MIND OVER MACHINE OVER MATTER: A STUDY OF ELECTRO-ACOUSTIC PERFORMANCE PRACTICES

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ABSTRACT

At such an exponential rate of development, technology has become more accessible in numerous facets of our lives. Electronics have been thoroughly integrated in most human enterprises—a trend that also permeates the realm of music. Where electronics and music intersect, however, familiarity typically dissolves. Despite live electronics having been incorporated in music since the middle of the twentieth century, there remains a remarkable degree of apprehension from performers, and ambivalence from listeners. The capabilities of music technology were deficient and unpropitious to real time electro-acoustic performances until recent decades, by which time performers and listeners have begun to embrace the genre. Nonetheless, traditionalists in the field of art music often remain hesitant to do so out of unfamiliarity with the technology as well as a grounded, if not parochial, sense of what music should be. It is out of such underdevelopment that a study in electro-acoustic performance practices becomes both relevant and necessary to an evolving musical culture.

This investigation in particular is realized through case studies of three performance contexts that utilize an electronic component in tandem with acoustic sound sources. The highly interactive performance environment of the Princeton Laptop Orchestra will be explored, to be followed by Mason Bates's composition *Mothership* for wind ensemble and electronics, and *(un)selfish object* by Baljinder Singh Sekhon II for marimba and audio signal processing. These three analyses are intended to provide extensive and varied examinations of electro-acoustic contexts as well as a survey of performance considerations for musicians who utilize electronics.

ESTABLISHING A FRAMEWORK FOR ANALYSIS

Before a worthwhile discussion of electro-acoustic performance practices can begin, it is necessary to establish a working definition of the genre. An electro-acoustic performance involves "any music that is produced, changed, or reproduced by electronic means."[1] There must first be a mechanical component, whether an acoustic instrument or voice, which then requires interaction with an electronic component. The degree and nature of interactivity between the acoustic and electronic components may vary, which allows for considerable diversity within the genre of electroacoustic music. The analyses to follow will demonstrate the scope of variance in aspects such as the preparation and physical execution of the music, recognition of the electronic component's role in the performance and the potential need for compromise from the performer.

A second prerequisite to discussion encompasses an examination of lexical semantics. Throughout this study, a distinctive use of the terms "electro-acoustic" and "electroacoustic" will be implemented meticulously. Whereas in most literature about the genre the use of a hyphen is merely a stylistic decision, the hermeneutic implications here are critical. For the purposes of this study, the use of a hyphen in the term "electro-acoustic" implies an inherent separation of the electronic and acoustic elements of a performance. Both elements are obliged to interact via an interface to develop an integrated musical experience. The term "electroacoustic," in eliminating the hyphen, describes the musical experience as an integrated whole perceived by a listener. The use of a hyphen, therefore, designates the interactive means to an end, while the omission of a hyphen describes the end result of the performing process.

A complete study in electro-acoustic performance practices would benefit from taking into account those of conventional acoustic music. Additionally, it is essential to recognize its ever-evolving nature. As musical genres evolve over time and develop with the communities surrounding them, the musician's approach to performances also adapts.[2] Jonathan Dunsby, author of *Performing Music: Shared Concerns*, claims that a performing musician can achieve true mastery over a piece of music through an academic comprehension of it, holistically encompassing analysis and history.[3] That is to say, once a cerebral mastery over the music is reached, concurrent with the development of technical proficiency, the musician can then transmit this knowledge through an instrument. The human body plays an active role in conveying a piece of music, not only in the literal execution of the written composition but also in the delivery of human expression and interpretation. An acoustic instrument reacts to the musician's motions in real time and responds with a dynamic and timbral correlation to the intensity of movement. For instance, swaying from the hip may add weight to a given note, and an arm lift during a sustained sonority or cadence might convey a momentary sense of freedom as felt by the performer.[4] A cognitive awareness of such mannerisms, included in Dunsby's previous assertion, is typically fundamental to one's musical training and becomes a natural psychological aspect of performance.

In collaboration with a general understanding of acoustic performance practices, a study of those in electroacoustic music also entails a familiarization with different methods and technologies that have been used through the course of history. One of the earliest widely known examples of the interaction between acoustic sound sources and electronic manipulation occurred in Paris in 1948, with Pierre Schaeffer's pioneering experimentation called *musique concrète*. His music was composed on magnetic tapes and comprised recordings of everyday sounds. These natural, prerecorded sounds became subject to various recording techniques including speed alterations, tape reversal, and overdubbing.[5] Even this, however, is predated by Halim El-Dabh's work *Ta'abir al-Zaar*, translated as *The Expression of Zaar*. El-Dabh used a wire recorder to capture the sounds of an Egyptian zaar ceremony, which were subjected to modification and distortion.[6] As tape music became more accessible, composers such as Mario Davidovsky, Otto Luening, Charles Wittenberg, and Wendy Carlos experimented with live interaction between musicians and recorded sounds.[7] Non-tape electroacoustic music was also gaining traction with the invention of electronic instruments: Thaddeus Cahill's unsuccessful Telharmonium (1897), Léon Theremin's eponymous Theremin (1920), and Maurice Martenot's additionally eponymous Ondes Martenot (1928).[8] When Musical Instrument Digital Interface (MIDI) technology became standardized in 1984, connectivity between synthesizers and personal computers saw universal compatibility, allowing the general public to produce electronically generated music.[9] With the advent of MIDI, the stage was set for the materialization of music programming languages. Programming environments such as Max/MSP, Pure Data, and others serve as visual platforms for the fabrication of intricate performance frameworks that integrate MIDI, live sounds, and audio signal processing. These programs allow a user to input commands and establish an order of operations (referred to as a "patch") to accomplish virtually any task.

Additionally, electro-acoustic performances often require extensive logistical forethought. Whenever performing a composition with electronics, it is essential for the musician to have a thorough command over the operation of the technology being utilized, as well as an awareness of troubleshooting techniques. Three electro-acoustic performance contexts will be addressed in this study: the interactive ensemble environment of the Princeton Laptop Orchestra, Mason Bates's composition *Mothership*, and a solo marimba work by Baljinder Singh Sekhon II entitled *(un)selfish object*. Each of these demand logistical considerations completely separate from any musical action, as will be discussed.

Electroacoustic music, being the resultant integration of two contrary elements, necessitates particular considerations if the integration is to be successful. In any electro-acoustic performance, the musician should recognize the performing state of the electronic interface. *Mothership*, for instance, utilizes the electronic interface as an instrument under human control, while the electronics in *(un)selfish object* serve as a manipulative interface in the performing process. Across such a spectrum, it can become difficult for the musician to convey human expression through an electronic medium. In order to achieve freedom of expression in an electro-acoustic work, the establishment and maintenance of control over the sonic environment is vital. That is to say, the musician needs to maintain consistent personal control over every aspect of the performance, including the mind, body, instrument, and electronics. When the musician has legitimate control over the performance environment, there can be a genuine interaction between the electronic and acoustic components, resulting in an integrated electroacoustic experience.

PERFORMANCE CONTEXT: PLOrk

Conventionally speaking, it might appear inconsistent to include a discussion of the Princeton Laptop Orchestra, an *electronic* ensemble, in a study of *electro-acoustic* performance practices. Especially for an analysis in which syntax is made critical, the subject seems glaringly inappropriate. Upon further consideration, it will become evident that the Princeton Laptop Orchestra is not only pertinent to the mutuality and interaction of human musicians and live electronics, but indeed relevant to the realm of electroacoustic music and its performance contexts. The Princeton Laptop Orchestra, or PLOrk, is an ensemble occupied by students from Princeton University who use laptops in conjunction with a variety of interfaces to perform music both composed and improvised. Such interfaces subsume the contexts of programming languages such as Max/MSP, Pure Data, SuperCollider, and ChucK, among others, as well as gestural controllers including joysticks, keyboards, smart phones, and touch screen tablets. The ensemble has become largely an avenue for students to explore electronic music composition, the functions and execution of programming environments, and electronic music performance.

Each member of PLOrk performs on a "meta-instrument" consisting of a laptop, interfacing equipment (including a multi-channel firewire interface, amplifier, and a sensor interface for interpreting data received), and a hemispherical speaker equipped with six independently addressable internal speakers.[10] Participation in PLOrk requires a fundamental comprehension of the meta-instrument, as well as the operation of any other interfaces being used, e.g., the programming environment, controller, or other external audio stimuli. Participating students must also be able to prepare themselves for rehearsals and performances, and are often taught to troubleshoot their own instruments.

While visiting a rehearsal on October 14, 2013, I was invited to improvise with PLOrk by Dr. Jeff Snyder, who currently directs the ensemble. Before the rehearsal could begin, Dr. Snyder assisted me in configuring the Max patch through which they would improvise. The group improvisation utilized joystick controllers in cooperation with the meta-instrument. The patch interpreted buttons and gestures, and corresponding sounds were delivered through the hemispherical speakers. A significant degree of interaction took place between each of the five performers involved, as well as between individual performers and their instrument. While reacting to sounds heard from fellow ensemble members, each musician was able to maintain personal control over their meta-instrument via a gestural controller.

In this type of environment, the electronics serve as instruments to be controlled by human performers. The patches designed by the ensemble are, by nature, completely dependent on human programming and input, and allow for interaction between performers as well as an environment conducive to improvisation. In certain situations, the electronics can also serve as a manipulative interface via audio signal processing patches that receive live input from the performer, process and alter the data, and output a corresponding sonority. Since programming languages were introduced in the 1980s, new possibilities have been created for exploring the electronic sound spectrum. Audio signal processing allows musicians to generate sounds that would be otherwise impossible.[11] In addition, gestural controllers including joysticks, accelerometers, and potentiometers provide an avenue for interpretation and expression from human performers through which synthesized music can be nuanced by live gestures, as well as techniques characteristic of acoustic instruments. This includes tapping a touch screen, striking a drum pad, or shaking an iPhone. It is this vicarious relationship that places a normally purely electronic ensemble in the realm of electroacoustic music.

PERFORMANCE CONTEXT: *MOTHERSHIP*

An acoustic ensemble as intricate as an orchestra or wind ensemble comprises several independent elements, all of which collaborate toward the same objective of unity in performance. The addition of an electronic component does not alter the objective, but adds a new layer of complexity to the process of achieving it. The use of electronics in an acoustic ensemble can be traced as far back as 1954, when Edgard Varèse premiered his work *Déserts*, which involves the interpolation of electronic tape sounds between sections of music performed by an acoustic ensemble.[12] At that point in the chronology of electroacoustic music, the logistical practicality of integrating electronics in a live performance was doubtful at best; the very idea of electronic music was an alien one, largely due to the limited capabilities of technology and lack of familiarity with it at the time. Varèse understood the impracticality of such integration and the electronic tape interpolation was thus made optional.[13] Even if an orchestra in the mid-twentieth century decided to perform with the electronic tapes, any true interaction between the ensemble and electronics would be minimal, if not chimerical altogether, being that the tape sounds are merely interpolated between sections of performed music, and both elements are utterly independent. The purpose of Varèse's composition, rather, was to demonstrate that both acoustic and electronic music shared the same elements of timbre, rhythm, and dynamic changes.[14]

Since 1954, electroacoustic ensemble compositions have made remarkable strides, to the point where electronics can interact in real time with a traditional acoustic ensemble. The following decades saw the growing popularity of synthesizers and other means of electronic music production, in addition to experimentation by various composers, resulting in works like Mario Davidovsky's *Synchronisms No. 6* (1970), Pierre Boulez's *Répons* (1984), and more recently, Steven Bryant's *Ecstatic Waters* (2008), which is remarkable for its use of live recording and looping within a live wind ensemble. Composer Mason Bates exhibits a wide range of capabilities in his 2011 work entitled *Mothership*. The piece was originally written for orchestra and live electronics, with an arrangement by the composer replacing the orchestra with a wind ensemble. The College of New Jersey Wind Ensemble, under the direction of David Vickerman, programmed the piece for two performances in its 2014 concert season. Via a patch designed in Max, the electronics are designed to replicate sounds reminiscent of a fictionalized spacecraft along with synthesized percussion sounds.

The composer constructed two different interfaces for the realization of the electronics. One such possibility, intended only for Bates's personal execution in performance, involves real time activation of electronic drum pads for sound production. With live triggering, Bates is in complete control of, and is therefore responsible for, every electronic sound in the performance of his work. This requires precise timing of strokes on the electronic drum pads in addition to complete comfort with the arrangement of triggers and the sounds mapped to each of them. The secondary performance method consists simply of a laptop with a QWERTY keyboard interface. This option is to be used when the composer himself is not present for the performance, and entails the laptop performer pressing predetermined keys, each corresponding to a cue notated in the score. Once a key is pressed, the preprogrammed series of sounds mapped to that key is initiated. The score cues each keystroke in a spatial order so that the laptop performer merely presses consecutive keys from left to right.

The use of a QWERTY interface as opposed to real time activation of a drum pad comes with sure benefits, as well as inherent flaws. As a composer, Bates strives for consistency and accuracy in a performance of his work. This is more likely than not the most vital reason for making the QWERTY interface as simple as possible. With cues to strike consecutive keys, the performer is less likely to strike an incorrect key. That being said, a simple QWERTY controller that triggers sound files with a single stroke can be problematic if the performer does strike an incorrect key. The wrong file being initiated at a given moment can distract the other performers, and even an attentive audience. Synchronization is another issue in the forefront of electro-acoustic performances that incorporate a laptop. Any possible delay time between the keystroke, interpretation of data, and output of the audio signal must be taken into account and compensated for in a live performance, lest the electronics become rhythmically out of phase with the ensemble. While the space bar serves as an emergency kill switch for the audio playback, the performer ideally would avoid such a necessity diligently as an effort toward a successful, unhindered electro-acoustic performance.

The QWERTY performance tactic bears strikingly analogous caveats to Bates's alternate method of live triggering. Synchronization remains a central concern, as does accuracy in execution. Contrast between the two performance options manifests itself in the delegation of responsibility over these performance aspects. The QWERTY interface demands the anticipation of delay and compensation from the laptop performer as well as the ensemble. Once initiated, the tempo of the sound files cannot be reconciled. Therefore, the ensemble must be able to adjust for any discrepancies. Conversely, when triggering drum pads in real time, the electronic performer must be cognizant of the ensemble's pacing so that total synchronization is achieved.

Where the human musician is concerned, it is crucial to maintain direct control over the electronics in all stages of performance. Simon Emmerson describes *control intimacy* as an essential facet of an electro-acoustic performance. The human performer should take all necessary steps to retain total control over the sound environment. One must be aware of every aspect of the electronic interface and maintain control "over mobility and directionality of original and modified source sounds."[15] In *Mothership*, the composer includes with the score specific, detailed instructions for the physical configuration of the laptop and speakers on stage, so that human control by the performers is kept minimal. Bates adjures the use of two loudspeakers on stage, in addition to monitors for the conductor and musicians. He includes instructions for the sound technician at the performance as well as for the laptop performer, in which preparation instructions and performance controls are included. Bates maintains a substantial degree of control intimacy over his work, perhaps more so than could a composer of purely acoustic music.

Be that as it may, control must eventually be conferred to the laptop performer, upon whom the responsibility of control intimacy lies. The electronic interface, whether in the form of a laptop or live drum pads, is in fact an instrument for sound production dependent on total human control. In the case of *Mothership*, truly intimate control over the electronic instrument depends on the collaboration of the composer, conductor, sound technician(s), and ultimately the laptop performer himself. While the performer would ideally assert control over the sounds being triggered and synchronization with the ensemble, other musical nuances, from dynamics to overall human interpretation and expression, are limited by the nature of the electronic component. Volume control is taken out of the hands of the performer, since Bates specifically requires in his instructions that the laptop volume be set to maximum for the duration of the performance. From there, the sound technician may adjust levels relative to the ensemble if need be, although the sound files have supposedly been balanced by the composer.[16] A desire for intimate control over the composition and its performance, with all its hardware and software components, warrants ancillary precautions.

In the performance of a piece with multiple electronic components, including a laptop, multiple cables and monitors, loudspeakers, and a mixing board, accuracy and consistency in preparation is integral to success. Sound technology can often prove temperamental and an order of operations must be accounted for when configuring the equipment, much like the preparation of any acoustic instrument. Once all is set, it is then necessary to test the electronic interface with the sound technician to confirm that it indeed functions properly. These actions are likely foreign and even overwhelming to a performer that is unfamiliar with sound technology. Nevertheless, such a case justifies them as safeguards for performance malfunctions.

PERFORMANCE CONTEXT: *(un)selfish object*

Audio signal processing has also existed in some form since the mid-twentieth century. Early electronic composers such as Karlheinz Stockhausen experimented with acoustic sound manipulation, notably in his composition *Mikrophonie I* (1964), which consists of a large tam-tam and six performers: two performers assigned to strike, scrape, and otherwise stimulate the instrument, two separate performers assigned to hold microphones to the tam-tam at varying distances and positions, and two final performers at the sound console to pick up harmonics and other sonorities typically inaudible with the unaided ear.[17] Gordon Mumma continued this tradition in 1967 with his composition *Hornpipe*, in which an electronic listening device would obtain pitches and overtones produced by a solo horn player in the concert hall, and manipulate them with increasing intensity.[18]

Over the last half-century, the use and elegance of audio signal processing technology has been developed appreciably, if still unavoidably imperfect. Baljinder Singh Sekhon II's composition *(un)selfish object* (2007) for marimba and electronics comprises a solo marimba player with a pitch tracking program developed in Pure Data, a programming language which bears a resemblance to Max/MSP. While both Pure Data and Max/MSP are object oriented programming environments with similar functionality, Pure Data is essentially an open source and slightly simpler version of its counterpart. Within the programming environment of Pure Data, Sekhon has constructed a score following program that begins with two directional microphones placed over a standard five-octave marimba. The microphones feed into an interface that transfers the audio input to the laptop via its USB port. The Pure Data patch is configured to pick up the marimba's acoustics and respond when particular notes are struck, producing preprogrammed sounds. These include sustained pitches as well as metronomic tape sequences. Pitch tracking programs are not a new invention, as evidenced in trombonist and composer George Lewis' 1993 *Voyager* experiment, in which a computer produces real time accompaniment and an improvisation environment to the live, human instrumentalist.[19] A level of interaction this deep is comparable in *(un)selfish object*, as further deliberation will make evident.

One of the primary issues with performing *(un)selfish object* is not in the marimba writing or the configuration of the patch, but rather is intrinsic to Pure Data itself. Being a moderately simplified version of its predecessor and programming cousin Max/MSP, Pure Data is more prone to flaws. Such glitches can cause unintended alterations to the execution of the patch, or simply a malfunctioning of the patch itself. It is interesting to note that Sekhon has not made the piece commercially available for purchase "because of the complexities (and unpredictable nature) of the electronics."[20] For *(un)selfish object*, such unpredictability can result in a failure to recognize input from the microphones, undesired feedback, and misfired cues. The performer must have a fundamental understanding of the necessary equipment and the operations of the patch, and similarly to *Mothership*, all preparations must be done accurately and consistently to allow for proper functioning of the electronics in performance.

In the process of exploring the patch and its operations, the struggle I have most often encountered is one of consistency; while some attempts to activate cues in the patch were successful, others were not, despite exacting preparations of the equipment and software. As anticipated previously, such incidents would involve faulty reception of acoustic sounds and inconsistent electronic output, as well as feedback of ambient noise. After troubleshooting, these situations often necessitated restarting the patch or Pure Data itself. This complication is simply a derivation of Pure Data's inherent imperfections. Sekhon has given the option of a second performer to oversee the Pure Data patch in the case of any unexpected occurrences. The auxiliary performer may follow along with the score to trigger sounds manually or terminate the patch's operation as a safety measure.[21]

The nature of *(un)selfish object* exhibits true interaction of the human and electronic component in the *electro-acoustic* environment, allowing for a balanced and integrated *electroacoustic* experience. In several cases, the human performer acts as a catalyst, triggering electronic sounds throughout the score. The first instance of this occurs in measure 33 of the piece, when the marimbist strikes an accented E5 (relative to the designation of middle C as C4). This triggers the first programmed sound in the patch: an electronically generated E5 that sustains the otherwise limited resonance of the marimba. This occurs eleven more times during the piece with a progression of pitches, until measure 113, when the marimbist sustains a roll on G5. Upon detecting this, the patch initiates the first of four tape sequences. The tape sequences are in strict rhythm and typically last for several measures, requiring the marimbist to perceive the tempo generated by the patch and synchronize with it. Contrary to the case of sustained pitches, the tape sequences allow for the electronics to become a catalyst in performance, requiring the human performer to become the follower. The electronics are never truly autonomous; in order for the tape sequences to be initiated, the patch must detect the corresponding input from the human performer. However, Emmerson states that in a musical discourse, if the audience perceives that one event seems to cause another, then in the context of the sonic experience it has done so, the true catalyst notwithstanding.[22] Where the overall musical experience is concerned, the extent of causality established by either participant of an electro-acoustic performance is contingent on the perception of the audience.

Despite this, it is still possible for the human performer to maintain control over the sonic environment with a familiarity of the electronic interface and its capabilities, as well as a cognizance of necessary musical subtleties. According to Emmerson, this includes "an awareness of timbral nuance, level sensitivity, and inter-performer balance."[23] In the case of *(un)selfish object*, the electronic component serves as an interface for manipulating and sustaining acoustic sounds from the perspective of the audience, but also as a seemingly autonomous performer in the form of tape sequences. With a total awareness of the sonic environment and the interactions taking place, as well as a fundamental technical understanding of the electronics, the musician should not be caught off guard by any aspect of the electronics, including malfunctions. At this point, the musician can remain in control of the acoustic and electronic components, thus enabling human expression and interpretation through the acoustic instrument.

Even this is subject to the patch's tolerance and perceptivity. At rehearsal letter B (to be henceforth referred to as "Reh. B"), which marks the climax of the introduction, the marimbist sustains a fortissimo E minor triad. Sekhon's harmonic voicing here involves horizontal motion in addition to its explicit verticality; the upper voice rises from B3 to E4 while the left hand sustains a major sixth between G2 and E3 in the marimba's bass register.[24] The sustained E octave manifests undeniable prominence of pitch class E, along with its harmonics, produced naturally by the marimba. As noted previously, the first electronic cue is an E5 in measure 33. Although this occurs after Reh. B, the microphones could plausibly recognize an unintentional E5, produced via harmonic resonance, and trigger the first cue inadvertently. Therefore, at Reh. B, the marimbist should be aware of such possibilities and endeavor to channel the same climactic intensity through the marimba while sustaining the E octave with a more sensitive physical approach.

FORESIGHTS

As a result of its own nature, a study in electro-acoustic performance practices cannot be entirely complete in the foreseeable future. The case studies discussed provide examples of paradigmatic situations in the domain of electro-acoustic performances. Even so, electroacoustic music is continually evolving, undergoing new developments on a regular basis. Through this evolution, a distinction between "electro-acoustic" performances and an integrated "electroacoustic" musical experience may become a semantic necessity, as delineated previously.

Despite any advancement, the interactive process will always pose the issue of human control over the sonic environment and communication of expression through an electronic medium. The musical dialogue that occurs in *(un)selfish object*, for instance, is strikingly balanced and implies a perceived mutual causality between the human musician and electronic component. The musician is able to manipulate the written music with a considerable degree of interpretation, although this must be done with an acute awareness of the responsive capacity of the electronic patch. In the near future, current issues of logistics and consistency in performance will likely become more familiar to musicians, and there will be greater comfort in dealing with electronics. The Princeton Laptop Orchestra is one of several recent endeavors to make live electronics a more mainstream aspect of performance, as well as a user-friendly prospect in the face of a turbulent history of acquiescence alongside an established classical canon. This was seen particularly with early compositions such as *Déserts*, which was notorious for unsatisfactory sound quality from the electronic tapes and fraught with logistical difficulties, although such circumstances were subject to the technological capabilities of the time. With the advent of programming languages and possibilities for real time interactions with live electronics, compositions of this sort have become more common and more accessible, both to performers and spectators, as evidenced by Bates's *Mothership*, among other works.

As performers continue to program more electroacoustic music, pushing the boundaries of technological and artistic capabilities, new issues may arise regarding further interactions between the human and machine. The question lies in the extent to which electronics will progress, and whether the human musician will even become superfluous or obsolete. This, however, remains to be seen, and is both impractical and premature to anticipate with any specificity. Nevertheless, a familiarity with live electronics and the processes of interacting with them in a performance, however rudimentary, is vital to the advancement of electro-acoustic performances, or more broadly, electroacoustic music itself.

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