Live Processing Into the 21st Century: Delay-Based Performance and Temporal Manipulation in the Music of Joel Ryan, Radiohead, and Sam Pluta

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Live processing is altering and affecting the sounds of instruments, live without the aid of fixed media, to create new unique sounds that are an independent voice in a musical performance. This performance practice emerged as an important musical activity in the twentieth century and evolved with digital technology around the turn of the millennium. This dissertation explores the musical results of three recorded performances in which electronic performers digitally manipulated the sounds of other performers. In the first, Joel Ryan processes the soprano saxophone of Evan Parker in *Instant 1*. In the second, English rock band Radiohead features two live processing duos on *Everything in Its Right Place:* with Ed O'Brien processing Thom Yorke's keyboards and Johnny Greenwood processing Yorke's voice. Finally, Sam Pluta processes the trumpet of Peter Evans on a track called *Event Horizon*. Each recording is analyzed using spectrographic images, which are representations of musical sound that allow for the precise measurement of musical gestures. I argue that delay-based performance and temporal manipulation are key musical characteristics common to all three recordings, defining both smaller-scale and large-scale designs. Additionally, I argue that the generative technology that produces these delays does not produce the music on its own but rather the human control of the electronic sounds allows for successful performances within this aesthetic. Using Kramer's conceptual vocabulary, along with a technique I developed

called phase cancellation analysis, I show that contemporary delay-based performance using digital technology challenges the concept of extreme discontinuity as it is usually defined.

In my original composition, *Recorded Ruins*, for amplified quintet (bass clarinet, trombone, piano, violin, and cello), I aimed to explore a different kind of fusion between acoustic and electronic sounds from the kind of live processing discussed in the research portion of this dissertation. Instead of using computers to manipulate delayed samples of the acoustic instruments, synthesized tones generated from computer software were emitted through transducers placed on the piano strings, converting the piano into a giant loudspeaker. The frequencies from the transducers were tuned to specific overtones of the strings, while the rest of the ensemble then tuned to these microtonal frequencies or performed with different intonations, creating an extended just intonation tuning system.

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Preface

This dissertation would not have been possible without the support of many people throughout the years. To Amy Williams, Eric Moe, Aaron Johnson, Roger Dannenberg, and especially Mathew Rosenblum for being an amazing dissertation committee. To my parents, Mark and Holly Riordan, who helped me every step of the way. To Matt Aelmore and David Bernabo from my band called How Things Are Made, who let me try out these live processing strategies as I studied each of these techniques. To Colleen O'Reilly, who helped me with proofreading. To Joel Ryan and Sam Pluta for the great interviews. And most importantly, to my wife, Amy Crippen, and my son Dyllin Wood for their love, support, and patience throughout this process.

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03-21-2023

1.0 Introduction

Since the turn of the millennium, it has become commonplace for live electronics to share the stage with acoustic performers. Advances in computer technology have allowed composers and performers to synthesize sound in real-time and manipulate the sound of other instruments. From this technological evolution, a new category of composer-performer has emerged. These composers perform in concert using electronics as their primary instrument.

Live processing has its roots in and can be viewed as a sub-branch of computer music or electronic music. It is a sub-branch defined primarily not by style or genre, but by the means of generating sound. The moment composers started to amplify acoustic instruments, the sound had become processed, resulting in timbral transformation. However, the acoustic instrument's sound and its amplified signal are perceived by the listener as a single voice. What differentiates live processing from the simple act of amplification is delaying the signal until it is perceived as a separate voice, allowing for further transformation. In her article entitled "Live Processing and Improvisation," Dafna Naphtali defines live processing as "to alter and affect the sounds of acoustic instruments, live, in performance (usually without the aid of pre-recorded audio), and in this way, create new sounds, which in turn become independent and unique voices in a musical performance."[1] This independence is the direct result of a delayed signal.

[1] Dafna Naphtalion, "Live Sound Processing and Improvisation," *NewMusicBox*, October 5, 2017, https://nmbx.newmusicusa.org/live-sound-processing-and-improvisation/.

Although many recent publications discuss and examine current electronic and computer music from many vantage points, very little has been written about live processing. One of the main aims of this dissertation is to demonstrate the analytical potential of these delayed and manipulated sonic structures. While live processing is not a specific genre, I argue that two compositional features figure prominently in many cases. One is the prevalent use of what I call “delay-based performance” and the other is “temporal manipulation.”

The use of repetition in music is ubiquitous. It has been used in music worldwide for millennia for the repetition of phrases in genres such as canons, fugues, African call and response, and jazz improvisation. Delay is a sub-category of repetition and differentiates itself by specific electronic processes. As opposed to an exact physical replication of a sound, delay is defined as an audio signal processing technique that records an input to an audio storage medium and then plays it back after some amount of time. For this project, I define “delay-based performance” as the act of delaying the signal of an instrument in real-time with the intent of creating an independent musical voice. The act of live processing requires a minimum of two performers on stage, one that performs their instrument and another that performs and alters the delayed signal of that instrument. It is the use of delay which differentiates live processing from other types of electronic performance, such as digital synthesis or the playback of pre-recorded audio.

In his 1988 book, *The Time of Music: New Meanings, New Temporalities, New Listening Strategies*, Jonathan Kramer defines “discontinuity” as a disruption in a work’s consistency. Most Western music contains discontinuities; otherwise, there would be no suspense, little information, and no contrast. Discontinuity can occur in both acoustic and

electronic music. However, Kramer argues that “extreme discontinuity” can only occur in electronic music, where recorded sound is spliced, reorganized, and played back in a different order. Kramer states, “the simple act of putting razor blade to tape created the most powerful musical discontinuities as well as the most unexpected kinds of continuities. A composition can now move instantly from one sound world to another.”[2]

Delay-based performance and extreme discontinuity are not new in electronic music. In fact, delay is one of the most commonly used technological strategies for applying effects to music, yet its use is under-theorized. Since the 1950s, delay-based performance has been at the heart of creative musical endeavors, from rock bands, dub reggae producers, electronica DJs, ambient music performers, and contemporary classical ensembles, but little analytical attention has been paid to this innovative practice. While the cost and size of equipment required for creating delays, such as echo and reverb, once limited the use of such techniques to the recording studio's confines, anyone with access to a computer or a smartphone can now utilize delay in live performance. This newfound accessibility has not only brought delay from the studio to the stage, but it has also allowed musicians to manipulate audio signals like an instrument, affecting the structural outcome of performances.

While tape delays and tape splicing were very prevalent in mid-twentieth-century electronic music, the fusion of these two techniques was challenging to execute in a live setting. At the time of Kramer's publication of *The Time of Music*, extreme discontinuity rarely existed outside of the recording studio. The turnaround time between splicing tape

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[2] Jonathan Kramer, *The Time of Music: New Meanings, New Temporalities, New Listening Strategies* (New York, NY: Schirmer Books, 1988) 69-70.

and performing the composition through loudspeakers in a concert hall is too long to be considered a real-time process. Additionally, delay-based performance was initially limited to the tape echo duration and its feedback led to predictable repeated results. Composers wishing to use extreme discontinuity in a live setting had to navigate the logistics associated with tape carefully. These limitations were lifted with the introduction of digital technology with the speed of computer processors, which allowed for performers to reorganize the structure of the delayed material. In this context, I define “temporal manipulation” as the real-time performance of digitally restructured recorded material. Combining this approach with delayed recorded material in real-time paved the way for a new type of electronic performance: live processing.

Who are the contemporary innovators of live processing? How, specifically, does temporal manipulation operate within their music? To address these questions, this dissertation explores the music of Joel Ryan, Radiohead, and Sam Pluta, and discusses salient features of their work involving live processing that have barely been addressed in the literature on electronic music to date. These three case studies were chosen for several reasons. All of them incorporate improvisation into their work. They use customized digital processes that are manipulated by gestural controls in their live performance. All electronic signals result from delay and temporal manipulation, and they perform in duos alongside a performer that supplies sound to be manipulated independently by the live sound processing musician. These examples are live recordings with no overdubs, so all electronic sounds are generated in real-time. On the track *Instant 1* from the album *Live At “Les Instants Chavirés”*, Joel Ryan processes the soprano

saxophone of Evan Parker.[3] English rock band Radiohead features two overlapping duos: Ed O'Brien processes the keyboards of Thom Yorke, while Johnny Greenwood processes a recording of Yorke's voice on *Everything In Its Right Place* from an online video of a live performance from 2016.[4] Finally, Sam Pluta processes the trumpet of Peter Evans on the track titled *Event Horizon* from the eponymous album.[5]

This dissertation begins with a discussion of methodologies of music analysis using spectrograms; computer images of music sound that have emerged as one of the most useful tools with which to examine non-notated computer music. I will then briefly analyze some twentieth-century compositions that demonstrate delay-based performance and temporal manipulation in order to show the history of relevant technological advancements and their influence on live processed music. Next, three representative recordings—by Joel Ryan, Radiohead, and Sam Pluta—are analyzed in relation to performed gestures by the acoustic performers, and the delayed live processed gestures by the electronic performers. I argue that an original analytical methodology using phase cancellation is a useful strategy for isolating performers' layers within each recording. Finally, I discuss delay-based performance and temporal manipulation in relation to musical structure and computer technology. I also explain the possible trajectory of live processing in the future, drawing on the concept of idiomatic organization and musical affordances as theorized by David Huron and Jonathan De Souza.

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[3] Evan Parker with Noel Akchoté, Lawrence Casserley and Joel Ryan, *Live At "Les Instants Chavirés"*, Leo Records – LR 255, 1998, CD.
[4] Radiohead Public Library, accessed December 6, 2020, https://www.radiohead.com/library/#amsp/2016-07-29-lollapalooza/.
[5] Sam Pluta and Peter Evans, *Event Horizon*, Carrier Records – 024, 2014, MP3.

1.1 Analytical Methodology

In his foreword to *Electroacoustic Music: Analytical Perspectives*, Jean-Claude Risset states: “This new [electroacoustic] music has been little discussed in writing, in part because much of electroacoustic music does away with the score, a document that had heretofore seemed essential. The lack of an objective representation makes it difficult to study these works.”[6] The music studied in this dissertation exists solely in the form of audio or video files. Because of this, alternative analytical methodologies must be developed and utilized. One useful strategy involves the imaging of musical sound using spectrum analysis. For example, music theorist John Latartara has employed spectrograms for the analysis of music by early twenty-first century laptop composers to reveal musical characteristics of repetition and noise.[7] Latartara’s approach is an update of ideas found in the work of Robert Cogan, a pioneer in using spectrograms for music analysis.[8] Many theorists use these spectrograms to observe entire frequency content, including harmonics as well as noise bands, plotted on the x-axis. However, for my research, it is essential to note how events unfold over time on the y-axis.

Spectrograms create a visual representation of the composition that can then be analyzed in conjunction with the aural experience of the music. For this project, spectrograms are used as an aid in revealing audio delays and extreme discontinuity. These images do not show us what we hear, but they provide supporting evidence for our

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[6] Thomas Licata, *Electroacoustic Music: Analytical Perspectives* (Westport, CT: Greenwood Press, 2002).
[7] John Latartara, “Laptop Composition at the Turn of the Millennium: Repetition and Noise in the Music of Oval, Merzbow, and Kid606,” *Twentieth Century Music* 7, no. 1 (March 2010): 94.
[8] Robert Cogan, *New Images of Musical Sound* (Cambridge, MA: Publication Contact International, 1984).

musical perceptions. It is best, therefore, to think of spectrograms as models of the work, like any other analytical graph or chart (Schenkerian, Neo-Riemannian, etc.), which do not represent any final, absolute truth about the music concerned.[9]

To better understand how spectrograms can be used to analyze delay-based music, it is useful to observe a few excerpts from related works from the twentieth century. These examples demonstrate how the use of delay in music, and its effects on musical time, occurred during the age of analog tape, providing historical context that is relevant to the research on recordings from the digital era. Additionally, these examples will help to define relevant terminology. As in the works of Joel Ryan, Radiohead, and Sam Pluta, all the historical excerpts examined here differentiate themselves from many musique concrète examples in that they are process-based pieces that use delays of real-time performances to generate musical materials.

1.1.1 Linear Determinism in Brian Eno's Discreet Music

English producer and composer Brian Eno created tape loop-generated compositions with the intent of blending into the surrounding soundscape instead of demanding the listener's attention. The delays utilized in some of his pieces are deliberately stagnant. Figure 1 is a diagram presented in the liner notes of the recording of *Discreet Music*.[10] This diagram demonstrates how this ambient music was created by using two reel-to-reel tape machines. The first tape machine records the performance of

[9] Latartara, "Laptop Composition," 94-96.
[10] Brian Eno, *Discreet Music*, Obscure Records – Obscure No. 3, 1975, CD.

a synthesizer. The tape skips the second reel of that machine and feeds into the second machine's playback head. The distance between the two devices determines the length of the delay, which is approximately six seconds. The machine's output signal is sent back into the first tape machine, which records the overlapped signals, creating a perpetual audio loop.

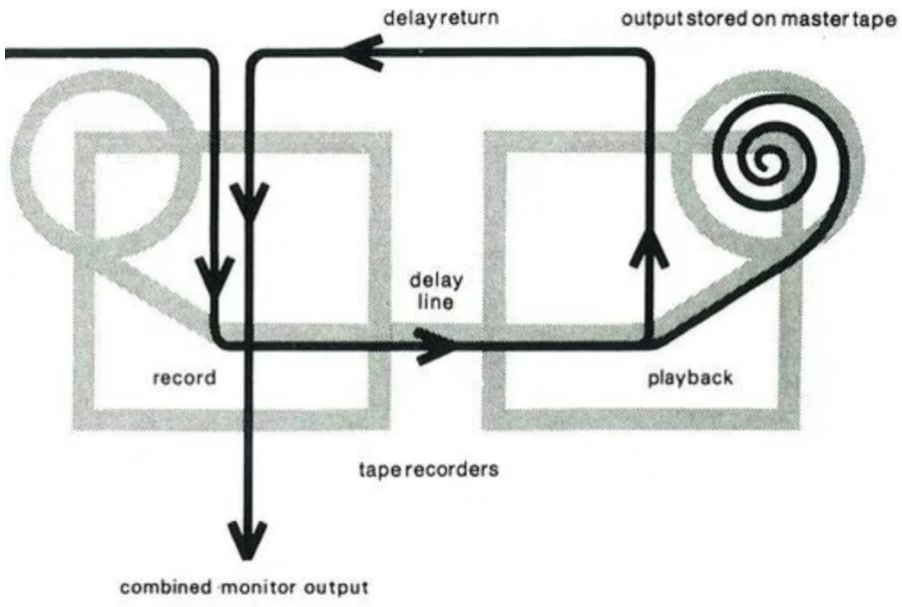

Figure 1 A diagram of Brian Eno's tape delay system from the *Discreet Music* LP liner notes.

Figure 2 is a spectrogram of 1:32 to 2:42 of the recording that displays how predictable these kinds of delay systems can be. A two-note gesture is introduced around 1:33 and repeats until 2:37. The only reason any of these sounds fade away is that Eno set the volume of the delay return to be quieter than the incoming synthesizer signal; otherwise, every new sound could potentially remain a part of the piece from the moment they were introduced. This process is one of the most common strategies in delay-based music, and it is frequently practiced today by many guitarists who perform with a looper

pedal. It represents a kind of linear determinism, or any potential for predictability, where the delay system is set before a performance and no additional real-time manipulation of the signal is applied. The listener becomes aware that once a sound occurs, it will reoccur until it ultimately fades away. The only unpredictable element that could occur is the introduction of a new sound.

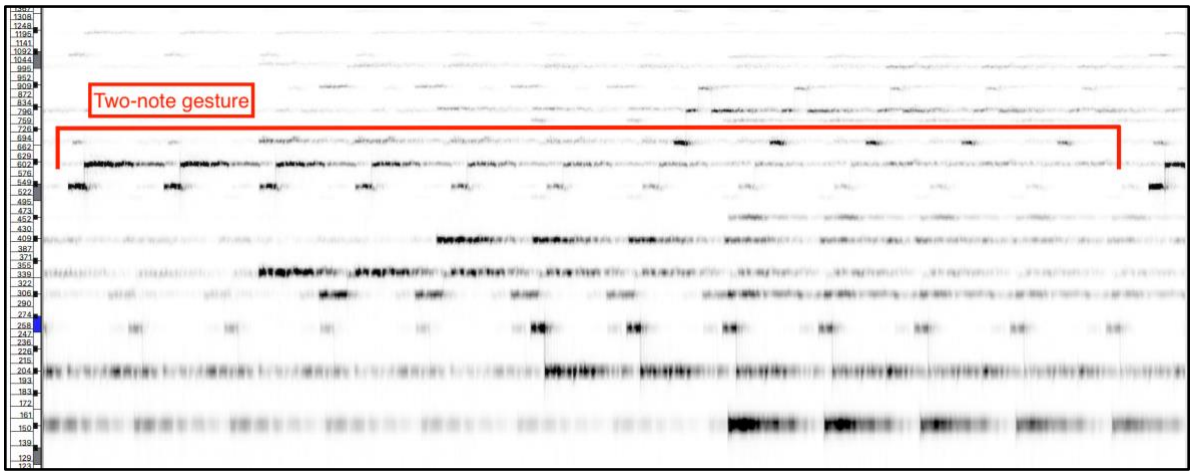

Figure 2 Brian Eno's *Discreet Music*, spectrogram of 1:32 – 2:42

Jonathan Kramer would refer to this process of working with time as "goal-directed time," a temporal continuum in which events progress towards predictable goals. He would also classify this as linear time, a principle of composition and listening under which events are understood as outgrowths or consequences of earlier events.[11] Sonic events that occur earlier in the recording define the entire structure of *Discreet Music*. A synthesizer gesture is performed, and the listener hears the repeat of this gesture due to

[11] Kramer, 43-52.

the tape delay system. In this example, low levels of mediation are required to perform the delays.

1.1.2 Discontinuity and Linearity in Pauline Oliveros's I of IV

American composer Pauline Oliveros used a very similar tape delay system to Eno's, except she employed a method that disrupted the linear determinism by inserting a mixer in the feedback line. This allowed her to manipulate the amplitude of the delay return signal and introduce new sounds at unexpected times.[12] Figure 3 displays clearly defined disruptions and little evidence that her 1966 composition *I to IV* is the product of an 8-second tape delay system.[13] The piece begins with a loud drone that is much longer than 8 seconds, concealing a beginning or an end to the loop. Except for a few short electronic bursts in the background, nothing changes in the piece for the first 45 seconds. At 46 seconds, a jarring disruption of new electronic bursts occurs, forcing their way to the foreground while the drone's volume instantly sinks into the background. Disruption 1 occurs for about 6.5 seconds before disruption 2 interrupts with harsh sustained tones for only 2.5 seconds. Oliveros achieves this level of discontinuity in two different ways. First, she moves textures from foreground to background, such as the intro drone, by drastically adjusting the delay return signal volume. Secondly, she uses sonic disruptions that are asynchronous with the 8-second delay. These strategies continue throughout the

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[12] Pauline Oliveros, *Software for People: Collected Writings 1963-1980,* (Sharon, VT: Smith Publications, 1984), 44.
[13] Steve Reich, Richard Maxfield, and Pauline Oliveros, *New Sounds in Electronic Music (Come Out / Night Music / I of IV)*. Odyssey – 32 16 0160, 1967, CD.

composition, preventing clichés that occur in most delay-based performances of the twentieth century such as direct repetition and linear determinism.

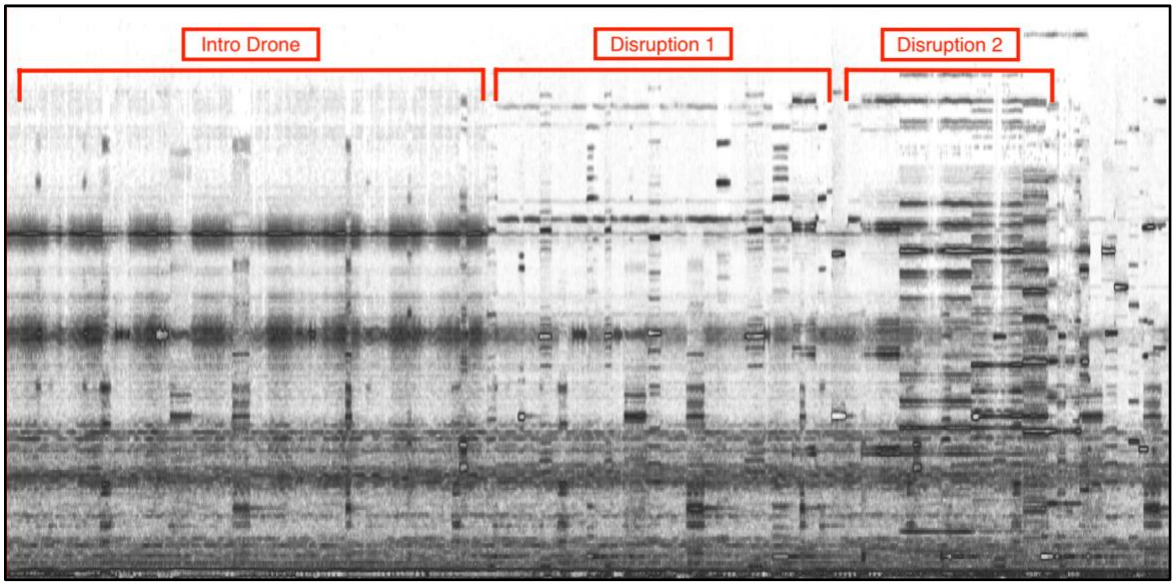

Figure 3 Pauline Oliveros' *I of IV*, spectrogram of 0:38-0:57

The artistic intent of Eno's and Oliveros' works may be very different, but they share a similar performance approach. They both employ two reel-to-reel tape recorders and delay line feedback; Eno sets up his generative system and focuses on the synthesizer part, while Oliveros juggles the volume of the feedback line while introducing disruptive electronic gestures. This solo performer approach to delay-based performance comes with some logistical limitations that do not occur when a performer operates the delayed signals' timing like a second instrument in real-time. To introduce extreme discontinuity into the timing of the tape would create a form of frequency modulation, a technique embraced by Jamaican dub reggae producers.

1.1.3 Tape Speed Manipulation in Mikey Dread's Saturday Night Style

By the mid-1960s, many dub reggae producers in Jamaica increasingly devoted their time to live production activities. Multitrack recording machines were employed to disassemble a musical performance, and many of these engineers were known to push their equipment beyond its intended limits. A fundamental strategy executed by these producers when creating real-time dub mixes was to use tape-delay units in radical ways to either intensify the established rhythms of a song or to violently decenter them. Instead of sending a constant stream of sound into a delay loop, a dub producer would perform a mixing board like an instrument by deciding which sound will enter the tape delay and how prominently. Additionally, they would control how much of that delayed sound would be fed back into the delay line and even alter the tape's playback speed, changing the frequency altogether. In this context, the producer does not create the initial audio signal but instead acts as a manipulator of the signal, bringing the concept of studio trickery to the stage by twisting attenuators in real-time.[14]

The song *Saturday Night Style* by Jamaican producer Mikey Dread differs from *Discreet Music* and *I to IV* in that the multitrack tape already contains a pre-recorded performance of an ensemble. This specific recording was chosen for analysis as very few live recordings of high quality exist from this time period, and because the actions of the

[14] Michael E. Veal, *Dub: Soundscapes and Shattered Songs in Jamaican Reggae* (Middletown, CT: Wesleyan University Press, 2007), 55-76.

producer in this studio context represent what a sound engineer would frequently do in a live setting. To better understand what is occurring in this excerpt, I will apply the vocabulary that American composer and conductor Butch Morris uses in his book *The Art of Conduction: A Conduction® Workbook*.

Morris is the originator of *Conduction* (a term borrowed from physics), a type of structured free improvisation where he conducts an improvising ensemble with a series of hand and baton gestures.[15] Some gestures instruct the ensemble when to play and stop; others specify articulations, rhythmic pulsations, and to adjust dynamics. The list of potential cues any performer would need to learn is quite large, as some of the more complex gestures instruct players to memorize as many as four different moments. These improvised moments can return with another cue later in the performance. This strategy creates a compositional form in a performance practice that is usually spontaneous and lacks structure.

Morris also created a series of cues and terms specifically for electronic instrumentalists to record another instrument and play back the sample later in the performance, an electronic version of the memory cues. An instrument making a sound that is to be sampled is referred to as “grounded,” while the sound that is recorded to the tape is considered "trapped."[16] It is important to note that a trapped sound can lay dormant in the tape before it is played back, but in many cases, such as *Saturday Night Style*, the trapped sound is audible almost immediately after the grounded sound. This vocabulary will be useful later when analyzing Joel Ryan, Radiohead, and Sam Pluta's music.

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[15] Colin Larkin, in *The Guinness Who's Who of Jazz* (London: Guinness Publ., 1992), pp. 293-294.
[16] Lawrence D. "Butch" Morris, *The Art of Conduction: A Conduction® Workbook* ed. Daniela Veronesi (New York, NY: Karma, 2017), 131.

Figure 4 shows the evolution of a single grounded sound as it is trapped into a short loop and its sound deteriorates over 18 seconds. In this excerpt of *Saturday Night Style*, the grounded sound is an overdriven vocal syllable trapped and immediately released.[17] As shown in the spectrogram, the trapped sound's pitch bends upward before settling into a traditional loop. The pitch bends in this context are created by increasing the playback speed of the tape delay. Combined with tape noise, the frequency modulation alters the timbre and saturates the loop for about 6 seconds. The trajectory of the saturated loop is disrupted by a second pitch that bends down and then quickly returns up to the original pitch. The abrupt gesture collects more saturation, mutating the loop almost into a drone instead of a simple repeat. The volume of the feedback signal is decreased shortly after the 0:50 mark, preventing any further repetition.

[17] Mikey Dread, *African Anthem – (The Mikey Dread Show Dubwise)*, Cruise Records –CRUZ 001, 1979, CD.

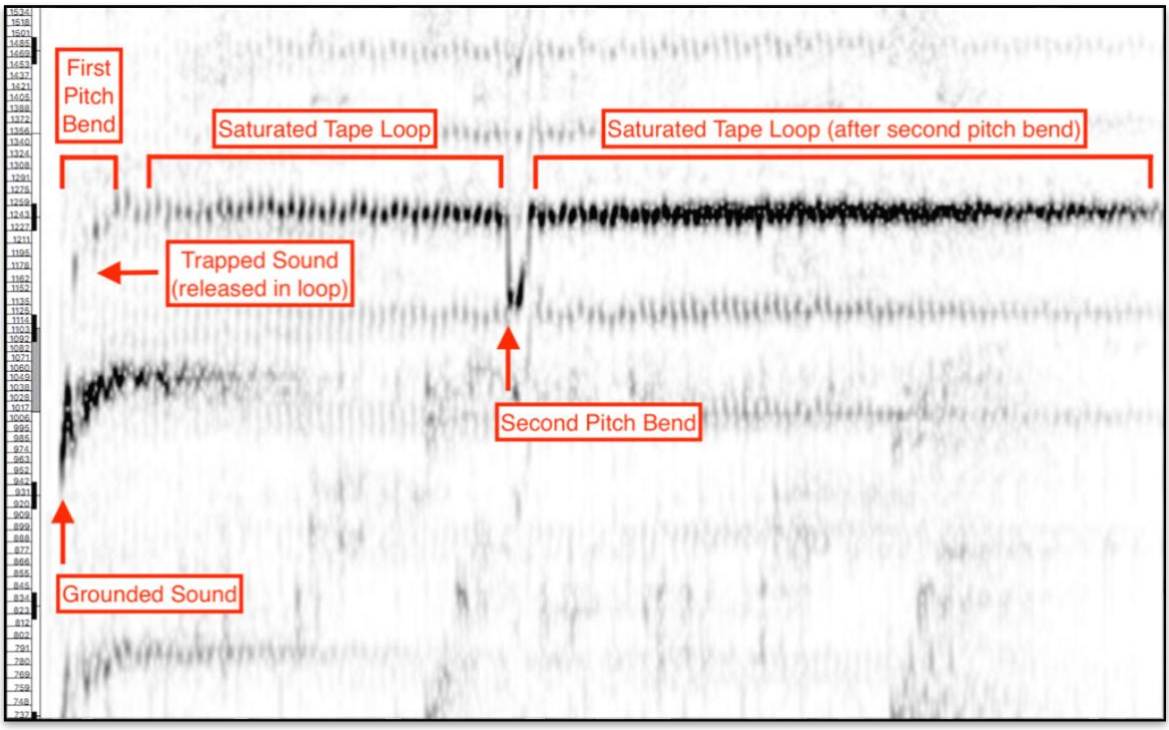

Figure 4 Mikey Dread's *Saturday Night Style*, spectrogram of 0:31 – 0:51

Mikey Dread's approach includes several disruptive elements throughout the 18-second gesture. The trapped sound is less than a second in length, and the loop that is released is almost equal in duration. The repetition that emerges from the initial trapping is asynchronous from the song's beat, creating a discontinuity. The frequency modulation caused by the pitch bends disrupt the continuity established of this new loop. Additionally, the change of tape speed alters the duration of each repetition. This rapid-fire approach to operating a mixing board changes a short sound into a much longer sound independent of the original sound source. Such a sound is not possible with the strategies employed by Eno and Oliveros, where almost all of their sounds enter a loop and thicken the texture. Dread's approach is to act as a gate, strategically selecting the smallest sounds with a shorter delay to create a much longer tone independent of the source; this requires a

higher level of mediation than Eno or Oliveros. The use of a mixer as an instrument in real-time by an electronic performer paves the way for a new type of performance practice that is still used today in the delay-based performance world.

Dread is able to shorten or lengthen a loop with ease. Nevertheless, this technique comes with a caveat: once a sound enters the loop, increasing the duration lowers the pitch frequency, while the inverse occurs when shrinking the length. This technique creates a different kind of predictability, along with the simple fact that the proportions of every loop generated will never change. Direct repetition is prevalent in tape-generated delay-based music of the twentieth century, and the most common way to alter this repetition is to change its speed and duration concurrently. In his article, "Characterizing Idiomatic Organization in Music: A Theory and Case Study of Musical Affordances," Canadian music theorist David Huron defines instrumental idiomaticism as the degree to which a given means of achieving a specific musical goal is significantly easier than other hypothetical means. According to him, it is possible to use performance/instrumental models to identify aspects of the musical organization that may be accounted for by idiomatic concerns.[18] Using a recording device as an instrument, delay is an idiomatic trait that is common with this performance practice. Up to this point, even though delay-based music from the analog era does not have a specific timbre and resulting gesture associated with it, it is still mostly comprised of repetition directly related to the modulated frequency of the grounded source. It is important to examine another level of disruption

[18] David Huron, "Characterizing Idiomatic Organization in Music: A Theory and Case Study of Musical Affordances," *Empirical Musicology Review* 4, no. 3 (2009).

that challenged this linear determinism even further, before gaining an understanding of the innovations of Joel Ryan, Radiohead, and Sam Pluta.

1.1.4 Extreme Discontinuity in Karlheinz Stockhausen's Solo

Many experimental composers of the twentieth century explicitly eschewed repetition, so one might assume that Karlheinz Stockhausen would be an unlikely candidate to create delay-based music. However, for his composition entitled *Solo*, he successfully created a system that could alter a delay's duration without changing the frequency. Stockhausen designed a recording device that contained seven play heads in order to enable different delay times on the same piece of tape. The duration of a loop could be altered mid-performance, avoiding the predictability of direct repetition. This technique emulates a type of splice that traditionally could only be executed within a tape studio, taking Kramer's concept of extreme discontinuity to the stage.

Stockhausen's device for *Solo* emulated the concept of a splice by jumping from one position of the tape to another, splicing time live in the concert hall without the use of the tape studio, and without excessive turnaround time. Additionally, he increased the levels of disruption by instructing three assistants to "perforate" the sound by quickly attenuating the volume down and back up.[19] The assistants routed the grounded sound to one or both recording tracks and attenuated both the feedback level and the amplification of sound emitted by the loudspeakers. This process resulted in a regular,

[19] Karlheinz Stockhausen, "Solo Für Melodie-Instrument Mit Rückkopplung (1966)," in *Texte Zur Musik 3*, DuMont Dokumente (Cologne: Verlag M. DuMont Schauberg, 1971), 85–91.

though transformed, periodic recurrence of the initial material, while the soloist added new material over it, live and in front of an audience.[20] A trapped sound could be released in one channel while also being stored in the other channel, potentially feeding into a delay with different timing. This process created eight layers of potential disruption, allowing for one of the few extreme discontinuity examples to exist in delay-based music produced by tape.

Each recording of *Solo* sounds different due to the high levels of chance allowed by the composer, which provided various possible grounded signals to the ever-changing feedback system. The recording presented in figure 5 is by bassoonist Knut Sønstevold, who performed the fifth of six different delay schemes provided in the score.[21] The spectrogram represents an excerpt where the delay times shift from 11.4 seconds in section 3 of the composition, to 8 seconds in section 4. Gesture 1, from the 11.4-second delay, occurs four separate times. Its spectral content appears differently in each occurrence due to the inclusion of delayed material from previous temporalities, new musical materials introduced by the performer, and what Stockhausen refers to as perforating, or brief attenuations of the feedback volume that occurs in the two channels of the delays. A multiphonic, labeled as “mult.” in the spectrogram, occurs three times and is part of the 8-second delay. Gesture 1 and the multiphonic overlap, yet they are from different delayed temporalities. These different delays occur together because the new 8-second delay time started at 9:22. Furthermore, the “trills,” which occur three times,

[20] Jonathan Harvey, *The Music of Stockhausen: An Introduction* (Berkeley and Los Angeles: University of California Press, 1975).
[21] Knut Sönstevold, *Sönstevold plays Stockhausen*, Nosag Records – nosag CD 042, 2000, CD.

are heavily perforated by the third occurrence and barely resemble the initial sound. The same level of disruption occurs with the two-note motif.

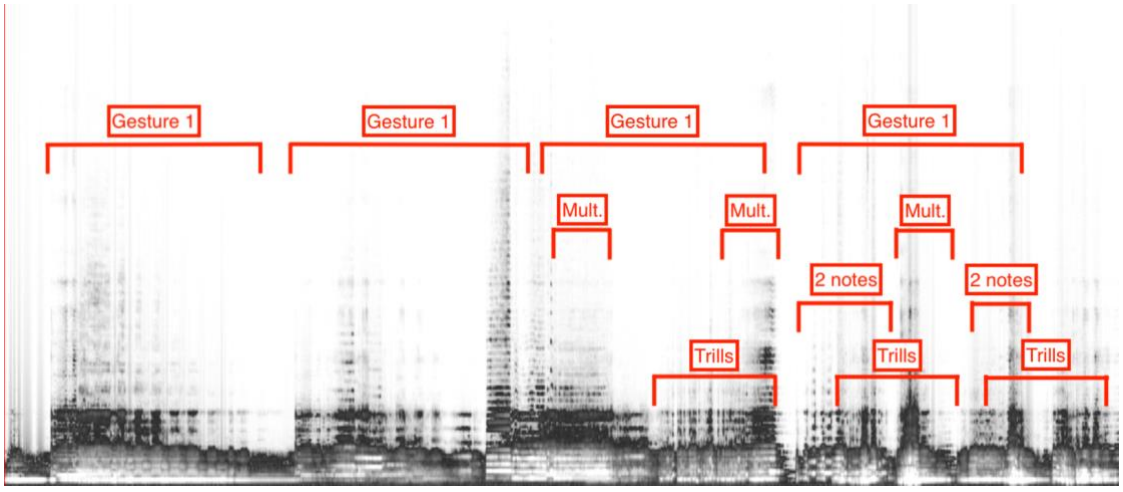

Figure 5 Karlheinz Stockhausen's Solo, spectrogram of 9:00 – 9:52

Stockhausen's use of extreme discontinuity for *Solo* shatters many of our preconceptions when thinking about tape delay-based music. The multiphonics, trills, and two-note motif are all a product of the 8-second delay. However, with higher levels of mediation, their perforated repetitions, overlapped with the 11.4-second-long gesture 1, challenge the listener's expectation of a cliché feedback loop system. With these factors at play, the results can be very unpredictable, but in fact they were not extreme enough for the composer.

In notes for a 2002 performance, Stockhausen concluded that "it will still be a long time until young musicians will be able to learn the interpretation of *Solo* with suitable

mobile apparatuses."[22] He pushed the concept of using a tape-recording device as an instrument to its absolute limit by emulating a tape splice in real-time. The extreme discontinuity that exclusively emerged from the tape studio of the 1950s could now be performed on stage instantaneously. However, some elements of the analog medium are still stifling. The use of a multiple-tape head device is expensive and difficult to operate. With tape machines maximized beyond their fullest capabilities, delay-based performance could not evolve any further. It would take the emergence of a new technology a few decades later to challenge performance practice—digital sampling.

1.2 Analog Recording Versus Digital Sampling

The core concept in digital audio recording is *sampling*, the converting of continuous analog signals (such as those from a microphone) into discrete *time-sampled* signals. This process differs from analog audio recording in that the waveform encoded on tape is a close analogy of the original sound waveform picked up by a microphone. Analog recording continues to be refined but faces fundamental physical limits.[23] Even the most advanced analog recording devices used for delay have restrictions such as the recording tape head, the playback head's placement, the length

[22] Karlheinz Stockhausen, *"Solo* (1965/66) Version für Trompete mit Rückkopplung (Dauer ca. 15½ Min.)" / "*Solo* (1965/66) Version for Trumpet with Feedback (Duration ca. 15½ Minutes)," *Programm zu den Interpretations- und Kompositionskursen und Konzerten der Musik von Stockhausen 27. Juli bis 4. August 2002 in Kürten / Programme for the Interpretation and Composition Courses and Concerts of the Music of Stockhausen July 27th to August 4th, 2002 in Kuerten,* trans. Suzanne Stephens (Kürten: Stockhausen-Verlag), 23–24, 50–51.
[23] Curtis Roads, *The Computer Music Tutorial* (Cambridge, MA: MIT Press, 1996), 9.

of tape, the playback's speed, and the delay return signal's feedback. Figure 4 displays how the frequency manipulation in Mikey Dread's *Saturday Night Style* is directly related to the tape speed, as it is impossible to adjust the speed without adjusting the frequency. Additionally, the only way to alter the length of a tape delay in real-time is to include multiple playback heads, as demonstrated in Stockhausen's *Solo*. These restrictions do not exist in digital sampling, which opens new possibilities for extreme discontinuity.

In popular parlance, “sampling” means making a digital recording of a relatively short sound. The term “sampling” derives from established notions of digital sampling and sampling rate. All sampling instruments are designed around the basic notion of playing back pre-recorded sounds. Instead of recording to magnetic tape, samplers record to a digital buffer, in which samples are stored, saved, edited, or referenced in conjunction with different digital playback strategies. Sampling synthesis is different from waveform synthesis in that a sampling system scans a large wavetable that contains samples of pre-recorded sound. The sampling wavetable's length can be arbitrarily long, limited only by the sampler's memory capacity.[24] Initially, most samplers were standalone instruments. With the advancement in the speed of processing and size of memory capacity, the fusion of digital sampling and playback can exist in a modern laptop computer.

Digital sampling has led to many new playback strategies that were not possible during the analog era. For example, sample playback can be any duration as long as it is not larger than the buffer's size. The direction of playback is free to change at any time, as a sample can play backward just as quickly as it can play forward. The playback

[24] Roads, 117.

position can be moved instantaneously to any position in the buffer. Beginning and ending points of a selection can create a seamless loop, or a bidirectional loop can happen by alternating playback directions. Additionally, the number of layers from a single sample can be increased with ease. Instead of relying on several playback heads, multiple loops can be layered on top of each other, performing from different positions, directions, speeds, and pitch-shifts.

In "Loop Aesthetics," Austrian composer Bernhard Lang's lecture at Darmstadt from 2002, he discusses the relationships between two or more loops of the same sampled material performed simultaneously, or as he calls it, "loop counterpoint." When performing two or more monophonic loops with different lengths simultaneously, there will be a constant oscillation of entry points. A recurrence of these loops presented with this strategy results in an ever-evolving contrapuntal collage, or what he calls "phase-shifted layering."[25] With the push of a button, a texture can quickly increase in complexity as the digital sampler performs more layers of asynchronous loops.

By default, changing the playback speed is no different from the analog method, where a one-to-one relationship exists between frequency and playback duration. However, recent digital processing algorithms allows a sample's frequency to shift up and down without adjusting the playback speed. Alternatively, the playback duration can change without the adjustment of the frequency. This new feature of digital sample playback challenges yet another concept associated with electronic music of the tape era. In his 1971 lecture "Four Criteria of Electronic Music," Stockhausen refers to the first

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[25] Bernhard Lang. "Loop Aestetics Darmstadt 2002 - Magenta." "Loop Aesthetics" (presentation, Darmstädter Ferienkurse, Darmstadt, Hesse, Germany, 2002), 2002. http://members.chello.at/bernhard.lang/publikationen/loop_aestet.pdf.

criteria of “the unified time structuring” as a phenomenon in which rhythms are sped up enough on tape to the point that they become pitches.[26] Much like Kramer’s outdated statement that extreme discontinuity can only exist in a tape studio, Stockhausen’s first criteria no longer applies to modern sample playback, as digital technology continues to challenge analytical perspectives that were defined during the tape-based era.

These idiomatic playback strategies can result in extreme discontinuity. Perhaps the most extreme and obvious of these is the order of playback. While the typical playback method of a digital sampler is to create a loop, playing samples out of order is just as easy as playing them in order. When a musician performs an ascending major scale on an acoustic instrument and records it into a digital buffer, the sampler could then play each note in a different order, resulting in a simple melody. The same can occur for absolutely any kind of digitally recorded sound. The default for a delay coming from an analog tape system is a direct repetition; the digital delay system can play the recorded material in any prescribed order.

Technology's influence on musical time goes beyond the topic of discontinuities. Jonathan Kramer has also discussed the concept of "turnaround time," or the time between completing a composition and the performance. As music became more complex and challenging to perform in the late eighteenth and nineteenth centuries, composers had to wait longer to hear their works.[27] The turnaround time from a tape studio to the electroacoustic concert hall was also extended. Digital technology, however, has cut the turnaround time for reorganizing digital samples to zero. Gone are the days

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[26] Karlheinz Stockhausen and Robin Maconie, Essay. In *Stockhausen on Music: Lectures and Interviews* (London: Marion Boyars, 1989), 91–96.
[27] Kramer, 76-79.

of early computer music composition, when composers had to wait several days while a digital data tape was translated into an analog sound tape.[28] Nowadays, when a live performer records into a digital buffer, the resulting delay could be scrambled instantaneously at the composer's desire without compromising with a direct repetition. The term extreme discontinuity is dated as it relates to dealing with tape. Instead, I am introducing the term temporal manipulation when referring to digitally restructured recorded material created in real-time. Newer possibilities for manipulating delays have expanded with the advancement of computer technology since the turn of the twenty-first century.

1.2.1 The Emergence of the Live Processing Performer

The term “musical assistant” has been loosely applied throughout music history to a musician, a translator, or an interpreter of musical ideas who works alongside the composer. The revolution of sound recording, synthesis, and transformation throughout the twentieth century caused the natural emergence of a new professional profile—someone who can work in research, writing, the creation of new instruments, recording, and performance on electronic devices during concerts.[29] When electronic compositions required real-time delay, it was necessary for an assistant to set up the delay system and manipulate the delay and feedback as prescribed by the composer. The performance notes in Stockhausen's *Solo* initially required no fewer than three assistants to perform

[28] Kramer, 76.
[29] Laura Zattra, “Collaborating on Composition: The Role of the Musical Assistant at IRCAM, CCRMA and CSC,” in *Live-Electronic Music: Composition, Performance, Study*, ed. Friedemann Sallis, Valentina Bertolani, and Jan Burle (Abingdon: Routledge, 2018), 59–61.

its complex tape delay system. The first assistant attenuated the microphone pick-up into the delay system's two channels; a second assistant manipulated the channels' feedback; and a third controlled each channel's playback.[30] Digital technology has rendered the assistants for this composition obsolete. A single assistant, armed with a computer and a MIDI controller, can now accomplish the tasks of all three people.

As the concept of delay-based performance has evolved with the advancement of technology, the musical assistants' potential role has changed. In recent years, the complex role of the "live processing performer" has evolved into that of a contributing, performing musician, sitting on stage within the ensemble and not regulated to the sound engineer position in the middle or back of the venue. To perform with live sound processing is to capture the sound of the acoustic instrument, delay the signal, and manipulate that signal further to create an independent and unique voice in a musical performance. With faster computers and more widespread use and availability of live sound processing software, live processing musicians have become more common over the last thirty years. To better understand this under-theorized trend, it is important to analyze case studies focused on some more recent innovators of this practice; Joel Ryan, Radiohead, and Sam Pluta.

[30] Karlheinz Stockhausen, *Solo: für Melodieinstrument mit Rückkopplung* (Universal Edition, 1966).

2.0 Joel Ryan and The Development of a Live Processing Instrument

As a member of the first generation of computer music hackers in San Francisco's Silicon Valley, Joel Ryan is a composer, improviser, and programmer who has long championed the idea of performance-based electronic music.[31] Starting from a scientific rather than a musical education, he moved into, via physics and philosophy, studying with Herbert Marcuse, Albert Hofstadter, Ravi Shankar, and Mexican film composer and guitarist Jose Barroso.[32] Before becoming a live processing pioneer, Ryan developed "listening software" in the late 1970s and early 1980s that improvised along with human performers at the Studio for Electro Instrumental Music (STEIM) in Amsterdam. He collaborated with musicians such as "Blue" Gene Tyranny, and did sound design for Robert Ashley.[33] Unlike many of his contemporaries, he was never interested in generating traditional wave synthesis, nor was he motivated to make hands-off AI constructs like his colleague George Lewis did with "Voyager" in 1987, which would create a situation where the machine had all of the fun while he looked on passively.[34] By the late 1990s, Ryan was looking for a way to play the computer as an instrument, with the goal of generating sound that was "as beautiful as a physical instrument."[35]

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[31] Joel Ryan, "BIO JR," accessed December 7, 2020, https://jr.home.xs4all.nl/bio1.03.html.
[32] Joel Ryan, "Joel Ryan," *ZKM*, accessed December 7, 2020. https://zkm.de/en/person/joel-ryan.
[33] Brian Olewnick, Review: Blue Gene Tyranny/Joel Ryan - The Intermediary (Lovely Music Ltd.), accessed December 8, 2020, http://www.squidsear.com/cgi-bin/news/newsView.cgi?newsID=845.
[34] Joel Ryan, "Improvising with Others," *Contemporary Music Review* 25, no. 5/6 (October 2006): 417-423.
[35] Joel Ryan, interview by the author, Amsterdam, NL., September 27, 2017.

Preferring a duo format of improvising with a virtuosic solo performer, he manipulates digital signal processing (DSP) to alter a soloist's voice, radically transforming everything in real-time. The resultant mix is not like a soloist with orchestra, but an entirely new orchestra. Instead of assuming an accompanist's role, which would generate sound to support the acoustic soloist like a concerto, he prefers four hands on every sound, a dual improvisation on "one" heterogeneous instrument. If either performer stops, the music stops.[36] Ryan has frequently performed as part of duos over the last couple of decades including with many pivotal figures in the development of free improvisation such as Evan Parker, Ned Rothenburg, Barry Guy, Noel Akchoté, Paul Lynton, and Agustí Fernández.

His distinct style is unique compared to other live processing musicians of his generation, such as frequent collaborator Lawrence Casserley, known for creating diffuse clouds of delays intended to break up the eventfulness of any moment in a performance. Unlike Casserley, Ryan does not seem concerned with documenting his work. According to his website, Casserley has published at least 24 compositions and several journal entries and is featured on at least 39 recordings.[37] Ryan's website, on the other hand, is sparse and mysterious. Only his solo album called *or Air* is listed on the site, along with some poetic musings on random topics such as philosophy and quotes from Japanese

[36] Ryan, "Improvising with Others," 417-423.
[37] Lawrence Casserley, "Lawrence Casserley," Lawrence Casserley - Home, accessed March 25, 2023, https://www.lcasserley.co.uk/.

literature.[38] Anyone searching for information about him has difficulty finding a complete discography.

When I met with him in Amsterdam in the fall of 2017, I was surprised to find out that he has been composing for as long as he has been making music. I witnessed a piece live for processed piano wire connected to a pickup microphone. The automation of the electronics was fixed with no prerecorded audio. Unlike the live processing excerpts in this document, the computer did all the processing with no hands-on real-time manipulation of the signal. Instead, Ryan whipped this piano wire around the stage while the computer altered the timbre. A true showman, when the computer effects changed drastically he gave an amused look on his face to the audience. Each subtlety of the piece was acted out by his physical gestures.

During my interview process with him, Ryan responded with extremely long and interesting stories that ranged from history and poetry to linguistics. Somehow these extended monologues would wrap back around to answer my initial question, sometimes as much as an hour later. It seems that Ryan is more focused on teaching, making music, and developing music technology than trying to preserve his list of works. If he isn't actively documenting his work, then someone else should. And that is why Ryan's excerpt was chosen for this document instead of, for example, Casserley.

Ryan, who was never the leader of any of the ensembles he performed with, does not want to generate sounds that intrude on the well-established space of veteran improvisers. When using delays, he prefers to keep things contained to a relatively short time scale and is conscientious about making the scale adjustable so as not to impose

[38] Joel Ryan, *or Air*, psi – psi 04.08, 2004, CD.

any artificial, or quantized time onto the music. Like Stockhausen's *Solo*, which relies on a custom-built tape delay, Ryan invented a personalized instrument to accomplish his artistic intentions as he could not rely on signal processing gear that existed at the time. As he put it, "the rules of thumb of engineering are basically antithetical to the development of instruments." Engineers are concerned with simplicity and design. However, simplicity, in his view, "eliminates all of the contingencies of the real world that make musical instruments interesting."[39]

Ryan's instrument is a computer and hardware setup based around customized software programmed in SuperCollider, a real-time audio processing programming language, and Max/MSP, a visual programming environment.[40] By creating a virtual processing instrument, he bypasses any decision-making that had been imposed by audio engineers of that time. He moves a computer mouse around like a bowing gesture of a stringed instrument to control the sound. This strategy creates a coherent image of the music he performs allowing for a higher level of mediation than analog tape delays. Claiming to be nauseated by the concept of infinity, a concept that many engineers promoted in the evolution of computing, he states he was never interested in building an electronic instrument that can do everything at any time. Instead, he made the computer software more concrete than it was designed to be by accepting the limitations of real-time performance and constraining his possibilities of sound transformation.[41]

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[39] Joel Chadabe, "Making Sound," in *Electric Sound: The Past and Promise of Electronic Music* (Upper Saddle River, NJ: Prentice Hall, 1997): 241–42.
[40] Ryan, interview.
[41] Ryan, "Improvising with Others," 417-423.

2.1 Phase Cancellation Analysis of *Instant 1*

Since making the transition from composing with computers to transforming the signals of performers on stage, Joel Ryan's live processed improvisations have been included on many recordings from the 1990s to today. His contributions to the album *Free Zone Appleby 2004* are uniquely complementary in comparison to other computer artists' usual fragmentation processes.[42] On *For Flowers*, he builds new sonic objects using material of his fellow improvisers by retaining the feeling of their sound while at the same time showing it from a different angle, or rather, from multiple angles, as if through a prismatic crystal.[43] On *River Tiger Fire* his processes are presented like a hall of mirrors, full of copies and counterparts.[44] However, I will focus here on the track *Instant 1* from the album *Live at "Les Instants Chavirés"* because of its historical significance.[45] This specific duo performance with virtuoso soprano saxophonist Evan Parker is the first live processed recording that was released featuring Joel Ryan, and this example represents a vital stepping stone in the evolution of digital live processing and delay-based performance.

Instant 1 features Parker and Ryan performing together in a seemingly endless continuum of sound for over 19 minutes. The processing parallels and envelops the acoustic playing as part of the live performance, instead of as a post-production overlay of studio trickery. Ryan's approach of creating a four-handed instrument is on full display

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[42] Evan Parker, *Free Zone Appleby 2004*, psi – psi 05.05, 2004, CD.
[43] Léandre/Maneri/Marguet/Ryan, *For Flowers*, Leo Records – LR 396, 2004, CD.
[44] Agustí Fernández, *River Tiger Fire*, Fundacja Słuchaj! – FSR BOX 4CD 01|2015, 2015, CD.
[45] Evan Parker with Noel Akchoté, Lawrence Casserley and Joel Ryan, *Live At "Les Instants Chavirés*". Leo Records – LR 255, 1998, CD.

as it is difficult for any listener to discern which sound is a live saxophone and which is the computerized version of it. These blurred lines between acoustic and electronic create an analytical problem: when observing this stereo track, what is the saxophone, and what is the delay?

If there were a way to separate the two layers from their source, it would be easier to analyze the two sound layers' interaction. One potential solution is the use of phase cancellation, a phenomenon where two signals of the same frequency and amplitude are out of phase and completely cancel each other out. Usually, this process would leave a track completely muted. However, if some of the waves are out of phase, this would only remove some of the signals. In this specific example, we only have two channels to work with; the stereo track's left and right channels. By inverting the left track's phase and placing it on top of the right track, any initially identical waves would mute, and vice versa. After repeating this process for an inverted right channel on top of the left, a stereo track would remain that is absent of any signal that sat directly in the center of the stereo mix.

The way live processed music is usually recorded makes the phase cancellation process useful. An instrument, such as Parker's soprano saxophone, is typically amplified by a single microphone panned to the center of the recording. The signal of live processing comes directly out of a computer's stereo output. Additionally, the processes can easily become spatialized and diffused throughout the stereo field. After applying the phase cancellation procedures to a performance involving live processing, the acoustic instrument's signal will disappear and reveal only the computerized stereo signals. Take this result, and invert the phase once again and place it on top of the original track, and everything in the stereo field will disappear revealing what was panned directly to the

center. In this specific case, the soprano saxophone will appear without any computerized sound in the stereo field.

The use of phase cancellation does not remove musical layers in the manner of Schenkerian analysis. Instead, it isolates layers of a documented performance into their tracks to be studied further in a spectrogram. As useful as this process is for this type of analysis, it is important to note that it comes with shortcomings. For example, if the soloist is panned off-center, or if the electronics are in mono, then phase cancellation will not work. Even if each performer is sitting within the correct stereo spectrum, as in *Instant 1*, then a few problems still exist. Microphone bleed from the electronics can appear in the soloist's microphone, and any electronic signals that venture into the center of the stereo field will be omitted from the phase-cancelled electronic track and instead placed on the soloist track.

Despite these potential pitfalls, it is still a valuable strategy to isolate these recorded layers from each other before observing the relationships between the acoustic source and the delayed signal in a spectrogram. To demonstrate this, figure 6 is a spectrogram of only the center layer of *Instant 1* from 12:30 to 12:38, revealing a repeated two-note gesture, A4 and B4, performed on the soprano saxophone in the center channel. It is difficult to identify what is happening with regard to the soloist and live processing interaction while listening exclusively to the studio recording as is. However, isolating the center layer of this moment using phase cancellation reveals that this specific gesture is grounded as Ryan traps the sample into his live processing instrument.

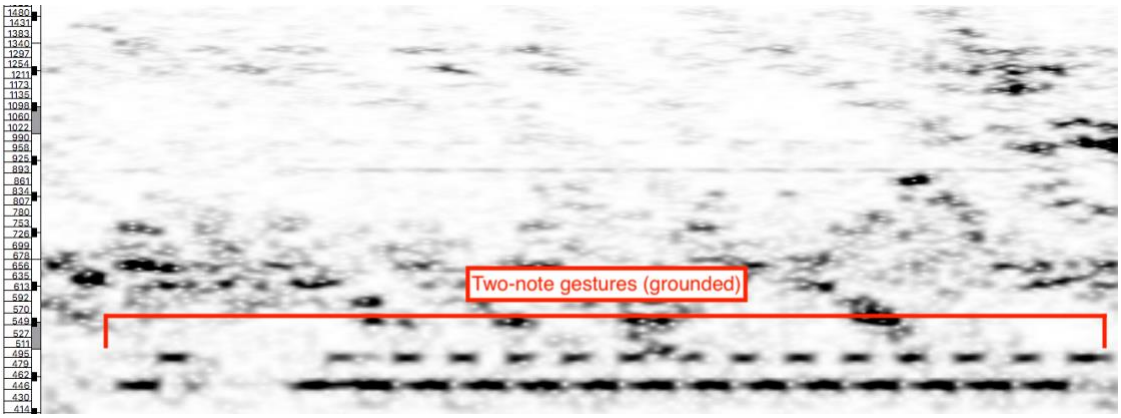

Figure 6 Joel Ryan's Instant 1, spectrogram of 12:30-12:38 (center layer)

All additional frequencies displayed in this specific spectrogram are trapped electronic sounds that have been live processed previously in the performance. For example, as displayed in figure 6, the two-note grounded gestures return in the center layer as a trapped electronic sample in figure 7 from 13:25 to 13:31, almost a full minute after Parker had performed the gestures. What is different about the sample is the frequency; sounding are a D3 and E3, which are pitches that cannot be performed on a soprano saxophone, revealing that Ryan had altered the sample's frequency without altering the duration of the initial performance.

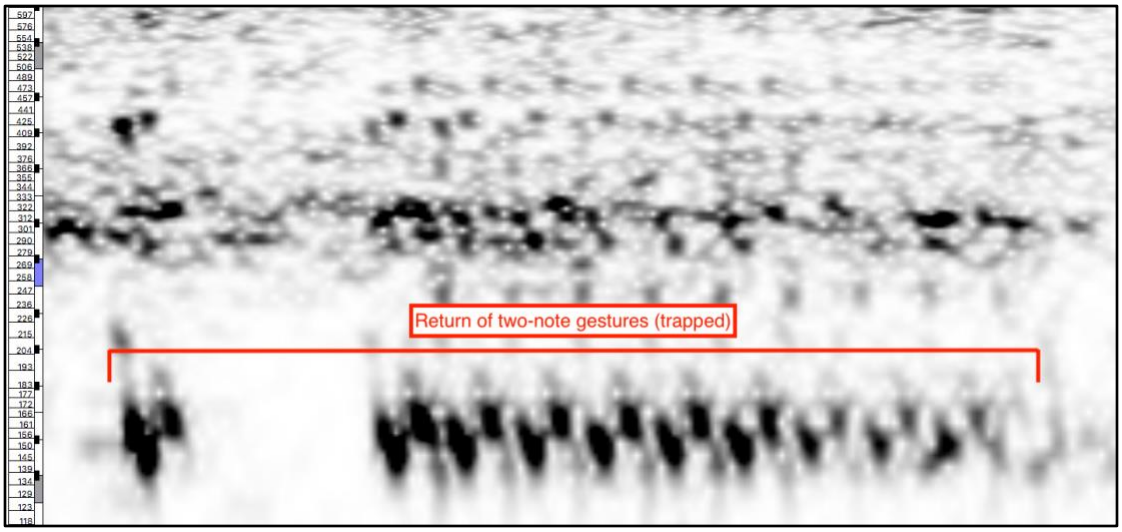

Figure 7 Joel Ryan's *Instant 1,* spectrogram of 13:25 to 13:31 (center layer)

The two-note gestures return around 13:38, along with several new digital processes. In addition to sounding between the pitches approximately D4 and E4, an octave above the original sounding trapped sample, and a fourth below the original grounded sounds, these new trapped sounds are polyphonically diffused across the stereo channels and rhythmically fragmented. Figures 8 and 9 show fragmented loops of the newly transposed two-note gestures looping asynchronously in the left and the right channels. The rhythms of each of these layers are out of sync, sounding much shorter than the trapped sample initially presented in figure 7 and demonstrating the "phase-shifted layering" technique described by Bernhard Lang.[46] These layers continue throughout this section until they fade out at approximately 14:03.

[46] Lang, "Loop Aesthetics."

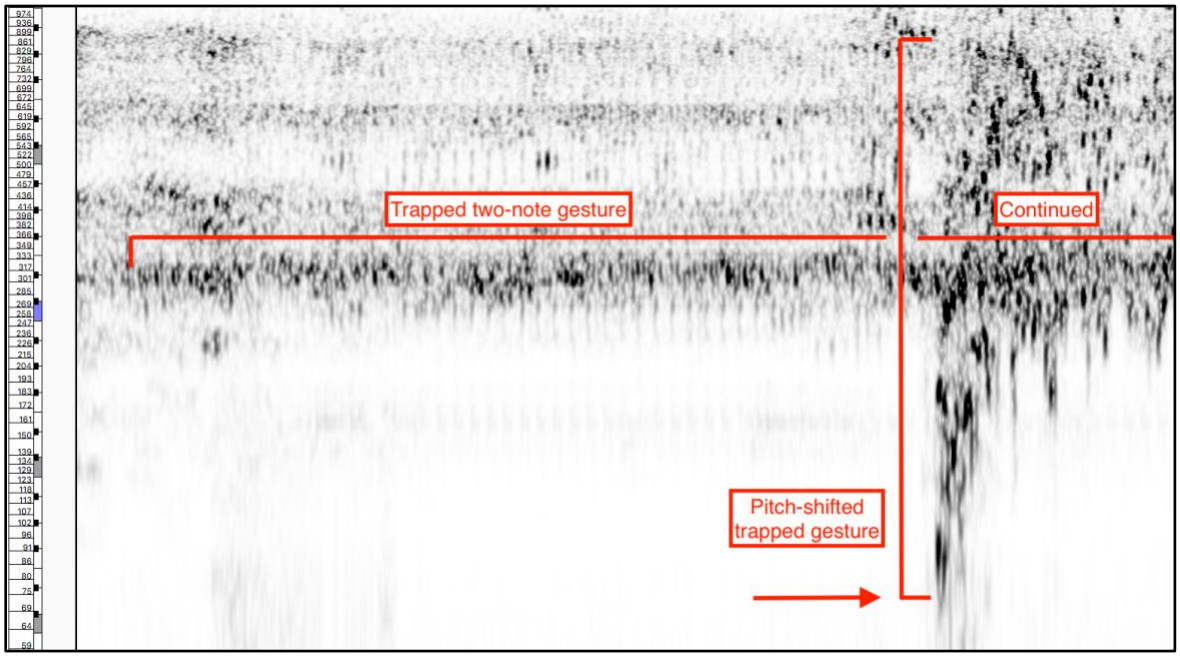

Figure 8 Joel Ryan's *Instant 1,* spectrogram of 13:38 to 14:03 (left layer)

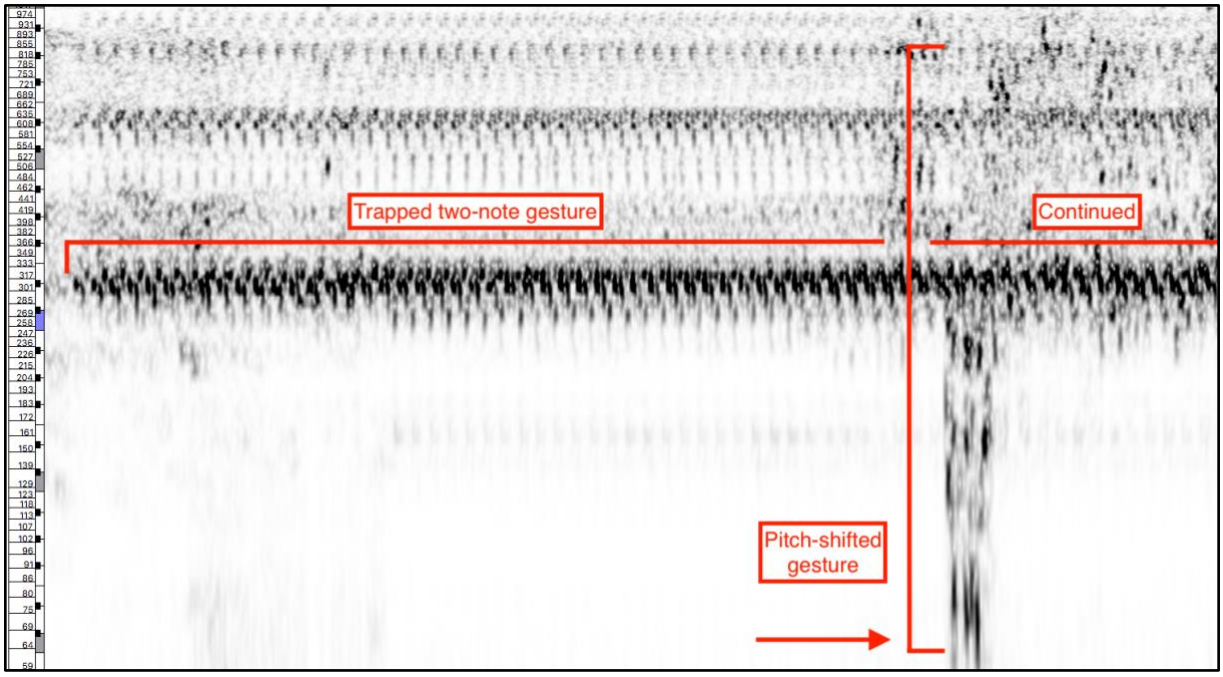

Figure 9 Joel Ryan's *Instant 1,* spectrogram of 13:38 to 14:03 (right layer)

At 13:55, Ryan introduces additional polyphonic layers of the two-note gestures presented at faster speeds with additional phase-shifted layering and higher frequencies. The trapped sounds are presented as newly grounded sounds that are re-trapped into additional audio buffers and then processed further. This is like the feedback technique of analog tape delays, but without the predictable direct repetition. In this case, the sounds are processed samples of previously processed samples. Seconds after introducing these new layers around 13:58, Ryan creates a large pitch-bend gesture as he radically transposes and slows the speed of the trapped sounds only to speed them back up again—a process not unlike the dub production of Mikey Dread. A similar pitch bend gesture occurs again around 14:12. Significantly, while Ryan has introduced many layers of new processing techniques that could only occur within the digital realm, concepts from the analog era survive in this new aesthetic.

The use of phase cancellation reveals layers that are hidden by the clouds of granular sounds. Parker's original two-note gestures (figure 6) are somewhat difficult to hear in the original studio recording. The separation of the center channel from the stereo channels reveals how trapped sounds moved from the middle to the stereo field. This makes it easier to distinguish the acoustic performer's sound from the live processed sound.

2.2 Improvisation with Joel Ryan's Live Processing Instrument

The spectrograms of *Instant 1* reveal how much music can be created from such a simple musical gesture using delay-based performance and temporal manipulation in

real-time. Figure 10 displays all the material Ryan generated by trapping Parker's alternating two-note gestures that began around 12:30. From here, Ryan chopped up and pitch-shifted several layers of the same sonic material and continued to do so until 14:37, not just perpetuating a feedback loop of layers of sampled audio but providing an electronic call-and-response, a basis on which Parker can improvise further.

A fundamental concept within electronic composition is the transformation of sound to create variation and development. Starting with a base set of sounds, transformations generate families of derived sounds, multiplying the diversity of the sound palette. As Curtis Roads observes in his book “Composing Electronic Music: A New Aesthetic”:

> In many works by Trevor Wishart, including *Redbird* (1977), sound transformation plays a role analogous to variation in traditional music. All sounds in his *Imago* (2002) derive from transformations of a one-second clips of two wine glasses clinking. Horacio Vaggione’s *Harrison Variations* (2002) is a 10-minute composition derived from the same clip. Despite reliance on a single sound as the germ of the entire work, both compositions exhibit remarkable acoustic heterogeneity. The lesson is that it is possible to start with any sound and derive a cornucopia of diverse sounds from it through transformation.[47]

[47] Curtis Roads, “Sound Transformation,” in *Composing Electronic Music: A New Aesthetic* (Oxford: Oxford University Press, 2015), 114-115.

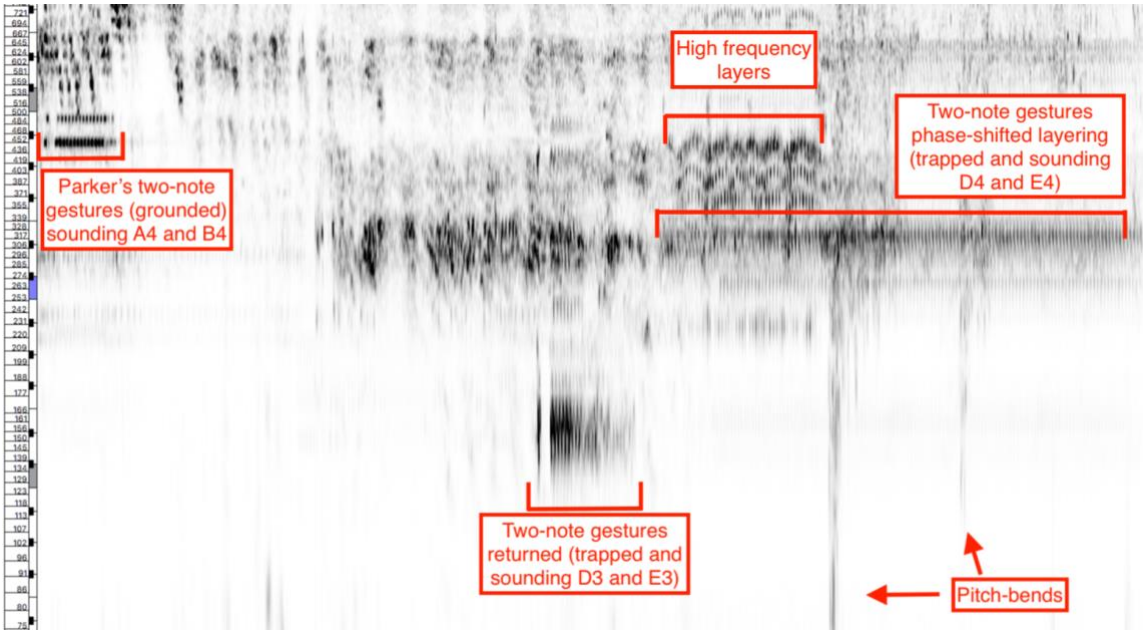

Figure 10 Joel Ryan's Instant 1, spectrogram of 12:30 to 14:37 (all layers)

Creating an entire composition out of a minimal set of sonic materials is a hallmark of much electronic composition. Joel Ryan fits within this aesthetic by limiting his set of base sound sources to those of a live performer. What differentiates Ryan's approach from other composers, such as Wishart or Vaggione, is that he is not working in a studio; instead, he is performing live on stage. Therefore, there is no room to go back and rethink any decisions about the samples of Evan Parker. Considering the obvious linear trajectory of time, Ryan's only way to generate his cornucopia of diverse sounds with the limitations of 1990s computer processing power was by harnessing the power of delay with his custom live processing instrument. These delays differ heavily from the tape manipulation and feedback loops associated with the analog era of delay-based performance. Instead, Ryan mangles the delayed samples heavily with polyphonic, asynchronous layers, and pitch-shifts many of the samples, embracing the possibilities of temporal manipulation in the digital realm.

2.3 Quantifiable Findings of *Instant 1*

To summarize the phase cancellation analysis of Instant 1 from 12:30 to 14:03, Table 1 reveals the quantifiable findings. The grounded source is the instrument trapped by the electronics. Trapped size is the length of grounded material stored in the program's buffer. The waiting period is the duration between the moment the grounded sound is trapped and the moment the trapped sound is audible. Finally, the trapped playback duration is the total time for all the trapped sound performed after its waiting period. Like the memory cues from Butch Morris' Conduction, the waiting period followed by the trapped playback duration create a formal structure from a freely improvised performance. This table will be used later in this project compared to the quantifiable findings from Radiohead and Sam Pluta.

Table 1 Quantifiable Findings of *Instant 1*

Grounded Source	Evan Parker's soprano saxophone
Trapped Size	6 seconds
Waiting Period	55 seconds
Trapped Playback Duration	38 seconds

3.0 Radiohead and Live Sampling

No rock band since the Beatles has so successfully occupied the elusive sweet spot between convention and experimentation as Radiohead. The English rock band's "sound has never piggybacked on any mainstream trends."[48] "Their commercial and artistic success" "stems instead from an ability to write music that balances expectation and surprise. Though most of their songs present the listener with myriad surprises and disjunctures, they only do so after first setting up rich expectations by tapping into things listeners have inherited from various musical traditions."[49]

On the surface, any excerpt by Radiohead is categorically unlike one by Joel Ryan, whose music is considered avant-garde because of the manner in which it incorporates free improvisation and avoids the solid rhythmic pulsation associated with pop music. However, there are striking similarities between Ryan's and Radiohead's approaches to live processing. The band has used this technique in almost every concert since 2000. Their global popularity provides strong evidence for my argument that live electronic performance and real-time processing are highly relevant to contemporary music. Since 1997, "five of the six records they released peaked at #1 on the UK and US charts."[50] Moreover, looking beneath the traditional rock song structure in songs such as *The Gloaming*, *Feral*, and *Daydreaming* reveals that they too execute live sample-based real-

[48] Brad Osborn, *Everything in Its Right Place: Analyzing Radiohead* (New York: Oxford University Press, 2017), vii.
[49] Osborn, *Everything in Its Right Place: Analyzing Radiohead*, vii.
[50] Osborn, *Everything in Its Right Place: Analyzing Radiohead*, vii.

time digital signal processing. To quote composer Tristan Murail, “the spectacular development of synthesizers, of electronic sound, owes considerably more to Pink Floyd than to Stockhausen.”[51] Perhaps the same could be said for Radiohead and their contributions to the developments in live processing.

After years of growing success in the 1990s, the band drastically shifted away from the style associated with their worldwide alternative rock hits towards a more experimental and electronic sound. After suffering several mental breakdowns in 1997 and 1998, lead vocalist Thom Yorke felt spiritually and creatively spent. Uninspired by the guitar-driven alternative rock music that the band was known for, he brought demos to the band inspired by English electronic acts like Aphex Twin and Autechre. Yorke has said that this cold, mechanical music made him feel alive again, giving him the same emotional connection that guitars once did.[52] "After that 1997 tour, we felt we had to change everything," said bassist Colin Greenwood. "There were other guitar bands out there trying to do similar things. We had to move on."[53] As a reaction to this internal crisis, they decided to reinvent themselves as songwriters and as instrumentalists.

The band brought songs into a radically different style, moving far away from snappy, straightforward rock songs. In January 2000, Nigel Godrich, the band's producer, suggested splitting into two groups in the studio: one would generate a sound or sequence with electronic instruments and vocals, and the other would develop it using post-

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[51] Tristan Murail, “The Revolution of Complex Sounds.” *Contemporary Music Review* 24, no. 2-3 (2005): 121–35. https://doi.org/10.1080/07494460500154780.
[52] Steven Hyden, *This Isn't Happening: Radiohead's Kid A and the Beginning of the 21st Century* (New York, NY: Hachette Books, Hachette Book Group, 2021), 13–23.
[53] Greg Kot, “Moving on Radiohead Sends out New Signals with ‘Kid A’,” Nigelgodrich.com, 2000, https://web.archive.org/web/20160313120012/http://nigelgodrich.com/press5.htm.

production editing techniques. One group began by creating a basic sequence or loop or noise, handing it over to the others to expand on.[54] This led to a discussion of how to recreate this studio approach on stage. Instead of relying on backing tracks of fixed media audio, they were fascinated by the concept of a live remix, embracing live electronics as a method of improvisation.

Inspired by the dub reggae producers of the 60s and 70s and the live electronics of the avant-garde, they began to experiment with live processing. The first of these experiments took place in one of their most known songs, *Everything in its Right Place*. Instead of traditional guitar rock solos, both guitarists, Johnny Greenwood and Ed O'Brien, swapped out their usual instruments for custom signal processing rigs and assumed different roles. O'Brien manipulated Yorke's synthesizer using an array of pedals initially designed for live looping. Instead of using his foot on guitar stompboxes, his hands manipulated the dials to sample the keyboard and restructure the order of the playback. Greenwood processed Yorke's voice using a Korg Kaoss Pad, an electronic instrument with an X/Y touchscreen designed for DJs to apply effects to tracks they play at clubs. The inclusion of the touchscreen and the live sampling capabilities allowed Greenwood to sample the vocal lines and manipulate the sample playback position using hand gestures, not unlike the bowing technique used by Joel Ryan and his live processing instrument.

This approach is yet another example of Kramer's "turnaround time" in which techniques that would traditionally take place in the tape studio are now executable in

[54] David Cavanagh, "I Can See the Monsters," *Q* 169 (October 2000), https://citizeninsane.eu/media/uk/q/04/pt_2000-10_q.htm.

front of an audience. This demonstrates how digital technology continues to challenge temporal manipulation by the allowance of higher levels of mediation. While both Greenwood and O'Brien were using commercially available hardware for their processing duties, it is worth noting that they also included custom patches built in Max/MSP, not unlike Joel Ryan and other live processing musicians of the avant-garde. In the case of Radiohead, two different electronic performers manipulate the same musician, albeit with different signals. These live vocal and instrumental transformations emulate what took place in the studio using Pro Tools, the industry-standard audio editing software. Examining how the band reproduces these vocal effects in a live performance reveals an embodied, performative approach to the technological component of these signal deformations that use delay.

3.1 "Everything in its Right Place"

Between the premier live performance at Théâtre Antique in Arles, France on June 13, 2000, and 2018, Radiohead performed *Everything in its Right Place* approximately 385 times.[55] Because of the quantity of bootlegged recordings, this song might also be one of the most documented examples of live processing for a single composition. The recording from Chicago, Illinois on July 29, 2016, is appropriate for analysis because the band posted it on their official online video archive known as the "Radiohead Public

[55] "Setlist.fm," Everything in Its Right Place by Radiohead Song Statistics, accessed March 24, 2022, https://www.setlist.fm/stats/songs/radiohead-bd6bd12.html?songid=4bd6dfd6.

Library."[56] Additionally, the high sound quality and stereo panning place Greenwood's and O'Brien's signals in opposing left and right channels, allowing phase cancellation analysis to separate their signals into separate layers with ease. The song is 4 minutes and 9 seconds long; however, the entire concert recording is presented as a single uninterrupted track. Therefore, timing citations for the analysis refer to the song's placement in the concert between 1:09:45 and 1:13:55.

The recording begins with Yorke performing a rubato improvisation in C Phrygian on a Prophet '08 synthesizer. Figure 11 is a spectrogram of this introduction with the highest notes (C5 and Db5) labelled as a grounded two-note gesture of which the trapped version will be revealed later in the song. O'Brien and Yorke exchange visual cues of "thumbs up" to indicate that that the grounded synth signal has been adequately trapped into O'Brien's pedals before the rest of the band starts the song in a 5/4 groove at 01:10:21, allowing for O'Brien to sporadically release manipulated trapped sounds throughout the performance. Then, starting at 01:10:37, Greenwood traps the grounded vocal F4 – C4 – F4 motive "ev-ry-thing" as sung in real-time. Immediately afterward, he begins to play back the deformed trapped motif, and a call-and-response continues between Yorke and both live processing musicians. Once Yorke completes all lyrics by 01:13:00, the band begins to jam on all the sonic material trapped earlier in the performance.

[56] "Radiohead Public Library," Radiohead Public Library, accessed March 24, 2022, https://www.radiohead.com/library/#amsp/2016-07-29-lollapalooza.

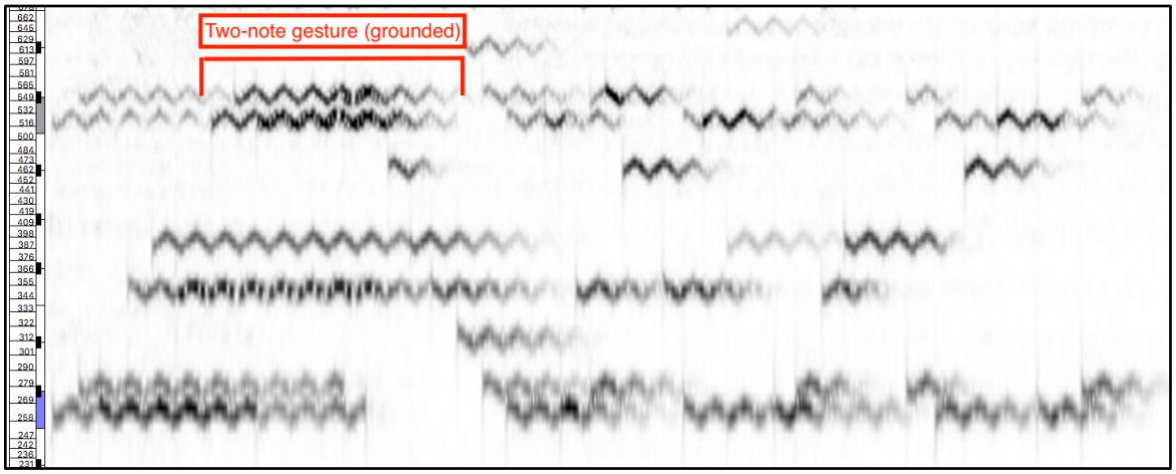

Figure 11 Radiohead's *Everything in its Right Place*, spectrogram of introduction

Figure 12 is a spectrogram of the grounded vocal line "What is that you tried to say?" located in the center channel. Figure 13 is the trapped version of the same vocal line somewhat altered and presented as an immediate response. Unlike the previously sounded trapped vocals, the lyrics are intelligible this time, or the quickly mutated call-and-response vocal transformations from earlier in the song. This is also the last grounded sound that Greenwood traps before improvising a solo from here to the end. Up to this point, O'Brien occasionally fades several different trapped synthesizer textures in and out, primarily collected from the introduction. By 01:13:04 he fades in the trapped segment of the two-note gesture of C5 and Db5 as displayed in figure 14. The frequency of the synth gesture remains unaltered while the rhythm is scrambled.

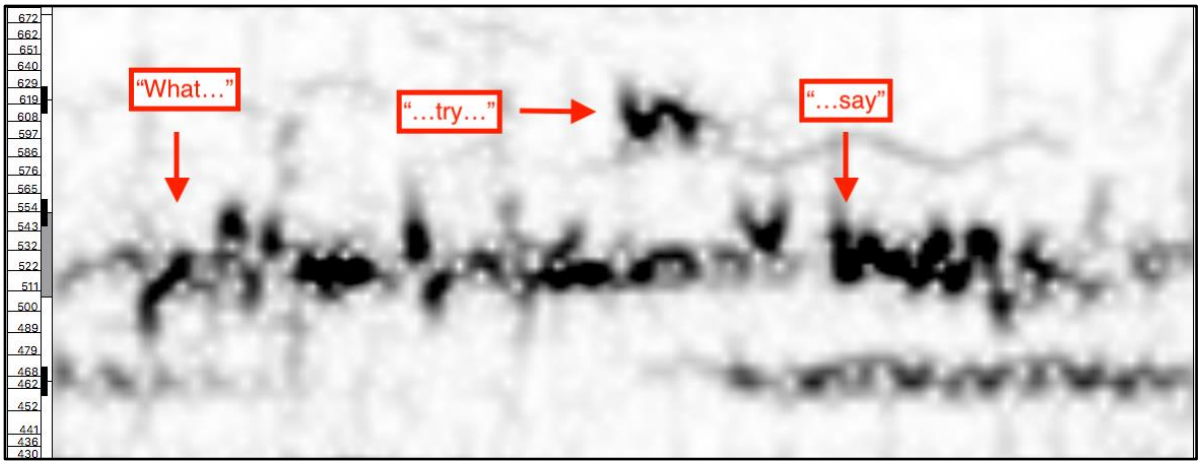

Figure 12 Radiohead's *Everything in its Right Place*, spectrogram of grounded vocal line, center channel from 01:12:18 - 01:12:23

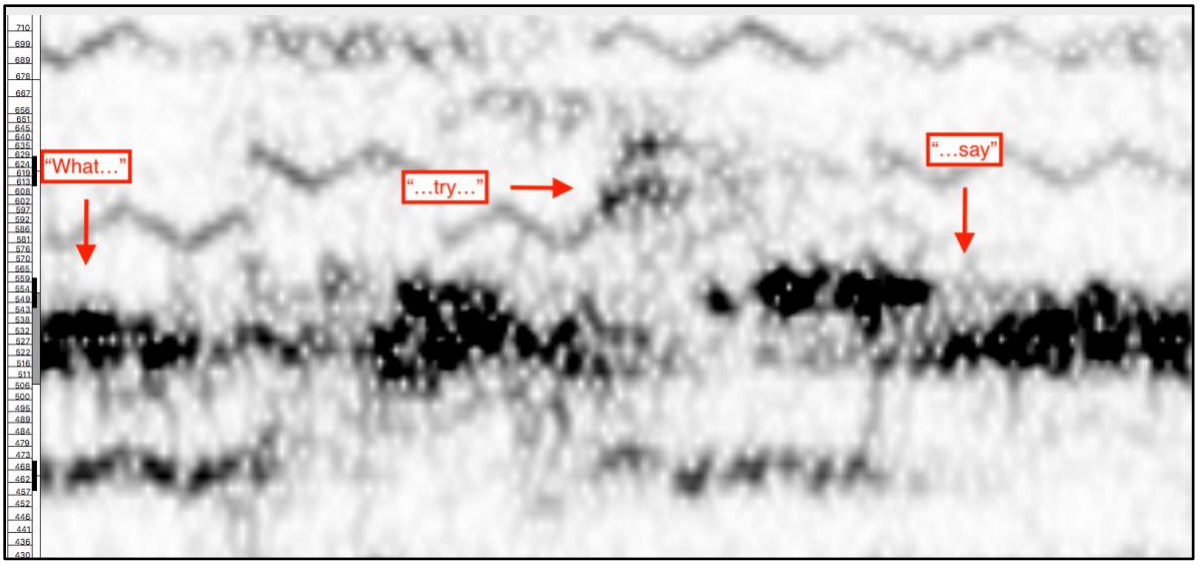

Figure 13 Radiohead's *Everything in its Right Place*, spectrogram of trapped vocal line, right channel from 01:12:23 - 01:12:28

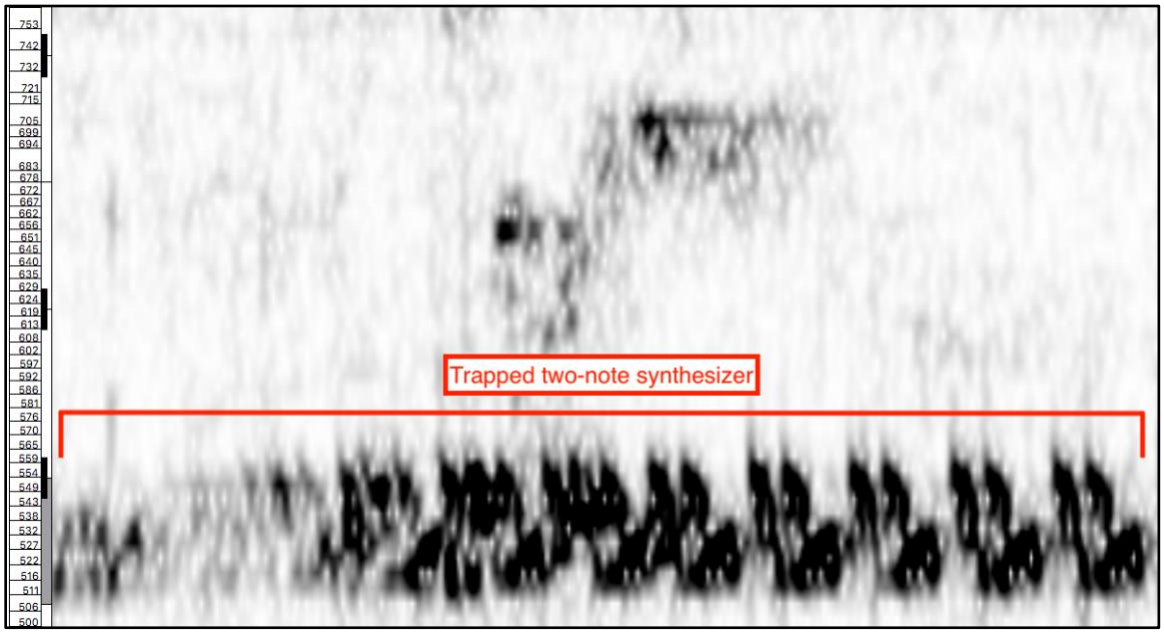

Figure 14 Radiohead's *Everything in its Right Place*, spectrogram of trapped two-note synthesizer gesture, left channel from 01:13:04 to 01:13:14

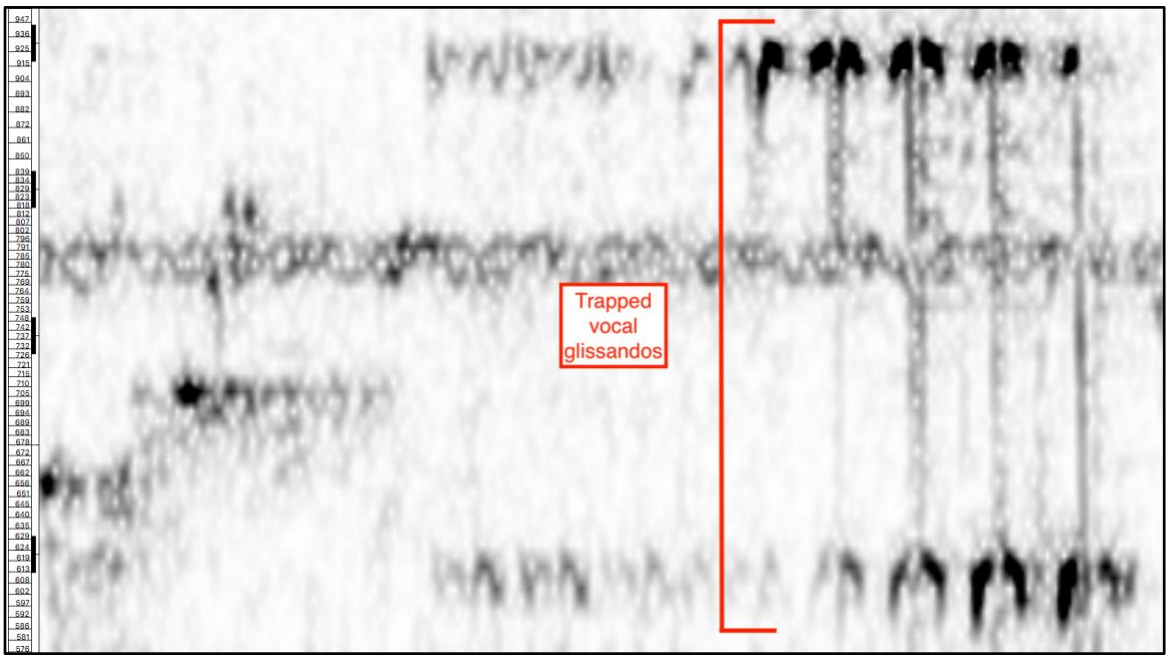

Figure 15 Radiohead's *Everything in its Right Place*, spectrogram of trapped vocal glissandos, right channel from 01:13:04 to 01:13:14

At this moment, Yorke stops singing and playing the synthesizer, giving room for the two live processing musicians to fill the space with a collage of trapped sounds. O'Brien fills the left channel with scrambled trapped synths joining Greenwood's trapped vocal glissandos which bend wildly between the 576hz and 936hz frequency range (Figure 15). This improvised duet is not unlike a "shout chorus" towards the end of a jazz arrangement, developing themes and motifs from earlier in the performance. If we were to remove the rhythm section from this recording entirely, what would remain is a granular cloud, not unlike the work of Joel Ryan. Radiohead creates a collage of sounds based on a minimal amount of instrumental (or, in this case, vocal) material. Motivated by the need to drastically change their workflow in the late 1990s, Radiohead embraced emerging technologies to transform and delay signals in real-time. Ultimately, the band brings polyphonic, asynchronous layers of delays that vary heavily in rhythm and frequency from the avant-garde to the popular music festival circuit, eschewing traditional guitar solos and exposing large audiences across the world to live processing.

3.2 Quantifiable Findings of *Everything in its Right Place*

Like the table presented at the end of chapter 2, tables 2 and 3 represent the quantifiable findings from Everything in its Right Place. Table 2 represents the live sampling in the left channel of the live recording, where Ed O'Brien is manipulating Thom Yorke's keyboard. Table 3 represents the live sampling in the right channel of the live recording, where Johnny Greenwood manipulates Yorke's vocals. Here, the data displays the different strategies of live sampling between the performers and the sonic results that

influence the formal structure of the music. Again, the material performed at the beginning of the piece was played back toward the end of the song.

Table 2 Quantifiable Findings of *Everything in its Right Place. Left Channel (Ed O'Brien)*

Grounded Source	Thom Yorke's Keyboard
Trapped Size	4 seconds
Waiting Period	3 minutes 22 seconds
Trapped Playback Duration	1 minute 22 seconds

Table 3 Quantifiable Findings of *Everything in its Right Place. Right Channel (Johnny Greenwood)*

Grounded Source	Thom Yorke's Vocals
Trapped Size	5 seconds
Waiting Period	0 seconds
Trapped Playback Duration	1 Minute 48 seconds

4.0 Sam Pluta: Laptop Improvisation and Delays of Delays

By the early 21st century, laptop computers started to appear more frequently on stage as a device to trigger fixed media samples and as customizable effects processors to provide signal transformations that went beyond the commercially available guitar pedals of the time. On-stage laptop presence brought visibility to this machine that formerly had a reputation for its use for spreadsheets and word processing. In addition, art-rock bands like Radiohead, Animal Collective, and Battles demonstrated the possibility of live sampling in front of wider audiences. At the same time, experimental laptop musicians such as Ikue Mori, Merzbow, Oval, and Matmos pushed the boundaries of what was possible with this emergent musical device.

In 2009, composer, laptop improviser, and sound artist Sam Pluta designed a live processing software instrument called “The Live Modular Instrument.” Written in SuperCollider, it was designed for live performance with instrumentalists. For the following decade, he performed and composed for Wet Ink Ensemble, International Contemporary Ensemble, the New York Philharmonic, and The Peter Evans Quintet. Following in the footsteps of Joel Ryan, he further developed this style of electro-acoustic free improvisation and performed with the same musicians, including Evan Parker.[57] Inspired by the music of Nine Inch Nails, Pink Floyd, and Radiohead, Pluta brought fresh ideas to live electronic performance.

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[57] Sam Pluta, “Biography” (published on his website), February 3, 2023, http://www.sampluta.com/biography.html.

His highly flexible software allows him to swap out any custom virtual processing module and change his performance approach to fit any musical setting. However, it is not just his custom program that allows for this versatility; he also developed a digital interface on an iPad that allows him to create a customized controller.[58] A common problem for laptop musicians, in general, is that the device was not initially intended for music. A computer keyboard and trackpad is not the ideal interface for controlling music in real-time. Portable MIDI controllers solved this issue but presented new challenges; a performer can only assign controls to the number of buttons, dials, and faders that come with the controller. A touch screen with custom programming allowed Pluta to create any number of virtual buttons, faders, and XY trackpads. There was no longer a physical limitation to the number of processes that could be manipulated simultaneously. Instead, the only limitations were the ones the programmer created for themselves.

Pluta's compositions that include live electronics borrow many of the processes that can be found in his improvisations. The first half of *Chain Reactions/Five Events* for string quartet and electronics is somewhat improvised, while the second half is strictly notated. During the first half, the score is described as an "algorithm" that contains several boxes with graphics, note-less rhythms, or articulations. Some boxes are labeled as triggers, and others are labeled as reactions. Each performer can choose to be in a state of triggering or reacting to any of these boxed notations. When triggering, performers can improvise and decide when is an opportune time to make the triggered sound. When reacting, performers must respond as quickly as possible to any sound by creating a new

[58] Sam Pluta, interview by the author, Chicago, IL., January 5, 2018.

sound from the reaction box. During this opening section, Pluta applies many granular processing effects similar to those found in his improvisations with Peter Evans.

The instruction to react quickly seems to mimic how he performs with other improvisers; rapid-fire, call-and-response. and a constant evolution of the sound. It is possible that many of the processing programs he uses for improvisation originated from his compositional output. As his performance practice influences his compositional aesthetic, his notated work influences his improvisations. To this day, Pluta continues to develop new ways to integrate technology into performances with acoustic instruments, both composed and improvised.

4.1 "Event Horizon"

Event Horizon is an improvisation between Sam Pluta and Peter Evans recorded live during the fall of 2013 in Buffalo, NY.[59] Like the concert recordings of Joel Ryan and Radiohead, there are no overdubs during the excerpt that is to be analyzed in this document. Beyond having a faster computer and higher level of control, Pluta resamples delayed material creating additional and unique temporal processes.

The first musical gesture of *Event Horizon* occurs at 0:05 with aggressive air sounds from the grounded trumpet, as displayed in figure 16, followed by the trapped granulated and scrambled filter delay of the trumpet one second later in the electronics, as shown in figure 17. For the first couple of seconds, the two instruments are fused into

[59] Sam Pluta and Peter Evans, *Event Horizon*, Carrier Records – 024, 2014, MP3.

a unified sonic entity and the two voices are indistinguishable. This approach is not unlike Ryan's and Radiohead's phase-shifted layering, except that the results occur aggressively and rapidly. Then, at 0:10, an electronic juxtaposition interrupts the introductory cloud with rapid-fire granular buzzing sounds that crescendo one after another. The method by which he re-samples previously trapped sounds, treating them as grounded for an entirely different temporal manipulation process, sets him apart from his predecessors.

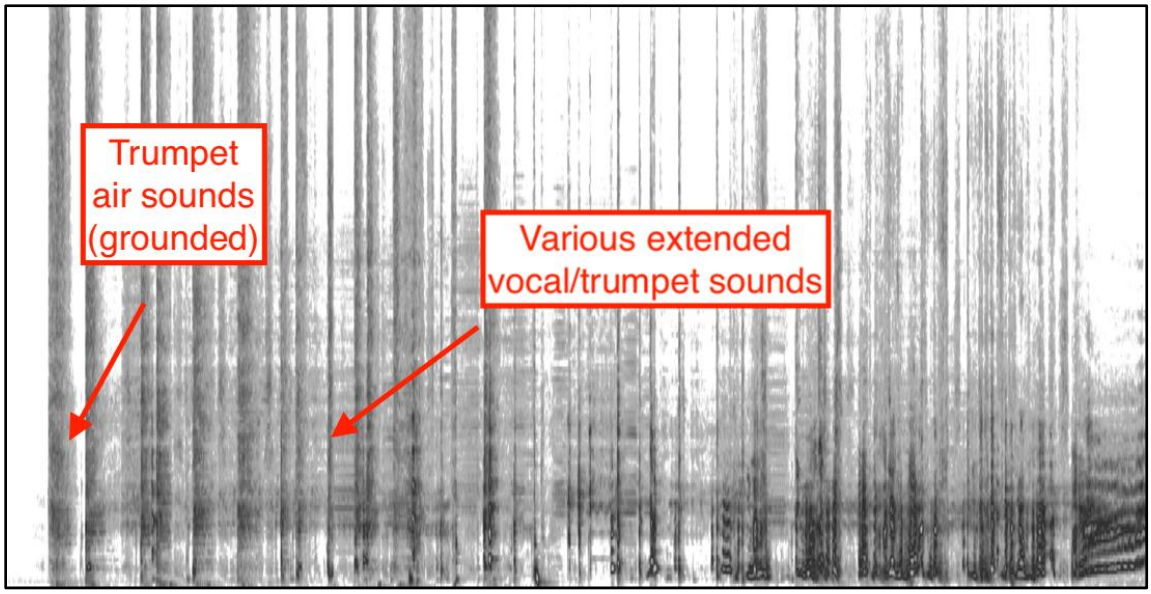

Figure 16 Spectrogram of Sam Pluta and Peter Evans' *Event Horizon* from 0:03 to 0:25 (trumpet layer)

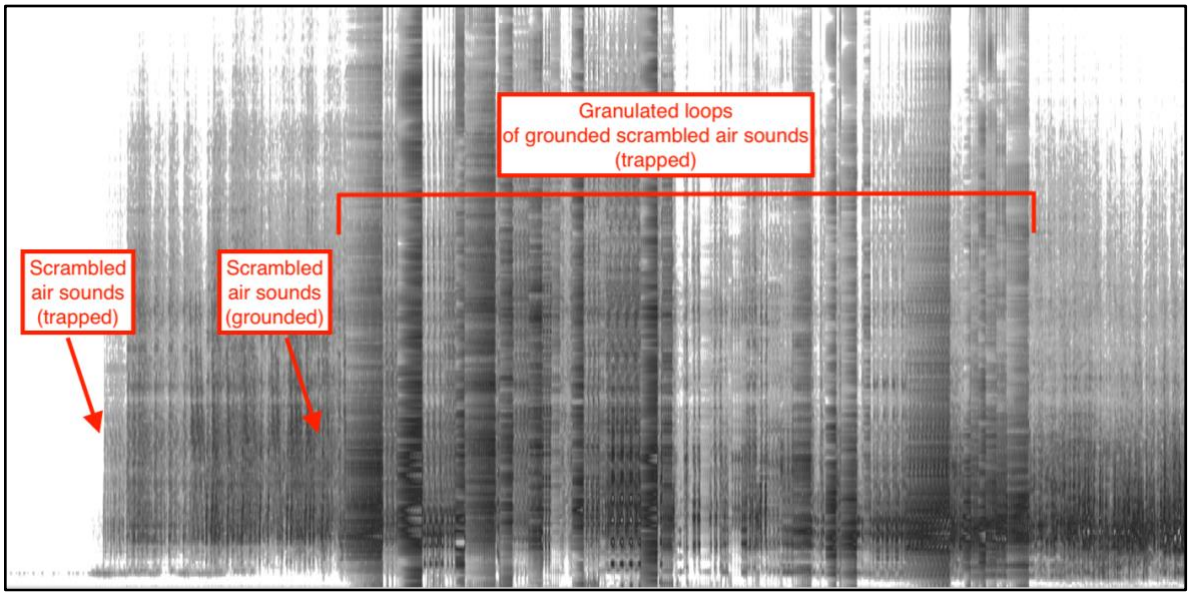

Figure 17 Spectrogram of Sam Pluta and Peter Evans' *Event Horizon* from 0:03 to 0:25 (electronic layer)

In his PhD dissertation, Pluta describes the virtual sound modules he frequently uses in his improvisations. At 0:10, a module occurs that he calls the "cycle gripper," a program that takes the input signal, grabs a small portion of its audio, and replaces the input signal by looping the recorded audio.[60] In this context, the input signal is the scrambled filter delay from 5 seconds prior, a delay of a delay. And because of the method in which the temporal manipulation is processed between this and the first effect, the resulting sounds seem foreign from the source material of the trumpet. This second layer of trapped granulated loops continues for the next 12 seconds before ceasing and revealing the original trapped material for another 3 seconds, allowing for Pluta to trap a new portion of that scrambled gesture.

[60] Sam Pluta, "Laptop Improvisation in a Multi-Dimensional Space" (PhD Diss., Columbia University, 2012), 21.

At 0:23, Evans vocalizes an ascending gesture, as shown in figure 18, which is carried further by Pluta trapping it and sustaining the scrambled delay from 0:25 until another cycle gripper juxtaposition interrupts it at 0:38 (figure 19). However, this return to the granulated loop motif as a second trapped layer is short-lived, as a new electronic process is introduced at 0:43. This third trapped layer is a delay of the second trapped layer. Pluta calls this the “loop machine,” a module that samples up to 8 previous seconds of sound at its inputs, and loops that material. This allows for the laptop performer to adjust the playback rate, creating a pitch-shifting effect on the sampled material.[61] Like the cycle gripper, it interrupts the input signal, which in this context is 5 seconds of granulated loops. From here, a frequency modulation effect occurs as he quickly runs his finger back and forth across the iPad screen. This activity occurs for the next 43 seconds until 1:01, when Pluta introduces a fourth trapped layer.

[61] Pluta, “Laptop Improvisation,” 22.

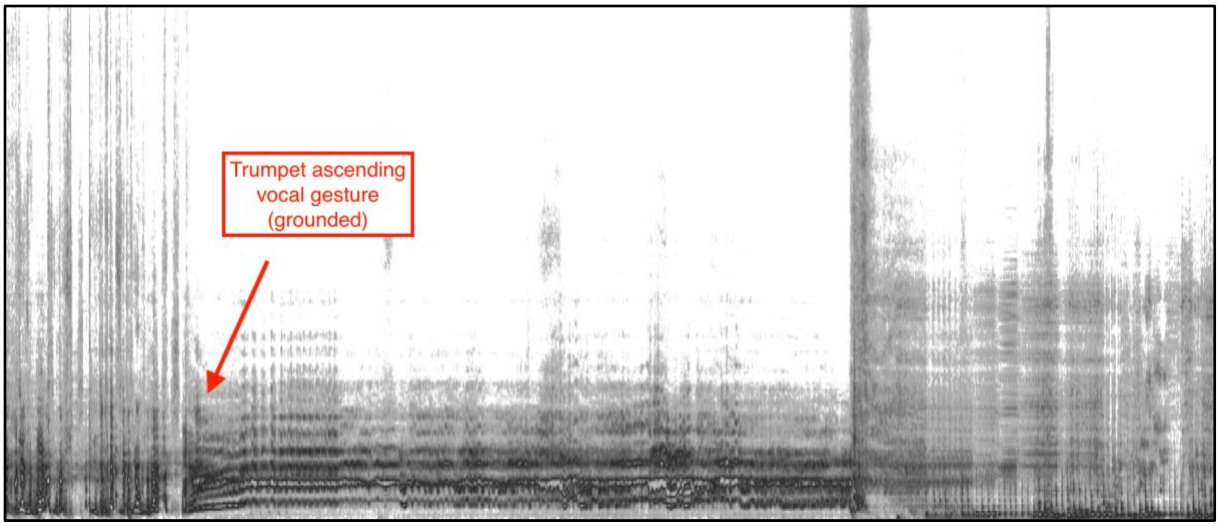

Figure 18 Spectrogram of Sam Pluta and Peter Evans' *Event Horizon* from 0:20 to 0:45 (trumpet layer)

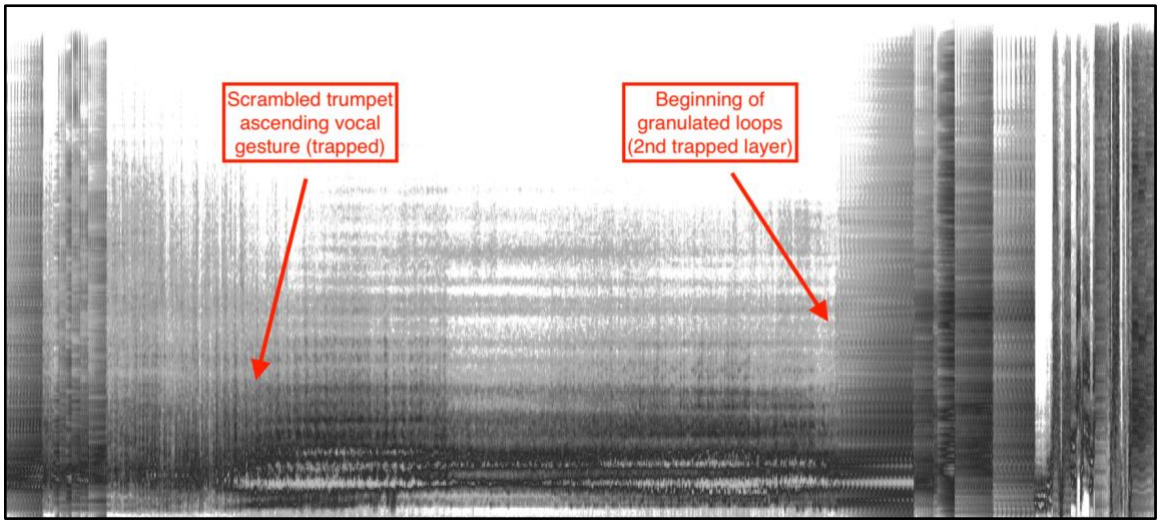

Figure 19 Spectrogram of Sam Pluta and Peter Evans' *Event Horizon* from 0:20 to 0:45 (electronics layer)

This time, a new effect appears that he calls the "harmonic shifter x," a module that takes a signal, records it into a buffer, then asynchronously plays the recorded buffer back with a granular synthesis unit generator. Additionally, the playback is pitch-shifted above

and below to just intonation intervals.[62] This time-shuffled fourth trapped layer is shown at the end of figure 20 and continues in figure 21. At 0:21, Pluta turns off the harmonic shifter x, revealing the previously heard third trapped layer of wild pitch-shifted sound before yet another interruption. This 3rd layer is trapped again in a short repetitive granulated loop. Unlike all the rapidly changing electronic sounds from the previous 80 seconds, he lets this buzzing tone sustain for an additional 23 seconds.

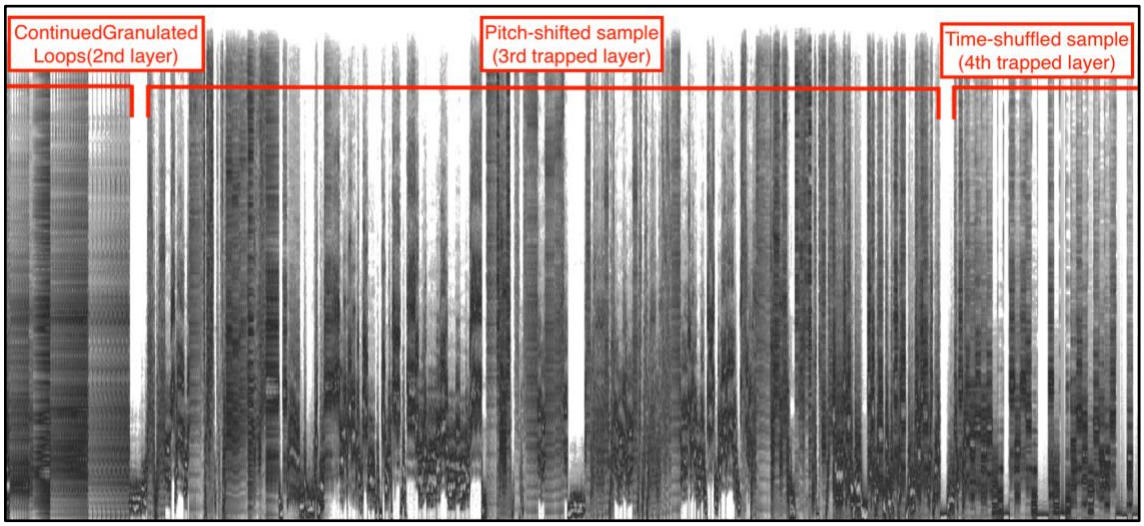

Figure 20 Spectrogram of Sam Pluta and Peter Evans' *Event Horizon* from 0:40 to 1:05 (electronics layer)

[62] Pluta, "Laptop Improvisation," 20.

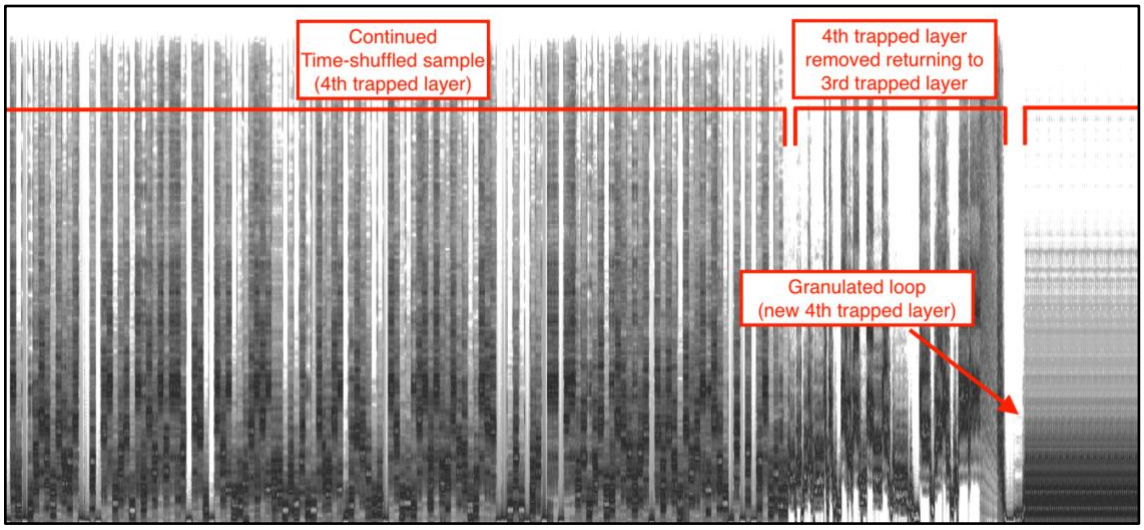

Figure 21 Spectrogram of Sam Pluta and Peter Evans' *Event Horizon* from 1:03 to 1:28 (electronics layer)

Throughout this improvisation's first minute and a half, Pluta and Evans engage in a rapid-fire call-and-response interaction. Without the limitation of clunky MIDI controllers, Pluta can trap any moment that Evans may throw at him. In response, Evans uses extended techniques to complement these alien sounds while engaged in hyperactive counterpoint. It would be easy for an audience member to assume that many of the electronics are synthesized, as they no longer sound like a trumpet once the second layer of trapped processing occurs. The further these delayed sounds are removed from their original source, the more unrecognizable they become.

Pluta's processes at any specific moment are not unlike the strategies of Joel Ryan and Radiohead. He uses similar filtered delays, live sampling, spectral pitch-shifting, and altered playback speeds. The two glaring differences from the other case studies are that he creates delays of delays, transforming the sound away from anything recognizable. He does so exceptionally quickly with the use of his custom iPad controller, resulting in

temporal manipulation, like tape splicing on stage. Pluta's aesthetic seems to reflect the ever-increasing processing power of laptop computers, and the new interactive possibilities resulting from the advancement of hardware controllers which allow for high levels of mediation, resulting in extreme discontinuity. The evidence extracted from *Event Horizon* shows that this work is in a natural lineage from the earliest case studies in this project.

4.2 Quantifiable Findings of *Event Horizon*

Tables 4 and 5 show the quantifiable finding gathered from the introduction of *Event Horizon*. In this improvisation, Pluta responds quickly by releasing sounds one second after they after they are trapped. Unlike Radiohead, who uses a single trapped sound to play back for well over a minute, Pluta's trapped playback duration from figure 5 contains five different layers of trapped material, as each layer is regrounded for another layer of processing. This strategy creates a higher level of variety for a more hyperactive interaction between performers.

Table 4 Quantifiable Findings of *Event Horizon* (0:03 – 0:25)

Grounded Source	Peter Evans' Trumpet
Trapped Size	5 Seconds
Waiting Period	1 Second
Trapped Playback Duration	12 Seconds

Table 5 Quantifiable Findings of *Event Horizon* (0:20 – 1:49)

Grounded Source	Peter Evans' Trumpet
Trapped Size	8 Seconds
Waiting Period	1 Second
Trapped Playback Duration	84 Seconds

5.0 Conclusion

The examples of Joel Ryan, Radiohead, and Sam Pluta, in comparison with the analog case studies from chapter 1, reveal that live processing techniques rely on temporal manipulation of delayed signals, instead of direct repetition. All data collected from the case studies in this research support the conclusion that computer algorithms impact the possible sonic outcome less than the mediation from live processing performers. The advancement of controller technology appears to allow for these higher levels of human mediation and quicker turnaround time. However, these live processing performers' instruments are essentially recording devices engaged in real-time performance on stage.

In his 1985 essay “Plunderphonics, or Audio Piracy as a Compositional Prerogative,” John Oswald argues that musical recordings themselves should be treated as a form of musical instrument. “A sampler, in essence a recording, transforming instrument, is simultaneously a documenting device and a creative device.”[63] “Plunderphonics,” a term coined by Oswald, is a music genre that exclusively uses sampled material, heavily remixing and reordering the sources and thus changing the context of the listening experience. This studio-based sound collage genre is not unlike the aesthetic of the live processing performers who exclusively use a live performer as their source material. For example, the track called *Margo Integer – btls* from Oswald’s

[63] John Oswald, “Plunderphonics, or Audio Piracy as a Compositional Prerogative,” presented by John Oswald to the Wired Society Electro-Acoustic Conference in Toronto in 1985, accessed January 28, 2023, https://www.plunderphonics.com/xhtml/xplunder.html.

album *Plunderphonics 69/96* consists of the final chord from the Beatles' song *A Day in the Life,* without any other sampled material.[64] He generates 47 seconds of material, changing the meaning of this chord, by pitch-shifting, changing the speed, and overlapping several layers of the newly created chords.

As displayed in tables 1 through 5, Ryan, Radiohead, and Pluta generate minutes of music from a single trapped musical sample on stage, not unlike the Western classical concept of building an entire composition from a single musical cell. In many cases, sonic events re-emerge minutes later, creating a more organic structure out of an improvisation that would have usually appeared to be spontaneous.

Considering the influence that this technique has upon the sounds the audience may hear, what role does a live processing performer play in a musical group or composition? Is it enough to sample a live sound, scramble it up, and play it back to the audience minutes after the initial sounding gesture? Sharing his thoughts on live sampling for his entry into the "Oxford Handbook of Computer Music" from 2009, experimental computer musician Tim Perkis expresses a harsh critique of this performance practice:

> I'm never interested in live sampling of other players and never really enjoyed playing in ensembles in which someone else is sampling me and playing back a modified version of my own voice. If I'm making a particular sound in an improv and I decide it's time for that sound to stop, I want it to stop. I suppose it's possible to make live sampling interesting, but only in very specific contexts, and most of the times I've heard it I've felt it was an obnoxious gimmick. Often, sampling not only muddies of the group sound, but seems impolite, overstepping each player's own sonic center.[65]

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[64] John Oswald, *Plunderphonics 69/96*, Fony/Seeland, 2001, CD.

[65] Tim Perkis, "Some Notes on My Electronic Improvisation Practice," in *The Oxford Handbook of Computer Music* (New York, NY: Oxford University Press, 2009), 164-165.

Perkis brings up some valid arguments regarding the role of a live processing performer. There is no mention of which musical performances he may be referring to, but there are clear balance issues with the limits of acoustic performance and the limitless computer capabilities. A computer can make the loudest sustaining sound on stage and playback seemingly endless layers of polyphonic material with minimal effort. This would inevitably swallow up any efforts by acoustic performers to participate in a performance. Considering this, how do Ryan, Radiohead, and Pluta find a balanced sound?

In his article, *Live Algorithms and The Future of Music* George Lewis explains that the direct study of improvisation is vital to the production of new ways of using information technology. He concludes with "improvisation is not only what people do when they play jazz or bluegrass, but also what they are doing when they play video games, surf the Net, or decide how to cross Main Street."[66] Like Lewis' comparison between improvising with technology and everyday life, let us observe another performance style outside of music that relies heavily on live sampled playback: live televised sports.

Marshall McLuhan, the noted communication theorist, commented on this topic regarding CBS Sports Director Tony Verna's invented system that allowed videotape machines to play back previously viewed material: "Until the advent of the instant replay, televised football had served simply as a substitute for physically attending the game; the advent of instant replay – which is possible only with the television – marks a post-convergent moment in the medium of television."[67] Not only did this invention change the

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[66] George E. Lewis, "Live Algorithms and The Future of Music," *CT Watch Quarterly* 3, no. 2 (May 2007): pp. 1–6.

[67] Cox Kirwan and Crean Mark. "It Will Probably End the Motor Car," interview with Marshall McLuhan, *Cinema Canada* (August 1976): 26-29.

experience of watching a televised game, but it also allowed for a new way to experience previously viewed events.

Many examples show the same event from multiple angles at different speeds, slowing the action down to re-observe the play from a new perspective. It is important to note that most moments of instant replay do not occur while the game is currently active. Instead, it happens during a space between game plays so the viewers will not miss anything live and will get an enhanced experience of what occurred before with a heightened perspective. This technique is not unlike a live processing performer capturing a critical musical moment and playing it back at different speeds, sometimes revisiting the same trapped motif with different processes. Furthermore, like the placement of the instant replay, Ryan, Radiohead, and Pluta emphasize these moments in ways that do not interfere with their fellow performers.

Music theorist Jonathan De Souza's *Music at Hand* offers an in-depth study of human and instrument interactions. Attention is paid to "technics," which could be described as a mode of knowledge linked to the interaction between humans and technology. The central thesis of this book is that "technics opens up possibilities for musical action and cognition. As I use instruments to make music, they also make me a musician."[68] De Souza's argument aligns with what my analysis shows about live processing – that it involves a unique form of human-computer interaction that is musical and creative. Live processing performers are, in fact, musicians that compositionally expand upon improvisations and compositions by reintroducing and modifying previously

[68] Jonathan De Souza, *Music at Hand: Instruments, Bodies, and Cognition* (New York, NY: Oxford University Press, 2017), 167.

heard material. Any guitarist can tap on a looper pedal, and any algorithm can be automated to execute similar functions. But it takes someone with a strong perception of their virtual instrument to not muddy up the sound but rather engage in a meaningful musical dialogue on stage. A common theme regarding this performance practice is the parasitic nature of live processing. The initial gestures are never initiated by the electronics but instead are a "response" to the initial instrumental "call." Evan Parker has performed many solo concerts, but Joel Ryan cannot use his instrument without another instrumentalist to process. The same can be said for all other case studies in this research. Live processing is inherently collaborative. It is a form of creative authorship that cannot be understood in isolation from group performance.

From Joel Ryan's custom instrument from the 1990s to Pluta's layers of delays two decades later, there are two significant differences in the linear trajectory of the evolution of this aesthetic. First, computer technology has gotten faster. The second change is the increasingly ever-present variety of controllers. All the case studies here have a musical relationship to their controller, much more so than the algorithms. As the development of such controllers progresses, so does the ability to navigate temporal manipulation.

Chapters 2 through 4 displayed various quantifiable data collected from the different case studies of Ryan, Radiohead, and Pluta. Tables 1 through 5 are now displayed in x-axis charts in figures 22 through 24. Radiohead is displayed twice to represent the processing of both O'Brien and Greenwood. Sam Pluta is also displayed twice as two excerpts from *Event Horizon* were analyzed. Figure 22 displays all the "trapped size" information initially displayed in tables 1 through 5. The trapped sizes do not vary much between the different examples, as the shortest example (Radiohead's

O’Brien) and the most extended example (Sam Pluta’s second example) only differ by 4 seconds. This might suggest that this is an ideal size for the live processing aesthetic. On the other hand, figure 23 shows an extreme difference in the waiting period between the case studies, suggesting that there is much more variation in this aspect of live processing performance.

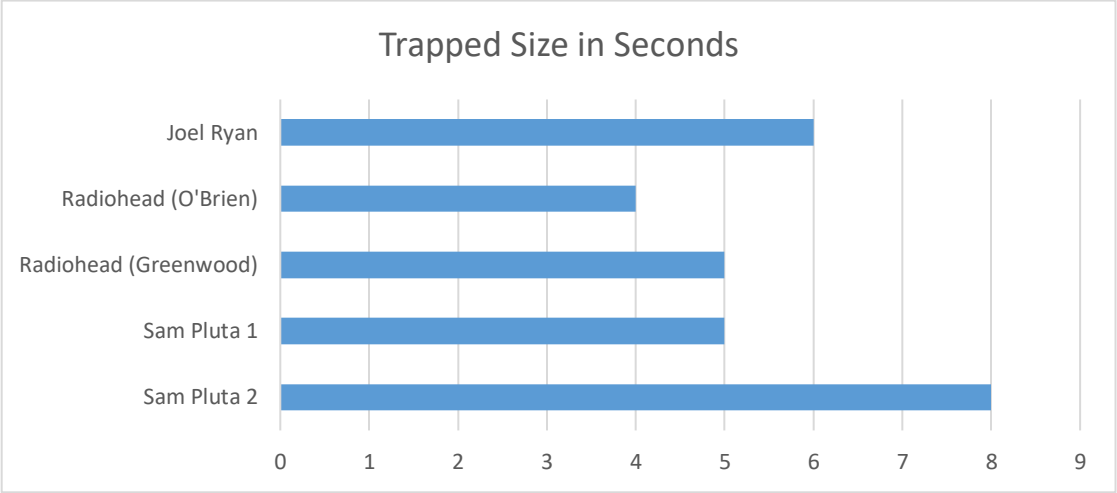

Figure 22 Chart of Trapped Sizes in Seconds

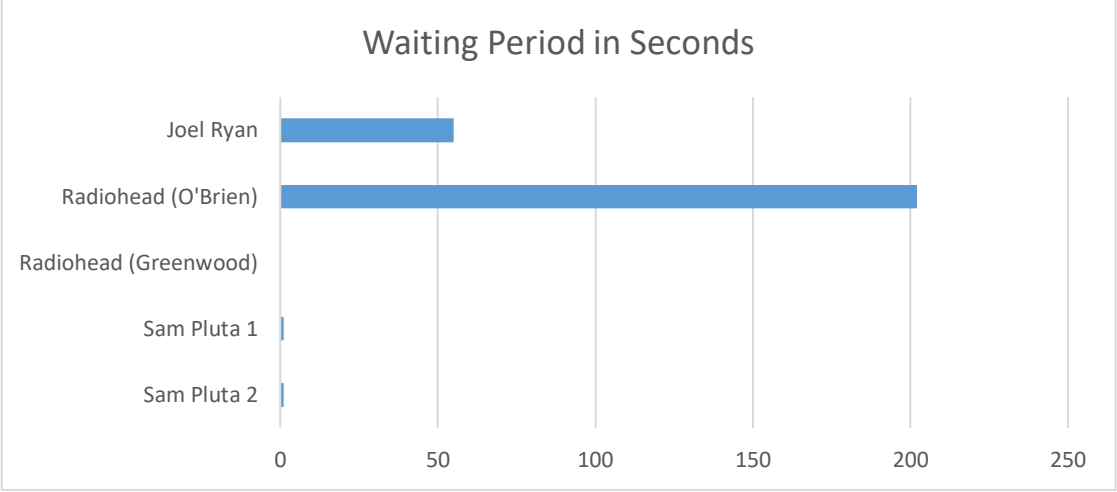

Figure 23 Chart of Waiting Periods in Seconds

Ryan's waiting period is 55 seconds, influencing the form of the improvisation while re-introducing material from almost a minute before. Radiohead's O'Brien has the most prolonged waiting period, waiting for 3 minutes and 22 seconds, bringing the opening material back during the soloistic section at the end of *Everything in Its Right Place*. Radiohead's Greenwood and Pluta start working with their trapped material almost instantaneously. The difference between these two extremes dramatically affects the structure of the performance. The longer waiting times have formal implications, while the short waiting times work as call-and-response. For Radiohead, with two different live processing performers, the different waiting times avoid the possibility of muddying up the performance with too many electronic layers that would distract the listener from the lead vocals.

As discussed above, all the performers have the technology to allow for longer durations, and the difference between the Greenwood and Pluta examples represents an artistic rather than technical considerations. For Pluta, the immediate response supports the rapid-fire improvisation between him and Evans. It is also worth noting that the most significant difference between Ryan and the other two case studies is the availability of a controller interface, allowing for more detailed manipulation of the delays. Ryan, equipped with only a computer mouse and a keyboard, does not have the detailed gestural control that Radiohead and Pluta have, resulting in a slower evolution of events. The artistic possibilities are constrained by technological limitations. It takes a great deal of real-time control to execute quick results when recording and playing back live sampled material, which likely plays a role in the length of waiting period.

Figure 24, displaying the trapped playback durations, are not unlike the sizes of the trapped sounds shown in figure 22. However, in this case, the results are more varied. Ryan's trapped material lasts 38 seconds, which fits with Evan Parker's "stream of consciousness" style of playing. The performers from Radiohead perform the most extended durations, well over a minute, which lines up with their use of sampled material during an extended jam section during the song's outro and transition into the next song. Pluta's recording represents the most variety within a single performance. The first excerpt, only 12 seconds, adds to the rapid-fire cut-and-paste approach of the agitated and focused duo improvisation. The second excerpt is 84 seconds but, unlike Ryan and Radiohead whose extended trapped durations create a cloud-like effect, Pluta's longer duration results from several layers of transformations. The delays of delays take the trapped material and alter it so that it is almost impossible to distinguish the grounded source from a synthesized sound.

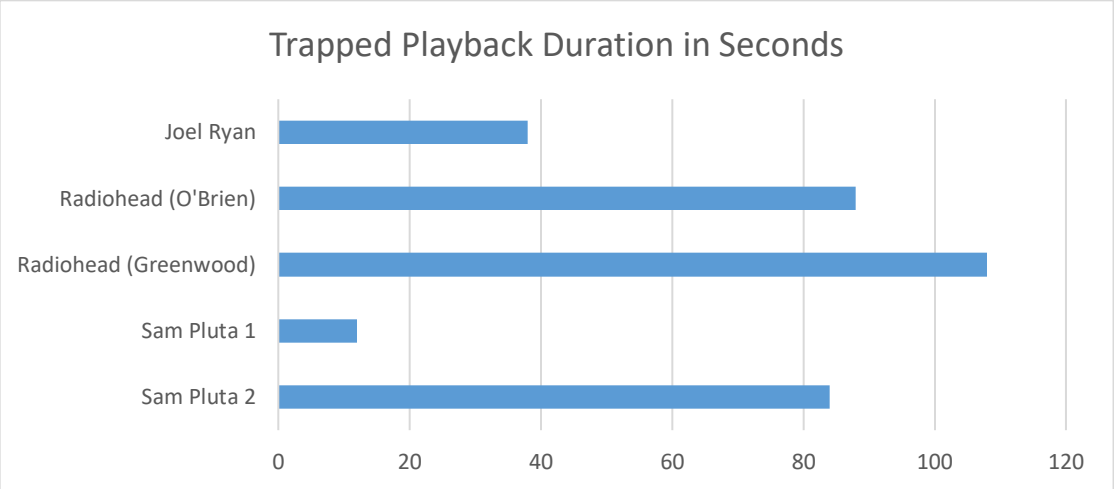

Figure 24 Chart of Trapped Playback Duration in Seconds

The timbral transformations that occur in these delays have more to do with the live processing performer's manipulation of time rather than with the alteration of the individual trapped sound. There are some instances in which computer processed pitch-shifting or minor spectral effects may occur, but the temporal manipulation of the material presented is more ever-present than any other electronic technique. While some have expressed skepticism about the human creativity involved in live processing, or felt that computer algorithms were doing the composing, my spectrographic analysis, along with the way I have rooted contemporary live processing in a longer history of tape-based music, shows that this is certainly not only the case. If anything, the technology that has the most influence on this kind of music is the ever-increasing number of controllers available for electronic performers—the level of gestural human control over the machine.

The history of pre-digital electronic music demonstrates this. For example, in chapter 1, the excerpt of Brian Eno's music showed the result of having almost no real-time control of the delays. The feedback percentage is fixed, as is the delay timing. Pauline Oliveros' excerpt showed the same process but with a different performance approach in which she actively introduces juxtaposed material at times that blurred the inevitable repetitions from the tape loops. Mikey Dread's excerpt displayed yet a higher level of control over the delay by altering the playback speed and the feedback percentage with rotary dials on a mixing board. Finally, Stockhausen's excerpt displayed an early example of restructuring recorded material by changing the position of the tape playback head. The results of these four excerpts demonstrate that increased real-time control over the properties of the delays results in higher levels of unexpected events.

There are no computer algorithms in any of these earlier excerpts. When computer technology entered the performance practice, new possibilities for manipulating delays became available. Algorithms are present, but the most significant factor in digital technology is not the digital signal processing; instead, it is the increased freedom of expression for the performer. To quote Pluta in a 2019 interview, "Computer music is at a point right now where there is not that much development in timbre in the sounds themselves; the development is in interaction."[69] Rather than functioning as a "gimmick," as Perkis declares, high levels of temporal manipulation made possible through delay-based performance allows performers to metaphorically "stay in their lane," to not muddy up the sound, and to participate in the music making process without dominating the sonic spectrum. Our relationship with live sampled sound will likely continue to be a part of live electronic performances, as technology is giving more human control over live processed signals, the order in which these signals are presented, and the formal structure of these kinds of performances. To revisit McLuhan and his commentary about instant replay, "we live in the world of the instant replay. Around the planet, all the events are not only being recorded but replayed."[70]

[69] Jeremiah Cymerman, "Episode 202, Sam Pluta," 5049 Records, April 8, 2019, http://www.5049records.com/podcast/sam-pluta.
[70] Family Theater Productions, "Marshall McLuhan Interviewed by Father Patrick Peyton, C.S.C. - Part 1 of 3," YouTube, January 20, 2011, https://www.youtube.com/watch?v=vVCuE4vGgK8.

5.1 The Future of Phase Cancellation Analysis, and Other Potential Strategies for Musical Analysis

The strategy of phase cancellation analysis developed in this research did not require any specific software. The separation of these layers can be done using any digital audio workstation. There are, however, commercially available plugins that remove the center signal from a stereo mix. Additionally, newer pieces of software use AI technology to remove instrumental layers. For example, the company Izotope offers “RX,” a program for digitally repairing audio files that now includes an option to remove entire instrumental layers. The software divides the audio track into four categories: "vocals," "bass," "percussion," and "other." Of course, with many examples of AI and mixing, errors are made, artifacts are introduced, and defining what is a particular instrument is often best left to a human.

The same could be said for the company Celemony’s “Melodyne” program, which was designed for tuning recorded signals in post-production; it can also remove instrumental layers. Smartphone apps are also now available that allow inexpensive ways to remove layers from songs. The initial intent was for karaoke fans to remove lead vocals from their favorite songs or for bedroom producers to create their remixes. Like the phase cancellation approach, which has its shortcomings, these newer technologies provide potential strategies for music analysis of musical recordings. Further research into this area is needed as it presents a unique potential for the future of analysis.

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Recorded Ruins Score and Notes

It was my intent to compose a piece that reflected the research that was presented in this project. I went to great lengths to reverse-engineer many of the strategies presented by the musical examples that were analyzed. This process expanded my programming and performance skills and I have since composed many pieces that include live processing. However, I deviated from this initial plan when I received a commission from pianist Steven Drury for Callithumpian Consort. The piece was to be rehearsed and premiered at the New England Conservatory in Boston. I was reminded that, while electronics were encouraged for this commission, rehearsals were to start prior to my arrival in Boston. This meant that the electronics had to be performed in a simple manner without my presence. I had to figure out a bullet-proof strategy through which a stranger could read directions and operate a customized computer program without any confusion or technical issues. This was the impetus for *Recorded Ruins* for bass clarinet, trombone, violin, cello, piano and electronics.

Live processing can be difficult for a novice. Issues with feedback, adjusting volumes, and capturing the wrong grounded sound could potentially ruin a performance. Live processing techniques that do not require my presence address this issue by sequencing and automating a series of amplitude and filtering envelopes that are triggered by a cue system, which is usually a MIDI pedal. This works fine with a solo performer and a laptop, but to attempt this with a chamber ensemble with multiple microphone inputs seemed like an accident waiting to happen.

I cancelled the idea of live processing and decided to explore the use of transducers, or sound exciters, to be placed inside of an acoustic piano. I built a simple setup consisting of a small portable stereo amplifier, two sets of speaker cables, and two small transducers. The pianist plugs this system into the headphone jack on their laptop. I provided a simple customized program built in Max/MSP that could be run for free on demo mode. The user interface was simplified so that the patch contained a simple on/off button, and a numbered cue system triggered by pressing the space bar. Different cues start or stop a series of sequences consisting of either filtered bursts of white noise, or square waves. The pianist is instructed to move transducers to specific piano strings throughout the piece and press the space bar at given cues. The synthesized square waves are tuned to specific overtones of the string that a transducer is touching. The shared resonance with the transducers ignite the strings, causing a roaring effect as the body of the piano acts like a giant loudspeaker. Since there are two transducers receiving signals from the right and left channel of the stereo mix, two strings with different overtones can sound at the same time, creating extended just intonation intervals from an equal tempered piano. From here, the remainder of the ensemble is prescribed to tune with or against these sounding tones.

This compositional approach differs from my research regarding temporality because no computerized delays are present. However, there is a similarity between the parasitic use of technology in live processing and the use of a laptop to alter the timbre of an acoustic instrument. Here, the sounds emitting from the transducers alter the timbre of the acoustic piano. Just like in live processing, technology shares the stage with

acoustic instruments and participates in the live construction of sound. However, this approach requires low level of mediation by the performer.

The title *Recorded Ruins* comes from a debate I observed in an internet comment section regarding composer Jim O'Rourke. Many of his devoted fans admire the few indie rock albums he recorded in his earlier days, and choose to discredit the hundreds of experimental albums he has produced since the 1990s. One commenter, frustrated by the lack of indie rock material in recent years, typed "Jim just loves to ruin recordings with all his noise stuff." Another commenter replied, "More like the sound of recorded ruins." I'm not entirely sure what the last commenter meant. However, I found the petty and entitled attitude toward making music that is more experimental than they desired to be humorous, especially since I prefer his later work and listened to it frequently while composing this piece.

Link to composition:

https://d-scholarship.pitt.edu/44416/2/_Riordan%20-%20Recorded%20Ruins%20-%20Score%2Bnotes-04-10-2023.pdf