

Performing Performance Spaces: Amplifying Context in Live Music

Ana Schon

anasch@media.mit.edu

Massachusetts Institute of Technology

Cambridge, United States

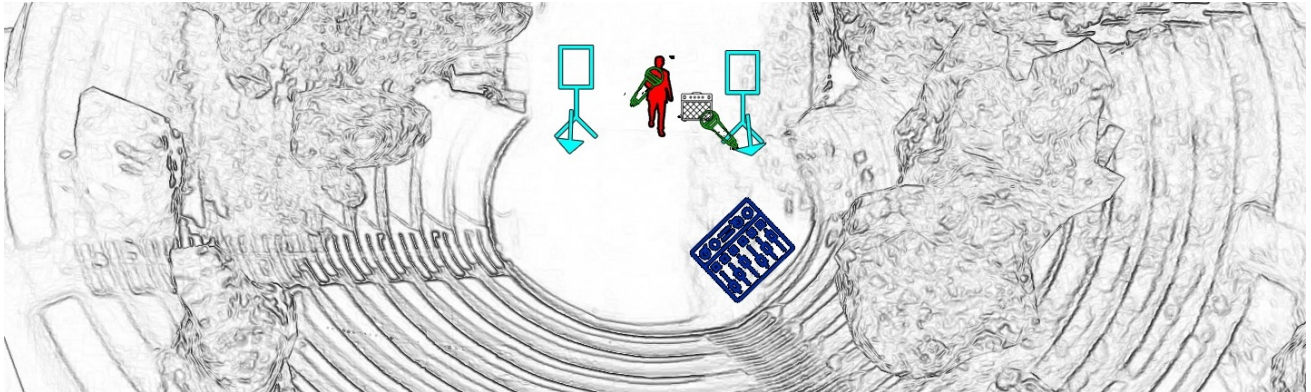


Figure 1: Stage plot of an outdoor concert in an amphitheater.

Abstract

From basements, to clubs, to stadiums, the spaces that become venues for music performances carry unique acoustic qualities that can present sound reinforcement challenges, but aurally distinguish them from one another. Interactions between these qualities and the music become avenues through which audiences and musicians interface with the performances and with each other, building community and musical connections in physical space.

The project described in this paper presents a series of concerts using a digital acoustic-exaggeration system built on the HISSTools Impulse Response Toolbox and other processing to capture, transform, and heighten acoustic qualities of each venue. The system allows performers to modulate these qualities' prominence using a MIDI controller, encouraging participants, both musicians and audiences, to share musical experiences that foster awareness of context and strengthen relationships with the space and each other.

Qualitative audience and performer responses and spectral analysis of the spaces' Room Impulse Responses (RIRs) suggest a relationship between noticeable acoustic qualities and increased awareness of the relationships between sound, space, and people. The concerts' structure, framing as listening experiments, and venue choices were also important factors in prompting reflection about both groups' participation. This opens up possibilities for live performance practices and interfaces that center sound-space-participant relationships.

Keywords

Live performance, Unconventional venues, Acoustic exaggeration, Expressive environments

1 Introduction

Our relationships with the places we inhabit have long been inseparable from their auditory imprints, from reverberation in a Gothic cathedral to a birthday song in a kitchen. These sonic signatures, and the way they resonate, serve as markers of the familiar, and frame our relationships with places and what we expect to find within them [5]. Especially in popular music, performances often take place in spaces not designed for amplified sound, with smaller-scale concerts using makeshift venues in residential basements, living rooms, or acoustically untreated bars and clubs [20]. These vernacular spaces display unique acoustic features that can present sound reinforcement challenges, causing feedback or unwanted resonances.

However, said acoustic qualities can also be part of what distinguishes one performance context from another for a band on a long tour or an audience member attending many shows in a city. Smaller venues tend to function as social environments and as room for artistic advancement [25]. They often create a sense of community between their occupants, both performers and audiences.

This paper investigates the sense of space and identifiable place [18] involved in live music, its fleetingness, and the collective experience. The project follows observations from situated experiences in a series of performances that encourage their audiences to pay attention to their physical context, and explore it through a digital system for expressive acoustic exaggeration, alongside collective, in-person experiences and individual reflection. Responses show a relationship between audible acoustic characteristics, framing experiences as listening experiments, and specific reflections. This points to new methods for directing attention to context as well as content in live music.



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2 Background

2.1 Acoustic Perception

Architectural, climate, and material characteristics define reverberant qualities in a space (T). Timbral reverberation characteristics are defined as functions of T . The system used in this project mainly takes into account the following reverberation parameters as defined by [2]: 1) T , the time it takes the sound level in a room to decay by a certain amount, 2) EDT , the initial part of the decay curve, plus Bass/Treble Ratios, which compare low/high frequency T in relation to mid-range.

Research as far back as the 1960s [8] links measurable acoustic qualities of concert halls with subjective perceptions [16], [27], [30]. Shared language to describe acoustic phenomena helps us understand how they affect perception, and helps audiences and musicians express preferences. Kuusinen et al. [21] find heterogeneous preferences, which indicates that there may not be an easy definition of "good" acoustic sound, especially considering these studies' focus on un-amplified Western classical/academic music. A smaller body of literature studies rock and pop venues, where music is amplified [4]. Adelman-Larsen identifies that lower BR and higher TR achieve "togetherness", where the performers can hear the audience's reactions. While this literature identifies more pleasurable acoustic qualities, it does not necessarily look for environments that prompt reflection, or new connections between the audience, performers, and space.

2.2 Adopted spaces and community: DIY, Co-Presence, and Audience Experience

Responses to COVID-19-quarantine-era virtual concerts widely expressed feelings of missing co-presence and social interaction [14]. There had long been a sense that these were important aspects of live music, and their absence highlighted their significance [6]. Kronenburg examines how live music can create identifiable "places" within physical spaces delineated by aural and visual experience [18], only existent while the performance is occupying them. He differentiates between different types of spaces where these "places" form, with "adopted" spaces being designed for other purposes but informally used for music. Adopted spaces make up a significant portion of the venues where music scenes start; they may appear as soon as a stage or loudspeaker system is added to a public place [19]. DIY and punk subcultures tend to practice the adoption of spaces, using homes and warehouses to create artistic and community places [12] where these are otherwise inaccessible, too expensive, or reject their forms of expression [7]. These practices with adopted spaces serve as reminders that live music is a transient experience heavily tied to its context and those who engage with it.

A major goal in building audience participation technologies into live performances as in hyperaudience systems is that the augmentation of the audience's interaction increases their sense of contribution to the performance [29], where their "physical engagement strengthens the mental engagement and vice versa."

In this project, the "identifiable place" described as by Kronenburg [18] intersects with the behavior and participation of the people occupying the space to form a "performative place." This framing lets us consider interactions between these different components, and prompts us to qualitatively investigate audience reflections [22]. Here, the role of the audience is not just in the generation of the performative place but as a consequential

intervening agent in its content, whether or not this is mediated by technology.

2.3 Artistic Precedent in Utilizing Sound & Space

Over the years, many artistic projects have featured sound environments shaped by the acoustic space they occupy. An early example is Alvin Lucier's "I am sitting in a room" [23, 3: "I am sitting in a room"], where he records reproductions of an original recording playing through an acoustic system repeatedly until the recording sounds only like the ringing resonant frequencies of the room. Lamont Young and Marian Zazeela's *Dream House* features a very frequency-dense drone resonating through an apartment, letting listeners hear different sounds by moving through the space, with audible variations on movements as small as a turn of the head [17].

A Blank Page [9], by Celeste Betancur, with acoustic design by Luna Valentin, creates a continually-changing environment by processing the sounds of the orchestra and combining these sounds with "a dynamic virtual acoustic space" [1], partially with modified acoustic captures of the venue.

Pauline Oliveros also focused particularly on acoustic space manipulation [26], with performances by the Deep Listening Band using her Expanded Instrument System to put live instruments through acoustic captures of a cistern with long and particular T , and later with the cistern's acoustic space being recreated at EMPAC [24] with a distributed speaker array. These largely evoked an external acoustic space in the concert's venue.

These works focus on the aural experience of spaces, and how audiences explore them by listening, but less so on the interlaced relationships between the performers, audiences, spaces, and music. This project addresses these relationships and how they interact with a shifting acoustic environment used as an expressive resource.

3 System Design

The digital processing in this project was referred to as the *PPS* (*Performing Performance Spaces*) system. It was iteratively designed from the goal of enabling musicians to control the exaggeration of sonic qualities of the acoustic environment by adjusting processing on their amplified instrumental and vocal signals in real time. This was meant to bring participants' attention to the acoustic space they occupy together, and how it shapes the performative place's emotional and interpersonal effect. The system was prototyped first in offices, then in informal tests, and later shared in 4 public performances during the first half of 2025.

In the frequency domain, the impulse response (IR) of an acoustic system in a room (RIR) is deconvolved into a frequency curve. In the time domain, the response is defined by T and EDT among other parameters. Playing a signal convolved with the RIR of the acoustic system into the same acoustic system excites reverberant frequencies to a higher degree, and the decay curve becomes more pronounced. This allows for a variation of the acoustic system with more exaggerated frequency and decay curves, though the difference is not obviously audible without a pronounced frequency response, or without repeating the process several times as in Lucier's work.

Early tests showed that the pronounced frequency response of repeatedly playing and recording a signal in the same acoustic space could be obtained through auto-convolution: recording the output of playing an IR as the input signal for a convolution

algorithm where it is also the IR (so that if the original IR is $g(t)$, the auto-convolved IR $h(t) = g(t) * g(t)$) (see Figure 2).

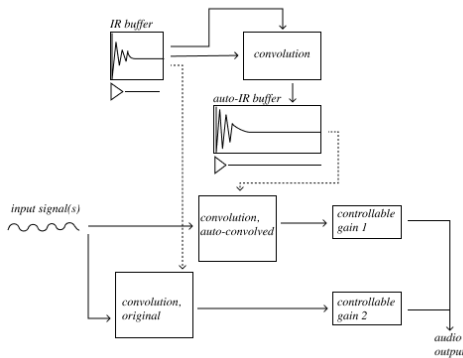


Figure 2: Auto-Convolution routing example with input signals

The acoustic exaggeration system was implemented on MaxMSP with the HISSTools[15] library. A mono RIR with each loudspeaker was captured into a buffer~using the exponentially swept sine (ESS) method with a Dayton Audio EMM-6 omnidirectional analysis microphone in the center of the audience area. The auto-convolution output was recorded into a buffer~. Instrument inputs were routed to be convolved with the appropriate channel for the stereo image as a wet signal whose gain could be controlled.

Early prototyping sessions indicated that it might be important to have strategies that communicated to the audience what was changing in the exaggeration of the acoustic features, such as a comment or example at the beginning of the performance. It also became clear that it would be crucial that the effect be timed to be meaningfully related to the music.

4 Performances

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

4.1.1 Performance Description. The first public performance with the PPS system was done across 3 rooms in the Media Lab building, highlighting the acoustic differences between them while encouraging the audience to explore and reflect. The author performed original music written for the piece with a rock band (two guitars, bass, drumset, and vocals). The performance was shown twice in the same evening.

The three rooms contrast with each other as follows:

- (1) Room 1 (first floor lobby): a very large area with 4-story ceilings at the highest point, tile floors, and glass elevators close to the center, in front of which the stage area was set up. $EDT_{lobby} = 1544, 5ms$
- (2) Room 2 (classroom 341): a small-medium classroom with ceilings about 10 feet tall, carpeted floors, and acoustic treatment on 1 wall. The stage area was set up by back wall. $EDT_{341} = 677ms$
- (3) Room 3 (Multi-Purpose Room (MPR)): a roughly 60 ft x 60 ft flex space with double height ceilings, carpeted floors, and one wall covered in full-height windows. The stage area was set up close to a corner. $EDT_{MPR} = 946.7ms$



Figure 3: The Lobby



Figure 4: Classroom 341



Figure 5: The Multi-Purpose Room

A similar audio setup was used in each room, with a Behringer X32 console in all rooms, QSC K12.2 mains and KS112 subwoofers for the first two rooms, and for the last room, 15" Duran Audio 3-Way Axys Uniamp speakers, with one 18" Duran Audio Axys subwoofer. The audio for processing was sent to a MacBook and returned using the USB card on each X32 (see routing diagram in Appendix ??, Figure ??). A MIDI foot controller with 2 expression pedals and 10 switches was mapped so that the first expression pedal controlled the volume for the "first level" reverb from each raw RIR, and the second expression pedal controlled the "second level" reverb from each auto-convolved RIR. The switches were handled by the bassist and controlled which instruments were passed through the reverb. See GUI in Figure 6.

At each stage of the performance, the audience was welcomed into the space and its acoustic signature with a spoken introduction. For the second show, the introduction also included

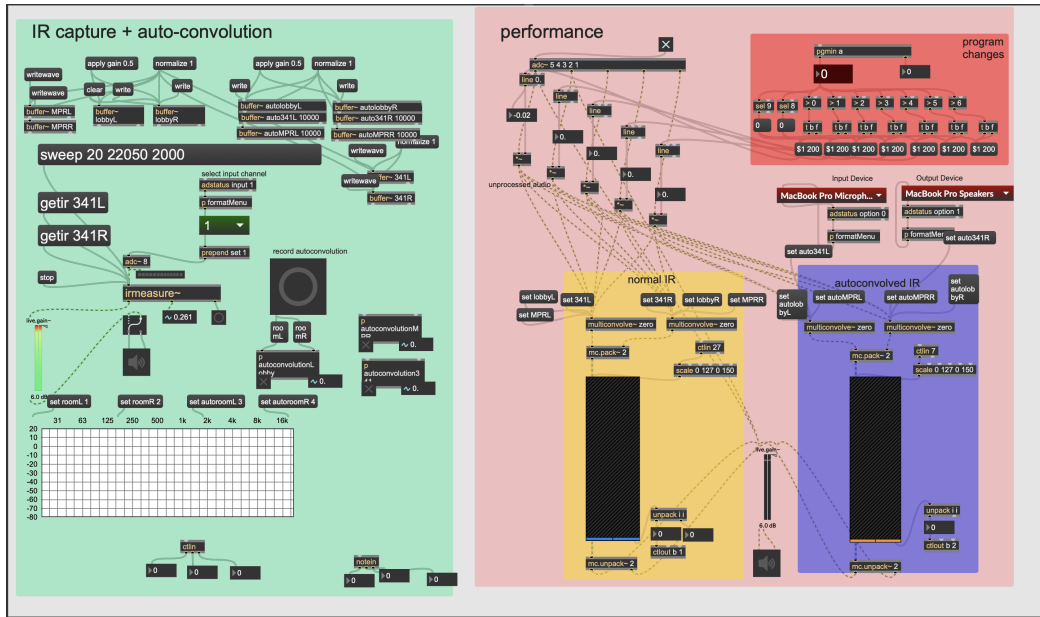


Figure 6: GUI for the *Here...NOW* MaxMSP patch color coded by function. Green = acoustic capture, Red = visualizes instrument gate toggles, Yellow = "first level" reverb gain, Purple = "second level" reverb gain

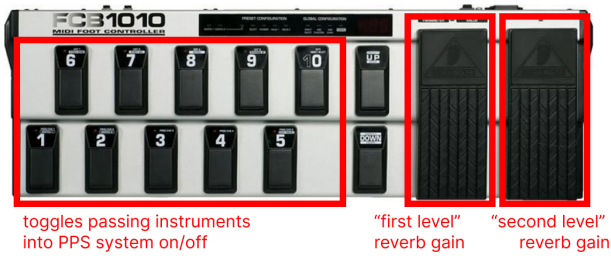


Figure 7: Mapping of foot controller to PPS system for *Here...NOW*

relationships to music	amount, n=17
music fan	11
musician	7
artist in another field	4
producer or audio engineer	4
write-in "art enthusiast"	1

Table 1: Self-identified relationships to music in *Here...NOW* audience survey * multiple choices allowed

a listening exercise where the whole group clapped together once and listened for the room’s response. The audience were asked what they noticed about the acoustic response to the clap. To show the space’s acoustics and the exaggeration transforms, the author then sang a verse of an acapella interlude. Over the course of the verse, the “first level” reverb was turned up, then the “second level,” auto-convolved reverb.

After the interlude came the song written for each space. Performers increased and decreased the reverb over the course of the song as needed, and toggled the switches that passed instruments to the processing as rehearsed.

The thematic arc of the piece followed the varying intensity of a feeling of familiarity, related to the perceived acoustic scale of the spaces through the ways distance can make things blend together. The first space had more exaggerated reverb when familiarity was higher, while the second exaggerated the small, confrontational scale of the space to emphasize discomfort and unfamiliarity portrayed in the music.

Due to technical difficulties, for a significant amount of the first performance the processing was inactive. For the second show, the PPS system was active throughout, and the practice

of having performed the piece before made the spoken elements and transitions shorter and more fluid.

4.1.2 *Audience Responses.* An anonymous audience survey was offered through a QR code to get feedback and a sense of audience reactions. From around 200 attendees, the survey received only 17 responses. The survey asked responders to identify their relationship(s) with music, meant to relate their backgrounds to the technical aspects of their responses and contextualize their observations. As seen in Table 1, responders shared varied relationships with music and the arts, several of which overlapped, and helped understand variations in hearing and how they described sound.

The rest of the survey asked open-ended questions to request first positive, then negative feedback. Table 2 shows phrases, words, and themes that repeated across multiple responses to either question sorted into "positive", "neutral", and "negative" reflections. Some observations, such as “behavior changes in audience/musicians depending on space” were shared both as a positive and a negative. Some responders only shared positive or only negative reflections.

Overall, responders seemed intrigued and curious about the concepts, and considered them novel, although they were a small portion of the audience. They shared reflections on ways the

theme	notable repeated audience observations	amt., n=17
positive reflections	differences in relationship between spaces and sound of music	8
	more connection/closeness in smaller space	3
	novelty in use of multiple/unusual spaces	2
	lighting as positive factor	2
ambiguous reflections	behavior changes in audience/musicians depending on space	5
	noticing audio processing	2
	preference for one space over the other	5
negative reflections	issues with sound clarity/volume	5
	audio processing too subtle/hard to hear	4
	discomfort/pressure in smaller space	4
	dissatisfaction with volume/worse sound quality in 341	2
	lighting as negative factor	2

Table 2: Common phrases and words in *Here...NOW* survey responses

experience made them feel, and what they observed about the environment’s effect on the performative place. There were also critiques of technical and communication aspects of the execution. These responses were critical in continued development of audience survey methods, and of the *PPS* system to be more clearly audible and expressive.

Observation from this first experience showed the importance of setting expectations by introducing the audience to the basic idea of the *PPS* system, what it does, and how it interfaces with the rest of the performance elements. To the performers (and some audience members in conversation), the first showing was more chaotic, harder to follow, and less engaging than the second. In the latter showing, the interactions were clearer, and each space was introduced with the exercise of essentially producing an impulse response by clapping and listening.

4.2 Concert Series

4.2.1 Description. The experiences and feedback from *Here...NOW* made it clear that there were aspects to improve and expand on. The following concert experiments were set up to address these aspects, but also investigate other key questions, specifically considering the music community of the area where the experiences were taking place, in this case greater Boston. How could it look 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? These concerts considered the following:

- Using locations where live music does not typically happen which allow planned gatherings and stumble-upon discovery. Since the concerts took place in summer, these were outdoors
- Taking into account the variety and fluidity of the city’s music community, prioritizing varied backgrounds and genres while focusing on long-term relationships with the city
- Technically improving the *PPS* system to allow a musician not intimately familiar with it to use it expressively, and

- Framing the concerts to encourage the audiences to listen and connect with each other, while encouraging the performers to experiment

Three concerts were scheduled over a month. The artists’ involvement included the performance and a later private interview. Excerpts transcribed from interviews are edited for legibility. The audiences were asked to complete an optional anonymous survey for these concerts.

Technically, the audio setup for the concerts was similar to the one from *Here...NOW*. A stereo PA was used (with no subwoofers as there were no bass instruments), routing audio to the *PPS* system in stereo through a digital console and audio interface. Addressing feedback from *Here...NOW*, the *PPS* system now included 4 stages of exaggeration, all adjusted for minimal phase:

- (1) Inverted: Using the `irinvert~` object, to get a frequency response inverted over the X axis and approximate a “neutral” -sounding space
- (2) “First level” reverb, the same format as in *Here...NOW*
- (3) “Second level” reverb, the same format as in *Here...NOW*
- (4) “Fifth level” or “mega-convolved” reverb, obtained by performing auto-convolution of the original RIR 5 times

See the GUI in Figure 8.

The artists controlled the reverb with the same foot controller used for *Here...NOW*, with one expression pedal fading between stages, and the other controlling the output volume of the effect. This granted access to a wider range of more obviously audible exaggeration types while minimizing complexity from additional controls. The author served as audio engineer and *PPS* system handler. The flow of the concerts was similar. The team set up audio and the *PPS* system in the space 2-4 hours before concert and captured RIRs. The performer soundchecked and rehearsed with the system for ~1 hour before the scheduled time, and requested any customizations (CA2 asked for the expression pedals to be flipped). When the audience arrived, the author introduced the project, the *PPS* system’s functionality, facilitated the clap exercise, led Q&A with audience, and introduced the performer, who played for ~45min. At the end, the audience were asked to complete the optional survey, and the clap exercise performed again.

Concert 1 (C1) featured a singer-songwriter (CA1), who played a violin improvisation and original folk-punk songs for electric guitar and voice. The venue was Dertouzos Amphitheater. This was the space most similar to a “conventional” performance venue in the series, though it is not typically used for music (Figure 10). The audience consisted of ~12 people, seated largely on the lower rungs of the amphitheater. Audience members came and went, and explored the space when CA1 suggested they experiment with listening locations.

Concert 2 (C2) featured the frontperson of a local band (CA2) performing solo versions of their original indie-rock songs and ambient improvisations on voice and electric guitar. The concert took place at the Lower Courtyard, a landscape sculpture by Richard Fleischner [11]. The setup faced the semi-circular concrete wall of the sculpture and the building behind it to exploit the reflections that emerged (see Figure 11). This concert had an audience of ~20 people, seated and mostly stationary on the concrete wall and in front of it.

Concert 3 (C3) featured a local R&B/Caribbean fusion artist (CA3) with a keyboard accompanist. CA3 also requested the ability to see the UI of the *PPS* system to get not just auditory but also visual feedback. This concert had the smallest audience

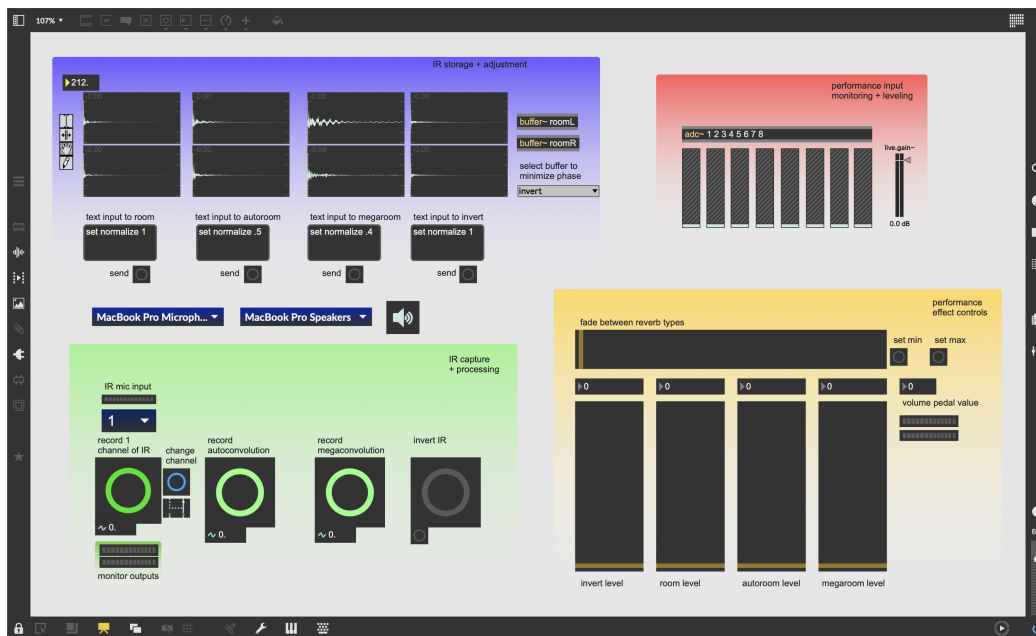


Figure 8: GUI for the PPS system used during the concert series. IR Capture was more abstracted and visuals simplified. instrument gates were changed to volume controls and disconnected from foot controller.

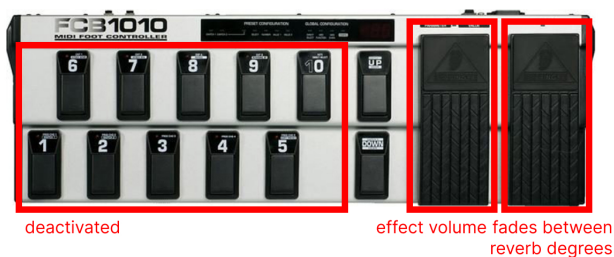


Figure 9: Foot controller mapping for concert series



Figure 11: A diagram of the setup for C2, with the path behind the stage area. The audience sat on the semi-circular structure on the right.

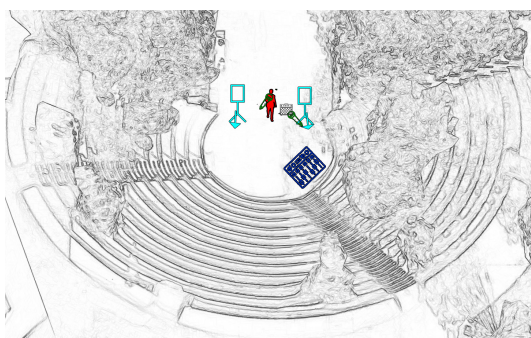


Figure 10: A scheme of the layout for C1, with the stage area and PA system at the open end of the amphitheater, facing towards the seating.

of the three (~10 people at any given time), likely because it was postponed and took place at noon. The space was also less secluded (Figure 12), and attendees circulated frequently. CA3 encouraged audience participation through call-and-response and talked about the performance’s context. Early on, 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 after.

The concerts were advertised by the author and artists to their networks on social media, and to the MIT community through mailing lists and flyers on campus. The audiences were largely MIT-affiliated.

4.2.2 Audience and Performer Reflections. The concert series survey differed from the *Here...NOW* survey by asking more specifically what audience members noticed about their relationship with the space, the music/sound, and other people in the space, plus positive and negative reflections. Response rates and content varied between concerts; for C1 and C3 <30% of the audience responded to the survey, while for C2 it was approximately half (Table 3).

Responses to the survey were diverse, but trends emerge. Several responders noticed various positive aspects of their relationship with the performance, noting the interactivity of the clap exercise, feelings of proximity or immediacy, or feeling like part of

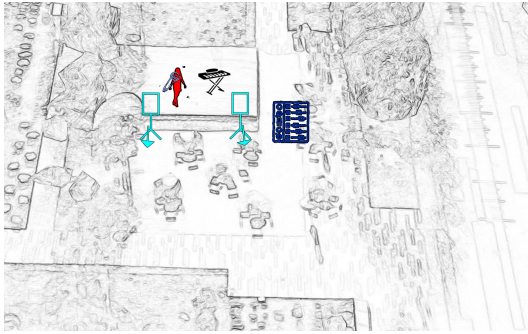


Figure 12: A diagram of the setup for C3. The audience sat at the tables shown the stage area.

Relationship to music	C.1	C.2	C.3	Total self ID's per category
Musician	2	2	1	5
Music Fan	3	9	4	16
Music Community Member	2	3	0	5
Music Researcher	1	1	0	2
Artist in other field	0	6	0	6
Total responses per concert	3	10	4	17

Table 3: Self-identified relationships to music and arts in concert series audience survey * note multiple choices were allowed per response

an environment (the last one mostly in C2). Most responders mentioned the environment outside of the musical content at least once, noticing various sounds and visual elements, plus passersby. Some responses critiqued the sound quality, one in C1 stating that “The effects were sometimes too subtle or just sounded like feedback”, and two in C3 noticing a “boomy”, “muddy” or “overpowering” quality to the reverb that distracted them. 10 responses across all concerts mentioned a positive relationship with the music or musical content, calling it “beautiful”, or describing how they connected with the songwriting (Table 4).

In her interview, CA3 mentioned how explaining the audio processing was another way she connected with the audience, noticing them showing interest in the specifics and paying more attention. “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 and how it changed. For CA2, there was a moment that stood out as a marker of the type of space the performance occupied. Early in the concert, they were playing with their eyes closed, to only 5 or 6 attendees. “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, this is a real performance.” This exemplifies how the performative place is not inherent to the space, does not exist until the performance creates it, but then is perceptibly there, and leaves an imprint. CA1 said of his relationship to the space that there were pieces of music where the effect was especially clear, such as one particular song with longer, dwelling chords, and “chang[ing] the individual notes

theme	common audience observations	C1	C2	C3	Total (n=17)
positive performance factors	clap exercise		3	2	5
	performer/ audience interaction		3	4	7
	proximity/immediacy	1	2	2	5
	feeling immersed/incorporated	1	4	1	6
	artist’s voice	1	1	2	4
	performers experimenting as positive outcome	1	2	3	6
external factors	positive relationship with music/musical content		8	2	10
	sound environment outside performance	1	6	3	10
	machine hum/HVAC	1	1		2
	wind/nature sounds	1	5	1	7
	people passing by	1		1	2
	temperature		5	1	6
	visuals	1	1	1	3
negative performance factors	sound quality critiques	1		2	3
	feeling distant	1			1

Table 4: Common themes in responses

and how it’s expanding in the space in real time.” He described the experience as an exercise in listening, noticing nuances in his playing. He mentioned that adjustment as a challenge in balance and learning how far the effect should go.

Overall, audience responses to the concert series showed curiosity about contextual aspects, and engagement with the experiences as listening exercises. Responders shared observations about the spaces that could have only come from being part of musical experiences in them. Reactions show shifting relationships between audience, performers, spaces, and music. Contrasts between these interactions merit analysis of differences between spaces, and which kinds of spaces prompt which interactions. The artists shared generally positive reflections about using the PPS system as an experimental tool. Their uses of the system showed different approaches to exaggerating the acoustic environment expressively, from emphasizing certain words, to exploiting resonant drones, to adding energy. They also gave feedback on ways of handling the system more consistently.

5 Technical Analysis of Acoustic Spaces

During the concerts, and especially *Here...NOW*, participants expressed preferences for some acoustic spaces over others. Their reasoning varied, but it is interesting to compare the acoustic qualities of the spaces and their effects.

As seen in figure 13, RIRs for the *Here...NOW* spaces vary widely. Crucially, their timbral characteristics diverge, see table 5. BR is hard to calculate accurately for these RIRs¹, so in this case the TR may be more representative of how they affect sound and shows how they differ. In the lobby, treble reverberates weakly, while in 341 this measure is >3 times stronger, and in the MPR in between. Frequency bands with the longest reverberation also vary; in the lobby they are in the 500Hz-1000Hz range (around

¹for this paper, a modified bass ratio calculation is used to account for the high noise floor; it is calculated with the low band at 132Hz: $BR_{pps} = \frac{T_{132Hz} + T_{250Hz}}{T_{500Hz} + T_{1000Hz}}$, but may still not be indicative, as T_{60} for the lowest bands can result up to 14s.

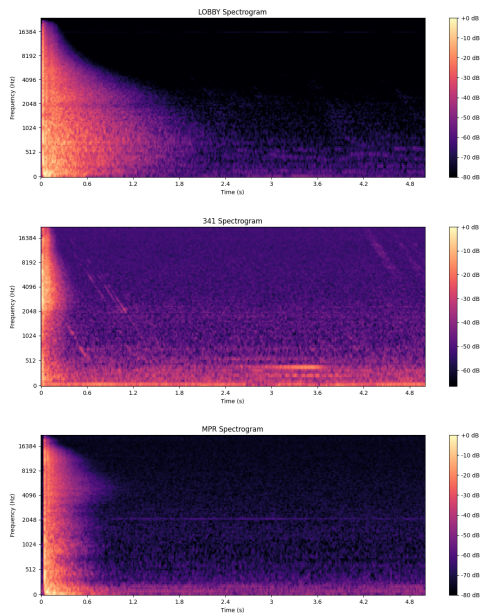


Figure 13: Spectrograms for the Lobby, Room 341, and Multi-Purpose Room (used in *Here...NOW*)

Space	BR_{pps}	TR
lobby	0.535	0.829
341	0.501	2.848
MPR	1.179	1.378

Table 5: Modified Bass Ratio and Treble Ratio for the *Here...NOW* spaces

the first harmonic of singing voices), while in 341 they are in the high range of human speech between 4kHz and 8kHz. The MPR is more even, with longest T in the 4kHz-8kHz band, but a less pronounced difference.

Audience responses showed slight preference for the MPR’s acoustics, with some audience members also mentioning the Lobby (some favorably, but some also negatively). One reason may be vocal/speech intelligibility. When audience members mentioned an acoustic space negatively, they described vocals as “muffled”, or the music as lacking “clarity and fidelity.” In positive reflections, they noted “balance.” The preference for the MPR coincides with findings by Adelman-Larsen about preference for a lower T in low frequencies, and higher in speech-related frequencies [4], while being reverberant enough to avoid leaving sounds exposed.

These preferences do not necessarily match what was most audible when exaggerated, however. When the original initial decay was very short, it remained short. When the frequency response was flatter, it remained relatively flat, as figure 14 shows.

When the opposite was true, resonances became clearer and more audibly reverberant. See figure 15, displaying more obvious resonant peaks that stayed louder longer, and anti-resonances. In practice, spaces with more audible acoustic features (a longer T , EDT or strong resonances) were more audibly exaggerated, and seem to have prompted slightly more specific reflections about the effect of the acoustics on perception, positive or negative.

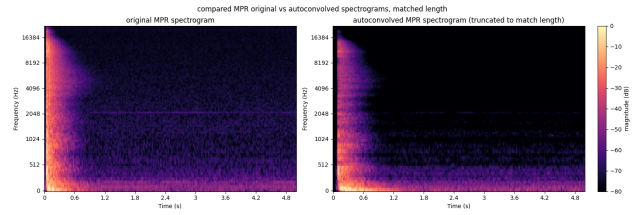


Figure 14: MPR spectrograms, original vs. auto-convolved, matched length

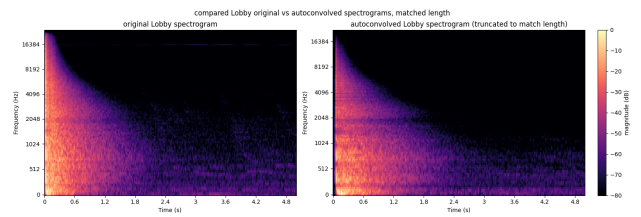


Figure 15: Lobby spectrograms, original vs. auto-convolved, matched length

During the concert series, audiences were not comparing spaces to one another. Instead, the question was how performers used the acoustics of each space as an expressive tool. Auto-convolving several times exaggerated resonances and anti-resonances. But even here, the amount of information in the original IRs impacted how noticeable these transforms sounded.

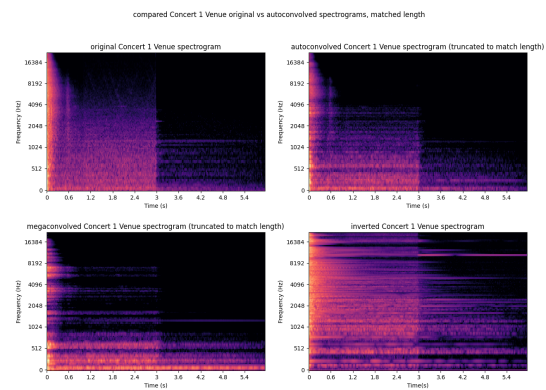


Figure 16: C1 venue spectrograms, original vs. auto-convolved vs. mega-convolved vs. inverted, matched length

The C1 venue, in figure 16, showed early reflection peaks becoming emphasized and lengthened by each level of auto-convolution, while their antipeaks are amplified in the inverted RIR. Note also the reflection at 0.6s in the original and how it is “blurred” but still present in the mega-convolved RIR.

The C2 venue has similarities, and particularly several discrete reflections between 200 ms and 600 ms, see figure 17. It also has some artifacting in low frequencies, likely from wind. This RIR has fewer, wider bands that resonate when mega-convolved. It retains more time-domain information, with discrete reflections remaining noticeable. These wider resonant bands may have been a factor in how CA2 used the reverb in this space “as a timbral effect”.

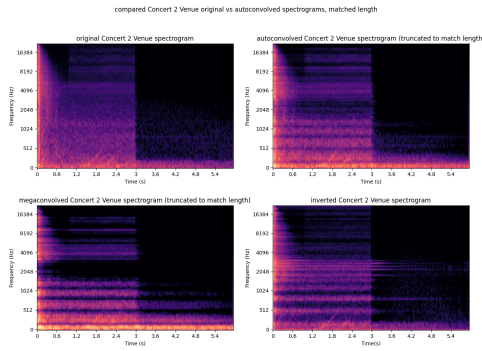


Figure 17: C2 venue spectrograms, original vs. auto-convolved vs. mega-convolved vs. inverted, matched length

The C3 venue also displays some (narrower-band) discrete reflections up to 400 ms as visible in figure 18, but overall its RIR decays faster than the other 2, with a T20 of 198 ms. There is a strong resonant band around 100 Hz—which may account for the “muddy” resonances some audience members pointed out.

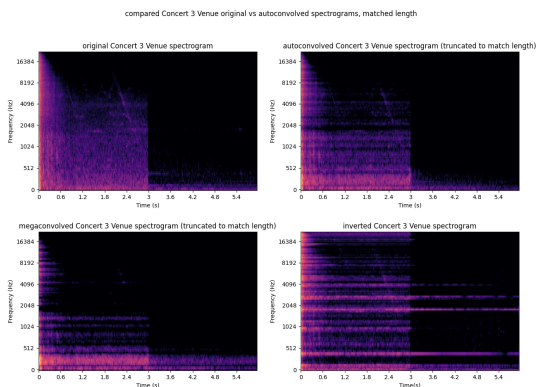


Figure 18: C3 venue spectrograms, original vs. auto-convolved vs. mega-convolved vs. inverted, matched length

Another characteristic of all the outdoor RIRs is a persistent level of wide-band noise around -60 dB that disappears at 3 seconds. Neither the audience nor the musicians nor the author observed this flaw during the concerts or in recordings, and when convolving a continuous signal, it is not perceptible, but it is noticeable when listening to the mega-convolved RIRs as audio clips. However, the imperfect captures may have affected outcomes throughout.

Overall, the system was able to exaggerate certain features of the acoustics of these spaces, especially in the frequency domain (see 19 for detail). Exciting resonant frequencies could cause feedback, which could have been mitigated systems like Caviar [3], although this may also have minimized some acoustic characteristics. Given the noise present in the outdoor concerts, these may be appropriate to repeat with higher-quality RIR captures.

6 Discussion

6.1 Listening as Intervention

Over the course of the project, a trend started to emerge: the PPS system was enabling the performers to experiment, but it

was not the only feature of the concerts achieving that effect. As previously discussed in 4.2.2, CA1 mentioned that the experience stood out to him as a “thinking concert.” When participants explored the space, they reacted to the differences between vantage points, and CA1 got another visual feedback layer to reinterpret aspects of his music. In *Here...NOW*, physical movement also prompted the audience to contrast the perceived effect of transforming acoustic environments.

Other relevant factors were the use of unconventional spaces (every concert), concert structure (in *Here...NOW*), and the explicit framing of the concerts as a listening experiment, which audience members knew would require a different level of participation through reflection later. The clap exercise prompted audiences to listen, but its participatory aspect also may have increased the feeling of contribution to the contents of the experience as described in Van Troyer’s *Hyperaudience* [29].

Another element was the performers musically experimenting with the acoustic effects. In a way, they were enacting the musical impact of the spatial-acoustic context that already reappears in the discourse around effects of musical performance on its participants. This idea is addressed by Kronenburg [19] in terms of how aural/visual qualities of spaces contribute to the creation of identifiable (here “performative”) places. This impact is more noticeable when it perceptibly changes the music itself: CA1 mentioned dwelling more on certain chords, while CA2 used the ringing from the extreme transformations as a drone, and CA3 emphasized certain words using the effect. Like in the Oliveros and Betancur pieces, there was real-time interplay between the musical content and the acoustic expression in how the artists manipulated their sound actively.

The makeup of the audiences likely contributed; some aspect of the concerts (the music, their relationship to the musicians, to the venues) led audience members to participate. Visual and multi-sensory factors were also influential, echoing findings by Coutinho et al [10]. What stood out came not only from the measurable characteristics of the space, but what it *felt like*.

6.2 Limitations & Future Work

6.2.1 Sounds. Although the PPS system generally allowed for exaggeration of some acoustic qualities of the spaces, auto-convolution over several times results in highly emphasized, easily excitable resonant frequencies that sound unpleasant. Feedback rejection might have helped address this challenge. Inverting impulse responses to somewhat cancel out acoustic characteristics was especially challenging, as a filter that counteracts the frequency peaks and troughs at one point in time cannot phase-cancel reflections in a physical space. The HISSTools *invert~* transform offered an approximation, but could not fully solve the issue.

All PA systems used were stereo, meaning that the project could not address some spatial aspects of room reverberation. This contributed to the difficulty of inverting acoustic qualities: instead of spatializing the various directions sound may reverberate from (with distributed loudspeakers, for example as Meyer’s Constellation [28] or wave field synthesis [13]), the system placed the exaggerated reverberation in the same spot as the direct sound.

6.2.2 Usage. Deploying with the PPS system presented still-unsolved difficulties for performances. Although it was largely functional, it required close supervision to avoid distortion and artifacts, and the RIRs were noisy. Some performers commented on the MIDI controller, suggesting more granular controls would

have given them more expressive and replicable ways to use the system and navigate through reverb stages. However, they all mentioned using it to enhance musical moments, whether it was emphasis on certain words (CA3) or adding “personal extra energy” (CA2), especially with the more extreme variations. Future work could also include co-design of strategies for more musically-related timing.

Another helpful addition may have been a visual (e.g. lighting) depicting exaggeration type and intensity as some audience members mentioned it being difficult to distinguish changes.

6.2.3 Audiences. Research with human subjects, especially one-time audiences, has inherent constraints. There are limits to what we can glean from their responses, and to our ability to follow up about longer-term effects. Audiences self-selected to participate due to familiarity with some aspect of the project, so the participant pool was not random either. Survey participation rates were also low—what might we have learned from audience members who did not feel strongly enough to share their thoughts?

7 Conclusion

Throughout this project, we encountered various examples of the immediate and wider context’s effect on a performative place, and how the qualities and limitations of that place can be utilized to foster new relationships with others and with musical experiences. Future work includes addressing technical challenges, quantitative research into the mechanics of these relationships, and wider projects using temporary music performance spaces in pursuit of a longer-term techno-musical listening practice. This project lays the groundwork for a kind of performative place that centers the sensory experience of occupying a space with others and directs attention not only to the performance, but also to where it lives, and how it affects us.

8 Ethical Standards

This work was done as part of a Master’s thesis. The survey for *Here...NOW* was done under MIT COUHES exemption E-6508, and for the concert series under MIT COUHES exemption E-6716. All surveys had a pre-screening stage to publicize that participants were only eligible if they were 1) 18 and up 2) participating voluntarily, and 3) aware they were able to end their participation at any time. No identifying information was gathered. *Here...NOW* was funded by MIT Artfinity festival. Concert series performers were contacted by the author, and paid a honorarium by the Opera of the Future research group for their time. C3 was presented in collaboration with MIT Open Space Programming.

Acknowledgments

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A Appendix

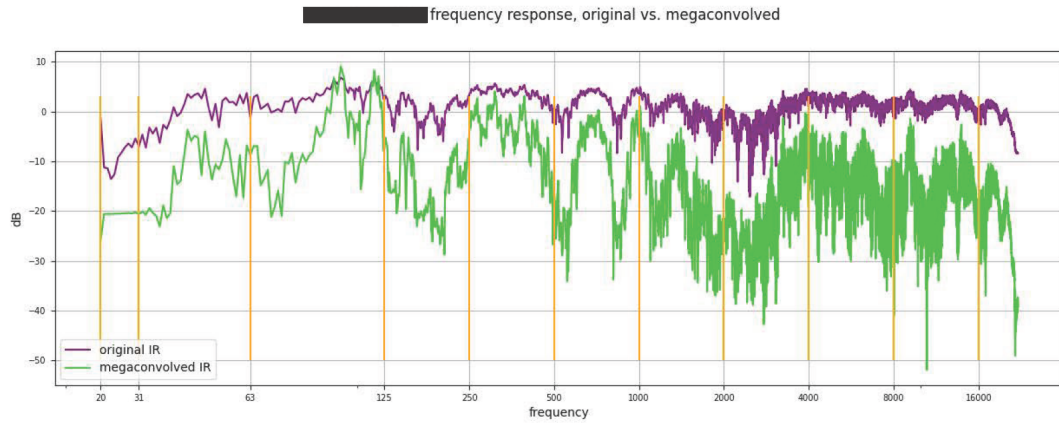


Figure 19: Frequency Curves for C2 venue original vs. mega-convolved RIR.

Documentation of the project is available at <https://pps.media.mit.edu>