

Performing Performance Spaces: Expressing Context in Live Music

by

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School of Architecture and Planning,
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Abstract

From basements and living rooms, to bars and clubs, to stadiums and arenas, the spaces that become venues for music performances bring with them unique features that can present sound reinforcement challenges. This is especially the case with smaller, lower budget community-run or pop-up performance spaces, which may display more non-ideal characteristics like a higher electrical noise floor or unique acoustics. Qualities like these, coupled with the people occupying the space, distinguish one performance context from another—to a band on a long tour or to an audience member attending many shows in the same city.

This thesis is structured around a series of live concerts using a digital audio processing system that captures, exaggerates, and reproduces unique acoustic qualities of the spaces where the concerts are taking place. This allows performers to exaggerate these qualities expressively by modulating their prominence with a MIDI controller.

The concerts feature performances by the author as well as local Boston-area musicians. They aim to encourage their participants, both musicians and audiences, to share a musical experience that fosters awareness of context, the here and now, and shows the significance (in music and beyond) of the places we occupy and the people we share them with.

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1 Introduction

Our relationships with the places we inhabit have long been inseparable from their auditory imprints, such as reverberation in a Gothic cathedral, chatter in a bustling marketplace, or a birthday song in a kitchen. These sonic signatures, and the way they resonate in the space that holds them, serve as markers of what is familiar, and frame our relationships with places and what we expect to find within them.¹

The spaces that become venues for music performances carry with them unique features that can present sound reinforcement challenges. For many acts, especially in the world of popular music, performances take place in spaces not built for music, with even major tours opting instead for sports stadiums which are designed to accommodate more

people.² This comes with a trade-off in sound system complexity to adapt to the acoustics of a huge, reverberant space full of unwanted resonant frequencies. On a smaller scale, many acts perform in makeshift venues in residential basements or living rooms, or in bars and clubs that have not been acoustically treated.³

These smaller, vernacular, unconventional performance spaces, especially those used for pop-up or community-organized performances, display characteristics that present challenges for sound reinforcement. A higher electrical noise floor can interfere with amplifiers and create unwanted buzzing, for example, or some acoustic features can create resonances that make it difficult to amplify microphones without causing feedback. Qualities like these, coupled with the behavior and composition of the group of people occupying it, are also part of what distinguishes one performance context from another for individuals in the space—from a band on a long tour to an audience member attending many shows in the same city. Furthermore, these venues often create a sense of community between their occupants, performers and audiences alike, functioning as social environments as well as room for artistic advancement.⁴

1. Algargoosh et al., “The impact of the acoustic environment on human emotion and experience: A case study of worship spaces.”

2. Bloomberg, “Making Musical Magic Live.”

3. Kronenburg, “Sound Spaces.”

4. Murphy, ““Lost in the Noise” DIY Amateur Music Practice in a Digital Age.”

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I have been putting on music shows for almost my entire life. As a performer, I started out as part of an acoustic duo project, Borneo,⁵ which has performed at major venues in Buenos Aires, Argentina such as the Centro Cultural Recoleta,⁶ as well as more intimate ones, like the NEMPLA auditorium.⁷ In Boston, I have been part of shows in informal settings, multipurpose rooms at churches and at the Media Lab, small clubs like Cafe 939 at Berklee College of Music,⁸ and more established venues like Shubert Hall as a supporting act.⁹ As a sound engineer, I have contributed to performances in various places like black box theaters,¹⁰ concert halls,¹¹ rooms not meant for music performance at MIT,¹² and churches. The variance in the sound and feel of all these types of venues has been a main source of motivation for my research work.

In this thesis, I take into consideration in-person experiences with music as places of collectivity: the idea of “classic liveness” as presented by Philip Auslander, “physical co-presence of performers and audience; temporal simultaneity of production and reception; experience in the moment”.¹³ This idea serves the interest of investigating the sense of space (perceived and conceived¹⁴) and identifiable place¹⁵ involved in live music, its fleetingness, and the experience of occupying it with others. The project is structured around live performances that encourage their participants to pay attention to the physical context where these experiences are taking place, and explore that context through acoustic exaggeration and transformation (described in Chapter 5), collective experiences, and individual reflection.

The work described in this thesis is also documented on the companion website, which includes video and audio, as well as a software download for the *Performing Performance Spaces (PPS)* acoustic exaggeration system: <https://pps.media.mit.edu>

5. Schon and Monk, *Borneo*.

6. *Festival Clave - Día 2*.

7. *Borneo on Instagram*.

8. *Berklee Songwriting on Instagram*.

9. Julieta Venegas, *With Special Guest Ana Schon at Boch Center Shubert Theatre*.

10. Machover, *Project Overview* < VALIS.

11. Machover, *Overstory Overture*; Machover, *FLOW Symphony*.

12. Shand and Cherep, *ORGANOLOGY*; Shand, *Transmutations*.

13. Auslander, *Liveness: Performance in a Mediatized Culture*.

14. Lefebvre, Nicholson-Smith, and Lefebvre, *The production of space*.

15. Kronenburg, *Live architecture*.

2 Background

This chapter provides background to the overlapping contexts and theoretical elements that make up the basis of this project. It addresses definitions and implementations of key room acoustics and acoustic perception concepts, as well as background from performance studies and ethnomusicology work that shapes the language used in this thesis. Next, it contextualizes this work with other related commercial, music technology research, and artistic projects.

2.1 Acoustic Perception

Acoustics research has long inquired into audience perceptions of spaces' sonic characteristics. Studies as far back as the early 1900s have sought to define the best acoustics for musical applications, such as Sabine's study in the design process of Boston Symphony Hall.¹ Later works² link various measurable qualities of concert halls with subjective acoustic perceptions.³ Several of these studies⁴ use variations on the semantic pairs of opposite labels as defined by Wilkens.⁵ For example, rating between "brilliant" or "dull" could be associated with the treble ratio of a room. Having common language and definitions to describe acoustic features helps us understand how they affect perception.

An acoustic space is generally characterized in relation to how sound waves travel through the air inside it (which can vary with humidity and temperature, for example), as well as how they reflect off (and are absorbed into) its surfaces and create reverberation, which can vary based on the shape and size of the spaces, and the materials that constitute the surfaces. All of these features define how much, and how long, sound reverberates in the space, a quality named reverberation time. It is generally referred to as T , with some characterization of which aspect of T is being measured, whether that is more general for the whole frequency spectrum, or a specific part of the signal in the frequency or time domain.

1. Sabine, "Architectural Acoustics."

2. Beranek, *Music, Acoustics & Architecture*.

3. Hawkes and Douglas, "Subjective Acoustic Experience in Concert Auditoria."

4. Sotiropoulou, Hawkes, and Fleming, "Concert Hall Acoustic Evaluations by Ordinary Concert-Goers: I, Multi-dimensional Description of Evaluations."

5. Wilkens, "MEHRDIMENSIONALE BESCHREIBUNG SUBJECTIVER BEURTEILUNGEN DER AKUSTIK VON KONZERTSAELEN."

Some of the most significant time-domain parameters of room acoustics measurable from captures of the room's reverberant sound, according to⁶ are:

1. **Reverberation Time**, defined as the time it takes the sound level in the room to decay by a certain amount. Although initial calculations were for 60 dB of gain decrease, in practice this parameter is commonly calculated for 20 dB or 30 dB of reduction after the sound source has stopped emitting (which is understood to be

when the gain is around 5 dB below the start value). This is because the noise floor in many spaces will simply be too high to accommodate a 60 dB difference. The time for a certain gain decrease (*gain*) is still calculated in relation to 60 dB, by the equation

$$T_{gain} = \frac{60\text{dB} (t_{-gain-5}) - (t_{-5})}{(-5\text{dB}) - (-gain)}$$

, multiplying 60 dB by the time it took for the sound to decrease by *gain* (with t_x being the time at which the gain is xdB), divided by how much the *gain* decreased.

2. **Early Decay Time**, which also defines a decay measure, but of the initial part of the decay curve between 0 and -10 dB.

$$\text{EDT} = \frac{60\text{dB} (t_{-10\text{dB}})}{-(-10\text{dB})} = 6(t_{-10\text{dB}})$$

This measurement correlates more directly than T with the “*reverberance* perceived during running speech and music”,⁷ (as opposed to T only really being audible when the source has stopped emitting). However, it varies more than T between different locations in the acoustic space.

Other important acoustic parameters, which are taken into account less explicitly in this thesis are:

4. **Clarity** (C_{50} and C_{80}), which describes the separation between all the signals’ individual perceptibility, rather than blurring together in later reverberation by measuring

6. Gade, *Acoustics in Halls for Speech and Music*.

7. Gade.

“the ratio between energy in the impulse response before and after 80 ms”(or 50 ms depending on the definition).

5. **Gravity Time**, the center of gravity of the squared IR, defining the balance between early and late reflections,

6. and **Sound Strength**, the difference in dB between the same source in the measured room and in anechoic surroundings, which becomes “a function of T as well as room volume.” Measuring this parameter requires a measurement of the test signal in an anechoic chamber,

Some key timbral (frequency-domain) parameters are the **bass ratio** ($BR = \frac{T_{125\text{Hz}} + T_{250\text{Hz}}}{T_{500\text{Hz}} + T_{1000\text{Hz}}}$) and the **treble ratio** ($TR = \frac{T_{2000\text{Hz}} + T_{4000\text{Hz}}}{T_{500\text{Hz}} + T_{1000\text{Hz}}}$), where T_x is the reverberation time at the frequency defined by x . Both measure the reverberation time for their respective band in relation to the reverberation time for to mid-range frequencies.

There has been significant research into what types of acoustics people prefer, such as Ando’s landmark 1985 study⁸ of concert hall acoustics and subjective preferences for listening. Others have focused on musician preferences, for example Redman’s 2023 study of singers’ perception.⁹ Kuusinen et al.¹⁰ find listeners divided into two types: one preferring venues with a “louder, enveloping, and reverberant sound,” and one preferring more “proximate and clear sound,” although both vary with the type of music being played. Although the former aspects are directly correlatable to standard parameters of room acoustics, “proximity” is not as easily defined. The heterogeneity in preference indicates that there may not be an easy objective definition of “good” acoustic sound.

Furthermore, research in audience and musician acoustic preferences and perception tends to focus on concert halls designed for unamplified classical and academic music; there is a comparatively small body of work in this field relating to popular music-centric

8. Ando and Schroeder, *Concert Hall Acoustics*.

9. Redman et al., “Singing in different performance spaces.”

10. Kuusinen et al., “Relationships between preference ratings, sensory profiles, and acoustical measurements in concert halls.”

venues (where the sound tends to be amplified), or alternative spaces where music is performed.

Niels Werner Adelman-Larsen claims that before the year 2010, there was “no proper research” in acoustic perception for pop and rock concerts.¹¹ This gap motivated a long term study of musician and audio engineer preferences for pop and rock hall acoustics, and development of a series of recommendations for suitable reverberation time-frequency ratios for halls featuring amplified music. Adelman recommends low reverberation times in lower frequencies (specifically in the 125 Hz range), and higher in higher frequencies, claiming that this helps achieve “togetherness” since the musicians on stage will hear more of the frequencies that make up human voice and applause from the audience. He strongly recommends against a flat frequency response.

In 2023, this research was complemented by an investigation into jazz venue acoustics with preference surveys from musicians in the jazz community.¹² This found preferences that do not align closely with those from classical musicians and audiences; for example preferences in bass ratio being much lower for jazz musicians.

It is clear that appropriate acoustics vary widely depending on style of music and type of venue, and that they can generate varied environments that suit different types of interactions with the music. However, even with these studies, acoustic perception research for popular music focuses more on musicians and sound engineers rather than audiences, leaving open questions about acoustic effects on their aural experience.

Recently, researchers have also focused on how spaces evoke affective or emotional responses in listeners. A 2022 study by Algargoosh et al. found listeners to have stronger emotional responses to specific types of simulated acoustics, in particular highly-reverberant religious spaces.¹³ In their study, the same recording played in these virtual acoustic environments was “generally rated higher in terms of intensity of spiritual emotions than dry

11. Adelman-Larsen, *Rock and Pop Venues*.

12. Scott, “Foundations in Aural Architecture of Jazz Venues: An Examination of Room Acoustics & Multidimensional Analysis of Musician Preference.”

13. Algargoosh et al., “The impact of the acoustic environment on human emotion and experience: A case study of worship spaces.”

miliarity with the spaces, showing the strongest impact on those “very familiar” with this kind of acoustics. At the same time, other research suggests that it is not uniquely the sound of spaces, but the combination of visual, embodied and contextual components that creates convergent emotional responses, as explored by Coutinho et al.¹⁴

The way acoustic features frame human and musical interactions within a space has been shown to be significant across history, both in emotional impact as described above, but also for its effect on the activities that happen within it. In terms of worship spaces and their music, in the 17th and 18th centuries, Lutheran churches began having shorter re verberation times than their predecessors. This meant that music blended together less, enabling faster tempos than previous liturgical music, as audible in the contrast between plainchants from the Middle Ages or Renaissance, and works by J.S. Bach,¹⁵ as well as clearer perception of intricate counterpoint with interior voices as in Bach’s instrumental music. Although the purpose of the music was similar, the way it sounded, both in content and context, had changed.

But this relationship may be much older—ongoing research by Kolar et al.¹⁶ on cave systems occupied and intervened by humans in the Upper Paleolithic period has been using acoustic captures to recreate the acoustic environment our ancestors may have experienced and “contemplate how the soundscape could have shaped their experiences, communication, and ventures into the enigmatic depths of the cave”.¹⁷ This could give us insight on the positioning of cave paintings, how these spaces were used, and their impact on their occupants, and imply that the interrelationships between sensory modalities may have been much closer, and more consciously constructed, than previously understood.

This research frames important tendencies about audience and musician perceptions of acoustic context, showing some common ways their aural and emotional experiences are affected by these factors. It presents compelling resources and gaps in ways to intention

14. Coutinho and Scherer, “The effect of context and audio-visual modality on emotions elicited by a musical performance.”

15. Beranek, “Music and Acoustics.”

16. Kolar et al., “From room acoustics to paleoacoustics.”

17. *What did they hear? PaleoAcoustics in Chauvet-Pont-d’Arc Cave.*

ally focus on the relationship between sound, space, and context in the development of sound projects.

2.2 Adopted spaces: Punk, DIY, and co-presence

During the quarantines and shutdowns of the COVID-19 pandemic, live music slowed to a halt. Some major acts were able to create virtual experiences retaining the real-time aspects of liveness,¹⁸ often within the world of multiplayer video games, a medium that had been starting to gain popularity in the years prior.¹⁹ Others performed virtual, live streamed shows, which had also been gaining popularity before the pandemic, and allowed them to continue working in their field, albeit in a very different setting. This phenomenon was described as “better than nothing”²⁰ by some, and a new opportunity by others, but a widely expressed feeling was that of missing co-presence and social interaction. There has long been a sense that these were important aspects of live music performance, and their significance was highlighted when it was not possible for them to be present.²¹

In his book *Live Architecture*, Robert Kronenburg examines how live music performance can create an identifiable “place” within a physical space delineated by aural and visual experience,²² distinct from the wider context and only existent while the performance is occupying it. The book makes distinctions between spaces that are **adopted** (designed for other purposes but informally used for music), **adapted** (modified to accommodate music performance), and **dedicated** (designed for music performance). Adopted spaces make up a significant amount of venues where music scenes start out; they may appear as soon as a stage or loudspeaker system is added to a public place, but do not even require that much—a musician busking on the street creates an adopted venue as well.²³

The practice of adopting spaces as venues is one distinguishing quality of “do it yourself” (DIY) and punk subcultures, which situate themselves around the edges of mainstream

cul

18. Auslander, *Liveness: Performance in a Mediatized Culture*.

19. Gerken, “Fortnite”; Roblox, *Suiting Up for Motion Capture | Twenty One Pilots Concert Preshow*; Dahir, *BTS’s Virtual Concerts Connected People On A Global Scale Not Seen Before The Pandemic*. 20. Green et

al., "How live is live?"

21. Auslander, *Liveness: Performance in a Mediatized Culture*.

22. Kronenburg, *Live architecture*.

23. Kronenburg, "Safe and Sound: Audience Experience in New Venues for Popular Music

Performance." 16

ture, often the edges of cities, sometimes in warehouses, sometimes in residential homes. The venues are managed by the same people that perform in them, sometimes with limited budgets and equipment that does not always meet their needs. In some cities they may be vulnerable in their informal status and susceptibility to being priced or chased out of their spaces.²⁴ In Boston, Massachusetts, after the Boston Globe published an article praising the local underground scene in 2023, organizers decided to pause performances²⁵ to mitigate the risk from overexposure. With many small commercial venues closing in the city during the pandemic and in the years following,²⁶ something like this comes as a notice of how fragile the city's musical infrastructure can be.

DIY scenes sometimes appear where there is no other space to do live performance,²⁷ or where that other space is inaccessible because of its cost.²⁸ It can also emerge because artists cannot find commercial outlets for their work, or in an active motion against a perceived mainstream that Lauren Flood identifies with Michael Werner's counterpublics.²⁹ These spaces are highly valued by the communities they serve, whether it is because they represent a shared set of values and/or because they serve as social and artistic hubs.

This philosophy of appropriating spaces for a short time, using already-existent materials, and adapting them for collective experiences of creativity and connection serve as reminders that live music is a transient experience heavily tied to its context, which does not necessarily require a sophisticated design process and large budget to leave a lasting impact on its participants. In this project, the "identifiable place" described by Kronenburg³⁰ as the environment that emerges from the aural and visual cues of a space occupied by a live performance is combined with the wider contextual elements (such as the role of a venue in a city) and intersects with the presence and behavior of the people occupying it to form a "performative place."

24. Flood, "Building and Becoming."

25. Arnold, "There's a gaping hole in Boston's live music scene - The Boston Globe." 26.
- McDonald, "Amid squeeze on musical ecosystem, an old Cambridge venue gets new life."
27. Murphy, "'Lost in the Noise' DIY Amateur Music Practice in a Digital Age."
28. Bennett and Guerra, *DIY cultures and underground music scenes*.
29. Flood, "Building and Becoming," Introduction - DIY Sociability.
30. Kronenburg, *Live architecture*.

2.3 Technology-mediated performance & audience experience and participation

In the intersection between the field of Human-Computer Interaction and live performance technology, there has long been an interest in building systems that allow a live audience to actively participate in the performance they are experiencing, for example to create unique performative outcomes dependent on behavior or movement of the audience³¹ by mapping sensors to sonic elements. These systems can also enable the audience to directly input musical material, whether that is before or during the performance, as seen in in *City Symphonies*,³² or to act as part of the ensemble, as with the *Tutti*³³ system. Sometimes, they make it possible to share control between audience, performers, and technicians. Tod Machover's *Death and the Powers*,³⁴ for example, used both biological sensors on its singers and data input by a simulcast audience³⁵ to modify staging, lighting, and sounds.

A major goal in building audience participation into live performances is for the augmentation of the audience's interaction to increase the sense that they contributed to the performance directly,³⁶ where their active "physical engagement strengthens the mental engagement and vice versa." This way, the role of the audience is not just in the generation of the specific performative place but as a consequential intervening agent in its content, whether or not technology is mediating.

Other work has focused on creating opportunities for reflection after a performance. These can be through quantitative³⁷ methods such as disagree-agree scales that allow the audiences to share their experience. They can also be qualitative,³⁸ for example asking open-ended questions about specific aspects of the performance.

31. Feldmeier and Paradiso, "An Interactive Music Environment for Large Groups with Giveaway Wireless

Motion Sensors.”

32. Van Troyer, “Hyperaudience : designing performance systems for audience inclusion,” Section 3.5: A Toronto Symphony.

33. *Tutti – Music Technology at MIT.*

34. Torpey, *Death and the Powers* | *Opera of the Future* | MIT Media Lab.

35. Bloomberg, “Making Musical Magic Live”; Jessop, Torpey, and Bloomberg, “Music and Technology in Death and the Powers.”

36. Van Troyer, “Hyperaudience : designing performance systems for audience inclusion.” 37. Au, Zuo, and Yam, “Quantitative measures of audience experience.”

38. Lecomwasam, “The Distance Between Us.”

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Research into audience perception of performances has also looked into ways to gauge an audience’s interest, enjoyment or overall affective response in a musical context. Some work focuses on their real-time perception of error³⁹ especially as it relates to digital musical instruments and the boundaries of skill they establish, with error lying beyond those boundaries. Other work has focused on reactions to the implementation of technology in a performance.⁴⁰ Many of the projects that gauge real-time perceptions make use of the audience’s personal devices like cellphones, allowing them to actively input their reactions⁴¹ or leverage the sensors they include.⁴² These cases often aim to—but do not always—consider how to make those interactions as non-invasive as possible, and leave room for the audience to focus on their experience of the wider performance.

2.4 Automatic mixing, digital sound calibration, and other solutions for balancing room acoustics

Sound reinforcement techniques for tours (or more generally, for performing the same show in different places) often prioritize achieving sound that is similar, aiming for ideal even in very different conditions. Groups that travel with their own digital mixers will often have presets that do not change significantly night after night, although the balances and processing are modified to adapt to each venue and make it sound consistent.⁴³

To contribute to this search for consistency, there are projects from pro audio manufacturers that automatically calibrate the equalization curve for existing loudspeakers, such as those by IK Multimedia, Sonarworks,⁴⁴ and Genelec,⁴⁵ as well as RoomEQ Wizard.⁴⁶ These are more applicable to listening spaces like studios and movie theaters. In the live realm, rather than auto-calibration, engineers use tools like Open

Sound Meter⁴⁷ or SMAART,⁴⁸ which

39. Bin, "The Show Must Go Wrong: Towards an understanding of audience perception of error in digital musical instrument performance."

40. Hödl, Kayali, and Fitzpatrick, "Designing interactive audience participation using smart phones in a musical performance."

41. Hödl et al., "Large-scale audience participation in live music using smartphones." 42. Swarbrick et al., "Audience Musical Absorption."

43. Bloomberg, "Making Musical Magic Live."

44. Stamp, *Group test*.

45. Genelec, *GLM 4*.

46. Mulcahy, *REW - Room EQ Wizard Room Acoustics Software*.

47. *Open Sound Meter*.

48. Rational Acoustics, *Smaart Home*.

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provide valuable analysis that they can use to visualize room and system resonances, and make adjustments in loudspeaker EQ curves and time alignment.

Over the past decade, wave field synthesis has started to be implemented in audience facing venues. This was originally proposed in the 1980s as a sound reproduction technique able to create virtual acoustic environments⁴⁹ through loudspeaker arrays that create wavefronts. The Experimental Media and Performing Arts Center (EMPAC) at Rensselaer Polytechnic Institute developed a high-resolution version for use in artistic works in 2019⁵⁰ and has been using in productions since. A major commercial breakthrough from Holo plot allowed venues to leverage wave fields through beamforming to transmit audio directly to discrete positions in large audiences while avoiding reverberant surfaces,⁵¹ gaining the ability to somewhat ignore room acoustics. Holoplot has been implemented in new large scale systems at venues like the Sphere, in Las Vegas, and the Beacon Theatre in New York.⁵²

Some systems are built not to neutralize the acoustic environment of a space, but to alter it. Meyer Sound's Constellation⁵³ and D&B's En-Space⁵⁴ change the perceived acoustic features of a space through a system of microphones, loudspeakers, and digital signal processing (DSP) that modifies the reverberant characteristics. This allows venues to adapt to different types of performances depending on the acoustics they need. Systems like these are expensive (although typically not as much as changing the actual acoustic features of the room⁵⁵), and, in the case of Constellation, permanent. Outside the commercial realm, researchers at CCRMA (Stanford) have developed a feedback-canceling

resonator,⁵⁶ which can convey artificial reverb while canceling out audio feedback that can ensue.

These digital systems are reminiscent of concert halls designed with physical features that

49. IRCAM Room Acoustics Team, *IRCAM Wave Field Synthesis-Homepage*.

50. Goebel, "The EMPAC High-Resolution Modular Loudspeaker Array for Wave Field Synthesis." 51. "HOLOPLOT X1."

52. Hammel, "Inside the Sphere 167,000 Speakers Drive Las Vegas' Mega Venue." 53. Meyer Sound, *Constellation*.

54. d&b Audiotechnik, *The brand-new d&b Soundscape – More art. Less noise*.

55. Ross, "Wizards of Sound."

56. Abel, Callery, and Canfield-Dafilou, "A FEEDBACK CANCELING

REVERBERATOR." 20

allow for acoustic modifications through changes in distance of reverberant surfaces, room volume, or materials. This is sometimes done with reverb chambers and canopies such as in the Morton H. Meyerson Symphony Center in Dallas.⁵⁷ However, it has been taken to much more extreme effect at spaces like IRCAM's Espace de Projection,⁵⁸ designed to be variable in volume (through an inner mobile ceiling) and ceiling/wall absorption properties (by covering these surfaces in systems of automated rotatable prisms with varied absorption qualities in each face), but also in its ability to create "coupled rooms" that double the decay time.

These projects are extremely helpful in allowing spaces to adapt to necessary acoustic qualities for specific live performances, but do this by evening out or changing the unique characteristics of different spaces, rather than utilize them as a resource.

2.5 Sound, Space, and Place in Artistic Projects

In 1969, composer and sound artist Alvin Lucier made the first recordings of "I am sitting in a room" in the Brandeis Electronic Music Studio and his apartment.⁵⁹ Using two tape recorders, a microphone, and a loudspeaker, the score published as part of the *Chambers* compilation calls for a piece of text to be spoken into the recorder, then played through a loudspeaker, with a microphone re-recording it across the room. After repeating this process several times, the resonant frequencies of the space start to become more prominent as the signal transmitted through the air begins to take on more of its spectral

character istics, to the point where only the resonant frequencies are audible. The piece is often considered one of the first to incorporate room acoustics as a central compositional ele ment and not just a background for instruments to sit atop.⁶⁰ Like many of Lucier's pieces, it instead explores acoustic spaces as a way of "opening that secret door to the sound sit uation that you experience in a room".⁶¹ Later, he would mention being inspired by Amar Bose's use of the technique to test internal resonances in loudspeaker designs.⁶²

57. Morton H. Meyerson *Symphony Center, Concert Hall*.

58. Peutz, "The Variable Acoustics of the Espace de Projection of IRCAM (Paris)."

59. Lucier and Simon, *Chambers*, 3: "I am sitting in a room".

60. Collins, "'Alvin Lucier's I am sitting in a room'."

61. Lucier and Simon, *Chambers*.

62. Arts at MIT, *Evan Ziporyn Interviews Minimalist Composer Alvin Lucier*.

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One aspect that stands out about "I am sitting in a room" is that it is site-specific without being built to accommodate one particular site. It is completely dependent on where it is performed, but is not meant to occupy a specific space or type of space. In fact, Lucier takes note of the differences that arose between the sterile, bright studio he found unpleasant to be in, and the gentler, warmer acoustics of his carpeted apartment after performing the piece in both.

Lucier's work often explored what he called "sound situations," what the sound of certain contexts *felt* like. "Chambers" calls for the collection or creation of small resonant environments and their excitation. "Vespers," for playing music through echolocation. The score immediately after "I am sitting in a room" in the *Chambers* compilation, "(Hartford) Memory Space" (1970) directs the performers to listen to an outdoor sound environment and recreate their memory of it in another context. It is aimed at "urban, rural, benign, hostile" situations, and the discussion included in *Chambers* particularly frames it around the urban space.

The urban and built environment is especially ripe for exploration through sound. Maryanne Amacher's *City Links* (1967-79), for example, would broadcast the sounds of different parts of a city through a local radio station, bridging different spaces into the same sonic place.⁶³ For *Music for Sound-Joined Rooms* and the *Mini-Sound Series*, she

developed immersive installations in various buildings using sound that traveled through the air as well as the structure of the space. This created a sound structure unique to the architectural features, allowing the audience to traverse it and experience sonic variations from room to room and within each space, accompanied by lighting and visuals that helped tell the story.

Since 1992, Lamont Young and Marian Zazeela's *Dream House* has occupied a second floor in New York City. It features bright magenta lighting and a continuous 32-frequency drone piece resonating through a room. Like Amacher's works mentioned above, *Dream House* is a sound and light environment unique to the space it occupies: in the room, each frequency has its own points of resonance defined by the architecture which let listeners hear different sounds by moving through the space, with audible variations on movements 63. Amacher, *Selected Writings and Interviews*.

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as small as a turn of the head.⁶⁴

Edwin van der Heide proposes a similar exploration at a city scale in *Radioscape*,⁶⁵ which uses radio receivers carried by the audience to listen to the sound produced by several transmitters set up in different locations, sonically exploring their surroundings. In contrast, and more aligned with the interaction present in *Dream House*, Nicole Robson's *Being With The Waves*⁶⁶ is also built around the exploration of a space through sound, namely through demodulated ultrasound received by a set of modified headphones. It goes in the opposite direction from Van der Heide regarding the audience's interaction with the technology, contending that audiences should not have to be actively aware of, or holding, the technology being used to facilitate what they are experiencing.

Instead of modifying the sound to adapt to the space, Nicole L'Huillier inquires into what happens when spaces adapt to respond to sounds in *Spaces That Perform Themselves*.⁶⁷ She constructed a space within a cube with no floor whose internal shape can change through actuated rods that push and pull the inner fabric wall, hanging over a vibrating platform. A programmed score for that moving system, combined with vibration, sound, lighting, and touch from the occupant, creates an environment for cross-modal sensing and spatial composition.

There is also work that focuses on capturing the acoustics of spaces inaccessible to their audience, bringing the sound environment to them by recreating it in a performance or research setting. Pauline Oliveros, for example, had been using tape delay feedback to capture room sounds and create “virtual reverberant space that seemed to grow gradually in size”⁶⁸ since the 1960s before transitioning to a semi-digital Expanded Instrument System in the 1980s. The new version incorporated her accordion, and, later, instruments played by other performers, to create artificial acoustic spaces by modulating digital delay parameters. In the later half of the decade, she and Stuart Dempster made a recording in

64. Howard, *Mela Foundation*.

65. Van Der Heide, “Radioscape.”

66. Robson, McPherson, and Bryan-Kinns, “Being With The Waves: An Ultrasonic Art Installation Enabling Rich Interaction Without Sensors.”

67. L’Huiller, “Spaces that Perform Themselves.”

68. Oliveros, “Acoustic and Virtual Space as a Dynamic Element of Music.”

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an underground cistern with a reverberation time of 45 seconds. They performed the music of what they called the Deep Listening Band live alongside Panaiotis and David Gamper, trying to recreate the acoustic space of the cistern using digital delay processors. In 2012, for Oliveros’ 80th birthday, EMPAC staged a concert that convolved live instruments on stage through physically modeled impulse responses of the cistern.⁶⁹ This allowed the audience, which would not have been able to access the space, to experience the acoustic environment in a live setting.

A recent piece that makes expressive use of altering room acoustics is *A Blank Page*,⁷⁰ composed by Celeste Betancur with acoustic design by Luna Valentin, which was performed at Thomas Tull Hall at MIT as part of the 50th International Computer Music Conference’s concert for orchestra and electronics. The piece creates a dynamic, ever-changing environment by generating the score in real time and processing the sounds of the strings through granular and non-linear methods, and combining these sounds with “A dynamic virtual acoustic space, based on live convolution with Impulse Responses ranging from dry (0s) to 17 second”,⁷¹ partially with modified acoustic captures of the venue. These sounds blend the perception of space, electronic sound, and acoustic sound.

Works like these focus on the aural experience of these spaces, and how listeners explore them by listening. They present compelling approaches to interrogate the relationship between sound and places, and for us to expand on these strategies through a much less explored lens: the effects on the acoustic environment when it is occupied and shaped by live musical performance.

69. *Digital System at Rensselaer Will Allow Performers to Recreate Acoustics of Cistern Used in Iconic 1988 Recording* | News.

70. Celeste Betancur, “A Blank Page” – *Live at MIT | A Far Cry & AI-Powered Composition*. 71. *Concerts Hall Part 2 | ICMC 2025 Boston - International Computer Music Conference*.

3 Motivation & Previous Work

This chapter describes previous experiences and work done in the process of formulating this thesis, and how they shaped the lens through which this project was developed.

3.1 Some sound engineering observations: VALIS and Flow Symphony

My first experiences with the Media Lab revolved around the 2023 production of Tod Machover’s *VALIS*.¹ I became involved with the production first as an intern and later as a production assistant for this and other projects. This was the largest-scale performance in which I had been a technician. The systems, some of which were established before my involvement, were complex and could be fragile, but allowed the team to blend digital and acoustic instruments, process singers’ voices with Max Addae’s *VocalCords*,² and improvise with live AI-generated sound responsive to motion and touch sensors in a system designed by Manaswi Mishra and Nina Masuelli. My main responsibility was initially to

manage sound design and digital instrument technology for the piece, and the interactions between the various electronic elements. At its core, my role was to know where all the signals were coming from and where they were going at any given moment.

In early August, about a month before the premiere, the team learned that the lead sound engineer would no longer be available for the three performances, and I was asked to mix the show. Knowing the musical material closely, I was coached by the lead engineer during technical rehearsals and practiced how to create the balances between vocals, acoustic instruments, and electronic material for different moments of the piece. During my first week as a student at the Media Lab, we premiered the show.

Becoming so enmeshed in almost every aspect of the musical systems of the production gave me a unique perspective of how it worked. I developed an interest in how ideas and emotions traveled through the compositional and production process to reach the audience through all the elements of the show. I made a "routing diagram" figure 3-1,

1. Machover, *Project Overview* < VALIS.

2. Addae, *IN TENSE DIMENSIONS: A Song Cycle for Voice & Live Electronics* by Max

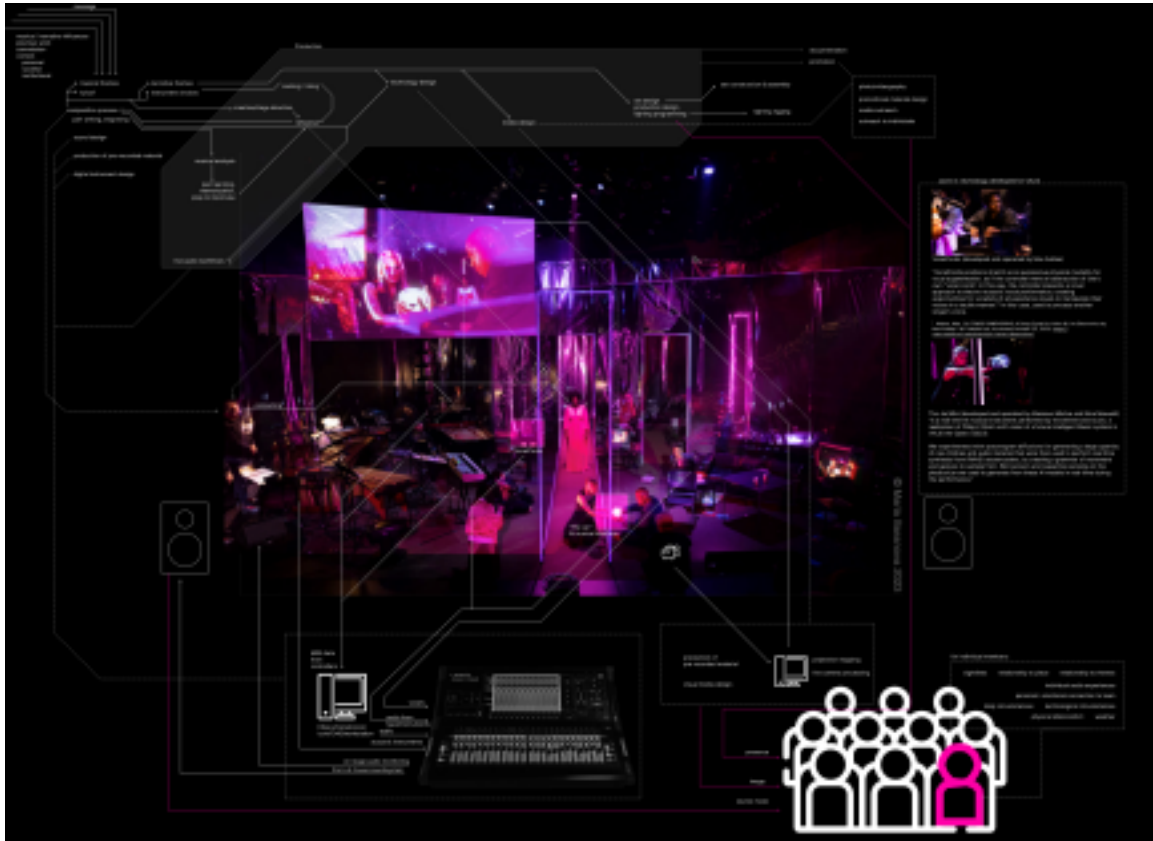


Figure 3-1: a “routing diagram” for how messages and ideas traveled through the VALIS production

a knowingly incomplete systematization showing different pre-production elements (message, musical/narrative influences, previous work, societal/personal/institutional context) taking shape as parts of the show that the audience notices consciously or not, and noting the interaction with what the audience as a whole and individually was bringing to the experience.

Although the “routing diagram” was an interesting way to visualize the process of reaching an audience through a production like this, especially one where there is a specific story and message, it is not an actually applicable way to conceptualize how art affects people. However, what did leave an impact on me about this project was that lower right corner of the diagram, beginning to explore the way the audience’s perception of the piece was colored by where, when, why they saw it, and what other context they brought with them.

In 2024, we began production on a new piece of Machover's music titled *Flow Symphony*³ commissioned by string orchestra Sejong Soloists. The piece explored the relationship between humans, technology, and nature through interactions between a string orchestra and the sounds of a specific river expressed in electronic samples and a live, sound-reactive AI audio system managed by Mishra. We premiered the piece in August 2024⁴ at Seoul Arts Center in South Korea, a contemporary, yet somewhat traditional concert hall with clear acoustics. Since then, we have produced it two other times, at Thomas Tull Hall at MIT in the context of the International Computer Music Conference, and at Jordan Hall for the final concert of the 2025 Morningside Music Bridge program.

These three performances took place 1) in different venues with varying acoustics and audio systems, 2) with different orchestras of varying sizes and dynamics, and 3) in different wider contexts that framed how the audience may have interacted with them. This made the experiences very different from each other, even though it was the same music being played.

Acoustically, the contrast between the venues was clearest in their varying reverberation time and treble ratio. In Seoul, the clear acoustics and moderate treble ratio made it easiest to achieve a balance where the strings and samples sounded at about equal levels, but the stage's comparatively high reverberance meant that it was more likely for the microphones on the instruments that fed the AI system to capture its own sounds, creating some feedback in the processing.

In contrast, Tull Hall has much higher reverberation outside of the stage and a low treble ratio. The hall is also designed in the round, meaning that the sound had to address several angles at once as opposed to facing the whole audience in the same direction. It also has loudspeakers both in front of and behind the audience, which made for an interesting resource to spatialize the sound of the AI and electronics, and distinguish it from the strings at the right times. And while in Seoul the orchestra was playing with

Machover explicitly as a conductor, at MIT they were largely self-conducted and needed to hear both the samples

3. Machover, *FLOW Symphony*.

4. Machover, *Tod Machover's new FLOW Symphony premiered in Seoul on August 24,*

2024. 27

and each other very clearly—which was challenging given the more muffled acoustics of the hall. This created a level of difficulty in establishing monitor mixes that would let them hear properly, and required us to use the physical acoustic dampening resources in the hall to our advantage.

The performance at Jordan Hall was different from the other two in its much higher reverberation time. While this makes it transmit smaller ensembles to the audience with a very proximate sound, the orchestra consisted of about 30 performers, and its interaction with the acoustics of the hall presented a larger challenge in creating a mix with the electronics that was not muddy, where the different elements were all audible and did not collide with each other. My strategy for this space was to focus more on the acoustic string sound, letting the water samples be more distant and come forward in waves, approaching and receding.

Just in terms of how the spaces and systems sounded, these three experiences were extremely different from each other. They helped conceptualize how different performance conditions for the same music can be both a challenge and a resource in creating an impact on its audience, requiring us to balance sonic elements very differently to achieve a, hopefully, similar emotional and artistic effect.

3.2 Connecting To/Through Music: The Jeanne R. Johnson Music Innovation Lab at the Dallas Symphony Orchestra

3.2.1 Concept

In late 2023, The Opera of the Future group started work on a collaboration with the Dallas Symphony Orchestra, who had commissioned us to develop a center for music education for children ages 6 to 18. The project went through a few different phases while conceptualizing what it could look like and reviewing how other projects approached this mission. We were compelled by the interactivity of places like the Haus der Musik in Vienna⁵ and the Museum of Science in Boston.⁶ We also looked to create activities that were visceral

5. *Haus der Musik in Wien.*

6. *Exhibits | Museum of Science.*

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and not didactic, guided by past Media Lab projects like the Brain Opera,⁷ and other interactive artwork. The main mission of the project grew into developing experiences that gave participants a new perspective of what music, and their relationship with it, could be, beyond the dichotomy of musician and listener. It was less about teaching particular concepts, and more about sparking a curiosity that could guide a long-term exploration of music, and how it intersects with technology and other interests.

As the concept developed, we established specific zones that explored a particular element of how we experience music:

1. **Instruments:** Direct, multisensory experiences with the mechanics of acoustic and digital sound production,
 2. **Creation:** Collaborative composition with Hyperscore,⁸ combining individual motifs and shaping them into a piece,
 3. **(E)motion:** Exploring the connections between music, movement, and emotion expression,
 4. **Archives:** Navigating music history through a model of recordings by the Dallas Symphony Orchestra,
 5. **SoundBooths:** Recording and shaping sound through effects and motion, and 6.
- Final Performance:** A collective experience where everybody is part of an orchestra.

Each research assistant working on the project led development of the activities for one

zone, with mine being *Instruments*.

3.2.2 Implementation

For the activities in the *Instruments* zone, we aimed to deconstruct how sound is produced in the digital and physical realm, and create an abstracted, but still direct interaction with these mechanisms. Initial explorations proposed opening up instruments to create tangible interactions with their mechanics, and trying to feature instruments that were functionally different from each other. It was important that the instruments showed certain characteristics: 1) not complicated to intervene, we would not need to completely dismantle the

7. *Welcome to the Brain Opera*.
8. *New Harmony Line, Hyperscore*.

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structure; 2) direct (or close to direct) relationships between interaction and sound production, and 3) not fragile, would be handled by children every day.

We chose to use a) a piano, b) a trumpet, and c) a large orchestral bass drum. For the latter two, we designed audiovisual digital activities that responded to physically touching or playing the instruments. For the piano, we returned to that initial idea of creating direct interactions, opting to just remove the mechanism and exposing the strings for participants to “be the mallet” and explore timbre by using mallets and sticks made



from different materials to

Figure 3-2: gutted piano

hit, rub, and strum the strings. Over the Summer and Fall of 2024, I led prototyping of the other two instrument activities in collaboration with some members of the team to deploy sensors on the instruments and the programs that responded to them.

For the drum, the goal was to show the way vibration spreads through a medium, in this case the drum head. When a user hit the drum head with their



hand or a mallet, a circle was projected expanding from where the hit happened. As an abstraction that aimed to simplify the concepts, the projection did not depict reflections or periodicity, only the transmission of an individual wave. On a technical level, the installation ran on a Raspberry Pi, outputting visuals to a projector mounted from the ceiling. Hit position sensing was done with a wide-angle camera and a piezo sensor, using a small computer vision algorithm to detect the largest shadow captured by the

Figure 3-3: projected drum

camera when a strong vibration was sensed. Removing false positives while still making the system sensitive enough was challenging to refine, but the final product was stable.

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In demo sessions with young people at the Media Lab and in Dallas, responses were largely positive, in no small part because the activity itself was identified as fun beyond the educational element.

The trumpet's higher level of complexity encouraged us to create an activity that made the interaction less mysterious. Masuelli, at the time a first year Master's student, developed a system of pressure sensors to hide in the valves, such that we could get a signal whenever one was pressed. With the trumpet held up by a base, we could display it side by side with a monitor to audiovisually depict how pressing a valve makes the total tube longer or shorter, creating slower or faster vibrations and altering its pitch.

The other major pitch-generating parameter of the trumpet is the

embouchure, by which the player vi

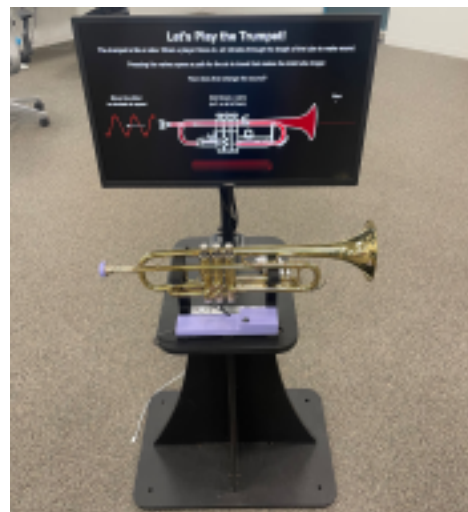


Figure 3-4: touch trumpet

brates their lips on the mouthpiece slower or faster, making the column of air vibrate at increasing harmonically related frequencies.⁹ To avoid the health risks of users sharing a mouthpiece, we decided to abstract away the embouchure, instead using a slider mounted on the base to move between partials. Whenever the slider or a valve changed state, the audio system would play a sample corresponding to the pitch the trumpet would make. This allowed us to have an audiovisual installation with information and representations of the mechanisms, but also enable users to play melodies and experiment.

A key goal of the *instrument* zone was also to address the way music is made in the digital realm. We implemented this in 2 activities.

9. Benade, "THE PHYSICS OF BRASSES."

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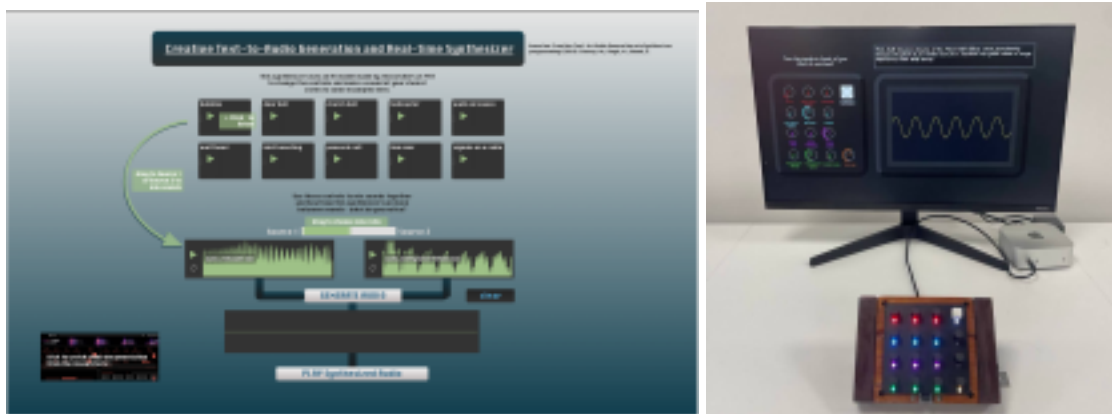


Figure 3-5: GUI for *WaveForm* and the interactive CTAG implementation.

The first (which began to be prototyped in March 2024) focused on audiovisual representation of synthesis and the building blocks of digital sound. By turning the knobs on a MIDI controller, users were able to change parameters of an audiovisual synthesizer built in MaxMSP¹⁰ and experience how that affected its audible and visible characteristics. We

named the activity *WaveForm*. Early versions presented all the controllable parameters simultaneously, but we quickly learned that it was important to start with a simple, easy to hear interaction and then increase the complexity level as users became more comfortable.

The final activity was presented in 3 stages, first controlling only the frequency (pitch), shape (timbre), and pulsing speed (showing the wave's amplitude growing and shrinking over time). Pressing a button on the controller added a new set of parameters to control qualities (shape, balance, and phase) of adding an additional wave at the same frequency. Pressing the button again accessed the final stage of the activity featuring controls for a delay, an arpeggiator around the original wave, and a flanger. Turning the knob for each parameter also displayed a short textual explanation of its function, sometimes including listening prompts. In workshops with children and demos with adults, users engaged with the activity in quite varied ways: some would change one parameter at a time, slowly learning what each could do, while others moved through the different stages quickly, using it more as if they were playing a synthesizer and changing the sound to create motifs.

10. *What is Max?*

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The second focused on the ways modern digital systems use machine learning to produce sounds and interpolate between complex signals in ways people may not think to. This activity used sounds created with Creative Text-to-Audio Generation via Synthesizer Programming (CTAG), developed by alumni of the lab.¹¹ Researcher Andrina Zhang generated 10 sounds with CTAG, and built software to control interpolation between any 2 sounds using a graphical user interface which we collaborated on programming.

3.2.3 Learnings

As the opening date approached, we understood that it was crucial to share the activities with the young people for whom we had been designing. This would not only help us observe how they actually interacted with them so we could learn what could be improved and how they could be better facilitated by staff, but also give us an opportunity to start putting the goal of building connections to music into practice. I led the organization of

one workshop at the Media Lab with teenagers from a Boston school, and the team at the Symphony Orchestra helped organize another with Dallas families after installing the activities in the space. We also gathered feedback from educators in our network. These opportunities to share the activities gave us insight into how we could better facilitate them and necessary technical performance improvements. However, what they especially highlighted was just how personal these experiences with music can be, as different people's interpretations and takeaways varied to a great degree.

The process of putting together the Music Innovation Lab was challenging on a technical and conceptual level, forcing us to iterate quickly and design with a wide range of users in mind. However, it also gave the team a huge amount of perspective and new skills. Personally, the idea that emerged of establishing varied relationships with music through visceral experiences has continued to guide how I approach connecting people to music.

3.3 Formulating sonic experiences of spaces

The live sound engineering ventures and design of interactive music activities described above prompted reflection on what kinds of interventions could highlight how specific and

11. Cherep, Singh, and Shand, "Creative Text-to-Audio Generation via Synthesizer Programming."

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personal our perceptions of musical experiences could be. The main way this manifested was in projects that focused on exploring the immediate environment through sound, specifically making audible certain qualities of people's non-replicable interactions with spaces.

*Playing the Room*¹² was developed as a series of modifications on an electric guitar to turn it into an antenna that captures electromagnetic interference and turns it into audio. This is used as the control input signal for a MaxMSP patch that plays different sounds depending on the frequencies present in the input signal. With this system, I was able to map the shape of classrooms and office spaces in the Media Lab building based on the location of the electromagnetic signals emitted by light switches, electrical outlets, computers, and more, and perform motion through these spaces.

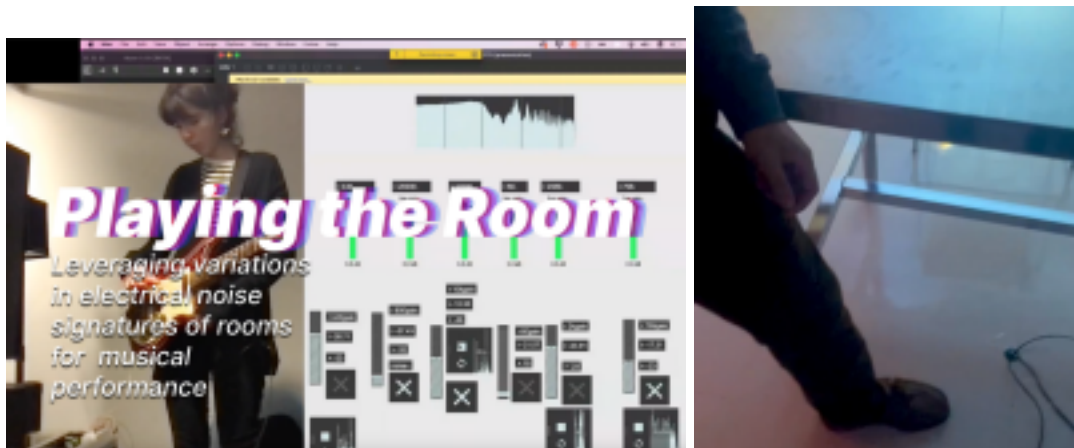


Figure 3-6: Thumbnail for *Playing the Room* and a participant & piezo sensor in *Kitchen Steps*

I have also been interested in amplifying the subtle, audible sounds of spaces. During an event on the 3rd floor of the Media Lab, I installed *Kitchen Steps*, with piezo microphones on the floor used to process the sounds of footsteps in a kitchen adjacent to the main room. These modified the “atmosphere” of a space that was familiar to visitors of the event, but suddenly warped by the sounds that existed in it. Visitors showed curiosity about how their interaction with the system affected its outcomes, trying out various walking 12. Schon, *Playing The Room - Demo video*.

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patterns, stepping in different parts of the room, or jumping to see who could get the loudest feedback.

In general, observing audience reactions to these early explorations shows promise in the potential of sound-space interventions that engage people to perceive the context they are occupying, and open up questions about the possibility of augmenting that interaction through experiences with live music.

4 Contributions

This thesis is built around a series of live music performances and technological interventions in varied adopted spaces in the Boston area (mainly on the MIT campus). These aim to make audible the structure, context, and acoustic qualities of the space they take place in by giving the performers tools to exaggerate aspects of the acoustic

environment. One of them, in March 2025, has the author as composer, performer, and ensemble leader. The rest take place over the summer of 2025, and feature 3 Boston-based musicians playing their usual repertoire in different spaces. See the companion website¹ for documentation of all performances.

Staging these performances serves a series of different purposes:

4.1 Room to listen: perspective and reflection

Live music serves as a social, community-generating place that can foster new perspectives in listening and performing for musicians and audiences. The sensory experiences of these events are tied to their physical spaces, and so the performative place that emerges can leave a huge imprint, shared across the group of performers, audience members, and others present. These concerts are a way to create opportunities for reflection by framing the events around the connections to people and places made through music.

These performances leverage their environments to emphasize the unique qualities of various spaces and help us learn how the differences between them may leave impressions on the participants, how their connection to a space (and the identifiable place that emerges) can be built and shaped through a live music experience.

4.2 The city as music community: a spotlight on the Boston, MA area

Just like live music is tied to the immediate context that surrounds it (the type/size/shape of the venue, day/hour of the day), it also exists in the wider context of, among other factors, 1. <https://pps.media.mit.edu>

its geographical location (neighborhood/town/city/state/country) and time period. Audience members, and often also performers (excluding maybe those visiting/touring through a city for the first time ever), will have some existing relationship to that context that results in shared or contrasting experiences which could shape the connections

made in the performative place.

Because this thesis project takes place in the Boston area, focusing on how the city's music communities come together, shift, and relate to the wider city is important to getting a richer understanding of those overlapping contexts and their impacts on the more immediate situation of the live concert. By involving musical artists based in the area and familiar with its scenes, we can learn from their perspective about how connections are made in the wider musical environment and how they relate to the acoustic space, as well as document some aspects of the current state of Boston as a music city.

4.3 Technical breakpoint: People-centric music tech

The idea of using acoustic space as an expressive tool in music performance is not new, but there has not been as much of a focus on the acoustic space where the performance is actually happening. To develop this idea, a key technical need is the ability to neutralize or exaggerate that acoustic space in ways that a musical performer can control dynamically as one of their expressive resources, to analyze how it can be leveraged in as part of these connective experiences.

Music technology is increasingly moving towards personalization (for example through interactions with large databases, recommendation algorithms, and metadata), promoting a sense of individualism that can turn into solipsism and isolation.² This project aims to offer a counterpoint that explores what emerges from performative places that create a momentary sense of community and how that can be supported with technology. This way, we can interrogate how we could build systems for music experiences with human subjectivity, community building and interpersonal connection at their center.

2. Pelly, *Mood Machine: The Rise of Spotify and the Costs of the Perfect Playlist*.

5 System Design

5.1 Theory

The system used for the performances in this thesis is designed to enable its musicians to **control the exaggeration of sonic qualities of the acoustic environment** by adjusting processing on their amplified instrumental and vocal signals. This is done in pursuit of the goal to bring their and the audience's attention to the acoustic space they occupy together, and how it shapes the emotional and interpersonal effect of the performative place, creating new impacts from the awareness of that shared experience in a space.

To achieve this, it was necessary to find a way to process the signals of the instruments to create those exaggerations, neutralizations, or other transformations of the acoustic environments. This hinges on the ability to capture, process, and reproduce the specific acoustic environments where the performances are taking place. To explain the design of the audio processing system, it is helpful to specify some room acoustics elements that are important to its function.

When a sound is played into a space, it expands outwards from the source, reaching receivers (like ears and microphones) directly, but also reflecting off (and partially being absorbed into or transmitted through) surfaces in the space, whose reflected waves reach those same receivers later, depending on the distance, see figure 5-1.

The same sound will reverberate differently in various spaces in one part due to their different size and shape, which define where waves can reflect, and therefore how long it takes for the reflections to reach the receiver. This also determines where standing waves can form and what frequencies will repeatedly reflect off the same surfaces to create room modes. Another major factor are the materials constituting these surfaces, which absorb and reflect different frequencies to varying degrees.¹ Depending on the locations of the materials, the sound that reaches the receiver will vary in its frequency distribution based on the surfaces off which it reflected. Altogether, a sound played into a space takes on the reverberant and timbral qualities of the space as it reaches the receiver acoustically.

1. Pierce, *Acoustics*.

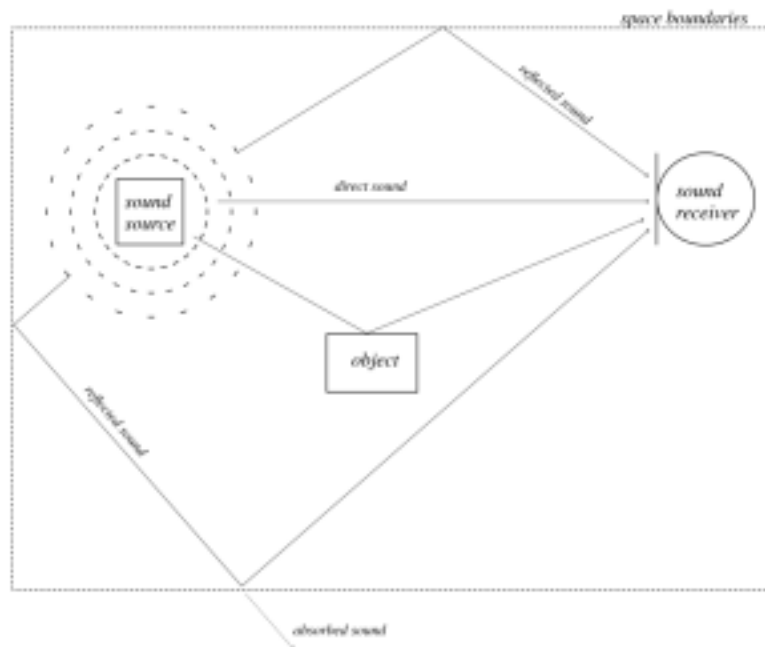


Figure 5-1: an abstraction of room reflections and absorption

With this in mind, we can capture the response to sound of a specific acoustic system: a space, sound source or sources (in this case, a set of loudspeakers, which can have their own frequency curve) at a certain location, and a sound receiver (a microphone connected to a recording device). To do this, an excitation signal (an impulse with an even distribution of all frequencies to be tested) is played through the sound source into system to be measured, and the acoustic sound of the system is recorded through the microphone as a digital audio signal known as an **impulse response (IR)**. This method is shown in figure 5-3. The IR is defined between the specific positions of the source and the receiver in the room—reflections will vary if either of them is moved, as they will be at different distances from the reverberant surfaces. The IR can be stored as audio to be analyzed or used later, and visually represented in terms of its waveform or as a spectrogram, as shown in figure 5-2.

Recent research recommends the use of an exponentially swept sine (ESS) as an excitation signal. The ESS is a sine wave whose frequency increases exponentially from the lowest part of the audible range to the highest (20 Hz-20 kHz) over a specified timeframe.

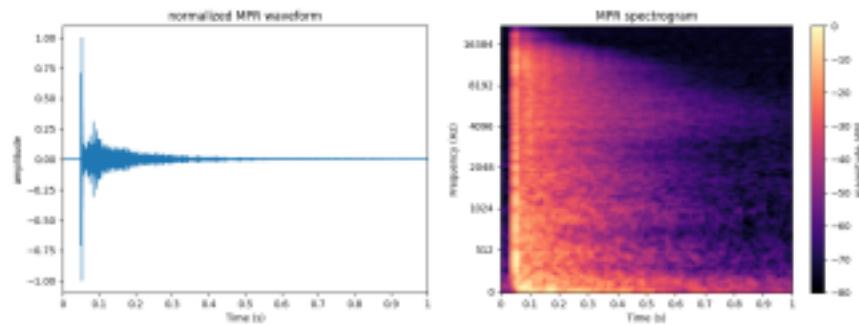


Figure 5-2: The normalized waveform and spectrogram for 1 second of the same IR

This is recommended especially for higher noise environments² and to avoid harmonic distortion. When using sine sweeps, the recorded signal is then deconvolved to get a time-domain signal where the start of each frequency band is aligned.³ For this project, capturing and processing IRs with the HISSTools Impulse Response Toolbox⁴ in MaxMSP was a straightforward solution that offered enough flexibility for the needs of the performances.

With the impulse responses of the spaces captured, they could now be used in **convolution**, an operation $l(t)$ between an incoming buffered audio signal (for example from an instrument) $f(t)$ and the signal that defines the IR $g(t)$, where $l(t) = g(t) * f(t)$. This imparts the timbral and time-domain reverberance qualities of the IR to the input signal,⁵ as shown in figure 5-4. In this implementation with HISSTools, convolution is calculated in near real-time with zero added latency (although the conversions to and from digital audio do add a minimal latency).

When the input signal has acquired timbral qualities of an acoustic system, playing it into the system excites the frequencies that reverberate prominently to a greater degree, and the decay curve becomes more pronounced. This lets us create a variation of the system with more exaggerated frequency and decay curves, though the difference is not very obviously audible unless the space has very strong resonances or a very pronounced

2. Müller and Massarani, "Transfer Function Measurement with Sweeps."

3. Harker and Tremblay, "THE HISSTOOLS IMPULSE RESPONSE TOOLBOX: CONVOLUTION FOR THE MASSES."

4. HISS: *Huddersfield Immersive Sound System*.

5. Abel, Gallery, and Canfield-Dafilou, "A FEEDBACK CANCELING

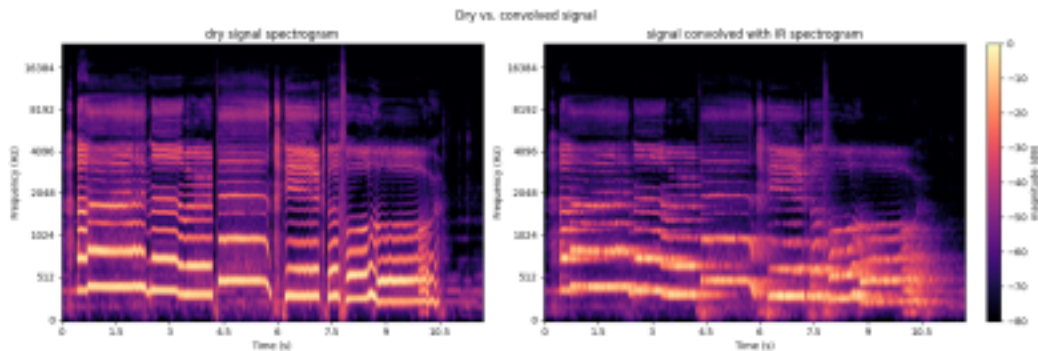


Figure 5-4: Convolution example

frequency response.

To follow the goal to *exaggerate* spaces' acoustic features in a perceivable way, another level of acoustic information proved to be necessary in making these time and frequency-domain features more noticeable. One way to achieve this was to obtain a power of the frequency response; that is, to multiply the amplitude of the curve such that peaks are higher and troughs lower around the x axis, see figure 5-5.

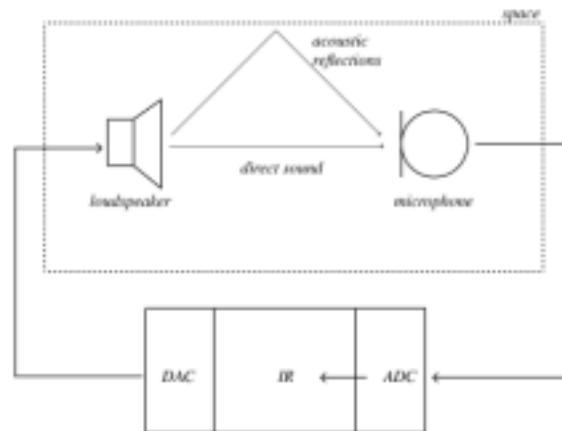


Figure 5-3: Impulse response capture diagram

A method with a simple implementation for the complexity of the captured signals turned out to be auto-convolution, which consists of recording the output of playing an IR as the input signal for a convolution algorithm where it is also the IR (which effectively means that if the IR is $g(t)$, the product $h(t)$ of auto-convolution is $h(t) = g(t) * g(t)$).

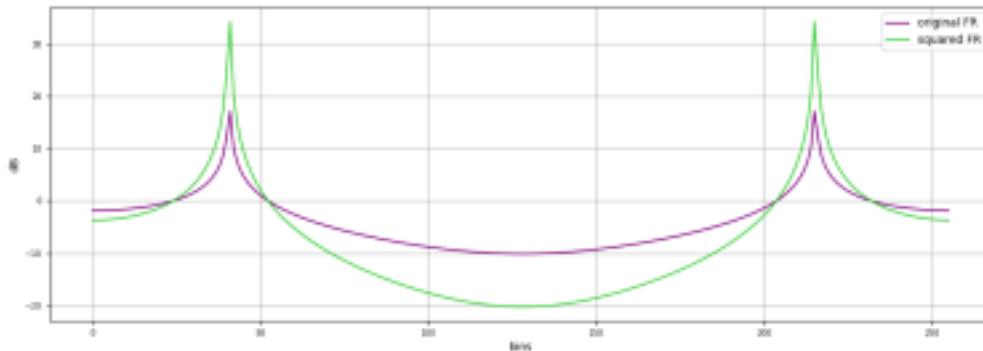


Figure 5-5: Example of multiplied frequency response of 2 sine waves with a frequency of 1Hz and 2Hz.

5.2 Initial Implementation

These exaggeration methods were implemented on a MacBook, using MaxMSP with the HISSTools library and various audio interfaces. For each performance, we took a mono ESS IR of each loudspeaker (for these performances, a stereo pair, though models varied) using a Dayton Audio EMM-6 omnidirectional analysis microphone placed in the center of the audience position, with the loudspeakers and microphone gain leveled to avoid distortion. This measured the response of the whole acoustic system, including the sometimes varying frequency curves of the loudspeakers.

With this signal recorded into a `buffer~` object in Max and the buffer normalized to an amplitude of 1, the auto-convolution was recorded into a fixed-length 10 second buffer, and also normalized to an amplitude of 1. The buffer of the original signal was saved as an audio file.

The architecture of the patch changed somewhat as the project went on to address issues that arose in specific performances, but this was the principle by which the various IRs were produced throughout.



Figure 5-6: an auto
convolution example in
Max

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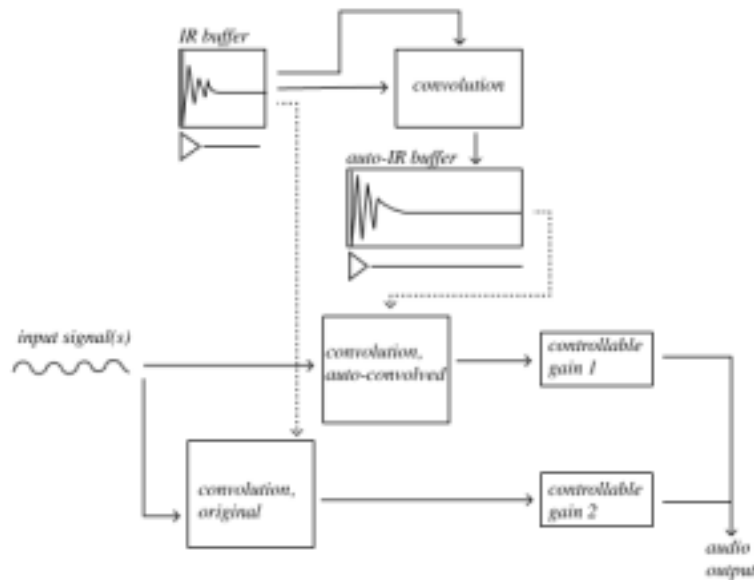


Figure 5-7: auto-convolution and routing diagram

With the IRs processed and usable for convolution, the instrument inputs were configured to be convolved with the left or right loudspeaker IRs for panned signals, or both for mono signals. Each stereo pair of convolved outputs was mapped to a MIDI controller allowing the performers to control its gain. In some performances, there were additional MIDI enabled switches that allowed performers to toggle the connection of certain instruments to the convolution chain.

Initial prototyping of these acoustic space exaggerations took place in various small meeting rooms and offices at the Media Lab. The first prototype with any audience was on February 11th in a conference room, featuring music by a colleague, and an audience of fellow graduate students. No data was collected, but a brief discussion indicated that it might be important to have strategies to communicate to the audience what was changing in the exaggeration of the acoustic features, whether it was real-time visuals, or a comment or example at the beginning of the performance. It also became clear that it

would be crucial that the effect is controlled in such a way to find appropriate moments to bring attention to the space in relation to the music.

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6 Here. . . NOW: a public performance of the MIT Media Lab with acoustic-expressive electronics

6.1 Performance Description

The first public-facing experience with the Performing Performance Spaces project was on March 13th at the MIT Media Lab. I composed *Here...NOW* for the band I usually play with and specifically around the site, using 3 spaces in the building contrasting in acoustics, size, and everyday use. This structure invited the audience to experience traveling between them, entering them as part of a performance context, and participating in a musical experience across these varying acoustic environments that created an expressive arc where they are different, but part of the same thing.

This performance of *Here...NOW* was part of a new arts festival at MIT called Artfinity, which supplied the budget for equipment rentals¹ and documentation. It was presented in an event we called *Moving Music*, shared with the East Coast premiere of Tod Machover's piece *MAICE*.²

6.1.1 System and Routing

The ensemble, like the majority of my original music performances, consisted of a drummer, an electric bassist, an electric guitarist, and myself playing a secondary electric guitar and singing. We set up a stereo loudspeaker system (plus monitor loudspeakers),

drumset, and microphones in each space the day of the show. For all performances, we connected the bass and rhythm guitar direct input to the console (i.e without amplifiers), and the lead

1. from MIT Audio Visual Services, as well as Guitar Center. We were also loaned equipment from the Media Lab's Studcom.

2. *Moving Music*.

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- 1 vocal microphone
- 2 rhythm guitar
- 3 lead guitar
- 4 bass
- 5 kick drum
- 6 snare drum
- 7 + 8 stereo drum overheads
- 9 analysis microphone (only used during setup)

Table 6.1: here...NOW audio inputs

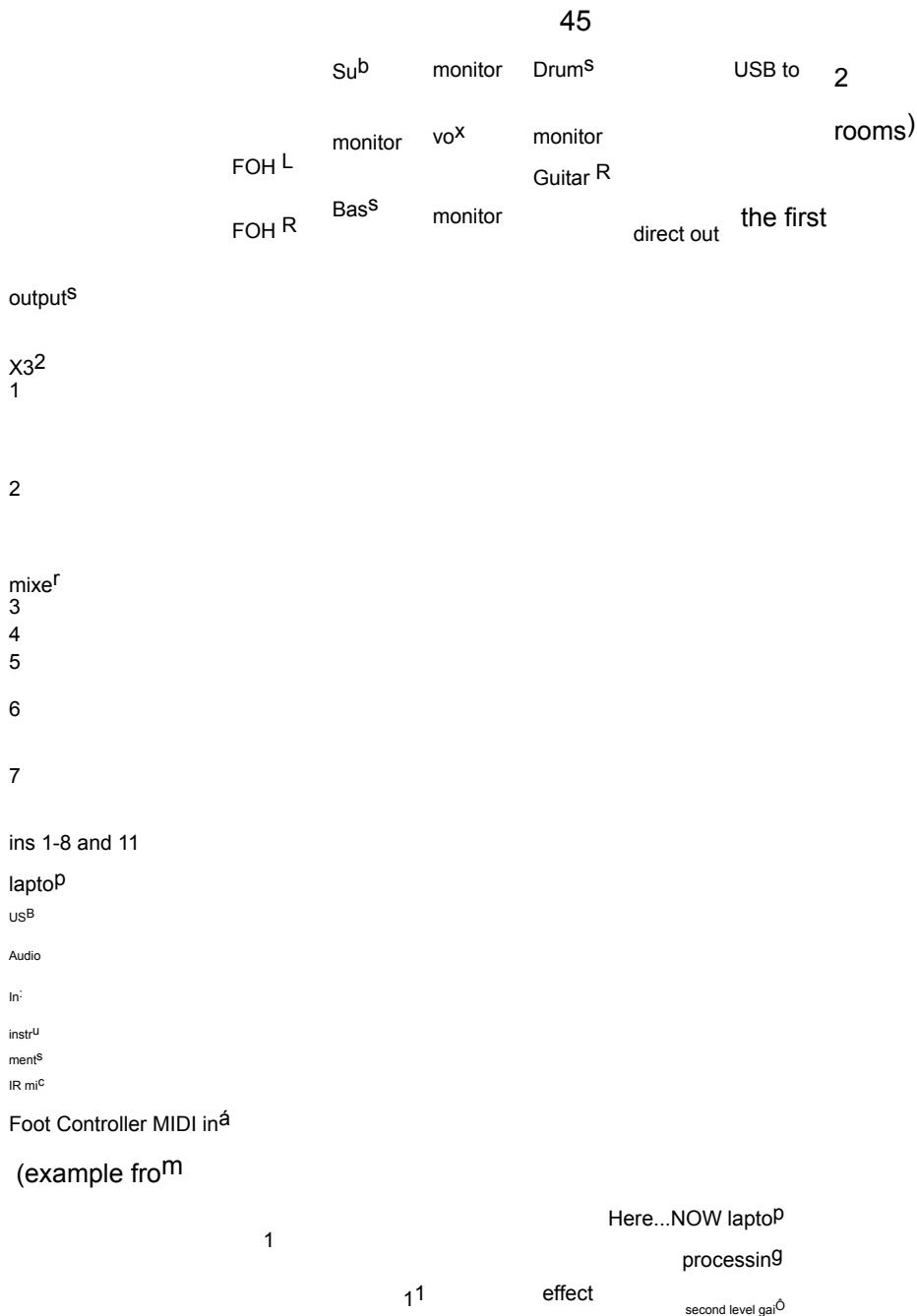
guitar through a JC120 amplifier (with a microphone), which the guitarist had to transport on wheels throughout the building.

The Performing Performance Spaces (*PPS*) system received 9 channels of audio input from the console, see table 6.1 .

We captured, normalized and processed the IRs of the loudspeakers in each space while setting up, without audience present and with minimal noise from people in the space. For this concert, we used the USB audio interfaces integrated in the front-of-house audio mixing consoles to pass audio to the computer, both for IR capture and performance processing. See figure 6-1 for routing diagram.

To control the amount of each reverb that plays through the PA, we used MIDI input from a Behringer foot controller with 2 expression pedals and 10 switches. Each of the expression pedals were mapped to the gain for one of the stereo convolution chains, and switches 1- 8 added their corresponding number of audio channels into the processing (e.g: switch 1 only passed the vocals, while switch 8 passed all inputs, while switch 3 only passed the vocals and guitars). This allowed the bassist and me to collaboratively select which instruments would be part of the reverberation, and how loud it would be.

The first space was the first floor lobby, with its tallest point four stories high, and a long and relatively narrow footprint. Its geometry, combined with its tiled floors and 2 glass elevators close to the center (see figure 6-3), make the lobby highly reverberant. The impulse responses taken here with the PA used for the performance had an early decay time (EDT) of 1544,5 ms as calculated with HISSTools in MaxMSP (this measurement referenced here

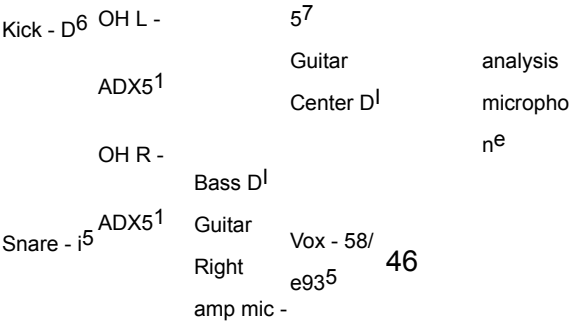


Moving Music - Here...NOW Lobby + 341 inputs & routing
input^s

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- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10

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audio out^t
L
processe^d
USB
audio out^t
R
processe^d
first level gal⁰ 0
0
switches 1..8 0

Figure 6-1: Routing for Here...NOW



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screen capture of the MaxMS^P
performance settings on the right.

Figure 6-2: A

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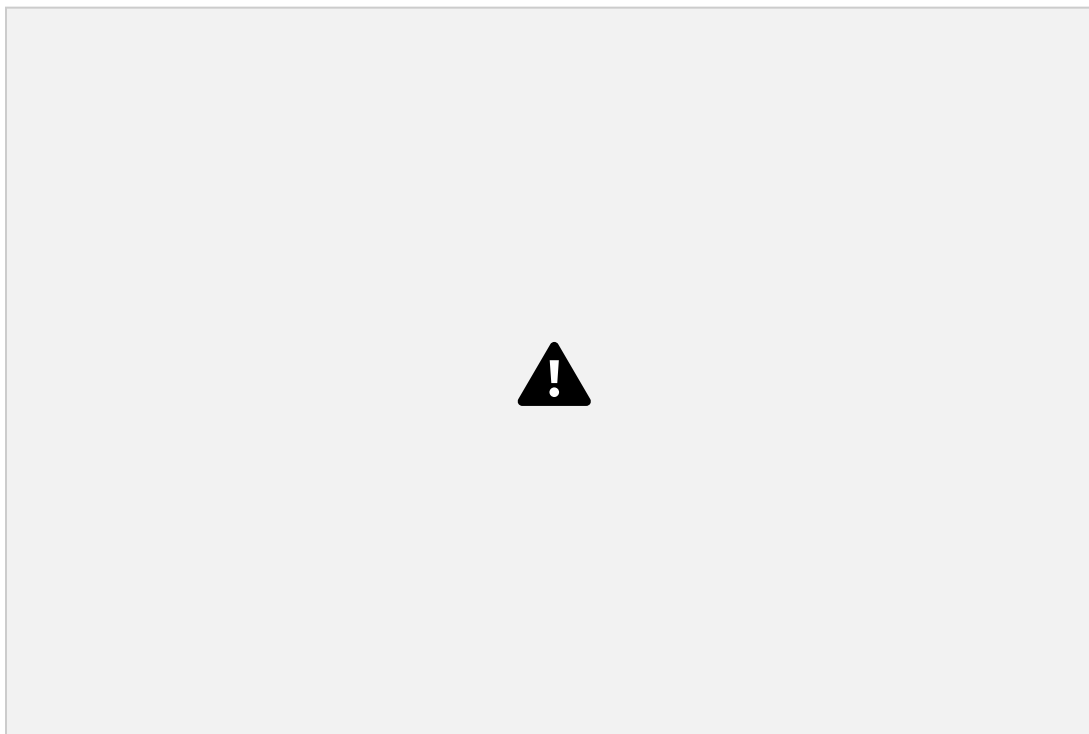


Figure 6-3: Room 1, the first floor lobby. Credit: Danny Goldfield

because of the rooms' high noise floor). This was also the check-in location and waiting area for the audience before the start of the show. The PA in this room consisted of stereo QSC-K12.2 loudspeakers and KS112 subwoofers, 4 QSC-K10 stage monitors, and a Behringer X-32C mixing board. We used a medium, rock-oriented drumset.

The second space was a medium-sized classroom and conference room on the third floor known as Room 341 (see figure 6-4), with ceilings about 10 feet tall, carpeted flooring, and acoustic treatment on 1 wall. This room has a shorter reverberation time, with an

EDT of 677 ms, about a third of the lobby's. The PA specifications were the same as the lobby, with a different, smaller drumset.

The third space was the sixth floor Multi-Purpose Room (MPR), a roughly 60 ft x 60 ft flex space with double height ceilings, and one wall covered in full-height windows (see figure 6-5). It is often used for events such as conferences, and on this night it would also house a performance of Tod Machover's MAICE, which required a stage changeover after *Here...NOW*. Despite its size, this room is not highly reverberant (it has an EDT of 946.7

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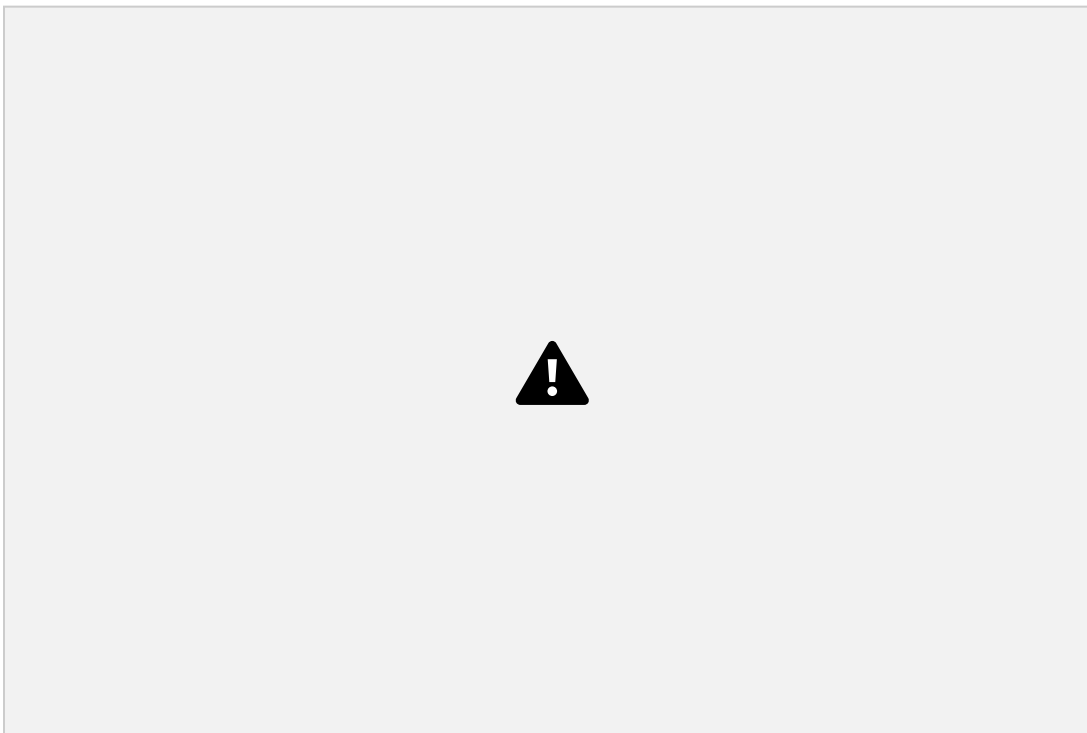


Figure 6-4: Room 2, a class/conference room on the third floor. Credit: Danny Goldfield

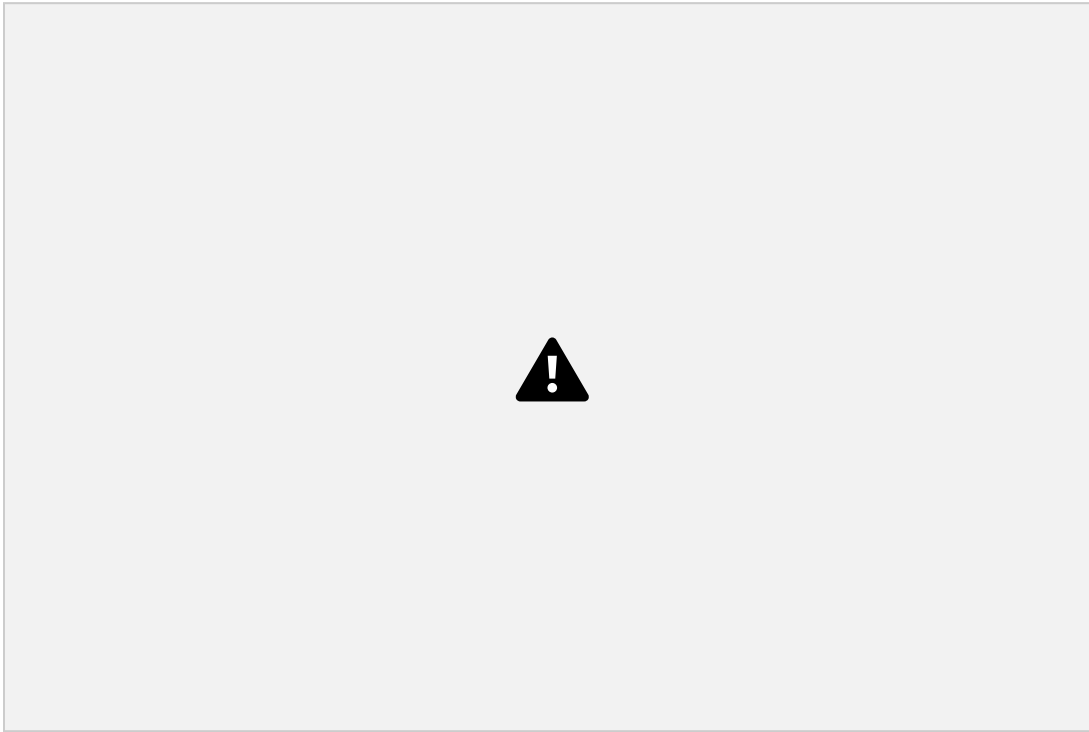


Figure 6-5: Room 3, the Multi-Purpose Room (MPR) on the sixth floor. Credit: Danny Goldfield

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ms), but early reflections appear later than in the other rooms, and it has a noticeable “slapback” reflection. The PA system in this room was different from the others—the main loudspeakers were stereo 15" Duran Audio 3-Way Axys Uniamp, with one 18" Duran Audio Axys subwoofer. The stage monitors were 4 Duran Audio U-12, and the mixing board was a Behringer X-32. We used a similar drumset as in the Lobby.

6.1.2 Compositions

The spaces were chosen early in the process of putting together this performance, and before composing the music. This created the opportunity to develop a thematic arc for the piece that echoed the experience of occupying each space and took advantage of the contrast between them: the Lobby’s expansiveness and sense of scale, Room 341’s intimacy and near-oppressiveness, and the MPR’s balance between the two. Those contrasts could prompt a variety of reflections, but something that stood out to me was the exposure created by that intimacy and in turn the equalizing factor of feeling further away, where details blur.

This prompted imagery of shared experiences, of the individual becoming the collective, and finally of a search for familiarity, which turned into the major thematic focus of the musical and lyrical content of the piece. Knowing we would have a structure of big, then small, then medium spaces, set a trajectory where the familiar, expansive, collective becomes confrontational, strange, and unknown, but we can use that uncertainty to find something new.

For three spaces, then, it made sense to compose one main song for each which echoed its place in this thematic arc. Scores and lyrics are included in the Appendix A, and recordings in the companion website.

Song 1: I was there

Performed in the Lobby, the first song contains lyrical imagery of long-gone experiences, summer, nostalgia, and a refrain that frames this imagery as memory, "I've never been here before/but I was there." It sits at a tempo of 130 BPM, with open, airy chords and

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a wide dynamic range. The guitars trade arpeggios and echo each other, while the bass features a repeating rhythm pattern that grounds the more volatile elements to the drums' forward motion. With each refrain, the whole band comes together into a rhythmic motif that reappears later in the piece along with moments of familiarity (figure 6-6):



Figure 6-6: The "familiarity" rhythmic motif in *Here...NOW*

During this part of the piece, the acoustic exaggeration served as a way to emphasize the sense of scale of this memory and the sense of being enveloped in it, accenting the shared rhythmic motif and certain vocal phrases.

Song 2: Signal

To create a moment of disruption and unfamiliarity, of confrontation with the strange, the second song, performed in Room 341, asks a question: "do you hear me now?" It places the narrator outside of control, in the backseat, in silence, without a friendly face to turn to.

The lead guitar motif that underlies the verses and chorus is tense and unbalanced, the vocal melody has an irregular, shifting shape, and the time signature is 5/4 to emphasize that instability. Instrumental parts start and stop and leave empty, exposed space with only the drums or vocals. After the direct confrontation in the first chorus, the piece transitions into a more aggressive bridge that pulls the harmony in uncomfortable directions, with the lyrics alternating between Spanish and English. This grows into a noise section, prompting improvised interactions between the band, a moment of intimate chaos with no certainty of what will happen next. The length of the noise section is not written into the chart; it is up to the guitarist and drummer to coordinate when to transition back into the second verse, of a different length than the first. By the end of the song, the question is not answered.

In this moment, the space is emphasized during moments of confrontation, to show the

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lack of certainty and response from the emptiness the narrator is asking. An immediate, short echo that does not provide very much to hold on to.

Song 3: To See Everything

The third and final song went through several different iterations before developing into the form in which we performed it. Much of the lyrical imagery was clear from the start; such as the chorus

I'm gonna let it wash over me
If nothing stays the same

I want to see everything,

which resonated with the thematic arc, a moment in finding oneself in the new and changing. But the musical content was more elusive until the “familiarity” rhythmic motif came together, and it became clear that another way to portray that was to incorporate musical themes from elsewhere in the piece. With that in mind, the lead guitar plays pieces of the vocal melody from “I was there,” while the chord progression brings in part of the tension from “Signal.” The song begins in half-time, small and shy, a moment of transition, and grows in confidence to a four-on-the-floor beat under the second verse, with lyrics that make the themes more explicit than ever:

I know this road
Like the back of my hand
Low tide, tall trees, wildlife
I’m halfway across the globe
Everywhere reminds me of a place I know, that changed...

That upwards growth continues until almost the end, where a brief moment of quieter reflection prompts the “familiarity” motif, and the lyrics announce “This is where I want to be,” marking the end of the show.

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For this last song, the space is exaggerated to emphasize moments of emotional resonance and scale, similar to the first.

Interlude: Sail

To introduce each space with a common musical element, the interlude “Sail” is an a capella vocal piece with 3 verses, one for each stage of the piece. Folksy, direct, and harmonically simple, it resets the tone and creates a throughline that restates a mission in part through the refrain “I’m gonna bring you home to me,” a search for something to bring home, and to bring the narrator back home. For each verse, half is in Spanish and

half in English. Each verse features specific imagery; first of places, second of traveling, and last, of a long term practice. In the third space, the band joins in on singing the last repetition of the refrain.

Having this common more literally repeated musical element also serves as a way to compare the different sounds of the spaces more directly; it gives just enough time to hear the space without any exaggeration, then the two different levels.

6.1.3 Performance

At each stage of the performance, the audience was welcomed into the spaces and their acoustic signatures with a spoken introduction that signaled what to expect. For the second show, it also included a synchronized clap by the performers and the audience. The audience were asked what they noticed about the acoustic response to the clap. As a test of the space's acoustics, and the exaggeration transforms, I then sang a verse of "Sail." Over the course of the verse, I slowly turned up the "first level" reverb to the maximum before feedback, then the "second level," auto-convolved reverb.

After "Sail," we played the song we had assigned to the space. For the first two spaces, the bass player and I shared the use of the foot pedal, with me increasing and decreasing the amount of acoustic exaggeration, and then assigning which instruments would be routed into the convolution chain. For some sections, it was more appropriate to have the whole band in the processing; for others, it was better to only have the guitars and vocals, or only

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the drums. In the third space, due to equipment constraints and the distance between the stage and the mixing board, where the computer sat, the sound engineer controlled the exaggeration reverb instead, following instructions I had given her during soundcheck.

We performed the piece twice; at 6 pm and at 8 pm, for largely different audiences (some audience members who came to the early showing chose to stay after). Setting up the PA and processing took somewhat longer than expected, and we were only ready at 5:45. We were able to introduce the show and perform without problems that interrupted it, but for a significant amount of the first performance the processing was unfortunately

inactive. For the second show, the *PPS* system was active the whole time, and because we had already performed the piece once, the spoken elements and transitions were shorter and more fluid.

6.2 Discussion

6.2.1 Performer Reflections

Doing the piece twice in one night, with varying degrees of technical success (technical issues causing the *PPS* system to not work at all for parts of the first showing, for example) brings up some points of tension noticeable from the perspective of performing with this system.

On the one hand, when the *PPS* system worked well, the soundscape that emerged was engaging and brought up clear contrasts between the spaces: the long, warm reverberation of the Lobby; the brightness of the conference room; the slapback-like, clear reflection of the MPR. Having chosen these spaces primarily for their acoustic differences, it was easy to encourage the audience to listen to them, even with the issues that arose.

On the other hand, there were some technical aspects of playing with the *PPS* system that were stressful and unwieldy, and that was distracting from focusing on performing and being expressive, which I noted as necessary improvements for future iterations. These are discussed further below in section 6.2.3.

With this iteration of the processing, it was also very easy for the audio to feed back. There was a balance that was hard to achieve between making the processing clear and audible, and going too far such that it created resonances that were unpleasant and did not add to the meaning of the performance. A large portion of this could be solved with different PA system design and microphone choices, as well as compression or some form of feedback rejection. However, in the moments where that balance was there, it created an intensely emotional effect. Some particular instances stand out where the

combination of the sound and the environment blurred and made me notice new facets of the spaces. In the Lobby, after it got dark, the noise of the elevators behind the stage moving was slightly picked up by the processing, made to sound larger-than-life, and timed with the lighting under them changing on to my fellow performers and the audience. This was a clear marker of context, and resonated deeply with the meaning of the song as it evolved to be *about this moment*.

Furthermore, in contrasting the two showings, one thing that becomes clear is the power of framing and dialogue as part of directing attention to the acoustic environments. One way this showed was in how my reduced nervousness and more fluid speech while asking the audience to listen to their surroundings at the very start of the second showing seemed to prime them to focus not only on the music, but on the wider environment of the concert. And it appeared like doing an exercise as a group along with that (the unison clap) shifted how they interacted with that environment and the other people in it, displaying more predisposition to respond to questions from the performers but also to talk to each other. In the transitions between the spaces, I heard audience members having conversations about what they were hearing, even with people they did not know, and engaging with the band, asking questions and offering help. The framing aspect of the experience may be interesting to investigate further and develop methods for, whether that takes the shape of more theatrical production elements like lighting and staging, a more in-depth or sensory descriptive dialogue, or different explicit prompts for the audience to explore the space and interact with the performers.

6.2.2 Audience Responses

As a way to gather audience feedback, we included an optional survey through Google Forms (MIT COUHES exemption E-6508). It had a pre-screening stage to publicize, according to MIT COUHES regulations, that participants were only eligible if they were 1) above the age of 18 2) participating voluntarily, and 3) aware they were able to end their

participation at any time. No identifying information was gathered. From around 200 attendees, the survey received 17 responses.

Participants were asked to self-identify with chosen categories of relationship to music, or write in a custom one. They were able to choose more than one category. 7 (41.2%) self described as musicians, and 11 (64.7%) as music fans. 4 (23.5%) answered they were artists in other fields, and another 4, producers or audio engineers. One respondent only identified as an "Art enthusiast" (write-in).

Over half of the respondents (8) mentioned noticing differences in the relationship between the spaces and the sound of the music, and 5 also mentioned behavior changes in the audience and musicians depending on the space, with one responding that "the performer's demeanor changed from room to room, showing the effect the space has not only on the music and audience but on the performer as well."

Although the spatial differences were clear and generally welcomed, it seemed like the processing could be subtle or too hard to hear, as 4 responses noted - and only 2 responses mentioned actively noticing the processing. This could be a positive if we wanted to avoid obvious or disruptive effects, but for a project that aims to direct people's attention to the sound of the space, it suggests that there was more we could do to make it audible. This is taken into account in performances with subsequent iterations of the system discussed in the next chapter, and differences are analyzed in the **Discussion** chapter.

In a similar way, 5 responses mentioned issues with sound clarity or volume, with some noting that the directionality of the loudspeakers made it hard for the audience members on the sides to hear. Room 341 (the smaller one) in particular was contentious: some responders mentioned dissatisfaction with the volume or worse sound quality. However, in

terpersonally, some (3) responses mentioned more connection, or closeness in the smaller space—though others (4) also stated discomfort with the dynamics or noticing "pressure" there. This may tell us that there are different priorities to balance between the

interpersonal and the technical, and that people experiencing the same event can express different responses based on their expectations and background, among other possible factors.

Responders often compared the different spaces, and in some cases the different performances in each space, and stated some preference of one over the other (5). Some stated reasons why one space may be better than another - one said they "thought the balance between the vocals and the instruments, and therefore the performance, was the best in the third room." Or comparatively, a dislike for one space over the rest: "The bright and cold light in the second room made the experience less pleasant" (interestingly, there are a few responses that brought up lighting: 2 as a *positive* aspect that can add to the environment, and 2 as a *negative* reflection, an aspect that took away from the experience).

Overall, responders seemed intrigued and curious about the concepts, and considered them novel. They shared reflections on how the experiences of the spaces made them feel, and what they observed about the environment's effect on the performative place. However, there were various critiques of the execution, both on technical and communication levels.

6.2.3 Technical notes: System functionality

This first public experience with the system showed some unexpected successes and obstacles in its technical execution.

Attempting to manage the processing and to also perform was challenging. Due to licensing and equipment limitations (mostly logistical), the laptop running the MaxMSP patch had to be moved from room to room along with adapters and dongles, as opposed to having three separate computers with independent processing set before the start of the concert. Although the impulse responses were taken before the performance, the one that corresponded to each room had to be selected while changing setups, which also made the transitions slower. On top of that, the connections we had available did not allow for the

computer to be on stage. If we were to produce this piece again, it would be important to use a networked audio protocol like Dante³ to enable that while not requiring additional hardware, or to enlist a dedicated systems manager that knows the patch and can set it up on behalf of the performers.

Exciting the resonant frequencies of an acoustic system also comes with a huge challenge: the threshold for feedback is much lower than when we are canceling out the resonant frequencies. Live sound best practices avoid that ringing for a reason—it is loud, and self-perpetuating; the longer it goes, the louder it gets. During the concerts, there were a couple of moments of audible feedback (one noted by a survey taker) that made it necessary to quiet the system quickly. It became clear that it was important to have a clear upper limit on the volume of the system such that it would be harder to get to that point.

On the opposite end of the scale, there were moments where, unless the effect was almost loud enough to cause feedback, it was hard to pick up on, even as a performer. Early in the Room 341 section of the first showing, even I did not realize that the system was not on when it was supposed to be coming through subtly. This plays a role in the question about volume dynamics like the feedback issue, but also raises the idea that there might be more and different ways to transform the acoustic capture for emphasis/exaggeration.

The two forms of the IR as used for *Here...NOW* are relatively similar, especially for flatter and less reverberant spaces. More detailed analysis of the IRs and their auto-convolved variants, as well as of the system as a whole, appears in the **Discussion** chapter.

6.3 Project conclusion

Overall, it felt like the objectives of the performance were generally met, even if it was not *only* thanks to the audio processing for acoustic exaggeration aspect. Making *Here...NOW* happen was significantly challenging, in one part because of the technical difficulties mentioned. The other major factor was that it was not logistically possible to rehearse the whole show in the spaces before the first performance, which did not give us time for those issues to come up and be addressed before sharing it with others. That

raises the question 3. *Dante - One Connection. Endless Possibilities.*

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on what makes a show like this most effective at conveying the goal of encouraging its audience to listen to, and appreciate, the space they are occupying.

On the one hand, having a certain degree of spontaneity and room for improvisation reinforces the “liveness” of the experience. While the music and the effect control moves were heavily rehearsed, we still had to make space for the possibility of error that arises with the variables of the concert. There were moments where the interaction with the acoustic environment was *reactive*, where something had to be changed without prior preparation (for example turning down the effect when feedback started). Could that have been a way that the audience noticed that the context of the performance was having an effect on its content? Perhaps another way to achieve this would have been to have part of the setup process take place in full view of the audience, letting them learn how the acoustic space operates together with the performers.

On the other hand, it is also possible that by having longer rehearsals in each space and coming to a deeper understanding of each space’s capacities and limitations before the show, we would have been able to *predict* the sonic effects of each of their acoustic environments with more accuracy. With this information, we could have generated a simulacrum of moments—other than the noise section in “Signal”—which still conveyed a similar reactivity to the audience, though with our knowledge of their outcome. Maybe, by creating rehearsed moments that emphasized the “liveness” of the performance and its intimate dependence on its environment, we could have generated more specific audience responses, for example.

7 Performing Performance Spaces: the concert series

7.1 Project description

After the first public experience with the Performing Performance Spaces project, it became clear that there was more to explore and improve about the *PPS* system, the organization of performances using it, and the way the project was communicated to an audience. The initial performance got mixed-to-positive feedback, and was an interesting starting point to think about how an audience can be guided to pay attention to the context of a live music experience through the exaggeration of its sonic qualities.

Since the start of this project, one of the main goals has been to create opportunities to foster communal, collective experiences through performances with the *PPS* system. It was specifically intriguing to take into account the music community of the geographical location where the experiences were taking place, in this case the greater Boston area, to bring together people whose experiences throughout the city may overlap. What could it look like for different spaces in the city to be re-signified as music places? How would local audiences interact with Boston-based artists, who share their experiences of living here, in performative situations that brought attention to the immediate context?

One way to address these questions was to host a series of concerts with this in mind,

letting different local musicians take over various spaces with their repertoire and the *PPS* system enabling them to control the exaggerated sound of the venue's acoustics. It was especially interesting to look for outdoor locations, which are rarely built with events like these in mind and allow for easy encounters with passersby who may stumble upon the events. For another layer of context, these were all on MIT's campus, bringing with it all the associations of a STEM-oriented research institute and not a concert venue.

Related to that, in conversations with various Boston-area music community members, one quality about the community that is mentioned often is the fluidity of its composition. One

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common trope in Boston is that artists start out and gain prominence while attending one of the many universities in the area, then move away once they graduate. When it came time to reach out to musicians to put together these concerts, I was interested in finding acts that had varied sounds, and varied histories with the city and its music community, but that were interested in being part of it long-term and involved for several years.

We scheduled three concerts over the course of a month, focusing on solo performers and duos. The artists' involvement included the public-facing performance as well as a private interview relating to their experiences with music communities, Boston specifically, and the concerts. They were all compensated for their labor. Excerpts transcribed here from interviews are lightly edited for legibility. We also included an anonymous audience survey (MIT COUHES exemption E-6716) to get responses about their impressions of the space, the music and sound, and the other people involved, both fellow audience members and performers. Like the survey for *Here... NOW* it had an elimination stage that clarified, according to MIT COUHES regulations, that participants were only eligible to take it if they were 1) above the age of 18 2) participating voluntarily, and 3) aware they were able to end their participation at any time. No identifying information was collected from the audience.

7.1.1 Technical description

On a technical level, the systems for the concerts were similar to the one used in *Here*. . .

NOW. We used a stereo PA (with no subwoofers this time as there were no instruments that had a range low enough to play through them), and a digital console that sent audio to a computer running a MaxMSP patch with the reverbs, which output the effect on the summed channels in stereo. Addressing some comments from *Here*. . . *NOW*, the *PPS* system now included 4 stages or types of exaggeration, all adjusted for minimal phase:

1. Inverted: Using the `irinvert~` object, “deconvolution of a Dirac delta function (a single sample spike in the digital domain) by an input IR”¹ to get a frequency response inverted along the X axis. This allowed for an approximation of a more neutral acoustic space with a flat frequency response, though it is not totally accurate in part because

1. Harker and Tremblay, “THE HISSTOOLS IMPULSE RESPONSE TOOLBOX: CONVOLUTION FOR THE MASSES.”

as used for the concert series^S Figure 7-1: A
screen capture of the graphic user interface
for the *PPS* syste^m



it cannot fully account for how the space reflects timbral information in the time do

main;

2. “First level” reverb, the same format as in *Here. . . NOW* (internally referred to as “room”);
3. “Second level” reverb, the same format as in *Here. . . NOW* (internally referred to as “autoroom”, from auto-convolved room), and
4. “Fifth level” or “mega-convolved” reverb, obtained by performing auto-convolution of the original IR 5 times (internally referred to as “megaroom”).

The artists were able to control the reverb with the same foot controller used for *Here. . . NOW*, using one expression pedal to fade from one stage to the next, and the other to control the volume of the effect’s output. This way, they had access to a wider range of more obviously audible exaggeration while retaining the simplicity of just 2 controls. We did not assign switches to allow only certain instruments into the processing. I served as audio engineer and was able to monitor both the levels of the acoustic sources and the functioning of the *PPS* system.

7.2 Concert 1: Fegan. . . The Dog, June 5th at Dertouzos Amphitheater

Eric Fegan is a singer-songwriter and multi-instrumentalist. He performs solo as Fe gan. . . the Dog and leads the band Not A Dog. The evening of June 5th, he played an improvised solo violin piece and original folk-punk-adjacent songs on voice and electric guitar. Dertouzos Amphitheater, located adjacent to the Stata Center (one of the main buildings for computer science at MIT) served as the venue. This space was likely the most similar to a “conventional” performance venue, but it is not typically used for music.

The impulse response was taken in the middle of the amphitheater, and the stage was placed close to the open end (see figure 7-3).

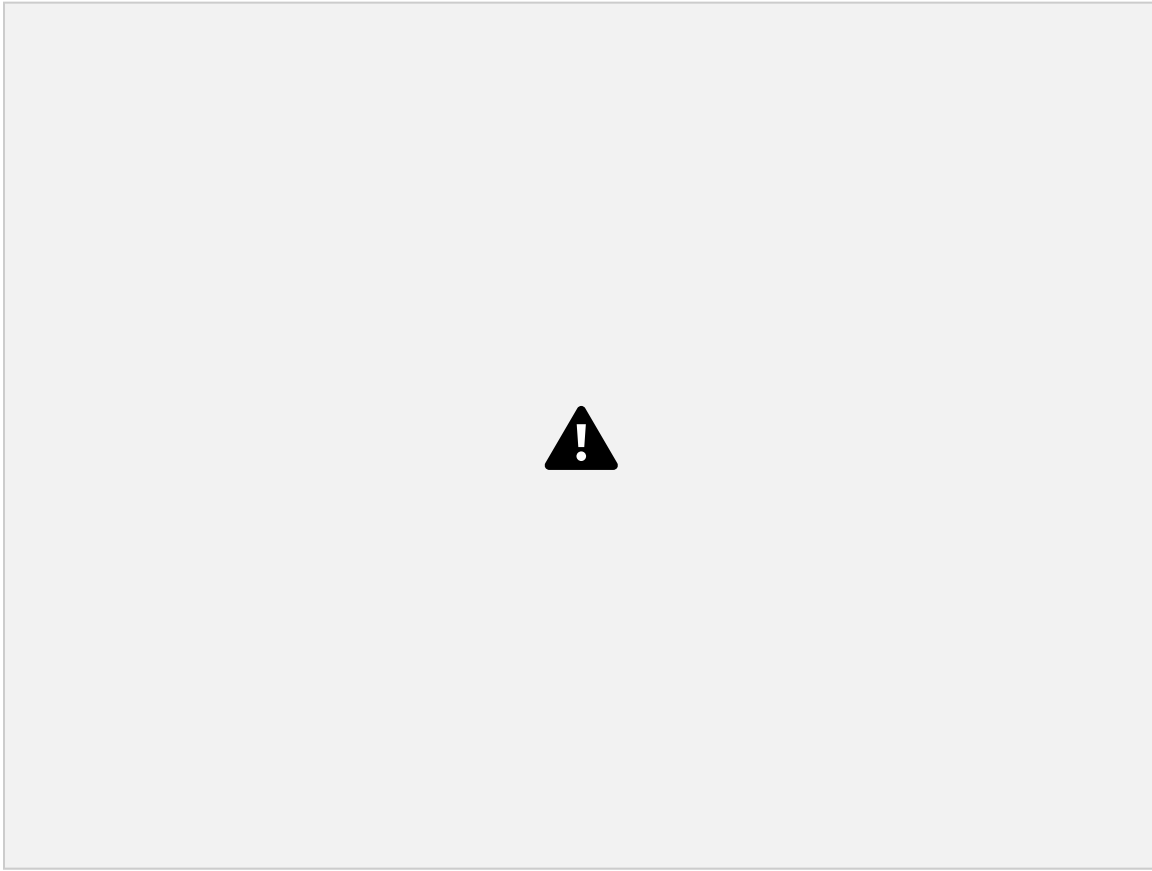


Figure 7-2: A photo of the performance by Fegan...The Dog.



Figure 7-3: A scheme of the layout for Fegan...the Dog's performance, with the stage area and PA system at the open end of the amphitheater, facing towards the seating.

It was an extremely hot day, so we placed the mixing desk and computer across the base of the amphitheater, off to the side where the trees shaded them. This proved to be more than necessary, as during setup the computer repeatedly shut down likely due to overheating. Fegan had an hour to rehearse, get acquainted with the system, and plan his performance with it. We used 3 microphone inputs: vocal microphone, guitar amplifier microphone, and violin direct input. They were all sent to the processing computer at levels equal to their amplified output. The mixing board was a Yamaha O1V96 connected to the computer through a Scarlett 18i20 interface, and the PA loudspeakers were the Duran Audio 3-Way Axys Uniamp loudspeakers used on the 6th floor for *Here...NOW*.

The audience, of around 12 people, seated themselves largely on the lower rungs of the space. At the beginning of the concert I introduced the project, and asked the audience to clap in unison together and listen to how the space responded. I then introduced the artist, and let him present his music.

Fegan started with an approximately 5 minute violin improvisation, during which he used

the pedals to control the effect, then moved to the guitar and played around 8 original songs, using the acoustic exaggeration at key moments. The concert had a relaxed, casual atmosphere. At about the 15 minute mark, Fegan also encouraged the audience to move throughout the space and listen from different positions to compare the spatial differences in the sound. Audience members came and went, and the total duration of the performance was about 40 minutes. At the end, we repeated the clap exercise, with the audience standing in the center of the amphitheater, where the acoustic reflections of the space are most audible and reverberate back to the source.

7.2.1 Audience and Performer Responses

The audience was encouraged to complete the survey before they left the performance. It received 3 responses. All of them self-identified as music fans, and 2 also as music community members and musicians. One also added music researcher to that list.

2 of the responses shared observations about aspects other than the direct content of the performance. One of them noted an acoustic effect: "Sometimes it sounded like a bow on a cymbal bouncing from different parts of the space. It made me more aware of the geometry of the amphitheater." They shared a strong emotional response from that: "It gave me chills at certain parts of the songs." However, they also noted that the balance of the effects was not always right, pointing out a swing between too subtle and feedback.

Meanwhile, the other response observed a certain distance from the musical performance and more of a proximity to the environment and soundscape; they mentioned sources of sound other than the music, and how moving to the back of the space led them to "notice the birds and people more."

Both of these responders also shared some interpersonal observations related to group behavior, one of them mentioning that "seeing others move around made me feel more able to do the same," and the other noticing passersby being attracted to the performance by virtue of it occupying an open space.

The remaining responder only mentioned impressions from the direct sound: they noted

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the "stereo effect was most present stage left," and a sense of proximity from the artist's voice, "as if they were talking directly to me."

In conversation with Fegan, he mentioned several of these aspects as factors that affected his experience performing. For one, he pointed out that the event was framed as a "thinking concert," giving him a chance to think while playing in a different way than how he usually performs. As he describes it, he usually "black[s] out, that's a thing for a lot of my concerts, I forget the 45 minutes I'm playing."

When asked about noticing his relationship to the space, or a new awareness of where he was, he said there were certain pieces of music where the effect was especially clear. He talked about one particular song with longer, dwelling chords and how he could now "change the individual notes and how it's expanding in the space in real time." He also noted that with the audience moving about the space and exploring, their different reactions based on the changing places where they were sitting added to his awareness that the sound varied around the amphitheater.

In relation to the music, he talked about the experience as an exercise in listening. Noticing slight differences in how he was playing: lingering on notes, listening and adjusting the effect. He mentioned that adjustment as a challenge in balance, seeing how far it could go (sometimes too far or not enough), and trying to capture sonically interesting moments, but that it was difficult to replicate these moments.

Overall, Fegan's responses show positive reflections about the experimental nature of the concert and the opportunity to try new things with a new resource to transmit emotion. He was optimistic both from his perspective as the performer and how his playing shifted, as well as for the audience's openness to "adjust their listening patterns" and find different ways to be impacted by the concert and its environment.

7.3 Concert 2: Tiberius, June 16th at the Lower Courtyard

Brendan Wright leads the project Tiberius, which has been local to Boston since 2019. The evening of June 16th, they performed solo versions of their original indie-rock songs and

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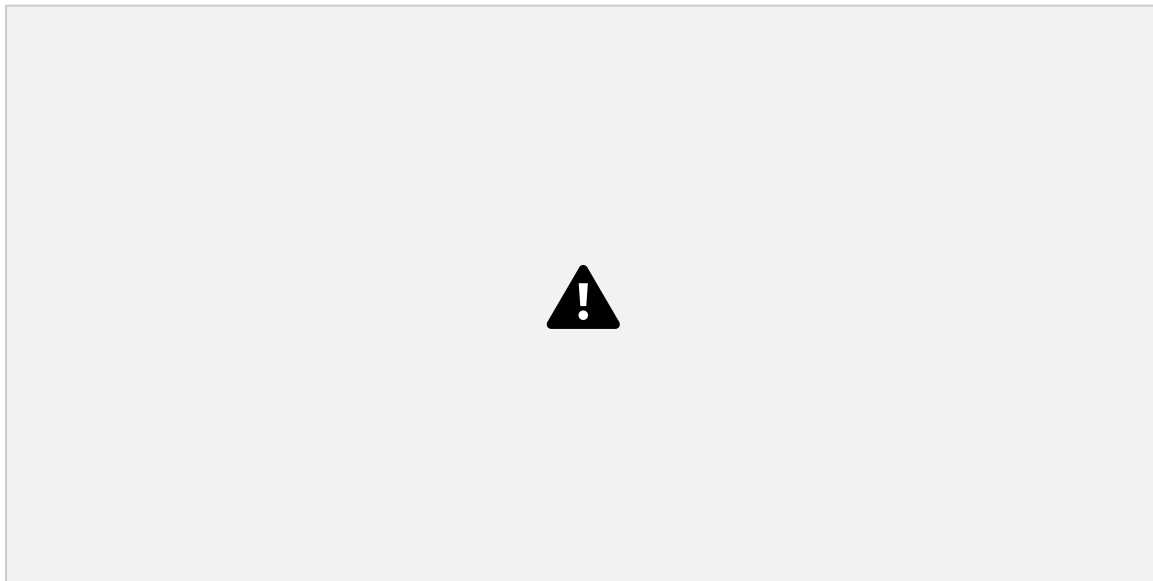


Figure 7-4: A photo of the setup for the performance by Tiberius

ambient improvisations on voice and electric guitar with effects. The concert took place at the Lower Courtyard, a landscape sculpture by Richard Fleischner² situated between the MIT Media Lab and MIT Medical buildings.

For this concert, we used the same mixing board, interface, and microphones for the voice and guitar as the previous, but were able to borrow a more portable and less noisy pair of QSC K10 loudspeakers for the main PA, with a Duran Audio Axys U-12 loudspeaker as a stage monitor. The mix position was next to the stage to simplify power cable runs.

We set up the PA system facing towards the buildings and concrete structure of the sculpture to exploit the reflections that emerged there (see figure 7-5). The day was cold and windy, and capturing the impulse responses was a challenge because of that. We waited until a lull in the wind and used a windscreen which helped diminish the low-frequency

rumble usually caused by wind hitting the microphone capsule directly.

After a short rehearsal in which Tiberius familiarized themselves with the system, the concert started at 6:30. I introduced the project and asked the audience to participate in the clap exercise, then let Tiberius take the stage. They played for about 35 minutes, then 2. Fleischner, *Lower Courtyard*.

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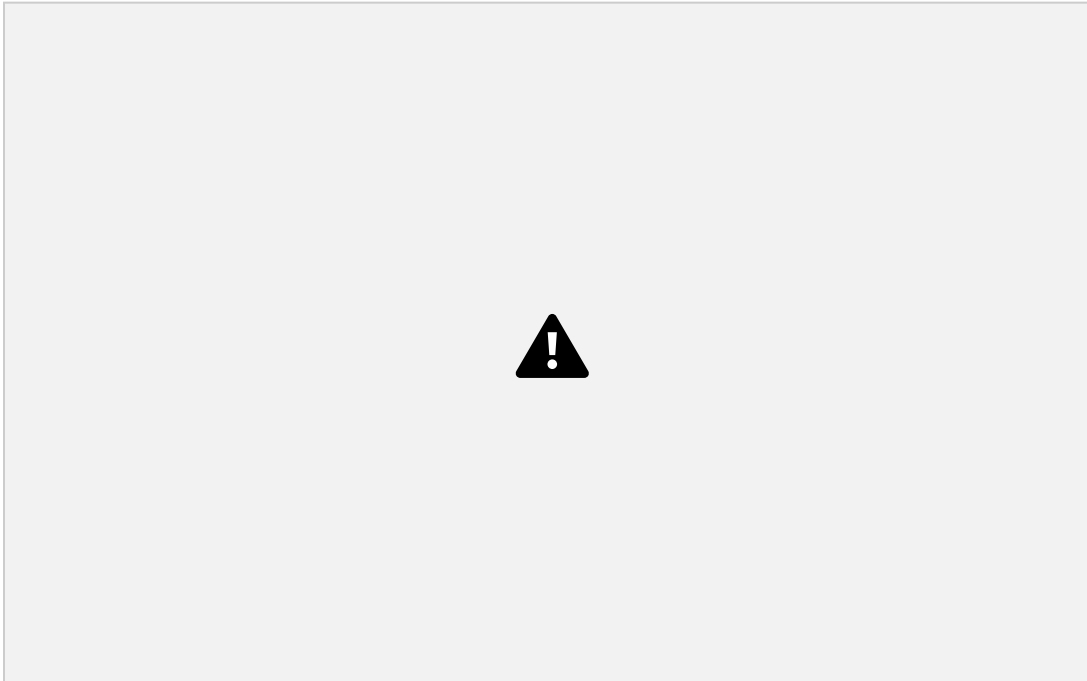


Figure 7-5: A diagram of the setup for the performance by Tiberius, with the path behind the stage area. The audience sat on the semi-circular structure on the right.

sitioning between original voice/guitar songs, and guitar improvisation using their effects pedals and the *PPS* system. Although we had soundchecked before, I took time over the first few songs to adjust levels and processing. At the end of the show, we repeated the clap exercise as new audience members had arrived after the initial one, bringing the total number of attendees to around 20.

The audience stayed generally still for this concert, likely in part because of the cold temperature, but the atmosphere was still relaxed. Tiberius spent time between musical moments interacting with the audience, asking questions and giving some context to the music they were playing.

7.3.1 Audience and Performer Responses

The audience was offered the option to participate in the same anonymous survey as the first concert. For this performance, it received 9 responses.

8 of the responders self-identified as music fans; 6 as artists in another field; 3 as music community members; 2 as musicians, and 1 as music researcher. The biggest overlap

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was between music fan and artist in another field, with 5 of the latter also identifying as the former.

3 responses (33%) mentioned the clap (exercise) as a moment where they noticed their relationship to the space; one of which said more about why: "you don't hear it until you do and then you can't not notice. It is a bit surreal, as if you're a fish noticing there's water all around you for the first time." 6 (66%) responses, including the one cited before, also used language related to **immersion** or **incorporation**: "it felt like the whole courtyard was in on" it; "i felt like i was *becoming part of the space*/floating off," for example. In the same field, 5 (55%) responses also point to a factor unique to an outdoor concert, whether that was the wind (2), the weather, (1), the natural environment (1), or the outside architecture (1). These responses convey an image of an environment that created a sense of belonging to the space, of involvement and reflection.

When asked about changes in their relationship with the music or the sound, only one respondent said they did not notice any, mentioning a "consistent vibe throughout." The rest diverged widely. 3 (33%) mentioned sounds from the environment (bird, wind) catching their attention, and 3 cited silence or the time between songs. 3 also mentioned dynamics of the performance itself, one of which said "the last song," and 2 of which noted the relationship and familiarity with the performer/performance growing as time went on.

Several audience members also noted their relationship with the performer changing when asked about their perspective of relationships with the other people there: 3 (2 of which had not noted it before) mentioned that aspect explicitly. 3 also mentioned other audience members. There were 2 instances where responders talked about becoming

introspective. 3 responses also said they did not notice a change in their relationships with other people.

Other responses that stand out are several praises of the music (4), and mentions of passersby (2). In general, responses seemed positive about the music, the sound, the concept, and execution. One responder also pointed out how Tiberius was using the *PPS* system “in an almost harmonic and timbral way,” which refers to the moments where they used the more extreme reverbs to create droning sounds to improvise upon.

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The way Tiberius talked about it in our post-concert interview, they described using the effect “to emphasize feelings, usually feelings of anxiety [...] or personal extra energy and then taking that away.” They mentioned looking to “produce contrast.”

When asked about their relationship with the space and how that changed over the course of the performance, there was one moment that stood out to them. At the beginning of the concert, they were performing with their eyes closed to only 5 or 6 people. “And then at the end of the song, I open my eyes and I think that’s the first or second song that it had really filled out [...] Maybe before it didn’t feel like an amphitheater. Or it felt more like just a green space. And then when I open my eyes, there are people there, and all of a sudden it felt like, you know, this is a real performance. This is a real concert.” This exemplifies how the place of the concert is not inherent to the space, does not exist until the actual performance creates it, but then it is perceptibly there, and it leaves an imprint.

And after that place expires at the end of the performance, something about the interpersonal dynamics they perceived changed: “before that performance, I was feeling more like a part of the space or like I was just another element in the space. And [...] I think I feel this way after most performances, I always feel very awkward, [...] like I’m a sort of stick out, like a sore thumb or like I’m outside of the space, or I feel very exposed.” It stands out how many audience responses described a sense of immersion and becoming part of the space during the experience, while Tiberius, in charge of creating that performative place, had an opposite reaction when the place was no longer there. They

cited the confessional nature of the songwriting, as well as possibly the fact that “for the last half hour, everyone was staring at me and not talking to anyone else.”

There is a vulnerability that comes across in the exposure of a solo performance, especially one where the music blends into the space, which they feel as though “really showcases the storytelling aspect of these songs.”

7.4 Concert 3: ZAMA, July 2nd at the Kendall/MIT Open Space

Rebecca Zama performs original R&B/Caribbean fusion under the name ZAMA. She performed with keyboard accompanist RJ at noon on July 2nd in the Kendall/MIT Open Space

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as part of a joint event between the Performing Performance Spaces project and the Midday Music series organized by MIT Open Space planning. Midday Music events, as the name indicates, take place at noon. The concert was originally advertised for July 1st, but high chances of rain led the Open Space team to reschedule it for the rain date on the 2nd.

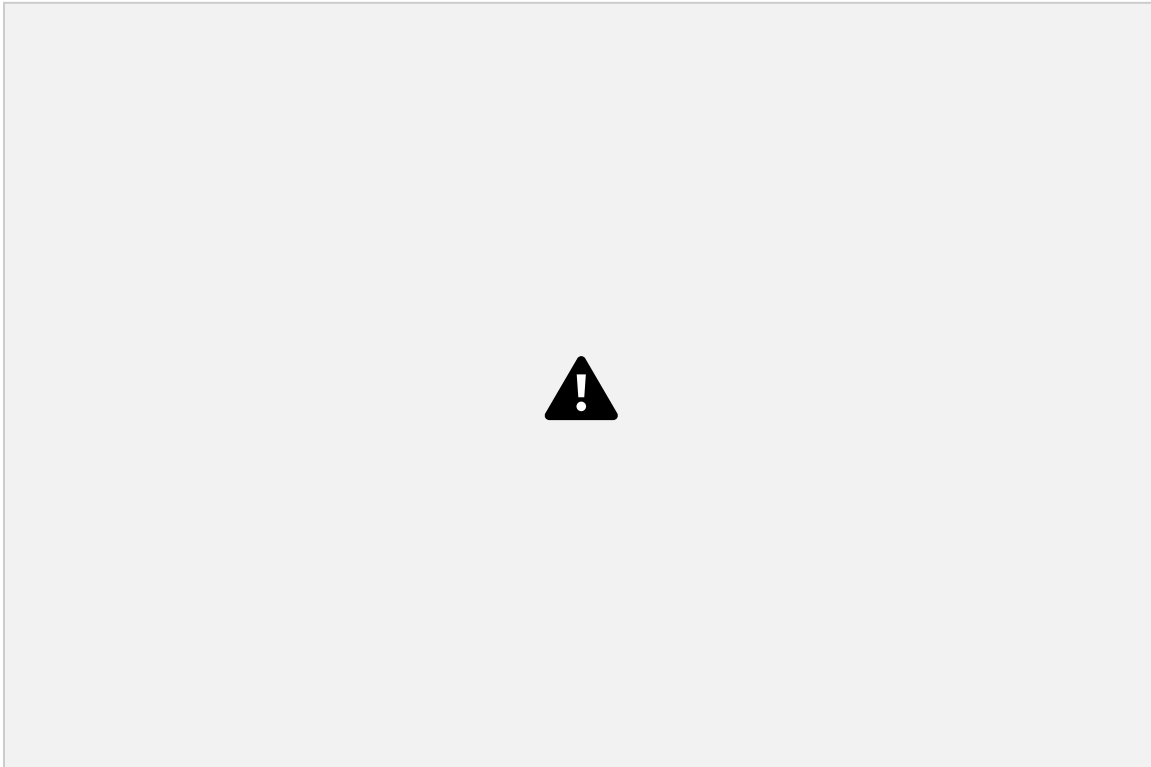


Figure 7-6: A photo of ZAMA performing at the Kendall/MIT Open Space.

This was the only concert out of the 3 to feature an accompanist, and the only one to use a keyboard. ZAMA also requested the ability to see the user interface of the *PPS* system to get not just auditory but also visual feedback on which effect was active. We used the same equipment as for the second concert; QSC K10 loudspeakers, Duran Audio Axys U-12 loudspeakers as stage monitors, and a Yamaha O1V96 mixer connected to the computer through a Scarlett 18i20 interface. We put the mix position next to the stage, in line with the loudspeakers.

Similar to the Tiberius performance, we had to be strategic about taking the impulse re



Figure 7-7: A diagram of the setup for the performance by ZAMA. The audience sat at the tables shown below the stage area.

sponses of the space as wind circulated in the plaza. We used a windscreen and waited for a lull, which helped avoid distorting the capture.

This concert had the smallest audience of the three (about 10 people at any given time), likely because of the date change. The space was also less secluded than the other two, and audience members came and went with greater frequency. Several brought food with them, ate, and left. I introduced ZAMA at the start and led the clap exercise, then handed over the stage to her.

ZAMA made the experience highly engaging, creating moments for audience participation through call-and-response melodies and talking to the audience about the context of the performance. The effect of the *PPS* system was most audible on her voice, less so on the keyboard, and she kept it quite subtle, using it mostly for emphasis on certain musical phrases. At the beginning of the show, the levels being sent to the computer were higher than they should have been, which briefly made the effect sound distorted, but they were adjusted to avoid this for the rest of the concert.

7.4.1 Audience and Performer Responses

The survey received 4 responses about this last concert. All 4 identified as “music fans,” with one adding “musician” and “music researcher.”

All 4 of the responses mentioned ZAMA's experimentation with the effects and how that made them hear the experience differently as a positive. One noted “it really made me think about how something like acoustics can change parameters like tone and mood.” Two of them added that it was valuable to hear her explain how she was using the system.

While one responder mentioned the “glitch” moments (which seem like the moments where there was some amount of distortion on the signals) as a positive aspect that made them think about the space, one of the others noticed “a strong resonance—a ‘boominess’—that wasn’t particularly pleasant,” adding that the sound seemed muddy and took away from the experience. A third responder noted that at some times the reverb and resonance were too prominent, “took me out of the coziness I felt.” This may have created a tension in the way they perceived their relationship to the space.

Two of the responders also noted the clap, one as an interpersonal interaction, and one as an interaction with the sound of the space. The latter also brought up other aspects of the space of the performance, the heat of the summer day, and being outdoors, and how that made it “a joy to sit outdoors and enjoy Zama’s beautiful music.”

Three of the responses also mentioned the interaction with the artist as an aspect that shifted their relationship with others present, one of them adding that it “became less like a bunch of people having lunch while she performed in the background,” and the other pointing out ZAMA talking about her interest in the technology she was experimenting with. One responder also noted that her interaction with the audience and “specific folks” prompted them to look “around the space instead of only looking at the stage.”

In our debrief after the concert, ZAMA shared her perspective as related to that aspect. Something she mentioned finding powerful about the outdoor, public space nature of this concert was that potential for chance encounters with passersby, “you’re able to find the

passerby who just was trying to get lunch and have a moment of solitude, and they're able to find music and to see that it can just be a pleasant part of someone's day in an unexpected way. [...]And music can bring people into spaces that they otherwise, you know, didn't necessarily plan to be." That unexpected musical experience becomes a way of finding connection and belonging "within that shared space with complete strangers."

She also brought up how explaining what was happening in relation with the audio process ing was another way to connect with the audience, noticing them showing interest in the specific type of musical experience and more attention to what was happening. "When you include people in the performance and they are a part of the experience, it made people, I think, even more in tune with what was going on because, oh, wait, I'm a part of this," she said when asked about her relationship with the other people present for the performance and how it changed. "I think that my goal when I'm performing is always to connect with the listener as much as I can." She noted how the audience's voices sounded in relation to her amplified one, "to hear what those voices coming together sounds like in a more muted space, right? Where you hear the vocals resonating off of the concrete and the buildings around you, and then being able to also compare that to, what if we had a little bit more reverb?"

For herself, she noticed conceiving of the different stages of the effect as a form of emphasis, especially for the 5th-level extreme exaggeration, "mapping it out beforehand and even in the moment[...] I want to place emphasis on this word, because I think that this word is what's going to transmit the feeling or the emotion that I'm trying to convey to the listener. [...]It just made me more intentional with the places that I want to provide emphasis." She had expected that she "would be focusing more on choosing the effects and focusing more on pedals than performing. And I found that after going through the first few minutes of the first song, that I wasn't really thinking any more, and my body was kind of just naturally allowing itself to the task at hand."

In terms of the space, the concert did make ZAMA "realize just how open [the space] was." Part of it, she said, was the effect, "and how it made the space feel big and yet feel

so small and connected. With so much open space, sounds can get lost. [...] Despite how big

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it is and how much open air there was, we so were able to get a centralized experience as well."

Overall, reactions to the system as used in this concert appear a little more mixed due to the sound of the effects, although responses to the musical performance itself were positive. It raises questions about the different acoustics of the various spaces and their influence on the *PPS* system, and what may make certain kinds of spaces most effective at creating an experience that brings attention to the acoustic environment as a shared place and prompts emotional reaction. However, there were elements of the experience that were effective at creating that connection, especially as relates to framing, acknowledging the space, and the interactions between the performers and audience.

7.5 Project conclusion

Audience responses to the *Performing Performance Spaces* concert series showed curiosity about the contextual aspects these concerts explore, and engagement with the experiences as exercises in listening. Those who responded to the survey shared observations about the spaces that could have only come from being part of musical experiences within them. There was a focus on the sounds present and what they meant, and how they related to audience experiences of the musical performance, especially of the environment that emerged around it. Varying reactions show interesting relationships between the spaces, the performative places, and the responses they elicited in their occupants. The contrasts between these interactions merit analysis of why some acoustic spaces may have been more effective than others at prompting these responses.

The artists that were part of the series shared generally positive reflections about using a system like this as an experimental tool for music performance. Their varied uses of the system showed different approaches to emphasizing the acoustic environment dynamically, from adding emphasis to certain words, to exploiting resonant drones and adding energy. They gave important feedback related to operating the system, hoping to achieve more consistency. More than that, they also offered valuable perspectives on making mu

sic live as an exercise in listening, and in creating a performative place that calls attention to its content, and especially its context.

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8 Other Performances

This chapter describes other performances using the *PPS* system where data was not collected, but which still provided insights that informed the rest of the project.

8.1 *Where Everything's New*

As a final project for a Media Lab project class structured around deep listening taught by my advisor,¹ I composed and performed a site-specific piece for the Media Lab atrium, vocals, nylon-string guitar, and electronics. It continued some of the themes from *Here...NOW* of recognizing the familiar in the new.

For *Where Everything's New*, I decided to take a more improvisational live-looping approach that incorporated not just the acoustics but also the sounds that occupy the atrium, sampling, cropping, and processing recordings made in the weeks before the final performance. The sonic palette included room tone filtered to find resonant frequencies and transposed into a pad that enabled me to play chords, as well as percussive sounds that emerged when people passing through or staying in the atrium interacted with it: Doors opening and closing, a ping-pong ball bouncing on the table in the middle of a game, footsteps going up and down the stairs.

This piece used the *PPS* system as a timbral resource, taking advantage of the low frequency resonances of the atrium as drones. Being able to take the impulse response of the empty atrium before the performance provided the opportunity to build the harmonic content of the piece specifically to complement these resonances.

With the piece being built as an Ableton Live project, I also decided to create a Max for Live version of the *PPS* MaxMSP patch, to simplify audio routing by having it as a plug in to which the vocal and guitar inputs were sent. The functionality was essentially the same, except audio was routed from the Ableton Live channels rather than directly from

the audio interface's inputs as in the MaxMSP patch. The interface was also adjusted to fit the dimensions of the Live interface, as seen in figure 8-1.

1. *Deeper Listening.*

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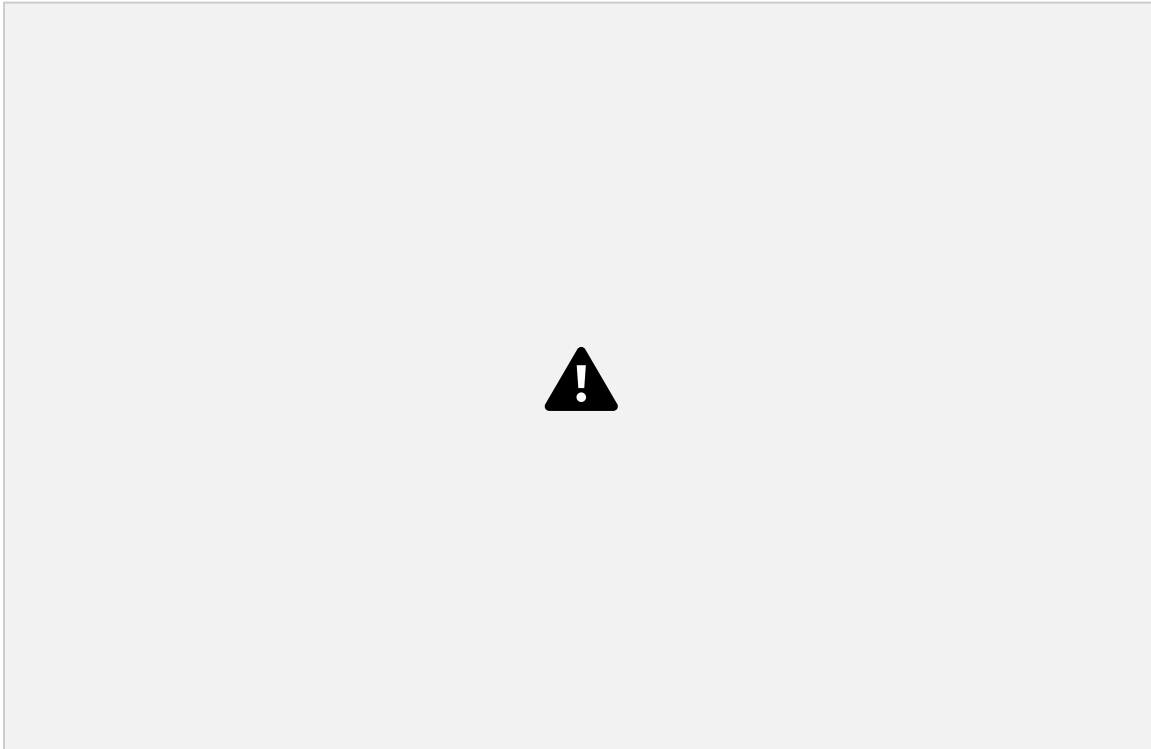


Figure 8-1: A screenshot of the Ableton Live project for *Where Everything's New*

Taking place in May 2025, this was also the first public test of the “mega-convolution” transform, which helped generate longer drones from the resonant frequencies using controlled feedback. The atrium is a relatively highly reverberant space, and the transforms emphasized that.

The performance started with only speech, a brief description of the project, turning into a more performative spoken word section where I listed the sources of sound for the piece while slowly turning up the different levels of reverb. When it was present enough to generate the low ringing, the more prepared musical content of the piece began, with the room tone pad serving as a harmonic base and the chopped percussive samples as drums in pre-made clips triggered and stopped according to the piece and improvisationally. All in all, the whole performance was about 8 minutes.

Although the focus of *Where Everything's New* was still related to encouraging its audience to listen to the space where we were sharing a musical experience, it was less so about

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the specific acoustic environment and more about all the sounds usually present in the space—most of which, because we had taken it over to perform in, were not audible while the performance happened. However, it was still a compelling exercise in using location specific qualities as expressive resources, which might be interesting to replicate in other venues.

8.2 A *Here...NOW* excerpt at the International Computer Music Conference

The 50th anniversary of International Computer Music Conference took place in the Boston area June 8-14, 2025, and selected an excerpt from *Here...NOW* to be performed in one of its concerts, on Thursday, June 12th.² The concert featured other pieces for soloists or small ensembles and electronics.

The ensemble that played *Here...NOW* reunited to perform a verse of the "Sail" interlude and "Signal" with the *PPS* system. Before playing, I led the clap exercise we had done for two performances already, and, although the audience participated in the clap itself, no one responded when I asked about their perception of the space.

The performance of the music went as expected, and the *PPS* system was functional throughout, in the version used for the concert series with 4 stages of exaggeration. Other differences from the original *Here...NOW* were the lack of audio input from the drums as the hall was unable to provide microphones for them, and of the input assignment switches due to the stage layout which required us to stand further from each other. Having more experience with the system, and a more robust design, made performing with it much less nerve-inducing, and easier to generate a sonic environment that was more audible and felt more related to the music. Comments from people we knew who were present echoed this sense.

Performing in this context also highlighted a vastly different, much more formal atmosphere that emerged here in comparison to the other concerts in this project. There are several 2. *Concerts Hall | ICMC 2025 Boston - International Computer Music Conference.*

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factors that may be reasons for this. For one, the space was much larger than the small classroom where we originally performed this part of the piece, which brought a longer reverberation time and a less intimate sound. We were much further from the audience, who were sitting in chairs (as opposed to sitting on the floor or standing like in *Here...NOW*, for example), while we occupied the stage in between equipment being used by other pieces. We were also participating as one small part of a much larger program with frequent changes in players, instrumentation, musical style, and tone, giving us a smaller window of time to connect with the audience. Additionally, that variety in repertoire and the academic environment may have meant that the audience were there for different reasons (whether they were there to learn from new musical techniques, to support a colleague, or to share a musical experience like any other), and the proposal of this one may just not have been compelling to some of them. However, this change in atmosphere from the much less formal *Here...NOW* and concert series did highlight how large of a factor context can be in those interactions between audience and performers.

