the voice can be perceived as vocal effects or an instrumental accompaniment to the solo voice, or even as an improvising partner, depending on processing strategies. I hoped with this work to expand the audio palette and expressive possibilities in opera, and I think I met that goal.

Performing with the EVII, the roles of singer, composer, conductor, instrumental ensemble, and sound technician collapse into one another. This automatically builds agency and independence for singer-improvisers, which was another primary goal. This way of working challenges existing hierarchies in the music business and will ultimately lead to the necessary changes in the genre as performers begin to explore their own expression.

This artistic research project allowed me to investigate the integration of interactive audio processing in opera in connection with an opera I had started working on with librettist Julian Crouch, and a second opera developed later with fellow improvisers. The interactive audio processing in both of these operas were performed by singers other than and/or in addition to myself, and thus my pedagogical goals were also successfully fulfilled.

I had planned to design and implement an interactive system, teach it to others, and incorporate it in three specific short sections of an opera. Instead, working with and designing this new system taught me about the path I have been on over several decades, revealed new paths to explore, and resulted in a new hybrid multi-vocal instrument. The EVII has afforded a rich new language of gestural performance and has become a primary performance instrument for me. Taking on the challenge of designing an interactive audio-processing and sound design system that could accommodate the unamplified voice *and* electronic sound, facilitate mobility in a dramatic performance and allow the choice making of the performer to be based on aural rather than visual cues was both more challenging and more rewarding than I anticipated. It is an ongoing project. As someone trained in the rigorous art of operatic singing and simultaneously drawn to artistic expression connected to the times we live in, I look forward to further opportunities to create hybrid work that draws on both of these interests.

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Appendix

List of works created during the Artistic Research period

1. *Motherlove* (2020) – for SATB choir and cellphones
2. *Flying Blind* (2020) – solo with mediated voices
3. *Island* (2022) - Music for video *Renewable Rikers*
4. *Future Past* (2021) Studio Loos – voice, mediated voices, augmented piano
5. *This Time Now* (2022) – vocal quartet, live electronics, spatialized singers
6. *Home* (2022) - Korzo, Den Haag, with Myra-Ida van der Veen & Anja Hertenberger
7. Norderval/Van Bergen Duo (voice and reeds, EVII and Mi.MU processing)
8. *AnimariAnimate* (2022) - quartet with Limpe Fuchs & Co, Kulturkirken Jakob
9. *Queering Time* (2022) – duo with dancer Maria Lothe, Fotogalleriet
10. *Timewrap* (2022) – solo, MuseumNacht, Studio Loos, Den Haag, NL
11. *Constraints* (2022) – MuseumNacht, Studio Loos – Norderval/Van Bergen/Bollen
12. Trio with Peter Van Bergen & Leslee Smucker (2022) - MuseumNacht, Studio Loos
13. *Norwalk 2* and *Norwalk 3* (2022) – duo improvisations with Miguel Frasconi
14. *Re-Seeding: Part 1 (Self)* (2023) jill sigman/thinkdance – music for dance
15. *The Sailmaker's Wife* (2021) –excerpts at SALT, VoxLAB VårFEST, Aug 2021
16. *Crane Reflects on a Favor*, Part 2 of *The Sailmaker's Wife* (2023) – VoxLAB VårFEST 2023

Public Lectures & Seminars

Art and Trauma – Public symposium, Kunsthøgskolen, Oslo, Norway, Dec 2019

International Conference of Live Interfaces (ICLI), Trondheim, Norway, March 2020

Conversation with Franziska Baumann – Video Interview, 2021

Renewing Opera – symposium with Franziska Baumann, Alex Nowitz, Oslo, Aug 2021

Midterm presentation – Studio Loos, Den Haag, Netherlands, May 2022

Nuts and Bolts – presentation of my work with Max/MSP – Oct, 2021

Renewing opera through collaborations with young performers – Symposium, Aug 2022

Keynote - International Conference on the Performer-Composer, Orpheus Institute Oct 2022

Queering Time - WoNoMute, University of Oslo, Feb 2023