Performing Embodiment

Negotiating the Body in the Electroencephalographic Music of David Rosenboom

by

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ABSTRACT

Beneath the epidermis, the human body contains a vibrant and complex ecology of interwoven rhythms such the heartbeat, the breath, the division of cells, and complex brain activity. By repurposing emergent medical technology into real-time gestural sound controllers of electronic musical instruments, experimental musicians in the 1960s and 1970s – including David Rosenboom – began to realize the expressive potential of these biological sounds. Composers experimented with breath and heartbeat. They also used electroencephalography (EEG) sensors, which register various types of brain waves. Instead of using the sound of brain waves in fixed-media pieces, many composers took diverse approaches to the challenge of presenting this in live performance. Their performance practices suggest different notions of embodiment, a relationship in this music which has not been discussed in detail.

Rosenboom reflects extensively on this performance practice. He supports his EEG research with theory about the practice of biofeedback. Rosenboom's work with EEG sensors spans several decades and continue today, which has allowed him to make use of advancing sensing and computing technologies. For instance, in his 1976 *On Being Invisible,* the culmination of his work with EEG, he makes use of analyzed EEG data to drive a co-improvising musical system.

In this thesis, I parse different notions of embodiment in the performance of EEG music. Through a critical analysis of examples from the discourse surrounding EEG music in its early years, I show that cultural perception of EEG sonification points to

imaginative speculations about the practice's potentials; these fantasies have fascinating ramifications on the role of the body in this music's performance. Juxtaposing these with Rosenboom, I contend that he cultivated an embodied performance practice of the EEG. To show how this might be manifest in performance, I consider two recordings of *On Being Invisible*.

As few musicologists have investigated this particular strain of musical experimentalism, I hope to contextualize biofeedback musicianship by offering an embodied reading of this milestone work for EEG.

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I extend my gratitude to Western Front Archive, who provided me access to an archival recording of David Rosenboom's *On Being Invisible* and to Courtney Brown for permission to borrow her characterization of *Music For Solo Performer* as the "Hello world" piece for EEG music found in the third chapter of this document.

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In memory of my father, who asked of me to do my best.

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ONE. INTRODUCTION

1.1 Project Overview

Beneath the epidermis, the human body contains a vibrant and complex ecology of interwoven rhythms such the heartbeat, the in- and exhalation of breath, the division of cells, and complex brain activity. By repurposing emergent medical technology into real-time gestural sound controllers of electronic musical instruments, experimental musicians in the 1960s and 1970s– including David Rosenboom, Alvin Lucier, Richard Teitelbaum, James Tenney, and others – began to realize the artistic and expressive potential of these biological sounds. These composers experimented with breath and heartbeat and often integrated them into their musical performances. They also used electroencephalography (EEG) sensors, which register the activity of various types of brain waves produced when the brain is in various perceptual and cognitive states. Instead of using the sound of brain waves as source material for fixed-media pieces, each of the aforementioned composers chose to take on the performative challenge of presenting this music in a concert setting, taking distinct approaches to making brain waves audible and musically expressive. Musicians amplified the waves' low vibrations through loudspeakers and used them to excite musical instruments and materials. Alternatively, they employed the waves' frequency as control signals to drive the then emergent voltage-controlled synthesizers. After the advent of digital computing, some musicians ported EEG data into complex autonomous musical systems residing on computers.

Although biofeedback and so-called "brainwave music" is often discussed as a homogenous trend, investigations into these composers' experiments reveal profound differences in their musical, technological, and performative approaches to music with EEG. Their performance practices suggest different notions of embodiment, a phenomenon which has not been considered in detail in relation to this music.

In his score for *Music for Solo Performer* (1965), Lucier calls for an assistant to outfit the performer with a biosensor as part of the performance.[1] He notes that "no part of the motor system is involved in any way" and that "control of the alpha consists simply of alteration of thought content."[2] Lucier emphasizes the theatricality of overcoming nervousness in order to successfully perform the piece, drawing comparisons to the anxiety of the subject of an experiment or a doctor's patient (white coat syndrome).

Rosenboom reflects differently (and more extensively) on this performance practice. His work with EEG is presented not only as musical performance and composition but also as research, supporting his own theories and arguments about the practice related to contemporaneous psychological studies known as biofeedback and as well as looking to philosophical schools of thought such as systems theory. Another output of this work is the extensive documentation of his own elaborate dynamical systems incorporating EEG sensors. Rosenboom worked with these biosensors for

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[1] Alvin Lucier and Douglas Simon, "Music for Solo Performer," in *Chambers,* 67–68 (Middletown, CT: Wesleyan University Press, 1980).

[2] Ibid.

several decades and has returned to it again and again over the years, allowing him to make use of advancing sensing and computing technologies. First performed in 1976, his piece *On Being Invisible* makes use of computers to auto-correlate EEG data, which drives a sophisticated, co-improvising musical system controlling timbral parameters of sound synthesis, melodic contours, and musical form.

In this thesis, I parse different notions of embodiment in the performance of EEG music. Through a critical rhetorical analysis of examples from the discourse surrounding EEG music in its early years (including Alvin Lucier's watershed EEG piece *Music for Solo Performer* and an interview with David Rosenboom on a nationally syndicated daytime television talk show), I show that cultural perception of EEG sonification points to imaginative speculations about the practice's potentials; these fantasies, I argue, have diverse and fascinating ramifications on the role of the body in the performance of this music. I contend that Rosenboom's rhetoric betrays an awareness and engagement with cultivating an embodied performance practice of the EEG. To show how this might be manifest in the musical performance itself, I consider his piece *On Being Invisible* (1976-77).

As few musicologists have investigated this particular strain of musical experimentalism, I will provide insight into EEG musicians' work by offering an embodied reading of *On Being Invisible*. In this study I maintain that these experiments in EEG music investigate the human mind/body beyond its "traditional" and "functional"

roles, emphasizing somatic, ecological, and phenomenological understandings of interactions between human experience and art.

1.2 Literature Review

The biofeedback works of Rosenboom have received relatively little attention in the musicological community. Consequentially, many of the secondary-source materials about the practitioners of biofeedback summarize their varied and extensive experiments as a whole, instead of portraying the nuances of their artistic, scientific, and philosophical aims.

Many music history textbooks, electronic-music monographs, and books devoted to experimental music cover only Lucier's *Music for Solo Performer* (1965). Peter Manning's *Electronic and Computer Music* discusses only *Solo Performer* to qualify Lucier as "the most adventurous" member of the Sonic Arts Union, but does not mention the term biofeedback.[3] Thom Holmes' *Electronic and Experimental Music* presents *Solo Performer* as the "first piece of music composed for amplified brainwaves – and not the last."[4] Michael Nyman's influential *Experimental Music: Cage and Beyond* cites only

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[3] Manning, *Electronic and Computer Music* (New York: Oxford University Press, 2004), 166.

[4] Holmes, *Electronic and Experimental Music* (London: Routledge, 2002), 204–205.

Solo Performer, but mentions other composers such as Richard Teitelbaum, Rosenboom, and Alex Hay, who emphasize live performance using brainwaves.[5]

General information on experimental music can be found in *Breaking the Sound Barrier: A Critical Anthology of New Music* edited by Gregory Battcock, *Dialectics in the Arts: The Rise of Experimentalism in American Music* by Catherine Cameron, Benjamin Piekut's *Experimentalism Otherwise: The New York Avant-Garde and its Limits, Experimental Music Notebooks* and *What's the Matter With Today's Experimental Music? Organized sounds rarely heard* by Leigh Landy, and Lydia Goehr's "Explosive Experiments and the Fragility of the Experimental."[6]

In my discussion of EEG music and embodiment, I begin by looking at what has widely become regarded as the first and perhaps most influential example of EEG sonification, Alvin Lucier's *Music For Solo Performer* (1965). In his many writings,

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[5] Nyman, *Experimental Music: Cage and Beyond* (Cambridge: Cambridge University Press, 1999), 106–107.

[6] Battcock ed., *Breaking the Sound Barrier: A Critical Anthology of New Music,* New York: E.P. Dutton, 1981; Cameron, *Dialectics in the Arts: The Rise of Experimentalism in American Music* (Westport: Praeger, 1996); Piekut, *Experimentalism Otherwise: The New York Avant-Gade and its Limits* (Berkeley, CA: University of California Press, 2011); Landy, *Experimental Music Notebooks* (Chur: Harwood, 1994); Landy, *What's the Matter with Today's Experimental Music? Organized Sounds Rarely Heard* (Chur: Harwood, 1991); Goehr, "Explosive Experiments and the Fragility of the Experimental," in *Elective Affinities. Musical Essays on the History of Aesthetic Theory,* 108–135 (New York: Columbia University Press, 2008).

Lucier often mentions his early break-through piece with EEG.[7] Lucier also offers insight about the piece's genesis and reflects on its dramaturgical and compositional implications in interviews.[8] These statements inform my interpretation of his performance practice, as well as help shape my interpretation of Lucier's overall aesthetic paradigm. I build on the various readings of the piece by scholars and composers alike, in particular Douglas Kahn's reading of the piece as a synthesis of the philosophy of John Cage and cybernetics, as well as the in-depth investigation of the piece and its performance practice

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[7] Writings: Alvin Lucier, *Music 109: Notes on Experimental Music* (Wesleyan, CT: Wesleyan University Press, 2012), 52–53; "Origins of a Form: Acoustical Exploration, Science, and Incessancy," *Leonardo Music Journal* 8 (1999): 5–12; "The Tools of My Trade," in *Contiguous Lines,* ed. Thomas DeLio, 143–160 (Lanham, MD: University Press of America, 1985); with Mindy Lee and Elie Siegmeister, "Three Points of View," *The Musical Quarterly* 65, no. 2 (April 1979): 281–295.

[8] Interviews: Alvin Lucier, "*Music for Solo Performer* (1965)," interview by Douglas Simon, in *Chambers* by Alvin Lucier and Douglas Simon, 69–81 (Middletown, CT: Wesleyan University Press, 1980); "Conversation with Alvin Lucier," interview by Arthur Margolin, *Perspectives of New Music* 20, no. 1/2 (Fall and Winter 1982/Spring and Summer 1981): 50–58; "*Vespers*: an Interview with Alvin Lucier," interview by J. D. Simon, *Arts in Society* 9, no. 2 (April 1979): 277–285; Interview by Walter Zimmerman, in *Desert Plants: Conversations with 23 American Musicians,* ed. by Walter Zimmermann (Vancouver: Zimmermann Musikverlag, 1976), 137–148; *Chambers,* interviews by Douglas Simon (Middletown, CT: Wesleyan University Press, 1976); "Sitting in a Room with Alvin Lucier," interview by Frank J. Oteri, *NewMusicBox* April 1, 2005, accessed September 28, 2014, http://www.newmusicbox.org/articles/sitting-in-a-room-with-alvin-lucier-alvin-lucier/.

set forth by Volker Straebel and Wilm Thoben in "Alvin Lucier's *Music for Solo Performer:* Experimental music beyond sonification".[9]

Some composer-scholars provide discussions of what they refer to as either biofeedback music, brain music, or biomusic to categorize these composers' experiments. In *New Directions in Music*, David Cope devotes about a page to biomusic as part of his chapter on experimentalism; however, he mentions only David Rosenboom by name.[10] More than any of his colleagues in early biofeedback or brainwave sonification, Rosenboom's reflections are both broad in conception and more nuanced in depth, and point to the philosophical implications of driving dynamic autonomous systems with information generated by the human body. His 1990 monograph *Extended Musical Interface with the Human Nervous System* is a summation of his research with the EEG.[11] His self-published *Collected Articles: A Selection of Previously Unpublished or Out of*

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[9] Douglas Kahn, "Alvin Lucier: Brain Waves" and "Edmond Dewan and Cybernetic Hi-Fi" in *Earth Sound Earth Signal: Energies and Earth Magnitude in the Arts,* 83–91 and 92–104; Helga De la Motte-Haber, "Extrem Schönes Donnern," *Neue Zeitschrift für Musik* 160, no. 2 (1999): 10–15; Matthew Rogalsky, "'Nature' as an Organising Principle: Approaches to Chance and the Natural in the work of John Cage, David Tudor and Alvin Lucier," *Organised Sound* 15, no. 2 (August 2010): 133–136; Sabine Sanio, "Ein Neues Verständnis von Musik," *Neue Zeitschrift für Musik* 161, no. 5 (September 2000): 24–31; Tom Delio, "The Music of Alvin Lucier," *Journal of New Music Research* 10, no. 2 (1981): 137–146; Straebel and Thoben, "Alvin Lucier's *Music for solo performer:* Experimental Music Beyond Sonification," *Organised Sound* 19, no. 1 (April 2014): 17–29.

[10] David Cope, *New Directions in Music* (Long Grove, IL: Waveland Press, 2001), 109–110.

[11] Rosenboom, *Extended Musical Interface with a Human Nervous System: Assessment and Prospectus,* Leonardo monograph 1 (Berkeley, CA: International Society for Arts, Sciences, and Technology, 1990).

Print Writings, his edited collection *Biofeedback and the Arts: Results of Early Experiments,* as well as various interviews illuminate much of the compositional and theoretical underpinnings of his music.[12]

For my case study of *On Being Invisible,* I draw on Rosenboom's writings, interviews and recordings of the piece. Rosenboom extensively documents the piece in *Extended Musical Interface with the Human Nervous System,* which provides crucial insight into the engineering of this auto-poetic system. The 1977 album *Invisible Gold* features an audio recording of the piece's premiere performance by the composer.[13] Also, Western Front Archive has graciously allowed me access to an audio recording of a performance at Western Front in Vancouver from February 28th, 1976 – just sixteen days after the premiere in Toronto.[14] Comparison of these sources allow me show the plasticity of the *On Being Invisible* EEG instrument.

The biomedical field has extensively documented various experiments with biofeedback as a therapeutic or rehabilitative technique; a summary of biofeedback's plentiful applications is not suited to this thesis. However, I consulted articles written by

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[12] Rosenboom, *Collected Articles: A Selection of Previously Unpublished or Out of Print Writings by David Rosenboom 1968–1982* (Piedmont, CA: David Rosenboom Productions, 1984); ed., *Biofeedback and the Arts: Results of Early Experiments* (Vancouver: Aesthetic Research Centre of Canada, 1976).

[13] Rosenboom, *Invisible Gold,* Pogus Records, 2000, CD.

[14] Western Front Archive, http://front.bc.ca/.

biomedical experts which use music as a stimulus in biofeedback experiments, examine explicitly the musical application of EEG, or provided general information on the EEG.[15]

The work of EEG musicians might be considered under the greater umbrella of electronic instrument design and gestural sound control. This thesis is indebted to the scholars who have offered taxonomies of gestural sound control as well as its implications in musical improvisation and composition. These phenomena are thoroughly investigated by Daniel James Overholt in his PhD dissertation "Musical Interface Technology: Multimodal Control of Multidimensional Parameter Spaces for Electroacoustic Music" as well as texts by Axel Mulder, including his dissertation "Design of Virtual Three-dimensional instruments for Sound Control".[16] Sergi Jordá's

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[15] Lloyd Gilden, "Instrumental Control of EEG Alpha Activity with Sensory Feedback," in *Biofeedback and the Arts: Results of Early Experiments*, ed. David Rosenboom, 27 (Vancouver: Aesthetic Research Centre of Canada, 1975); Ilias Bergstrom et al. "Using Music as a Signal for Biofeedback," *International Journal of Psychophysiology* 93 (2014): 140–149; John C. Shaw, ed., *The Brain's Alpha Rhythms and the Mind: A Review of Classical and Modern Studies of the Alpha Rhythm Component of the Electroencephalogram with Commentaries on Associated Neuroscience and Neuro- psychology* (Amsterdam: Elsevie, 2003); Barbara E. Swartz, "The advantages of digital over analog recording techniques," *Electroencephalography and Clinical Neurophysiology* 106, no. 2: 113–117 (1998); Gyorgy Buzsáki, *Rhythms of the Brain* (Oxford: Oxford University Press, 2011).

[16] Daniel James Overholt, "Musical Interface Technology: Multimodal Control of Multidimensional Parameter Spaces for Electroacoustic Music," PhD Diss., University of California, Irvine, 2007, ProQuest (3291442); Axel Mulder, "Design of Virtual Three-dimensional instruments for Sound Control," PhD diss., Simon Fraser University, 1998, ProQuest (NQ37736), "Getting a Grip on Alternate Controllers: Addressing the Variability of Gesture Expression in Musical Instrument Design," *Leonardo Music Journal* 66 (1996): 33; "Virtual Musical Instruments: Accessing the Sound Synthesis Universe as a Performer," *Simpósio Brasileiro de Computação e Música* (1994): 243–250.

2005 dissertation also thematizes gestural control of sound and is a source of both general and technical information on the subject.[17]

The community based around the conference New Instruments for Musical Expression, or NIME, is devoted to the exploration of gestural sound control in its many facets;[18] many articles from its proceedings inform my understanding of gestural sound. While much of the research presented at NIME is focused on specific musical interfaces, its first meeting — a study group at the larger Computer Human Interaction conference of 2001 – also invited several papers articulating the community's larger aims and providing general information on gestural data sonification, including those by Perry Cook, Sergi Jordá, David Wessel, and Matthew Wright. The article "Gestural Control of Sound Synthesis" by Marcelo Wanderley and Philippe Depalle provides general information on this practice.[19] Monographs dedicated more generally to electronic music also mention this phenomenon, including writings by Peter Manning, Thom Holmes, and Joel Chadabe.[20]

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[17] Jordá refers to this as "digital lutherie"; Jordà,"Digital Lutherie: Crafting musical computers for new musics' performance and improvisation," Ph.D diss. UPF Barcelona, 2005.

[18] NIME, New Interfaces for Musical Expression international conference: http://www.nime.org/.

[19] Wanderley and Depalle, "Gestural Control of Sound Synthesis," *Proceedings of the IEEE* 92, no. 4 (April 2004).

[20] Manning, *Electronic and Computer Music*; Holmes, *Electronic and Experimental Music*; Chadabe, Joel; *Electric Sound: the Past and Promise of Electronic Music* (Upper Saddle River, NJ: Prentice Hall, 1997).

Many artists, musicians, and composers have taken advantage of the affordable proprietary electroencephalographs such as the Emotiv and the NeuroSky which have emerged on the commercial market over the last fifteen years, using data to generate sonic materials, visuals, or drive kinetic motion.[21] The continuing stream of new artistic approaches and applications with the EEG as a gestural controller of media show the impact of the early pioneers in the 60s and 70s. However, an exhaustive survey of modern works which use EEG is outside the scope of this thesis. This more recent musical biofeedback work is sparsely represented in scholarship. Georgina Born and Mariam Fraser describe Bruce Gilchrist's *Thought Conductor #2*, an audio/visual work in which a performer generates EEG data which is transcoded into a musical score read by a string quartet, forming a feedback loop.[22] Australian sound artist Alan Lamb's *EEG Music* project is covered by Lindsay Vickery in her surgery of contemporary, noteworthy musical activities in Western Australia.[23] Alberto Novello's master thesis on EEG music provides a survey of approaches to the EEG amongst contemporary artists in his third chapter, including among others: Mattia Casalegno and Enzo Varrial's *Sounds of Complexity* (2009), an audio-video work in which recorded EEG wave is transposed into

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[21] Emotiv, accessed November 11, 2014 www.emotiv.com; NeuroSky, accessed November 11, 2014, www.neurosky.com.

[22] Born, *Twentieth-Century Music* 2, no. 1 (2005): 7–36; Fraser, "Making Music Matter," *Theory, Culture and Society* 22, no. 1 (2005): 173–189.

[23] Vickery, "The Western Edge: Some Recent Electronic Music from Western Australia," *Organised Sound* 6, no. 1 (2001): 69–74.

higher, audible frequencies; the Interactive Brainwave Visual Analyzer hardware designed and built by Luciana Haill, which she uses to drive her own quantized sound synthesis software; as well as Caludia Roble's *INsideOUT* (2009), a performance in which the performer uses the her OpenEEG hardware controller (an open-source EEG) to manipulate precomposed, multi-channel audio and video material.[24] Their case studies inform my own, as well as broaden the scope of Rosenboom's influence, which I articulate in my conclusion.

As well, there have been many scientific developments in the musical interpretation of EEG data, such as in the work of Eduardo Miranda, Andrew Brouse, Tim Mullen, and others.[25] This technical scholarship shows a more refined approach to analyzing and sonifying EEG signals than Lucier or Rosenboom, enabled by the developments in sensor technology. Although this work's importance in continuing a practical, musical, and material understanding of brainwaves registered by EEG cannot

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[24] Novello, "From Invisible to Visible: The EEG as a Tool for Music Creation and Control," MA Thesis, Institute of Sonology, 2012, accessed October 15, 2014, http://www.sonology.org/NL/thesis-pdf/Alberto%20Novello.pdf.

[25] Here are just a few examples of scholarship which furthers investigates EEG sonification: Eduardo Miranda and Andrew Brouse; "Toward Direct Brain-Computer Musical Interfaces," *New Interfaces for Musical Expression* (2005); "Interfacing the Brain Directly with Musical Systems: On Developing Systems for Making Music with Brain Signals," *Leonardo* 38, no. 4 (2005): 331–336; "Affective Jukebox: A Confirmatory Study of EEG Emotional Correlates in Response to Musical Stimuli," *Joint International Computer Music Conference / Sound and Music Conference* (2014); Grace Leslie and Tim Mullen, "MoodMixer: EEG-based Collaborative Sonification," *New Interfaces for Musical Expression* (2011); Mullen, Tim, Richard Warp, and Adam Jansch, "Minding the (Transatlanctic) Gap: An Internet-Enabled Acoustic Brain-Computer Music Interface," *New Interfaces for Musical Expression* (2011).

be understated, their specialization is beyond the more humanistic scope of this document.

Embodiment is a nascent interest in musicology. These efforts draw largely on the phenomenological writings on embodiment, many of which are ground in the work of Maurice Merleau-Ponty. His principal writings *The Phenomenology of Perception* (1945) and *The Visible and the Invisible, Followed by Working Notes* (1964) have influenced many philosophers, artists, and cognitive scientists. In contrast to René Descartes dualist separation of mind and body, Merleau-Ponty recognized that the body was not only a thing or a body part, but also the vehicle through which we experience the world.

Music scholars draw on this assertion by investigating how the experience of performing, listening, watching, or otherwise experiencing music can emphasize or encourage greater awareness of the world in an individual or community through the act of being mindfully present in the body. Scholars take many different angles and examine examples from different traditions, continents, and eras. Investigating the afro-Brazilian martial-art-influenced dance and music tradition Capoeira, Greg Downey considers how the embodiment of movement traditions — somatic familiarity – in audience listeners affects their understanding and engagement with the performance and practice of this art.[26] Jin Hyun Kim and Uwe Seifert examine the extended role of corporality in

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[26] Downey, "Listening to Capoeira: Phenomenology, Embodiment, and the Materiality of Music," *Ethnomusicology* 46, no. 3 (Fall 2002): 487–509.

algorithmic composition via gestural sound interfaces.[27] These diverse approaches have informed my own investigation of the body in EEG music and understanding of the relationship between embodiment and music.

Just as musicologists since the 1990s have evoked feminism, ecocriticism, Marxism, and other modes of criticism in their readings of musical works, investigations of the role of the body in musical works are increasingly prevalent in this field. Many authors rely on Merleau-Ponty in their varied approaches to a diverse repertoire of musics. In *Rhythm of Thought,* Jessica Wiskus invokes Merleau-Ponty's concept of "mythical time," a perspective on temporal perception which centralizes the body's participation in *creating* the "present" in her discussion of silence and musical repetition in Debussy's *Prélude à l'après-midi d'un faune*.[28] Blake Howe writes about Schubert's exploration of the body inhibited by disease in "The Allure of Dissolution: Bodies, Forces, and Cyclicity in Schubert's Final Mayrhofer Settings, drawing on Merleau-Ponty's notion of the body as the vehicle for all human experience."[29] Samuel Wilson draws on Merleau-Ponty's discussion of embodied technique in his analysis of "Srynade"

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[27] Kim and Seifert, "Embodiment: The Body in Algorithmic Sound Generation," *Contemporary Music Review* 25, no. 1/2 (February 2006): 139–149.

[28] Wiskus, *Rhythm of Thought* (Chicago: University of Chicago Press, 2013), 39–52.

[29] Howe, "The Allure of Dissolution: Bodies, Forces, and Cyclicity in Schubert's Final Mayrhofer Settings," *Journal of the American Musicological Society* 62, no. 2 (Summer 2009): 271–322.

by Helmut Lachenmann.[30] I draw on these authors' methodologies in my own discussions of the body in musical performance.

Because of their interest in musical experience, musicologists interested in embodiment emphasize performance – be it live or recorded – over traditional score analysis. As a result, many of these scholars employ performance analysis to evaluate the role of the body in a given performance. Although performance studies as an interest has its origins in theater and anthropology, musical performance analysis has been pioneered by scholars such as Nicholas Cook, Stan Godlovitch, and Philip Auslander.[31] I draw on these critical sources from performance studies for my case study.

In the related field of music cognition, an epistemological branch of systematic musicology, authors such as Mark Reybrouck, Marc Leman, and Lawrence Zbikowski suggest an experiential approach to music and art.[32] Discussion of embodiment in relation to specific styles of music or singular musician's work, embodied musical cognition has generated many papers and monographs in the last twenty years. Breaking from the

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[30] Wilson, "Building an Instrument, Building an Instrumentalist: Helmut Lachenmann's 'Srynade'," *Contemporary Music Review* 32, no. 5 (November 2013): 425–436.

[31] Cook, *Music, Performance, Meaning: Selected Essays* (Aldershot: Ashgate, 2007); Godlovitch, *Musical Performance: A Philosophical Study* (London: Routledge, 1998); Auslander, *Liveness: Performance in a Mediatized Culture,* (London: Routledge, 2008).

[32] Reybrouck, "Music Cognition and the Bodily Approach: Musical Instruments as Tools for Musical Semantics, *Contemporary Music Review* 25, no. 1/2 (February/April 2006): 59–68; Leman, *Embodied Music Cognition and Mediation Technology* (Cambridge, MA: MIT Press, 2008); Zibowski, *Conceptualizing Music: Cognitive Structure, Theory, and Analysis* (Oxford: Oxford University Press, 2002).

Cartesian-inspired disembodied study of the cognitive perception of musical structure, the study of embodied music cognition considers the role of the human body in the listening to and performance of music. These perspectives inform my identification of different strategies for the performance of EEG music and their implications on embodiment in the third chapter.

The works of Don Ihde, particularly the books *Embodied Technics* and *Bodies in Technology,* contribute greatly to my understanding of the relationship between technology and the body.[33] Francisco Varela, Evan Thompson, and Eleanor Rosch draw on Merleau-Ponty's fundamental assertion that we experience the world through our bodies and the practice of Buddhist mindfulness meditation to offer cognitive science a personal, experiential mode of observing the mind.[34] The book's critical exploration of the intersections between the embodied mind and Eastern philosophies allows me to contextualizes some of the observations made about the EEG by composers and public alike.

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[33] Ihde, *Bodies in Technology* (Minneapolis: University of Minnesota Press, 2002); *Embodied Technics* (Copenhagen, DK: Automatic Press, 2010).

[34] Francisco Varela, Evan Thompson, and Eleanor Rosch, *The Embodied Mind: Cognitive Science and Human Experience* (Cambridge, MA: MIT Press, 1993).

1.3 Methodology

In this thesis, I use several methodological approaches to shed light on Rosenboom's musical philosophy and his EEG work, the culminating piece Rosenboom's work *On Being Invisible* and its important implications in live electronic music and the relationship between the body and the performance of EEG music. Sensitive to language concerning the body, I analyze primary source material such as writings and interviews surrounding the performance of EEG in general and.Here, by referencing the ideas of Merleau-Ponty and Don Ihde, I intend to reveal the ways in which Rosenboom and others (Alvin Lucier, as a foil) consider the role of the body in EEG music performance.

In referring to the musical material of *On Being Invisible,* which is both a musical system and performance without a traditional score, I rely on a personal, subjective performance analysis of two recordings of the piece. Here, I draw on Phillip Auslander, who argues that recordings are not only artifacts of performances, but performances in and of themselves.[35] To offer the reader a representation of these recordings, I refer to figures containing waveforms created from the different performances in my performance analysis. Waveforms are more crude imaging representation of an audio recording than a detailed spectrographic analysis, which visualizes a recording's spectral anatomy; however, the present document is not concerned with laboriously revealing each

[35] Phillip Auslander, *Liveness Performance in a Mediatized Culture* (London: Routledge, 2008).

performance's particular sonic language, but rather the performer's potential to influence the dynamic creation of musical language.

1.4 Formal Structure

I divide this work into five chapters. The following chapter contextualizes Rosenboom's work by marking key innovations in the history of musical performance and improvisation with electronics and offer general insight into the practice of gestural data sonification or gestural sound control. Indeed, the aesthetic-philosophical bifurcation in time-based arts between practitioners of fixed media and those proponents of temporally indeterminate, interactive media has given shape to much of the development of electronic music from the 1960s onward. The work of Rosenboom and others discussed in this thesis overwhelmingly subscribe to the latter. Unlike composition which employs traditional Western classical instruments, an important characteristic of the instruments of live electronic music are their impermanent nature. Different iterations of musical instruments, which are a primary form of documenting the composer's efforts, may be represented in different recordings. Thus, understanding the performer > instrument relationship in electronic music is necessary for a deeper understanding the implications of *On Being Invisible*.

As well, technological innovations in engineering and the medical field provided composers with new tools for musical expression – in the case of these pieces discussed in this thesis, biosensors. In the second part of this chapter, I introduce a selective

taxonomy of sensors and provide modes of interpreting the meaning of these devices' data. Finally, I examine the electroencephalograph, surveying its history in both the medical and musical fields while offering some insight into the kinds of data it registers.

I introduce the concept of embodiment in chapter three and address various records of discussions about music using EEG between biofeedback composers and non-experts, and attempt to show a continuum of different attitudes towards the body in the performance of this music. Here I discuss principally the discourse surrounding the EEG experiments of both initial brainwave-pioneer Alvin Lucier as well as dedicated artist-researcher David Rosenboom, critically analyzing these composers' comments on their pieces, contemporary accounts of these experiments, and the artists' own writings, situating them within phenomenological contexts to show that the artists' own performance practices offer novel perspectives on the experience of embodiment in musical performance. To theorize these attitudes, I look primarily to the ideas of Merleau-Ponte and Don Ihde. Here I argue that Rosenboom, who has cultivated an extensive performance practice with the EEG, creates works in this genre which exhibit an awareness of the fluid relationship between mind and body .

In the fourth chapter, I present a case study of *On Being Invisible*. To begin, I provide contextualizing biographical information about Rosenboom and summarize his compositional output and philosophy. Then I offer comparative performance analyses of the two performances of the piece.

1.5 Terminology

In my thesis I use complex musicological terms as well as concepts from other disciplines. Some of them warrant clarification here. Under the umbrella term "electronic music" fall many concepts, often used interchangeably and misleadingly. Such terms as acousmatic music, electroacoustic music, musique concrète, elektronische Musik, computer music, club music, EDM, IDM often delineate sociological, political, and aesthetic differences. These terms imply a music which is fixed, which is to say it exists primarily as a recorded artifact performed by playback. My focus is on live electronic music, which points to electronically augmented musical *performance* by human or non-human agents (e.g. algorithm). Thus I limit myself to such terms such as live electronic music which describe accurately the process.

As live electronic music brings into question the Western concept of a work of art and conventional Western styles of composition, notation, musical parameters, including musical time, concepts such as composition and performance as process and musical improvisation are considered. Improvisation is a multifaceted and elusive concept and phenomenon. Many monographs, dissertations, and collections on improvisation in twentieth and twenty-first century musics have been devoted to investigating the manifold modes of improvisation, as well as its aesthetic, political, cultural, and spiritual

dimensions — most of which fall outside of the scope of this document.[36] Here, I discuss improvisation in relation to a performer's interaction with an electronic musical instrument and decision-making improvising systems. A piece involving performance with an interactive musical system or live electronic instrument is not unlike performance with traditional instruments; the actions of the performer may be deterministically may be rigidly set forth by a composer, or the performer may be simply left to discover for herself the embedded potentials of a system or instrument.[37] Naturally a given performance may fall between these two extremes, as many pieces in the tradition of live electronic music do, however most (including the piece centralized in chapter four) involve a great deal of what would be considered not-composed music. I further discuss these notions of improvisation in relation to Rosenboom's music in chapters three and four.

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[36] A few major contributions are Benjamin Piekut and George E. Lewis, *The Oxford Handbook of Critical Improvisation Studies,* vol. 1 and 2 (New York: Oxford University Press, 2012); Reinhold Brinkmann, ed., *Improvisation und neue Musik* (Mainz: Schott, 1979); Derek Bailey, *Musical Improvisation: Its Nature and Practice in Music* (Englewood Cliffs, NJ: Da Capo, 1980); Gabriel Solis and Bruno Nettl, eds. *Musical Improvisation: Art, Education, and Society* (Champaign: University of Illinois Press, 2009); Bruce Ellis Benson, *The Improvisation of Musical Dialogue: A Phenomenology of Music* (Cambridge: Cambridge University Press, 2003).

[37] Improvisation within the context of live electronic music has been dealt with in many contexts: Simon Emmerson, *Living Electronic Music* (Burlington, VT: Ashgate, 2007); Tim Perkis "Some Notes on my Electronic Improvisation Practice," in *The Oxford Handbook of Computer Music,* 161–166 (New York: Oxford University Press, 2009); Atau Tanaka, "Sensor-Based Musical Instruments and Interactive Music" in *The Oxford Handbook of Computer Music*, ed. Roger T. Dean, 233–257 (New York: Oxford University Press, 2009); George Lewis, "Interactivity and Improvisation," in *The Oxford Handbook of Computer Music,* ed. Roger T. Dean, 457–466 (Oxford: Oxford University Press, 1999).

The works of Rosenboom and other biofeedback musicians make varied use of the musical instruments which have come to be known as synthesizers.[38] As has been widely recognized, the term "synthesizer" is misleading. David Dunn suggests this "misnomer" may be due to industry-generated verbiage that purposed this technology strictly to the emulation of sounds of Western classical instruments.[39] Indeed, it was RCA's commercially produced instrument that was first called "synthesizer," which carried over to the unique instruments made by individual manufacturers such as Robert Moog and Donald Buchla. The synthesizer is an instrument in its own right, whose sonic morphology is no more "synthetic" than any other musical instrument's. Despite this inaccurate nomenclature, no reasonable alternative has been taken up by musicians or instrument makers. Thus I use the term synthesizer to describe generically this category of analog, voltage-controlled instruments, but will refer to specific makes and models of instruments when possible (e.g. Buchla 200 series Electronic Music Box, RCA Mark II, Moog 3P, etc.).

Biofeedback is a term Rosenboom has used to describe his experiments with brainwaves. The term is borrowed from studies in medicine and psychology wherein subjects are given some feedback based on an otherwise imperceptible bodily function,

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[38] Trevor Pinch and Frank Trocco, *Analog Days: The Invention and Impact of the Moog Synthesizer* (Cambridge, MA: Harvard University Press, 2002), 67.

[39] David Dunn, "A History of Electronic Music Pioneers," in *Classic Essays on Twentieth-Century Music: A Continuing Symposium,* ed. Joseph Darby, Richard Kostelanetz, and Matthew Santa, 106 (New York: Schirmer Books, 1996).

such as brain activity, heartbeat, or blood pressure. Lloyd Gilden writes that "studies have shown convincingly that subjects using some form of feedback can achieve significant increases in their alpha activity after several hours practice."[40] I use the term biofeedback to describe this feedback loop generically, and biofeedback music to describe music which utilizes this feedback loop as a dramatic element.

Lastly, I borrow from phenomenology the term embodiment, a complex phenomenon. I use embodiment to describe the experience or state of being present in one's own body. The term only emerged in Western philosophy in the later part of the 20th century, in the writings of such philosophers as Franz Brentano, Edmund Husserl, and Maurice Merleau-Ponty, but it has been applied in many disciplines. As a result, the term has taken on many meanings and may prove problematic in some contexts. My use of the term embodiment reflects my reliance on the work of several thinkers, including Merleau-Ponty, Varela, and Ihde, whose thoughts on embodiment inform the third chapters as well as the performance analysis in chapters four.

1.6 Significance and Contribution

Performers of live electronic music have utilized biosensors to craft unique musical instruments since the early 1960s. By in large however, the musicological

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[40] Lloyd Gilden, "Instrumental Control of EEG Alpha Activity with Sensory Feedback," in *Biofeedback and the Arts: Results of Early Experiments,* 27 (Vancouver: Aesthetic Research Centre of Canada, 1976).

literature has not addressed these novel approaches to act of musical creation from a somatic perspective. My thesis will fill this gap by focusing on one mode of technologically enabled musical interactivity: the EEG sensor, and will offer insight into the philosophical and scientific underpinnings of this music.

TWO. THE GHOST IN THE MACHINE: GESTURAL SOUND CONTROL AND THE ELECTROENCEPHALOGRAPH

2.1.1 Overview

Since the innovation of electric current and electrical engineering in the late 19th and early 20th century, inventors, engineerings, and musicians have experimented with ways of making music using these technologies. The worlds of analog and digital electronics have not only considerably expanded musicians' sonic palette, but they have also challenged instrument designers to reimagine the ways in which performers make music. The tradition of creating sensor-based electronic instruments for live performance largely aims to explore and achieve rich dimensions of expressivity, which can found in familiar, acoustic musical instruments, such as the cello, the zither, or the djembe. To the extent that the expressivity of a sensor-based electronic instrument may be understood as giving the performer robust, embodied control over the sound, this kind of expressivity may be referred to as gestural sound control. In the third chapter, I content that although Live electronic and performances contrast studio-based, composition-emphasizing practices of *Musique Concrète*, *elektronsiche Musik,* or modern-day electroacoustic music, wherein composers work off-line to create fixed-media sound pieces.[41]

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41 The use of these historic and robust studio-based practices as a foil to the pursuits of gestural sound control is not a condemnation of recorded music or fetishization of live, unmediated performance, but rather serves to distinguish the different aims of self-identifying communities which do not always overlap.

Although we might look more readily apply this term to between musical and instrument to electronic instruments, we might also consider the concept as a way of understanding the expressive relationships between musicians and acoustic instruments. In this chapter, I give a typology of various input sensors commonly used in the construction of electronic musical instruments and interactive sonic environments. At the chapter's core, I will delve deeper into the EEG, a specific type of biosensor. But first, I will discuss the live electronic music instrument and its design principles in relation to gestural sound control, since the concept is important to understanding the structure of the experiments addressed in later chapters.

2.1.2 The Anatomy of the Live-Electronic Instrument: The Meta-Instrument

Serge de Laubier coined the term "meta-instrument" as the name of his own electronic instrument, however, the term has been used by scholars and instrument creators to describe the generic ontology of an electronic instruments.[42] De Laubier's meta-instrument consists of an "musician-machine interface and a gesture transducer intended for electroacoustic music, multimedia work, and, more generally, for controlling

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[42] Daniel Trueman et al., "PLOrk: The Princeton Laptop Orchestra, Year 1," *International Computer Music Conference* (2006); Stefania Serafin and Matthew Burtner, "The Exbow MetaSax: Compositional Applications of Bowed String Physical Models Using Instrument Controller Substitution," *Journal of New Music Research* 31, no. 2 (June 2002): 131–140; Rebecca Fiebrink, Dan Trueman, Perry R. Cook, "A Meta-Instrument for Interactive, On-the-fly Machine Learning," *New Interfaces for Musical Expression* (2009).

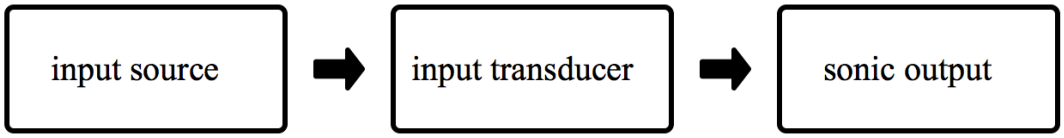

Figure 1. Sonic instrument ontology

algorithms in real time."[43] From this description, we can isolate three distinct entities: the human, the interface, and the media engine (see figure 1). Indeed, this high-level model may be used to understand both electronic and acoustic musical instruments. This understanding is systems-based. Applied to an acoustic instrument, the violinist and the violin can be understood independently as complex, self-regulating systems: glue holds the sides together with the front and back, acting in tandem with the sound-post to keep the instrument from collapsing in on itself from the tensions of the string . . .; the violinist has a skeleton which provides his or her body with structure, etc. The two systems couple to create a more complex system (an experience, an action) with multitudinous streams of feedback, input, etc. The present discussion of electronic instruments leverages this understanding of systemic relationships in its overview of the anatomy of electronic instruments: input source (agent), input transducer (interface), and media output (sound).

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[43] de Laubier, "The Meta-Instrument," *Computer Music Journal* 22, no. 1 (Spring 1998): 25; de Laubier and Vincent Goudard, "Meta-Instrument 3: a look over 17 years of practice," *New Interfaces for Musical Expression* (2006).

2.1.3 Principles of Data Sonification

Gestural sound control draws on data sonification, a broadly defined compositional technique which falls under the multimedia practice of transcoding. In principle, transcoding is the practice of translating information contained in one media to another, for instance: audio to video, video to light(ing), light(ing) to audio. This practice

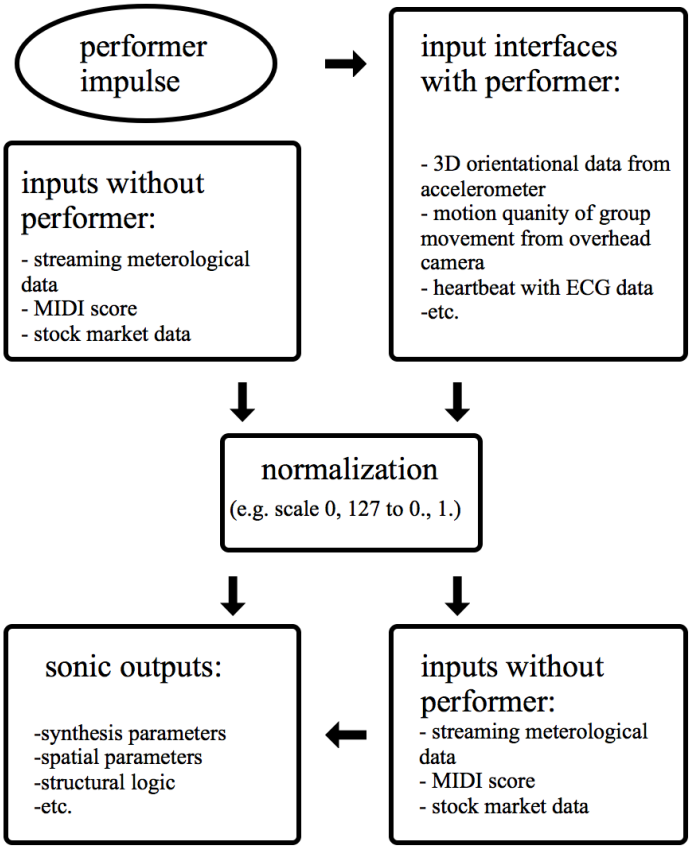

Figure 2. Digital Implementation of Data Sonification

is made possible by the materiality of data as manifest in the various numeric protocols which underly these media.[44]

Numeric protocols also underly traditional organizational hierarchies in Western musical, such as set theory, scale degrees, frequencies, and intervalic ratios; digital technologies have embraced this numeric gold standard, designating the digital computer as a hub which translates between media. Composers and sound artists often draw on this phenomenon to create different musical genres such as sound installations and electroacoustic musics.

Artists like German experimental film maker Oscar Fischinger and Hungarian painter and photographer László Maholy-Nagy first experimented with crude ways of sonification, such as painting onto film soundtrack and hand-etching grooves into LP records.[45] This laid the groundwork for later artists from the 70s onward, who embraced "big data" as artistic material. In the pioneering work *Earth's Magnetic Field* by composer Charles Dodge and scientist Bruce Boller, the Earth's average magnetic activity is mapped to sonic parameters. Dodge's description of this process is illustrative

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[44] In digital imaging, still or moving images are made up of a matrix of color cells called pixels whose individual hue is determined by a list of three numbers: the amount of red (0-255), green (0-255), or blue (0-255). Digital Multiplex 512 (DMX512), a theatrical lighting protocol developed for theaters, allows for multichannel control of the brightness (0-255) of up to 512 individual lights (theatrical or otherwise). In music technology, MIDI protocol (0-127) and Open Sound Control (floating point 0. - 1.) allows for the control of many musical parameters.

[45] Florian Dombois and Gerhard Eckel, "Audification," in *The Sonification Handbook,* ed. Thomas Hermann, Andy Hunt, and John G. Neuhoff, 301–333 (Logos Publishing House: Berlin, 2011)..

of offline sonification practices: “The musical interpretation consists of setting up a correlation between the level of the Kp reading and the pitch of the note (in a diatonic collection over four octaves), and compressing the 2,920 readings for the year into just over eight minutes of musical time.”[46] Data sonification also includes the direct translating of digital sample files into auditory playback (as in CD or Mp3s).[47]

Data sonification in fixed media works is similar to gestural data sonification, with the exception that offline or streaming data sets is replaced with real-time sensor data. Figure 2 shows both inputs with and without performers. While data sonification is generally considered as an exclusively digital practice, the transformation of input data into a sonic output can be implemented using both analogue and digital technologies.

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[46] Charles Dodge, *Earth’s Magnetic Field*, Nonesuch records, 1970, liner notes.

[47] Dombois and Eckel, “Audification.”

2.2 The Keyboard as Interface: A Legacy in Black and White

2.2.1 Acoustic Analogues: Interface Expressivity in Traditional Keyboard Instruments

Like electronic instruments, an acoustic instrument's expressivity is determined by performer impulse (agent > interface > sound engine).[48] Indeed, examining some acoustic instruments shows the critical influence an interface plays in an instrument's design. Below, I parse the expressivity of the interfaces of several historical keyboard instruments. An examination of keyboard instruments is especially relevant to the discussion of electronic instruments, as many early synthesizers inherited the black/white keyboard manual as their primary interface.

The plectrum mechanisms of keyboard instruments such as the harpsichord, the virginal, the clavicytherium, and the spinet decidedly fixes the instruments' sonic morphologies. Despite any variance of velocity in the depression of a key, a consistent, generic attack is triggered. The duration of the sound's envelope is a function of the string's acoustical properties; the performer has no control over when the sound will end.

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[48] Mulder, "Virtual Musical Instruments: Accessing the Sound Synthesis Universe as a Perfomer," *Brazilian Symposium on Computer Music* (1994); A concession to this claim must be made for the human body itself, which has many modes of making music. Because of its independence from external tools, we understand the relationship between body and instrument differently than with a violinist, for example. As such the human body can surely be said to be the most accessible of all instruments to play. The human voice is often theorized to be among the first tools utilized by humans for musical expression. Use of the human body as a percussion instrument is also common, as seen in the *palmas* (handclaps) of Andalusian flamenco music, the Juba dance of West African origin (which evolved into the African-American patin' juba or hambone), and the Indonesian *saman.* Body percussion finds also finds expression in Western music, such as the piece *?Corporal* by Vinko Globokar, or in popular performers such as Keith Terry or the group Stomp.

Thus, the instrument's timbre is a function of intervalic and rhythmic combination. Electronic musical instrument engineering refers to this type of haptic control as *discrete,* as opposed to *continuous.*[49] While the single manual instruments of this family offer only these timbral possibilities, more elaborate instruments feature two manuals. With these instruments, pulled stops create doublings at the octave, reinforcing its partials and augmenting its volume.[50] This type of timbral control is also *discrete*; the performer may choose only doubled or un-doubled timbre.

The Romantic pipe organ, as popularized by French organ maker Artistide Cavaillé-Colle (1811–1899), features a remarkably wide palette of pipe ranks, which avails performer and composer with timbral possibilities unprecedented in keyboard instruments. However, despite the myriad sonic combinations, this type of control is still as *discrete* as with the harpsichord; smooth transitions between timbres are not possible.

However, a now ubiquitous feature on organs originating in English organs in early 18th-century is the swell division, which provided continuous change in dynamics

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[49] This references the contrasting principles of discrete and continuous data. In discrete sound control, a gesture triggers a sound event (such as the onset of a sample), whereas continuous sound control offers the performer real-time control over the sound's envelope and timbre.

[50] This technique is the acoustic analogue to additive synthesis, the well-known procedure in electronic music, wherein multiple oscillators are orchestrationally combined at various intervals in order to create a rich harmonic timbres. This is also the case with organ registrations, which combine different ranks of pipes to create different timbres.

for some pipes.[51] Usually delegated its own manual, the swell is a rank of pipes contained within a large, wooden box called the swell box, which serves to soften pipes' sound in volume and timbre. The performer controls a set of doors on the swell using a foot pedal, giving the performer a larger spectrum of dynamics. We might say then that the performer has discrete control of envelope (though duration can be controlled by leaving the key depressed), *discrete* control over timbre, and *continuous* control over the volume of pipe ranks in the swell box.

In contrast to the plectrum-mechanism and wind-controlling keyboard instruments, the clavichord – famously the favorite keyboard instrument of pre-Classical composer C.P.E. Bach– employs a hammer mechanism, which results in a markedly different timbre than plectrum-action instruments. In this configuration, the attack velocity of the hammer is directly controlled by the velocity of the key's attack. Though this offers two dimensions of expression (what note and how loud), it is still discrete. However, the mechanical peculiarity of this mechanism allows for a unique mode of continuous expression; the hammer remains in contact with the string after attack, allowing for the tactile manipulation of the vibrating string by way of the depressed key. The results in subtle, *continuous* control over the string's frequency (known as vibrato in Western musical traditions). This expressive musical effect provides a degree of haptic gestural sound control, a novel feature amongst historical keyboard instruments.

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[51] Stephen Bicknell, "Organ Construction," in *The Cambridge Companion to the Organ*, ed. by Nicholat Thistlethwaite and Geoffrey Webber, 25 (Cambridge: Cambridge University Press, 1998).

The above examples illustrate that these instruments provide different modes and ranges of expression. Plectrum-mechanism keyboard instruments might be said to afford the least haptic expression. Although the clavichord might be praised for providing the most expressivity for tactile control of timbre, we might note that this control is *only* tactile and isolated to parts of the body involved in the depression and articulation of the manuals or pedalboards. The Romantic organ provides the widest palette of textures, but these can only be accessed discretely.

However, the above descriptions do not account for extended techniques which could be applied to the instruments. One could prepare a harpsichord in the manner of John Cage's experiments with the pianoforte, or manually excite the strings under the instrument's lid as Henry Cowell did with his stringed piano. Organs with mechanical key and stop action can also be exploited to supply pipes with less than the standardized amount of air, resulting in rich, interesting sonorities — however one does not have any wide range of control over how much air is supplied.[52] These approaches drastically augment the instruments' sonic ranges and introduce many variables of control and illustrates how important the interface is an intermediary *between* performer and instrument.

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[52] Two contrasting and notable examples of expressive extended techniques for organ can be found in György Ligeti's piece *Volumina* and Keith Jarrett's 1976 improvisations on the Baroque Trinity organ at the Benedictine Abbey in Ottobeuren, Germany, recorded on the album *Hymns/ Spheres,* ECM Records, 1976 LP.

2.2.2. Second Verse, Same as the First: The Keyboard in Early Electronic Instruments

Edward Varèse (1883–1965), an avant-garde composer of both acoustic and electronic musics, is often quoted as having prophetically supplied the compositional motivation for the electronic musics early in his career ("I dream of instruments obedient to my thought and which with their contribution of a whole new world of unsuspected sounds, will lends themselves to the exigencies of my inner rhythm"[53]). Although many composers were enchanted by the possibility of breaking the constraints of tradition, many early electronic musical instruments retained the familiar 7-white/5-black keyboard which dates back to Halberstadt in 1361.

Besides the theremin and the Ondes Martenot (which articulates pitch either discretely by keyboard or continuously via a slide mechanism), the keyboard is quite ubiquitous in the history of electronic-musical instruments.[54] The persistence of the keyboard is evident given the sheer number of keyboard-electronic instruments in the 1920s and early 1930s: the Electrophori (1921), the Staccatone (1923), the SuperPiano (1927), the Dynaphon (1928), the Ondes Martinet (1928), the Givelit (1929), the Trautonium (1930), and the Mixtur Trautonium (1932). As Overholt observes in these examples, the keyboard interface — not the sound-producing, electronic circuits

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[53] Edgard Varèse,"391," *391* no. 5 (June 1917), trans. Louise Varèse.

[54] Overholt, 17.

themselves – limits the performer to controlling only when a note sounds and when it does not.[55]

With the development of the commercial synthesizer through the 1950s, 60s, and 70s, the keyboard became an industry standard, despite alternatives offered by experimental musicians and progressive instrument builders.[56] Within months of each other, Donald Buchla (b. 1937) and Robert Moog (1934–2005) independently developed the first voltage-controlled synthesizer modules.[57] Buchla's instrument, the Buchla 100 Series Electronic Music System, was finished in 1964 and Moog's was completed in 1965. Still today, the companies they founded continue to be the most widely regarded and revered in the production of synthesizers. Although developed independently, both of their creations are remarkably similar in design; they both embraced a modular approach which used patch cables to combine the various sound production and manipulation components. These innovators' stance on their instruments' control and performance interfaces is what set them apart, however.

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[55] Ibid.

[56] Elements of these commercial synthesizers had been produced for principal electronic music centers of Europe, mostly by Harald Bode and Hugh LeCaine. These oscillators, filters, and ring modulators were prototypical to the innovations of Robert Moog and Donald Buchla, namely voltage control, in which electrical voltage is used to control the frequency of an oscillator or a filter.

[57] Morton Subotnick, Ramon Sender, and Maggi Payne, "The Genesis of the Buchla 100 Series Modular Electronic System," in *The San Francisco Tape Music Center: 1960s Counterculture and the Avant-Garde,* ed. David W. Bernstein, 166–167 (Berkeley: University of Berkeley Press, 2008).

Funded by grant from the Rockefeller foundation for $500, Morton Subotnik and Ramon sender commissioned Buchla to build the Buchla 100.[58] The Buchla 100 was unique in that it contained the first sequencer, a module programmable to produce patterns of voltages. These voltages can be routed to control different parameters involved in the synthesis process, such as frequency of an oscillator or a filter. It also featured a random voltage generator and a touch-sensitive plate interface (the Buchla 112 and 113), which could be tuned to a chromatic scale or any other frequency combinations. Subotnik intended to house the instrument at his studio, the San Francisco Tape Music center, a non-profit with countercultural leanings founded to support the development of experimental electronic music.[59] Sender was interested in retaining the keyboard to make the instrument more accessible. More interested in musical timbre than remediating traditional musical structures such as melody or harmony, however Buchla and Subotnik wanted to explore the synthesizers' nuances unencumbered by the keyboards' limitations. Buchla made his own opinion clear on many occasions; he considered pairing his synthesizer with a keyboard to be "unnatural".[60] Buchla did not

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[58] Robert Willey, "Don Buchla," in *Encyclopedia of Recorded Sound,* ed. Frank Hoffman, 292 (London: Routledge, 2004).

[59] Subotonik recorded "Silver Apples of the Moon," the first piece to be commissioned for long-play record.

[60] Donald Buchla, Maggi Payne, and David W. Bernstein, "Don Buchla," in *The San Francisco Tape Music Center: 1960s Counterculture and the Avant-Garde,* ed. David W. Bernstein, 163–177 (Berkeley: University of Berkeley Press, 2008).

produce a keyboard for his original system and never intended for his system to be equipped with them.[61] As a result, his systems were regarded by popular and rock musicians as esoteric and his name came to be synonymous with the experimental avant-garde. Despite their aversion to catering to mainstream consumers, Buchla's company Buchla and Associates, has kept the doors of Buchla's home office in Berkeley open since the 1960s, continuing to produce high-quality synthesis modules and systems.

Robert Moog, who was foremost an electronics expert and instrument designer, was less interested in upholding experimentalist philosophies through instruments. He did however sympathize with their motivations; Vladimir Ussachevsky shared with Moog the views of experimental and academic composers and their negative sentiment towards the keyboard.[62] However, Moog sided with the people around him, such as composer Herb Deutsch (b. 1932), tubist and synth pioneer Walter Sear (1930–2010), electroacoustic music pioneer Eric Siday (1905–1976), and Wendy Carlos (b. 1939), who saw the keyboard as a requisite for their own creative process as well as the future of the instrument. Indeed, early publicity about the Moog synthesizer prominently featured keyboard interfaces with the modules, cementing its identity in public mind as a keyboard

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[61] However, Buchla co-designed a computer-assisted digital instrument with David Rosenboom in the late 1970s called the Touché which featured a keyboard. They intended to draw on and adapt virtuosic keyboard technique to the synthesizer. The Touché was adapted to take input signals from percussion instruments for Rosenboom's piece *Zones of Influence* (1984).

[62] Pinch and Trocco, *Analog Days: The Invention and Impact of the Moog Synthesizer* (Cambridge, MA: Harvard University Press), 60; Ussachevsky contributed to the design of RCA's Mark II synthesizer, a predecessor to Buchla and Moog's solid-state instruments which was housed at the Princeton-Columbia Electronic Music Center.

instrument.[63] Moog's integration of the keyboard into later portable single-unit models accounts for his instruments' massive commercial successes over the years. Conversely, Buchla's adherence to his experimental sensibilities ensured both his cult-status in experimental circles and his relative obscurity among popular musicians.

2.3 Beyond (and Between) Ebony and Ivory: Alternative Input Modalities

Artists have exploited an enormous range of technologies to develop interfaces beyond the keyboard which emphasize the many kinds of physicality of performance. In these explorations, artists often look to create the most meaningful relationship between performer (human) and instrument (output). Axel Mulder's typology of sensor modalities delineates three (not mutually exclusive) categories: outside-in, inside-out, and inside-in.[64] These modalities are often employed in genres and contexts such as interactive dance, interactive installations, and electronic instrument design. Rather than attempt a historical overview of the application of all of these sensors, I draw and expand upon sensor taxonomy described Mulder in order to show some examples of the wide range of possibilities for creating complex input streams for sound instruments.

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[63] Ibid.

[64] Axel Mulder, "Human Movement Tracking Technology," Report 94-1 of the Hand Centered Studies of Human Movement Project (Burnaby, British Columbia, Canada: Simon Fraser University, 1994), accessed December 1st, 2014, http://www.xspasm.com/x/sfu/vmi/HMTT.pub.html.

Inside-out technology communicates information about the relationship between the sensor and the world. These can be worn on the body, or embedded in a physical interface. An advantage of these sensors is that their area of functionality is not limited by the spatial constraints of an external tracking system, though their respective wireless protocol imposes a range to varying degrees. Due to the logistics of outfitting the wearer with these sensors, these are generally used in performative settings, rather than in installations.

One example of an inside-out sensor is the magnetic fluxgate compass or the magneto resistive compass, which provide two-dimensional cardinal orientational data in relation to the Earth's magnetic field. Other inside-out sensors include multi-axis inertial measurement units (IMUs), such as gyroscopes and accelerometers, which communicate three-dimensional, locational information. When placed on the body, they are generally placed on larger parts such as forearm, upper arm, torso, or head as opposed to fingers or toes. Multiple sensors make possible calculation of joint-axial rotational data.

Formerly cost-prohibitive, these technologies are becoming increasingly affordable thanks to hardware-software platforms like Arduino, which have been largely embraced by the maker movement, interactive media, and instrument design. These sensors are somewhat obtrusive; their size and sometimes fragile nature inhibits the wearer of movements which might damage the device or injure the wearer (such as rolling on the floor). However, these sorts of sensors are becoming increasingly available in low profile (but as of yet, fragile) designs which may be stitched into textiles. In

pursuit of other resourceful, low-cost sensors, app developers and media artists have also developed tools to read accelerometers and gyroscopes inside commercially available products like Nintendo WiiMote controllers and smart mobile devices, making these sensors affordable and accessible.[65] Another inside-out approach is to use bluetooth devices equipped with signal strength indicators (RSSI) to roughly estimate the proximity between two devices.

Outside-in sensing methods read the movement within a given space and generally rely on the analysis of live video data from one or many cameras, a technique borrowed from the field of computer vision. Often, to accommodate cameras sensitive to infrared light, additional infrared is cast on the subjects to normalize the image. In computer vision, several analysis techniques can be utilized to find different types of motion in different settings. Analysis can show the location of fiducial markers placed on a body or object. Computer logic can determine what is moving in comparison to a static background. Frame differencing, blob tracking, feature matching, and centroid location are computer vision techniques for seeing movement which can serve as an input into a sonification instrument.

Outside-in devices are used in interactive, public installation settings as well as interactive dance and performance, but do not find themselves often associated with new

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[65] At the time of writing, pre-owned WiiMotes cost just $24.99 from corporate video game retailer GameStop (www.Gamestop.com). The Pew Research Center published a study in 2013 which concluded that 56% of US Americans owned smart phones; Aaron Smith, "Smartphone Ownership 2013," *PewResearch Internet Project* June 5, 2013, accessed December 13, 2014, http://www.pewinternet.org/2013/06/05/smartphone-ownership-2013/.

musical instruments. Microsoft's Kinect camera, which emerged as an air-controller for their Xbox video game system in 2010, pairs a RGBA camera and an IR camera. These cameras track 24 points of the body in real-time, recreating a three-dimensional skeletal model. This inexpensive camera and robust camera is often used in interactive dance and media installations.[66]

Complex 3D motion-tracking systems, made by companies such as Xsens or ProMove 3D, use a large array of cameras to track the movement of fiducial sensors worn on the body within a finite three-dimensional space. Movement analysis specialists, CGI animators rely on these systems for recording high-resolution movement data, but such powerful technology has also attracted many media artists.[67]

Electromagnetic field poles, most recognizable in Leo Theremin's instrument, were popularized by Robert Moog in the United States in the 1950s. Moog Music Inc continue to be among the largest and best-respected manufacturer of theremins. Moog also created the twelve poles used in John Cage's *Variations V* (1965) as well as the human-sized poles developed by Robert Moog for Joel Chadabe's *Solo, for theremin* (1979).

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[66] Min-Joon Yoo, Jin-Wook Beak, In-Kwon Lee, "Creating Musical Expression using Kinect," *New Interfaces for Musical Expression* (2011).

[67] Frédéric Bevilacqua, "Virtual Dance and Music Environment Using Motion Capture," *IEEE Multimedia Technology and Applications Conference* (2001).

Inside-in technology encompasses many on-body sensors, but do not provide locational information like those in the inside-out category. Some examples of inside-in technology are pressure sensors, like those used in Troika Ranch's seminal MIDIdancer suit (1997). Biosensors may also be considered inside-in sensors.

Indeed, biosensors peer into the invisible, undetected, or unconscious rhythms of the human anatomy. Manfred L. Eaton describes the seven principle types of physiologically activated gestural sound controls: the Galvanic Skin Response (GSR), the Electrocardiogram (ECG or EKG), the Electroencephalogram (EEG), the Electromyograph (EMG), Eye Movement Potentials, blood pressure, and respiration.[68] Not surprisingly, these kinds of biosensors were originally used in medical applications, falling into a large category of "borrowed sensors", discussed by Daniel Overholt.[69] Since the 1960s, biosensors have held an allure amongst artists since the 1960s for their potential to manifest externally the internal.

At first, applying the concept of "gestural sound control" to biosensors might seem strange. Indeed, activating or engaging most of these sensors requires no visible physical exertion — a basic condition for activating any of the sensors above. Although this is one understanding of gesture, it is also discussed in relation to human-computer

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[68] Eaton, *Biomusic,* 7–8 (Barton: Something Else Press, 1974).

[69] Overholt, 131–140.

interaction, speech, linguistics, and sign language, as well as more abstractly in music.[70] More broadly, we may understand gesture as either corporeal and non-corporeal. While embodied gesture in a corporeal context suggests movement, non-corporeal gesture may be understood as an abstraction. Gestural sound control seeks to link embodied gesture with abstract, musical gesture. I argue that, despite the lack of observable motion, the trained and conscious production of brainwaves is an embodied action taking place throughout the human nervous system and should thus be understood as a corporeal gesture. Thus, the sonification or transcoding of these electrical impulses is an effort to extend this physical gesture into musical, poetic gesture.

2.4 The Electroencephalograph: Technical and Musical Histories

In 1929, German scientist Hans Berger first published a paper documenting his methods and observations of his pioneering experiments with *das Elektrenkephalogramm.*[71] In this ground-breaking paper, he described for the first time alpha and beta brain waves – electrical activity in the brain. Alpha waves are periodic, sinusoidal rhythms with a frequency of approximately 10hz, whereas beta waves are

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[70] Cadoz, Claude and Marcelo M. Wanderley, "Gesture - Music," in *Trends in Gestural Control of Music,* eds. M.M. Wanderley and Michael Battier, 71–94 (Paris: IRCAM Centre Pompidou, 2000).

[71] Among his initial subjects was his own 16-year-old son, Klaus.

desynchronized.[72] With needle electrodes implanted in the subject's head, Berger was able measure EEG fluctuations in voltage caused by ionic currents within the brain's neurons. Berger observed that alpha waves were produced when the subjects' eyes were closed, and disappeared when their attentions returned to their external visual stimuli. Berger suggested these curious rhythms seemed to be originating from the brain itself.

Attempts to sonify brainwaves in musical or non-musical contexts began soon after Berger's innovation. Indeed, as early as 1934, E.D. Adrian and B. H. C. Matthews wrote that in their experimentations with EEG which built on Berger's work, they sonified alpha waves.[73] Evidently, in an even earlier example, an inventor submitted a strange contraption to the US patent office which proposed to transcode alpha brain waves into a control signal for a player piano — a claim which the office rejected.[74] Another early experimenter in this field was Italian pianist and composer Franco Evangelisti. Trained as an electrical engineer, began researching biophysics in an attempt to sonify brain impulses while working at the Studio of Experimental Electroacoustics of UNESCO in Gravesano, Switzerland as early as 1957.[75]

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[72] David Millett, "Hans Berger: From Psychic Energy to the EEG," *Perspectives in Biology and Medicine* 44, no. 4 (Autumn 2001), 522–542.

[73] E. D. Adrian and B.H.C. Matthews, *Brain* 57 (1934): 355–385.

[74] Ibid.

[75] Thorsten Wagner, *Franco Evangelisti und die Improvisationsgruppe Nuova Consonanza. Zum Phänomen Improvisation in der neuen Musik der sechziger Jahre* (Saarbrücken: Pfau 2004).

Meanwhile throughout the mid-twentieth century, great strides were made in the field of EEG studies. Since Berger's 1929 publication, a total of six main groups of brainwave frequencies have been identified in humans (many other types have been found in other mammals). These groups are defined by frequency and in most cases are not associated with a specific physiological mechanism in the brain. This typology, which first emerged in 1974, is more a loose set of characteristics than it is a set of rigid categories.[76] Berger established the naming convention of using Greek letters with his discovery of Alpha waves (~8.5Hz–12 Hz), which are produced when the brain engages an attentive, non-visual state, and Beta waves (12.5 Hz–30 Hz) are associated with anxious or concentrated mental activity and are desynchronized as mentioned above. Discovered by W. Grey Walter in the 1930s, Delta waves (.5 Hz–2 Hz) are produced during deep sleep, i.e. the third stage of REM. The brain produces sensorimotor rhythms (12 Hz–16 Hz) when it is in a state of physical stillness and embodiment. Gamma waves (30 Hz–80 Hz) are produced as a result of fast-paced mental processes such as acute concentration and elevated consciousness. In the company of more ethereal states of mind, such as trances, hypnosis, lucid dreaming, and the space between waking and sleeping, the brain produces Theta waves (4.5–8 Hz).[77]

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[76] György Buzsaki, *Rhythms of the Brain* (Oxford University Press: Oxford, 2006), 129.

[77] Simon Emmerson, *Living Electronic Music* (Aldershot: Ashgate, 2007), 139–140.

After World War II, scientists made technological developments which yielded more accurate ways of visualizing or sonifying EEG data, improving upon mechanical pen recorders or oscilloscopes.[78] In these cases, digital implementations of the EEG utilized the Fast Fourier transform to allow for spectral analysis of different brain wave signals. This important innovation, called the quantitative electroencephalograph (QEEG), provided richer and more nuanced data from a more portable, reliable machine.[79] It also allowed for the observation of Gamma waves, since pan-arm analog EEG recording apparatuses could only register frequencies of about 25 Hz and slower.[80]

Beginning in 1965, Lucier's experiments with *Music for Solo Performer,* were the most developed, artistically oriented ventures to date and paved the way for further artistic exploration of the EEG. It is often considered to be the first piece to sonify EEG data; James Tenney wrote a similar piece completely independently which was never performed called *Metabolic Music* (1965) just six weeks after Lucier's premier.[81] Some

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[78] Eaton, *Bio-Music*, 3.

[79] Barbara E. Schwartz, "The advantages of digital over analog recording techniques," *Electroencephalography and Clinical Neurophysiology* 106, no. 2 (February 1998): 113–117.

[80] György Buzsaki, "Cycle 9, The Gamma Buzz," in *Rhythms of the Brain* (Oxford: Oxford, 2006).

[81] Kahn, 278.

of the first to pick up from Lucier were Richard Teiteblaum and David Rosenboom.[82] Teitelbaum shared his approach to brainwave sonification with Rosenboom; Teitelbaum worked with brainwaves as control voltage for synthesizer modules. In the late 1960s, Teitelbaum first explored this mode of gestural control in his activities with the Rome-based experimental improvisation group Musica Elettronica Viva (MEV), which can be heard in the piece *Spacecraft* (1967). In a text devoted to his experiments with EEG, Teitelbaum discusses personally his experiences with the practice, writing lucidly about an anecdote of shared consciousness which inspired his solo brainwave piece, *In Tune.*[83] Although not as extensively documented as Rosenboom's work, Teitelbaum also approaches this endeavor from the perspective of an arts research un-afraid of blending "subjective" experience with "objective" science.

Another early pioneers of artistic applications of the EEG sensor is Manfred Eaton. Based at the ORCUS Research Center in Kansas City, Eaton began experiments in 1960 with sensory feedback which he called "Bio-Music." Eaton's experiments encompassed not only brainwave-sonification, but also mediated interpretations of pulse, breath, galvanic skin response, and blood-flow volume.[84] Eaton's writings theoretically

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[82] As a landmark piece in EEG sonification, Lucier's EEG piece is one of the subject of my discussion of embodiment in the third chapter.

[83] Richard Teitelbaum, "In Tune: Some Early Experiments in Biofeedback Music," in *Biofeedback and the Arts: Results of Early Experiments,* ed. David Rosenboom, 35–56 (Vancouver: Aesthetic Research Centre of Canada, 1976).

[84] Manfred L. Eaton, *Bio-Music* (Barton, VT: Something Else Press, 1973).

described a sensor-driven interactive system with embedded logic, which would enable the instrument to illicit sonic responses to musical input which would attribute a perceived, anthropomorphic intelligence to the system. After being exposed to Eaton's work at an electroacoustic music conference in Florence, Italy during the summer of 1968, Finnish electroacoustic music artist and developer of several novel control interfaces for modular synthesis Erkki Kurenniemi (b. 1941) developed an EEG interface to begin his own experimentations with brainwaves, DIMI-T, which maps the frequency of the performer's alpha waves to an oscillators frequency.[85]

2.5 Conclusions

Gestural sound control describes the ontology of live electronic instruments sensitive to gesture, in a facile sense, be understood as the complex relationship between the body, the input transcoder, and the (sonic) output. This practices draws on the many available input sources which offer different kinds of information about movement. Biosensors reveal to musicians movement data on a much smaller scale, providing insight into the nuances of the beating of the heart, the various kinds of brainwaves. As such, we may consider biosensors too as a type of gestural sound control. The electroencelpalograph

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[85] Mikko Ojanen, Jari Suominen, Titti Kallio, and Kai Lassfolk, "Design Principles and user interfaces of Errki Kurenniemi's Electronic Musical Instrements of the 1960's and 1970's," in *New Interfaces for Musical Expression*, 2007, 88–93.

has proven to be a popular source of inspiration for musicians looking to explore this physiological microrhythms.

THREE. EEG, EMBODIMENT, and TECHNOFANTASY

3.1 Elusive Embodiments: Defining the Buzzword

The discussions of EEG and gestural sound control in the previous chapter suggest this question: what is the role of the body in the performance involving EEG? What I investigate in this chapter is how composers and other observers perceive the EEG sensor, and what such receptions suggest about the EEG as a controller of sound with its own embodied, somatic performance practice. Since the first substantial wave of experiments in sonifying EEG during the 60s and 70s, the non-expert public has speculated about the possibilities of an EEG musical or artistic instrument, suggesting that ontologically simple experiments such as sonifying alpha waves might be lead to excavation of untapped musical imaginations or subconscious musicalities.

Such speculation suggests cognitivism, a theory of mind which stemmed from cybernetics. Cognitivism explains human cognition as computation, wherein symbols are understood as stand-ins for phenomena like numbers and acted upon according to pre-configured symbol definitions and rules.[86] Many thinkers approaching theories of mind from a phenomenological stance are quick to point out, cognitivism does not account for consciousness or experience. As such, such fantasies about musical applications of the EEG fail to observe the device's limited abilities; the EEG merely indicates the physical materiality of brainwaves, the presence or absence of this corporal gesture. Thus, such

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[86] Varela, Thompson, and Rosch, *The Embodied Mind: Cognitive Science and Human Experience* (Cambridge, MA: MIT Press, 1991), 40–43.

fantasies seem to equate the perception or imagination of musical logic with computational processing, undermining the role of the body in the musical experience, which many point to as the primary mediator of musical experience.[87]

As well, many performances using EEG suggest an alternative paradigm which embraces this theatrical view of the mind, exemplified by the characterization of music using EEG as an interface to control software of hardware synthesizers as "brain music." However, I contest that the performers of this music are – regardless of discourse – profoundly engaged with their own *embodied experience*, despite the perhaps impulsive tendency to associate a *disembodied experience* with this mode of musical performance.

In this chapter, I will first give a brief overview of Merleau-Ponty's two senses of embodiment, which are important to understanding the ways in which art or music promotes or distracts from an engagement with this worldview. Continuing, I also relate Don Ihde's concept of the technofantasy, which is a helpful way to characterize imaginings of technological possibility which idealize a disembodied interaction between humans, technology, and their environment. I will go on to look at some of the discourse surrounding musical experiments with the EEG in order to parse out what suggests cognitivism and what points to a more embodied view of human in-the-loop systems such as the EEG musical instrument. I take a close look at Douglas Kahn's analysis of Alvin

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[87] Marc Leman, "Musical Gestures and Embodied Cognition," *Actes des Journées d'Informatique Musicale* (May 2012): 5–7.

Lucier's seminal *Music for Solo Performer,* which argues that the piece exemplifies both the ethos of cybernetics and Cold War science as well as the experimentalism of Cage.[88]

Indeed, during the Cold War, generally defined as spanning from the end of World War II until the fall of the Soviet government, US and Soviet governments oversaw the expansion of state funding to scientific research. In an era ushered in by the United State's bellicose application of nuclear fission and escalated by the Soviet launch of the satellite Sputnik in 1957, both the US and Soviet governments competed not only in the realm of arms development; these state-sanctioned efforts were mirrored in education and the arts. The CIA infamously sponsored cultural events such as the International Conference of Twentieth Century Music in 1954 to tout and appropriate avant-garde music as a symbol of Western cultural freedom.[89]

I will also look to documents authored by Lucier himself to investigate the language he uses to describe his piece and the EEG. I draw on Kahn to show that Lucier is primarily interested with non-narrative dramaturgy driven by experiment as performance, which Kahn interprets as a Cageian aesthetic.[90] Here I intend to riff slightly on Kahn's analysis, suggesting Lucier's piece embraces a subtly cognitivist view of

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[88] Kahn, "Alvin Lucier: Brain Waves" and "Edmond Dewan and Cybernetic Hi-Fi" in *Earth Sound Earth Signal: Energies and Earth Magnitude in the Arts,* 83–91, 92–104.

[89] Frances Stonor Saunders, *The Cultural Cold War: The CIA and the World of Arts and Letters* (New York: The New Press, 2001), 186.

[90] Ibid., 88.

systems by showing how by emphasizing the autonomy of the brain, the dramaturgy described by Lucier imposes a Cartesian-stratified hierarchy of agency onto the body.

In contrast, I examine several records of David Rosenboom's work with EEG. Of particular interested is a popular and widely circulated TV interview by Mike Douglas with David Rosenboom and several key cultural icons (Chuck Berry, John Lennon, and Yoko Ono).[91] This moment captured on video is a fascinating cultural artifact replete with telling, excited imaginings of what experimental research with EEG could yield for the future of music. Unlike Lucier, Rosenboom's ethos is seemingly couched in the kind of countercultural thought articulated by Charles A. Reich in the 1970 book *The Greening of America* and Theodore Roszak's *Making of a Counter Culture: Reflections on the Technocratic Society and its Youthful Opposition.*[92] As such, these technofantasies may be understood as a countercultural reclamation of technology.

I discuss this conversation in particular, as well as in other interviews and extensive texts about Rosenboom's research in biofeedback. With my analysis, I intend to show that, despite a passionate enthusiasm for technofantasy, Rosenboom's engagement with embodied learning, Eastern approaches to embodiment such as Buddhist

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[91] "John Lennon, Yoko Ono & Chuck Berry with David Rosenboom on the Mike Douglas Show," YouTube video, 12:07, from a performance televised by NBC in February, 1971, posted by "John Blaney," August 21, 2011, https://www.youtube.com/watch?v=e-OaumT8w8o.

[92] Charles A. Reich, *The Greening of America: How the Youth Revolution is Trying to Make America Livable* (New York: Random House, 1970); Theodor Roszak, *The Making of A Counter Culture: Reflections of the Technocratic Society and Its Youthful Opposition* (Berkeley, CA: University of California Press, 1968).

mindfulness practices and Yogic traditions, and systems theory point to an intentional engagement with a conception of the body less governed by dualism. The investigation of the body and performance in this chapter looks forward to the next: a case study of Rosenboom's EEG work *On Being Invisible.*

3.2 Merleau-Ponty's Two Sense of Embodiment + Don Ihde's Technofantasy Device

Merleau-Ponty identifies two senses of embodiment. The first and more widely understood is the basis for the embodied mind thesis, which posits that body is the fundamental vehicle for our mind's experience of the world and, as such, the mind's perception of the world is a function of the body. Scholars in many different fields investigate this idea, including principally cognitive science, psychology, and philosophy. This thesis contrasts theories of mind such as Cartesian-inspired cognitivism.

Secondly, Merleau-Ponty uses the verb embody to describe the process of learning and mastering a skill. Don Ihde takes this up in his discussion of intentionality and demonstrates this kind of embodied learning by invoking the process of learning the flute.[93] Ihde's choice of a musician is of course apt; the embodiment process is familiar to those musicians who have overcome technical hurtles through practice resulting in their ability to clearly articulate and express their musicality. This sense of embodiment is as well central to the pursuits of gestural sound control of interactive sound; the user's

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[93] Ihde, *Embodied Technics,* 21.

performative relationship to his or her interface is critical to their musical experience and expressive abilities. As such, performers who have cultivated a *practice* of biofeedback are concerned with the corporeal entirety of the performance experience and less about the conditions of the brain.

As well, the ubiquity of corporal experience plays a major role in the phenomenon of embodiment. Embodied experience is marked by an awareness of the rich combinations of ongoing sensory phenomena, somatic learning and knowledge, and emotional experiences leading to an elusive and fragmented sense of the self.[94] Such a fragmented identity as such leads to ways of understanding self outside of strict confines of the body, or experience not existing strictly within what the mind can compute.

Finally, reflections on the EEG often border on technofantasy, a concept explored by Don Ihde in several of his works.[95] Technofantasies are the hypothetical scenarios or experiences which are enriched by invention. Rather than suggesting that technofantsies embrace either a dystopian/utopian paradigm, Ihde sees the technofantasy as a way of analyzing how we see ourselves through our interaction with artifacts. As such, it is useful to see such visions of ourselves as somewhere along the well-graded continuum between "embodied" or "disembodied". Ihde helps make this continuum concrete by providing us with a foil to Merleau-Ponty's embodied body: the abstract, generic body

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[94] Varela, Thomson, and Rosch, *The Embodied Mind: Cognitive Science and Human Experience* (Cambridge, MA: MIT Press, 1991), 60.

[95] Ihde, "Technofantasy and Embodiment" in *Embodied Technics*; Ihde, *Bodies in Technology.*

and object of scientific inquiry as described by Foucault.[96] In the case of individuals with extreme technofantasy which stress the disembodied, such as human/computer fusions which venture to blur virtual realities and real life, Ihde notes that their rational often stems from issues related to "body-disability or de-habilitated social skills."[97] Some of the examples related to EEG I discuss in following may not be this extreme as some of these extremely disembodied imaginings, but some do come close.

3.3 Alvin Lucier: "Giving Up Performance to Make it Happen"

3.3.1 *Music for Solo Performer*

Lucier devoted years to the project of brainwave sonification. His piece *Music for Solo Performer* is framed by a particular discourse of the body filtered by his experience as a composer. When he received the EEG sensor from Edmond Dewon, physicist with the Air Force and a part-time appointment at Brandeis University, his peers in composition encouraged him to record and speed up the low-frequency alpha waves to create a fixed media piece. Like Rosenboom, Teitelbaum, and many more recently, however, Lucier was primarily concerned with the "live" event of producing music with

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[96] Ihde, *Bodies in Technology*, 17.

[97]Ibid., xii.

electrodes and EEG.[98] In *Music for Solo Performer*, an assistant routes the "enormously amplified alpha waves" produced by the performer through a multichannel mixer to a number of speakers attached to various percussions instruments and mundane objects such as cardboard boxes or metal cigarette ash cans. By presenting it transformed only in loudness, Lucier shows an interest in keeping transparent the materiality of the performers' alpha waves; the brainwaves are transduced to sound by the speakers which ultimately resonate the objects placed about the stage. Lucier's *Music for Solo Performer* served as the perfect "Hello, World!" piece for alpha wave sonification and a watershed in the live performance of electronic music; its simple mediation introduced musicians quite plainly to the materiality of alpha-waves. The score is reproduced here in its entirety in the appendix.

Lucier's brainwave piece has a particular theatricality to it which casts it in a certain dramaturgical and aesthetic light. The stylistic tone of the text score, written by Edmond Dewan (credited in the score as a technical consultant) in an imperative, prescriptive voice, evokes the medical origins of the EEG apparatus. The relationship between performer and assistant suggests the medical subject and medical examiner; evoking the theatricality of the "militarized science of the Cold War, more specifically,

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[98] Two commercial recordings of performances by the composer exist which show that Lucier was interested in breathing new life into the piece by experimenting with different versions: the first, the LP Music for Solo Performer released in 1982, is a multi-tracked collage of eight different performances of the piece; Lucier, *Music for Solo Performer,* Lovely Music, 1982, LP, side A; the second was released on a Nonesuch records compilation from 1989, whose name suggests Lucier made improvements on the EEG system which he had recommended in the original score; Lucier, "Music For Alpha Waves, Assorted Percussion, and Automated Coded Relays," *Imaginary Landscapes,* 1989, CD.

cybernetics," which Douglas Kahn argues is its primary cultural context.[99] Kahn's analysis situates *Music for Solo Performer* in a cybernetic context, however I argue that, precisely because of the theatrical embrace of this militarized science, the piece's presentation and the discourse surrounding it more strongly resonate with cognitivism, a school of thought based in cybernetics which, despite cybernetics' best efforts to leave behind Cartesian stratification of the mind and body, equates the human brain with the computer.

Kahn also shows how Edward Dewon had a significant impact on Lucier, who described previously being at the dead-end of Neoclassical composition.[100] Dewon was befriended with Norbert Wiener, a pioneer in cybernetics who also wrote extensively about alpha brain waves in his seminal 1948 monograph *Cybernetics*.[101] Drawing on Gordon Mumma's characterization of the piece as a system, Kahn shapes an understanding of the "work" of the piece to be both its performances as well as its structural ontology. Thus we can understanding the formal electronics diagram of a structurally determined system to be part of score. Indeed, Lucier's EEG instrument is a

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[99] Kahn, 85.

[100] Ibid.

[101] Norbert Wiener, *Cybernetics: or Control and Communication in the Animal and the Machine* (Cambridge, MA: MIT Press, 1961).

closed signaling loop, wherein the performer receives sonic feedback on his or her alpha wave production of alpha waves.

However, Lucier's repeated comments about the performer's ability to "perform without moving" or that the "motor system is not involved in any way" betray the piece's preferential awareness to brain and thus suggests a disenfranchising of the body. How, after all, is the performer to complete the feedback loop without his or her body's rich sensing networks?

3.3.2 The Theater of the Mind: The EEG as *Camera Obscura*

In an interview with Douglas Simon, Lucier refers reluctantly to the theatricality of the piece: "I was prepared to . . .. accept the theatrical, although when I use the word 'Theatrical,' I feel cheapened somehow. . . all I did was take the EEG situation as a whole and, by doing that, make celebration of the event."[102] Simon notes that the piece centralizes the task of the performer to overcome "an obstacle, and the compositional mentality utilizes that in a positive way as a philosophical statement, the idea that the situation in the room is an extension of one's brain."[103]

But what about the body? Indeed, audience and performer are consumed in a performative environment which is metaphorically and dramaturgically an extension of

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[102] Lucier, interview by Douglas Simon, *Reflexionen,* 52.

[103] Ibid.

the mind. This description reminds of Descartes' usage of the *camera obscura* as an epistemological metaphor for the mind: the externalization of the internal is the dramaturgical driver; cymbals crash when the alpha waves roar, but "the motor system is in no way involved."[104] Indeed, even the piece's title suggests that it is the performer at the center of this work, a task to be done, to be overcome. This drama of overcoming is often successful and theatrically compelling; such dramaturgy has been explored in other ways by composers such as John Cage in his Freeman Etudes (1977-80) or the music of New Complexity composers such as Brian Ferneyhough, wherein "impossible" notational combinations endow the performer with compositional agency. Kim Cascone and other digital musicians explore the defects of digital media, in what he refers to as glitch music in the polarizing article "Aesthetics of Failure."[105] These examples are more experimental in how they experimental embrace of overcoming on a non-narrative level, however failure and overcoming is trope deeply rooted in the ethos of the Western Classical musical tradition in such phenomenon as virtuosity (Janos Starker and Zoltan Kodaly's *Suite for Unaccompanied Cello*), musical form (Beethoven's Romantic renderings of the

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[104] Ihde first brought my attention the *camera obscura* metaphor; I borrow his characterization of it as the "Theater of the Mind" for this as well; *Embodied Technics,* 3; Lucier, *Music for Solo Performer.*

[105] Cascone, "The Aesthetics of Failure: 'Post-Digital' Tendencies in Contemporary Computer Music," in *Audio Culture: Readings in Modern Music,* ed. Christoph Cox and Daniel Warner, 392–398 (New York: Continuum Press, 2004).

"heroic" or Harrison Birtwistle's *The Triumph of Time* [1984]),[106] or narrative handling of overcoming such as man's metaphorical overcoming of nature, such as in Strauss's tone poem *An Alpine Symphony.*[107]

An aesthetic of failure does little for furthering a performance practice or culture of technique for the EEG controller however; those innovations were left to Lucier's successors such as David Rosenboom and Richard Teitelbaum, or more recently Eduardo Miranda Reck, Joel Eaton, Laurent George to name just a few. More than any one single piece, *Music for Solo Performer* resides unsurpassed as quintessential performance of EEG music, not only because of its embrace of an artistic drama resonating with collective contemporaneous technofantasies such as cybernetics, but also in creating watershed of interest in EEG music. He cultivated his own performance practice for the various iterations of his piece he oversaw over the course of the many years he dealt with the piece, transferring technical performance knowledge directly to among other, prominent performers of experimental music such as David Tudor and Gordon Mumma. The indirect influence of Lucier's piece, however, is immeasurable; the piece is a departure point for any and all ventures in EEG sonification; Samson Young has homaged Lucier in his two EEG pieces *I am Thinking in A Room Different From the One You Are*

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[106] Martin Kier Glover, "The Drama of Harrison Birtwistle's 'The Triumph of Time'" in *Tempo* 66 no. 262 (October 2012): 2–11.

[107] Brooks Toliver, "The Alps, Richard Strauss's *Alpine Symphony* and Environmentalism," *Green Letters* 15, no. 1 (October 2011): 8–21.

Hearing In Now (2010) and his *Signal Path I: Homage to Alvin Lucier,*[108] Robert Ashley also video documented a long-form performance in his Music with Roots in the Aether series; a Dutch 2013 documentary film *No Idea But In Things* shows a performance of this and other pieces by Lucier and features discussion with the composer.[109]

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[108] Young, "I am thinking in a room different from the one you are hearing in now (homage to Alvin Lucier) (2011) - Trailer," Vimeo video, 2:57, posted by "Samson Young," accessed September 13, 2014, https://vimeo.com/27901896; Young, "Signal Path I: Homage to Alvin Lucier," *This Music is False: Samson Young* accessed September 13, 2014, http://www.thismusicisfalse.com/Signal-Path-I-Homage-to-Alvin-Lucier.

[109] Robert Ashley, *Music with Roots in the Aether* (New York: Lovely Music, 2005) DVD, originally released in 1976; Viola Rusche and Hauke Harder, *No Ideas But in Things: The Composer Alvin Lucier* (Mainz: Wergo, 2014) DVD.

3.4 David Rosenboom and the Countercultural Technofantasy

3.4.1 The Technofantastic Imagination: Solipsist Utopias

On one episode of the Mike Douglas show co-hosted by Yoko Ono and John Lennon from February 14–18th, 1972, David Rosenboom is invited to discuss his experiments with biofeedback and brain wave sonification. Aside from Douglas, Lennon, and Ono, they are joined by fellow guest, rock and roll songwriter, singer, and guitarist Chuck Berry. Rosenboom's appearance marked artistic research in biofeedback's fifteen minutes of fame.

Ono and Lennon's topics for their five shows were "love, peace, communication, women's lib, racism, war, prison conditions . . . and also to show the future direction, because [it's] beautiful."[110] Throughout the five days, Ono and Lennon share their characteristic optimism and utopian vision for the future. In just the first episode, they circulate a blank canvass through the audience for members to express and explore what Lennon and Ono describe as their inner, inherent artistic ability, encouraging the audience to touch each other in the process. They also explore culinary macrobiotic food with macrobiotic gastronomist Hillary Redleaf and talk environmentalism and political engagement with Ralph Nadar (whom Mike Douglas suggests should run for office).

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[110] Yoko Ono,"John Lennon, Yoko Ono & Chuck Berry with David Rosenboom on the Mike Douglas Show."

Although the Mike Douglas show invited co-hosts and guests ranging form Dick Gregory, Malcom X, and Liberace to Vivian Vance, Brooke Shields, and James Brown, John Lennon and Yoko Ono's week on the show reckoned as a counter-cultural tour de force. Unsurprisingly, this week of shows enjoyed a longevity beyond its initial broadcast; the network VH1 re-ran the episodes with Ono and Lennon for years before the rights were purchased by Rhino Video, who released the week of episodes on a commercially available video cassette as recently as 1998.[111]

Lennon, Ono, Douglas, and Chuck Berry's dialogue with Rosenboom about biofeedback and the EEG sensor is a fascinating example of the capabilities of technofantastic imagination. Throughout many of the segments during Ono and Lennon's five days, Mike Douglas offers a healthy dose of hokey jokes in attempts of creating either an atmosphere of levity or nonchalance. The six sit with legs sprawled out on the floor or cross-legged on an astroturf-green carpet; Mike Douglas introduces his guests, quipping cheekily: "now it's time for the floor show . . . biofeedback, I always thought that was heartburn." However the earnest curiosity his musician guests and co-hosts display for Rosenboom's work quickly changes the interview's mood to one of intrigued reverence. Berry, Ono, and Lennon, all pioneering and masterful artists of their own craft, marvel at the bountiful possibilities of how this clever transcoding might expand the artistic pallet.

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[111] "Brain Music for John and Yoko: John Lennon, Yoko Ono & Chuck Berry with David Rosenboom," *The Mike Douglas Show,* performance, interview, and discussions, originally aired on CBS, Philadelphia, PA, 1972, re-released by Los Angeles, Rhino Home Video VHS 1998.

Rosenboom introduces the concept of biofeedback, noting that a person can successfully create a biofeedback loop "through practice." He emphasizes this several times throughout the show, noting also that musicians, or "anybody who's been involved in some sort of discipline, like musicians, arts" are predisposed producing alpha waves on command, pointing to Merleau-Ponty's second formulation of embodiment. Rosenboom's work was especially concerned with this in particular, having documented a multi-day workshop he did at Brown University with twelve participants.[112] Rosenboom showed in his research that through practice, people could not only train the consistent production of alpha waves, they could also increase the amplitude of the alpha.[113]

Douglas asks: *"*What can this do for society?" and Rosenboom offers a sensible answer carefully tailored to the language of his audience:

> It seems like every time you see someone wired up and everything you think: 'oh boy is the last straw for Western culture; it's about time for me to go to India or China and live.' But it's a new kind of thing, which requires a certain attitude, a certain orientation which just hasn't been around. You have to learn – in order to do this – do things without trying to do them. You have to learn how to let things happen and not to try. You have to learn to be a person by

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[112] Rosenboom, "Three Day Biofeedback Learning Experience for Brown University," in *Biofeedback and the Arts:Results of Early Experiments,* ed. by David Rosenboom, 57–59 (Vancouver, BC: Aesthetic Research Centre of Canada, 1976).

[113] David Rosenboom, "Methods for Producing Sounds of Light Flashes with Alpha Brain Waves For Artistic Purposes," *Leonardo* 5, no. 2 (Spring 1972): 143.

> not trying to be a person. What would it be like if a stone had to try to be a stone?[114]

In his writings, he offers a more articulate vision of his experiments' potential impacts on society. "Mr. Science Meets Earth Mother" the introduction to the essay and presentation entitled "Homuncular Homophony," begins with a meditation on human hubris.[115] Rosenboom invokes British socially critical novelist E.M. Forster to suggest that art-scientists might offer more humbled direction for a humanity plagued by war. He acknowledges that his rhetoric is indebted to Cold War science**,** yet he contends quite passionately that science has produced "positive signs which show that we are aware and, better yet, still *participating* in evolution."[116] Later, he writes more specifically about the implications of his work with EEG:

> through the use of computers as appendages of man's brain and methods of learning with biofeedback, rates of information processing will be achieved that approach the speed of light, ergo, conception will be bound less

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[114] Rosenboom, "John Lennon, Yoko Ono & Chuck Berry with David Rosenboom on the Mike Douglas Show."

[115] Rosenboom's note about his essay states that it was "prepared for presentation at the Spring Join Computer Conference, Atlantic City, 1971 and the Audio Engineering Society Convention, Los Angeles, 1971 and based on a paper five at the University of Illinois Festival of Contemporary Arts, 1971;" David Rosenboom, "Homunculuar Homophony," *Biofeedback and the Arts: Results of Early Experiments,* ed. David Rosenboom, 1 (Vancouver, BC: Aesthetic Research Center of Canada, 1976).

[116] Rosenboom "Homunculuar Homophony," 1.

> necessarily with action, elicited or observed, and life will eventually be embodied in information-energy networks creating nonphysical art; spiritual art will be revived as established networks connect us firmly. Further, future man may be possessor of greater personal freedom as energies turn from violence, counterpart to our world of spatial boundaries, and are directed towards a metaphysical restructuring.[117]

Couched in the discourse of both cybernetics and counterculturalism, in this excerpt Rosenboom allows his project's aims and ambitions to blossom into a more fantastic, futuristic vision unafraid of optimistic speculation. Rosenboom's prediction of high-speed networks facilitating unfettered communication and non-physical art seems to have been fulfilled by the world-wide web; however brain appendages interfacing with this network remain, to the best of my knowledge, unexplored. His thinking seems to have taken a slightly different direction over the years; in a 1982 interview, he carefully distinguishes between the brain and computer, particularly in the domain of memory.[118]

3.4.2 "The Zen and the Yoga": Biofeedback, Eastern Mysticism, and Embodiment

Mike Douglas asks if "the Zen and the yoga . . can be used to produced alpha brain waves" – not a surprising question, considering those traditions' had been firmly embedded in American cultural consciousness since the 1950s. D.T. Suzuki and others

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[117] Ibid.

[118] Rosenboom, "In Conversation: David Rosenboom and Richard Teitelbaum," interview by Andrew Timar and Jon Siddal, *Musicworks* 21 (Fall 1982): 13.

created a wave of popular interest in Zen Buddhism as a intellectualized, secularized *Weltanschau* stripped of its formal traditions and complex rituals mediations.[119] The ideas of Suzukis and others were mediated by artists and intellectuals throughout the 1950s; Zen continued to prosper thanks to the founding of the San Francisco Zen Center and the Zen Center of Los Angeles in the 1960s.[120] Western culture was introduced to yogic practices, including but not limited to the physical practice commonly referred to generically as yoga, by teachers such as Indian nationalist, yogi, and poet Sri Aurobindo in his 1959 *The Synthesis of Yoga,* and by academics such as Theos Bernard, Columbia University's first Ph.D. in Religious Studies, who wrote the book *Hatha Yoga: The Report of a Personal Experience* (1947).[121]

Indeed, meditation and mindfulness practices originating from Buddhist, Hindi, and other religious and philosophical traditions are often invoked in discussions of both biofeedback and embodiment. After Rosenboom's brief answer to Douglas's question about Eastern influences, Lennon and Ono, clearly eager to contribute to the discussion, immediately bring up precedents in Hindi culture (yogic practices) for self-willed control

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[119] Robert H. Scharf, "Whose Zen? Zen Nationalism Revisited," in *Rude Awakenings: Zen, the Kyoto School, and the Question of Nationalism* (Nanzan Studies in Religion and Culture), ed. James W. Heisig and John Maraldo: 40–51 (Honolulu: University of Hawai'i Press, 1995).

[120] To name only a few works written by those who attended some of Suzuki's lectures: John Cage (*Book of Changes,* 1951), Alan Watts (*The Way of Zen*, 1957); Jack Kerouac (*The Dharma Bums*, 1957), and Erich Fromm (*Zen Buddhism and Psychoanalysis,* 1960).

[121] Paul G. Hackett, *Theos Bernard, the White Lama: Tibet, Yoga, and American Religious Life* (New York: Columbia University Press, 2012).

of biological processes such as blood pressure or heartbeat which are generally considered to operate on a subconsciously. Of course, embodiment and phenomenological analysis is deeply embedded in many Eastern practices, as shown by Varela, Thompson, and Rosch in their book *The Embodied Mind: Cognitive Science and the Human Experience.* In this 1991 text, they argue that a paradigm shift in philosophy towards non-Western cultures' attitudes could enliven Western culture, addressed in particular to cognitive science.

Rosenboom too acknowledges the affinities between his performance practice and various non-Western traditions and practices. In a description of the different brainwaves, he differentiates between the mental state associated with Zen ("high attention without a locally specific focus") in his characterization of alpha-waves and "Yoga-like states," characterized by "deep relation of perhaps daydreaming" in his description of theta-waves.[122] He goes so far to say: "I suggest that the Zen-like state associated with achievement of what we may wrongly associate with the word 'control', is, in fact, a striking example of the quality of subjective experience associated with true conscious participation in auto-poetic self-organization, including feedback with the environment."[123]

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[122] Rosenboom, *Extended Musical Interface with the Human Nervous System,* 32–33.

[123] Ibid., 19.

Like Lucier, Teitelbaum, and other musician-pioneers of the EEG, Rosenboom understood the materiality of brainwaves, which are not easily mapped onto traditional Western classical or popular musics. After having noted the declining interest in technology among experimental musicians, including Teitelbaum's group *Musica Elettronica Viva*, in a 1972 article, Rosenboom identifies as a primary problem in the continuing research of brain-computer musical interface the "finished product" mentality and "ego obsessions" of Western music.[124] He turns instead to Indian classical music, which he suggests may have been more "complex and better developed than our Western system" because of its emphasis on experience and listening instead of "creating composition by precognition."[125] The various brainwaves registered by the EEG do not hint at the musical material of an imagined symphony or rock and roll song, nor do they lend themselves to transcoding into such quantized musical genres.

Nevertheless, this kind of technofantasy seems to be many musicians' first when encountering the EEG as musical interface. After Rosenboom's brief statement about his work's promotion of Non-Western paradigms during the Mike Douglas interview, Berry asks: "Is the resulting factor music?" and Lennon answers excitedly that one "could eventually link [the EEG sensor] to Rock N' Roll" and the group is enlivened with excitement. Indeed, the nature of their technofantasies is worthy of investigation: it is

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[124] David Rosenboom, "Method For Producing Sounds of Light Flashes with Alpha Brain Waves for Artistic Purposes,"141–142.

[125] Ibid. 142.

hard to determine if they are more excited about a musical interface extended into the human-nervous system or circumventing the embodied action of performance in favor of a more disembodied, mining of subconscious musical idea.

In his article about the very "Love–Peace–Teen–Dream thing" espoused by Lennon and Ono on their five days on the Mike Douglas show, Dick Hebdige declares that this kind of uncompromising utopianism is now "over."[126] Rosenboom, in a more recent article on his work with biofeedback, writes:

> Originally touted by the press as a panacea for all that ails and the key to self-transformation, biofeedback is now perceived in a more sober light. However, biofeedback raises issues of self-consciousness that do not fit neatly into Western culture. The achievement of success with biofeedback requires discipline, intense and regular practice, and often meditative skills. These were consistent with views held in the 1960s of transcendence and the idealism of cultural transformation. These ideals faded with the rise of 'yuppi-dom' in the 1970s, as disillusionment grew when earlier hopes for change were seen to fail or to be forgotten and, in the 1980s, as self-realization was replaced by the necessity of socio-economic self-validation. In such a climate, lack of further substantive progress in applications can only be blamed on an unwillingness to pay the price of personal hard work to achieve transformation.[127]

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[126] Dick Hebdige, "Un-imagining Utopias," in *Sound Unbound: Sample Digital Music and Culture,* ed. Paul D. Miller, 83 (Cambridge, MA: MIT Press, 2001).

[127] Rosenboom, *Extended Musical Interface with the Human Nervous System,* 22.

Despite Rosenboom's careful observation about biofeedback (and by extension EEG experiments), every new iteration of a performance work using EEG seems to propagate the same kind of disembodied utopianism. In 2014, Becky Chung writes in an article published on the popular art and technology website *The Creators Project* that:

> . . . music has provided the most perfect experimenting ground for EEG artists. Yearning to get even closer to the genesis of their ideas, their internal, biological sources of inspiration, musicians have yearned for this technology for years. . . with EEG technology . . . anyone can now get even closer to witnessing the creative process, to envisioning churning artistic impulses without the uses of hands, mouths – one need only the active brain.[128]

Indeed, the utopia of the 1960s and 70s has gone the way of the world, but our disembodied rhetoric remains. Humanity's desire to exist without need for our bodies' persists in our discussion of technology beyond the utopia's bitter morning-after, written with the same kind of Romantic enthusiasm for technology's possible unveiling of "hidden" creatives powers – not unlike the Expressionists, empowered by Freud's psychological revolution of the unconscious.

Fundamentally though, it is clear from both composers' accounts discussed here that the EEG demands devoted practice and learning – the processing of embodying a skill – not unlike the practice which goes into developing technical proficiency with

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[128] Becky Chung, "10 Pieces of Music Created With Brainwaves," *The Creators Project*, June 25, 2014, accessed February 10, 2015, http://thecreatorsproject.vice.com/blog/10-pieces-of-music-created-by-brainwaves.

violin (or the clavichord). The German verb *verkörpern* may be translated as "to embody" and applied in contexts familiar to the English *to embody* when an individual is representative of a larger group or concept, the sensation of being in a body, but also – and equally interesting to investigations of embodied experience and performance – when an actor plays a part (*jemanden verkörpern).* This duality is a happy linguistic intersection; to embody a character figuratively requires a somatic awareness associated with embodiment literally.

Such an understanding of embodiment suggests we must consider (as a Gestalt) the body as the primary agent in performance. Although Lucier is clearly more concerned with the drama of his performance, performers of that piece must also be mindful of their bodies. Rosenboom is more deeply engaged with creating a performance practice of this music, the efforts of which I discuss in reference to his *On Being Invisible* in the next chapter.

FOUR. DAVID ROSENBOOM'S *ON BEING INVISIBLE:* THE CENTRAL NERVOUS SYSTEM AS GESTURAL SOUND CONTROLLER

4.1 Overview

In this chapter, I intend to first contextualize David Rosenboom's artistic output with a brief biographical sketch, then give an overview of his activities as a composer and researcher. Following, I will offer a performance analysis of his EEG piece *On Being Invisible* (1976–77), discussing in particular the piece's ontology, variable dramaturgy, and its emphasis on the body in performance.

4.2 Biography

David Rosenboom was born in small, Midwestern town of Fairfield, Iowa in 1947.[129] His university studies in music began at the University of Illinois, where he studied composition with Gordon Binkered and Salvatore Martirano and electronic music with Lejaren Hiller from 1965 to 1967. In addition to composition, he cultivated an interest in Indian music, conducting, and the performance of various acoustic instruments, including violin, viola, piano, trumpet, and percussion. From 1967 to 1968, he taught at the Center for Creative and Performing Arts at SUNY, Buffalo, where he also served as artistic director of the environmental and political activist performance group Electric Circus. He held a guest lecturer position at New York University from 1968 until

[129] Additional biographical information may be found at: "David Rosenboom," CalArts, accessed April 1, 2015, https://directory.calarts.edu/directory/david-rosenboom; "David Rosenboom," Lovely Music, accessed March 30, 2015, http://www.lovely.com/bios/rosenboom.html; "About," David Rosenboom, accessed March 12, 2015, http://www.davidrosenboom.com/about.

1970, when he moved to Toronto to become director of computer and electronic media research at York University. In 1979, Rosenboom was employed as the Darius Milhaud Professor of Music and the Director of the Center for Contemporary Music at Mills College. Since 1990, he has worked at California Institute of the Arts in Valencia as dean of the School of Music and co-director of the Center for Experiments in Art, Information and Technology.

Over the course of his active career, Rosenboom has collaborated with a variety of experimental artists. He played viola on Terry Riley's first recording of *In C* in 1968 and in Marian Zazeela and La Monte Young's Theatre of Eternal Music occasionally from 1970 to 1974.[130] He worked with singer and designer Jacqueline Humbert on the biofeedback work *Chilean Drought* (1974), performed and recorded with her (and her pseudonym J. Jasmine) and published her work, including two of her EEG pieces *Brainwave Etch-A-Sketch* and *Alpha Garden* in his *Biofeedback: Results of Early Experiments.*[131] He played with Donald Buchla, with whom he released the album *Collaboration in Performance* in 1978. Rosenboom also worked extensively with musician and composer Anthony Braxton. He played piano in Braxton's quartet on the album *Five Compositions (Quartet) 1986* and developed real-time compositional system

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[130] "Marian Zazeela," The Mela Foundation, accessed February 15, 2015, http://www.melafoundation.org/liteperf.htm; Terry Riley *In C*: (Sony Classics, 2009), CD, originally released in 1968.

[131] Jacqueline Humbert, in *Biofeedback: Results of Early Experiments* (Vancouver: Aesthetic Research Center of Canada, 1974), 150–152 and 156–157.

for Braxton to improvise with in the piece *Lineage, Enactment, Transfiguration, and Transference* (1992); a similar project from 1993 called *Extended Trio: Sampler* features jazz bass player Charlie Haden and South Indian mrdangam player Trichy Sankaran improvising with two computer-controlled Disklavier pianos.[132] He recorded on various albums, including *Vernal Equinox* (1976) with trumpet player Jon Hassell.[133] In 2012 he joined a diverse group of musicians from several musical cultures as a resident participant at matralab as part of ongoing Sandheep Bhagwati's Native Alien project (assisted by Navid Navab and Julian Stein), which aims to create robust improvisation and real-time composition software.[134]

Like the music of composers like Kenneth Gaburo, James Tenney, and David Dunn, Rosenboom's music engages with diverse areas of inquiry; Rosenboom such as systems theory, cybernetics, psychology, computer science, and philosophy. Rosenboom has also made meaningfully contributions as a practitioner to scientific inquiry;[135] notably, he is known for his work with biofeedback starting in the late 1960s and

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[132] Eleven Musicians and HMSL, *Hallways,* Frog Peak Music, 1993, CD.

[133] John Hassell, *Vernal Equinox* Lovely Music 1990 CD, originally released in 1977.

[134] "Native Alien Project," *MatraLab,* Accessed February 10, 2015, http://matralab.hexagram.ca/projects/native-alien/, "09 Native Alien with David Rosenboom," https://vimeo.com/43946733; Sandheep Bhagwati, David Rosenboom, Navid Navab, and Julian Stein, Posted June 12, 2012, "09 Native Alien with David Rosenboom, " Vimeo video, 29:24, accessed April 4, 2015, https://vimeo.com/43946733.

[135] Eduardo Reck Miranda and Marcelo M. Vanderley, *New Digital Musical Instruments: Control and Interaction Beyond the Keyboard* (Middleton, WI: A-R Editions, 2006), 207–209.

continuing even still today.[136] Rosenboom's large compositional output reflects the diversity of his musical and extramusical interests, such as real-time composition/ autonomous musical systems and systems theory; perception, temporality and musical form; performance and interfaces for computer music; and biofeedback and experimental psychological research.

In this vein, Rosenboom describes his work as "propositional music."[137] As such he describes his compositions as models or worlds, which exists as its own system of structures, vocabularies, and relationships. This compositional thinking is clearly to recognize in Rosenboom's open-form graphical scores; *Then We Wound Through An Aura of Golden Yellow Gauze* (1967) provides performers with a unique score – a kind of disk-shaped constellation map – which reveals different geometrical figures which are interpreted musically according to accompanying instructions. His 1984 *Golden Gestures* graphically prescribes information to be realized by any ensemble about the attacks, duration, and release of sounds. *Zones of Coherence* (2003) is a composition for one or many trumpets which exemplifies his propositional approach in realm of acoustic composition; here performers perform one of several "configuration spaces" consisting of

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[136] Rosenboom published an article as recently as 2014 on the subject "Active imaginative listening—a neuromusical critique. Frontiers in Neuroscience, Auditory Cognitive Neuroscience," in *The Musical Brain* 8 (2014): 1–7.

[137] Rosenboom, "Propositional Music: On Emergent Properties in Morphogenesis and the Evolution of Music, Part I: Essays, Propositions and Commentaries" *Leonardo* 30, no. 4 (1997): 291–297 and "Propositional Music: On Emergent Properties in Morphogenesis and the Evolution of Music, Part II: Imponderable Forms and Compositional Methods," *Leonardo Music Journal* 7 (1997): 35–39.

pre-composed patterns whose harmonic and structural material is derived form the golden ratio.

Rosenboom has involved himself in software engineering since his work with Donald Buchla on the Touché (1979–80) and 400 series synthesizers. During the former project, he was involved in the creation of FOIL (Far Out Instrument Language), the performance language for the Touché. He iterated on this language between 1979 and 1983, creating MetaFOIL, MetaHMSL, and FOIL–83, which provided scaffolding for algorithmic composition and other features. While working at Mills College with Phil Burk and Larry Polansky, Rosenboom developed computer software for real-time musical interaction and sound synthesis which built on MetaFOIL. The environment, called HMSL (Hierarchical Music Specification Language) is set of object-oriented extensions for stack-based programming language Forth. HMSL has been used by musicians such as James Tenney, The Hub, Chris Brown, and Phil Corner, in addition to the software's creators.[138]

Rosenboom has created staged works as well, such as evening-length performance art piece called *The Naked Truth* (1976). Another example is *The Brandy of the Damned,* (1967), an improvised theatrical piece performed with tape accompaniment whose title points to the George Bernard Shaw play *Man and Superman* (1905), in which Don Juan proclaims in conversation with the devil: "Hell is full of musical amateurs:

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[138] "HMSL homepage," Phil Burk, accessed April 3, 2015, www.softsynth.com/hmsl.

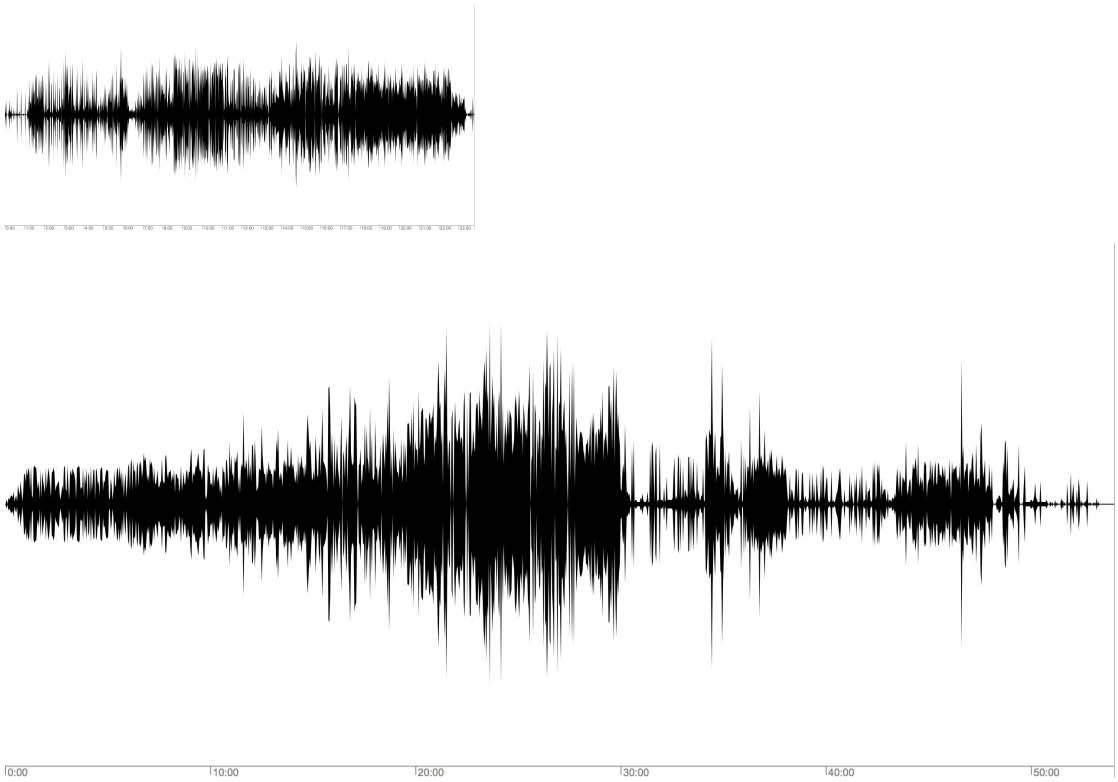

Figure 3. Waveforms of Two Performances of *On Being Invisible.* Above, rendering of Toronto February 12th, 1977 recording; below, rendering of Vancouver February 28th, 1977. Length of recordings are to scale.

music is the brandy of the damned!"[139] In 2009, he created the work *AH!* with poet and librettist writer Martine Bellen, which they reluctantly refer to as an opera, but not before calling it "an offering for the betterment of humanity of Earth today," "an immersive opportunity for illumination" and "a flight simulator for psychonauts."[140]

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[139] George Bernard Shaw, "Man and Superman," in *Nine Plays by George Bernard Shaw,* 631 **(**New York: Dodd, Mead & Company, 1935).

[140] Martine Bellen and David Rosenboom, "Prolegemenon to *AH!: Opera No-Opera,*" accessed January 1, 2015, http://www.davidrosenboom.com/sites/default/files/media/downloads/Prolegomenon%20to%20AH%21_0.pdf.

His electronic musical output includes both performative and fixed media works, including early "tape" pieces using analog synthesis, tape manipulation, and analog computer such as *City Music* (1968), *Telluspeep* (1967–1968), and *Internals* (1966). In *Music for Analog Computers: Music for Unstable Circuits* (1968), Rosenboom explores notions of stability through self-built chaotic circuits and analog computers. Another set of with live-electronics include his *Musical Intervention 1979* and *Musical Intervention 1982,* which features a which real-time compositional systems based on musical melodies and performers.

The musical interventions are among a number of performances Rosenboom was part of which draw attention to the Chilean military overthrow of democratically elected Salvador Allende and the political oppression and the dramatic effects of various natural disasters on the Chilean people during the military dictatorship of General Augusto Pinochet.[141] These pieces include *Chilean Drought* (1974) a collaboration with Jacqueline Humbert for speaker/chanter, piano, electronics, EEG performer, and percussion obligatto and *Rain, A Lament for the Peoples of Chile* (1976) for performance art ensemble.

Rosenboom's propositional music also includes the creation of dynamic, autonomous systems which allow performers to interact in constantly evolving ways. *Zones of Influence*, a collaboration with percussionist William Winant, exemplifies his deep and practical knowledge of this cybernetic approach to composition (1984–1985, revived in 2014). In addition to the many above-mentioned pieces, Rosenboom has

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[141] The musical material on which the musical interventions are based are the national anthem of Chile and the leftist-anthem "The Internationale", respectively.

explored real-time composition in the interactive work for eight vocalists, *Hunter/Hunted* (2005), a generative drum-accompaniment for mrdangam player Tricky Sankaran in *Layagnam* (1990), and a meditation on the evolution of language called *Systems of Judgment* (1987).

Rosenboom builds the piece *On Being Invisible* on his concept of musical holarchies, which draws on the work of Arthur Koestler, a Hungarian novelist and intellectual who lived in England. Koestler first wrote about the holon in his 1967 *The Ghost in the Machine* and further explored it in *Janus: A Summing Up* (1978), which offers an alternative to the two predominant theories psychological theories about the mind: Behavioralism, which drew largely on a Cartesian dualist view of the body, and Gestalt theory, which rejected dualism in favor of a synergistic view of the body as a whole greater than its parts. Koestler contended that there existed a view of the body which explained its self-organizing behavior in terms of systems.[142] This he called the holon: the smallest building block of his abstract, organizational system. Holons function in ensemble-stratified relationships within systems called holarchies. While perhaps the primary holarchy proposed by Koestler is the body, Koestler's philosophical texts branch outside of anatomy and psychology; he extends his holarchical paradigm to discussions of ecology, language and dialect, sociology, and even music. As such, the holarchy is a

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[142] Koestler, *The Ghost in the Machine* (Suffolk, England: Picador, 1976); Koestler, *Janus: A Summing Up* (New York: Random House, 1978).

kind of unified theory or worldview, which serves as a useful analogue to Rosenboom's propositional approach to composition.

Rosenboom's biofeedback pieces are far more plentiful than any of his contemporaries. Although he continues to work with brainwaves, his most prolific period of research, documenting this work in musical scores, and performance spans the 1970s. *Ecology of the Skin* (1970-71) is for live VOX keyboard and ten EEG performers, wherein the organ player improvises ten polyphonic voices, each of which is filtered independently by the ten EEG performers' alpha wave production. *Piano Etude 1* (1971) is for pianist outfitted with EEG electrodes; the player's alpha waves are mapped to the frequency of a filter applied to a shortly delayed piano signal. The pianist performs repetitive, notated patterns derived from the composition *How Much Better if Plymouth Rock Had Landed on the Pilgrims* in order to sustain his or her concentration for an extended period of time.

Portable Gold and Philosophers' Stones (Music with Trills) (1972) for one to four performers involves the production of both alpha and theta brains waves, wherein alpha waves build harmonic complexity run through tape delays, theta waves create clicking sounds reflected their frequency. *Chilean Drought* (1974) is for single brainwave performer whose alpha, beta, and theta wave production controls band-pass filters that gate the signals of tape recordings, and for pianist or mallet instrumentalist, who plays continuously a series of four quick arpeggiated patterns.

Ringing Minds (2014) is Rosenboom's most recent biofeedback composition; a collaboration with Alex Khalil and Tim Mullen, *Ringing Minds* explores the collective

neurological perception of three performers to generative musical events created by a lithophone performer and a violinist.

4.3 *On Being Invisible* – Towards a Performance Practice of EEG

4.3.1 Overview of Background Information and System Structure

On Being Invisible describes a stream of research that occupied Rosenboom during the late 1970s and yielded several artistic outcomes. Rosenboom combines his work with the EEG from the early 1970s with his interest in autonomous musical systems in the culminating endeavor. This complex system is a milestone in the development of a performance practice of the electroencephalograph; the system is designed for a performer who has masterful, embodied control over the EEG sensor. In the spirit of Rosenboom's propositional music, the *On Being Invisible* system proposes a single answer to the question of how to make music with EEGs, but its robustness and careful consideration of the entire, embodied performance experience is compelling.

The piece, which is the performed manifestations of this research, went through several iterations. The first version of the piece was premiered at Toronto's Music Gallery on the 13th of March 1976. This initial form lacked the EEG-input that was featured in later versions, but explored the functionalities of the self-organizing system which differentiated the *On Being Invisible* pieces from Rosenboom's earlier biofeedback work. Here, instead of EEG as impulse, microphones brought vocal sounds into a complex feedback loop. On February 12th 1977, Rosenboom premiered the EEG-controlled

version at the same venue.[143] He has performed the work occasionally, but set it aside until he iterated on it again with the sequel from 1992: *On Being Invisible II (Hypatia Speaks to Jefferson in a Dream).*[144]

Rosenboom describes *On Being Invisible* as "a self-organizing, dynamical system".[145] The musical action is primarily driven by the performer's intentional entrance into and exit from the system's loop by producing or ceasing the production of certain brainwaves. He writes:

> It is an essential characteristic of all parts of this piece that the performer must constantly ride a borderline between being, on the one hand, an initiator of action and, on the other, submerging him/herself in processes larger than him/herself. This requires that the performer become adept at manipulating his/her state of consciousness, application of willful actions, and the energizing or programmed personal response modes. This requires a great deal of practice and is the inspiration for the title, "On Being Invisible."[146]

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[143] Rosenboom, *Extended Interface with the Human Nervous System,* 78.

[144] Ibid., 124–127.

[145] Rosenboom, *Invisible Gold,* Pogus Records, 2000, CD, liner notes.

[146] Rosenboom, "On Being Invisible," in *Collected Articles: A Selection of Previously Unpublished or out of Print Writings by David Rosenboom: 1968–1982*, 5.

Rosenboom documents the system's various entities and their central algorithms extensively in his monograph.[147] Here, I will provide an overview of the system's ontology in the simplified paradigm presented in chapter 2. The EEG sensor and a signal analysis unit constitutes the system's input element.[148] The signal analysis unit performs transforms the signal into meaningful data. As such, very carefully engineered to be sensitive to the nature of its input signal, EEG analysis. In part one of *On Being Invisible*, Rosenboom applies an auto-correlation analysis to the EEG signal.[149] The resulting analysis is the primary driver of qualitative changes to the sound production including the timbres of the various voices present, musical time, and the temporal intervals of events.[150] A spectral analysis of the signals shows the distribution of energy across the frequency domain; the dynamic changes of this analysis drives subtle changes in orchestrational palette. This logic is executed by an Interdate Model 74 minicomputer,

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[147] The depth which Rosenboom goes into in this 1990 document, almost fifteen years after the piece's premier, bears testament to the importance of this system to his work; Rosenboom, "Part 4 – *On Being Invisible* – Using ERPs to Build Formal Musical Holarchies in Real Time,"in *Extended Musical Interface with the Human Nervous System,* 74–97.

[148] Rosenboom notes that this was a Correlation Function Computer and a Fourier Analyzer produced by Princeton Applied Research; Rosenboom, *Extended Musical Interface with the Human Nervous System,* 79.

[149] Correlation is an form of signal analysis which shows the similarity in the behavior of two signals. In auto-correlation, a signal is compared to a slightly delayed version of the same signal.

[150] Rosenboom, "On Being Invisible," 3–4.

and delegates the sound production of sound to a Buchla 200 synthesizer, the systems output.[151]

This logic in driven by the most fascinating element of the system: its "model of musical perception", which anticipates the ways in which the performer and audience members would perceive the sounds generated by the system.[152] These predictions are checked against a dictionary of behaviors in EEG signals in order to determine whether the system's predictions were true or false, which informing the probability of the system making similar musical changes in its subsequent decisions.[153] As a result, its impossible to imagine or predict the sonic world of this piece; in the following analysis I sidestep any definitive attempts at that task with exhaustive descriptions of musical events. Instead, I am interested in showing the nature of musical changes made by the system by comparing two recordings of different performances with this system.

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[151] Rosenboom's system accommodates additional configurations of the system. One example is a touch sensitive keyboard, which could register different intensities of touch-pressure. These phrases were also fed into the minicomputer and into the language building engine. In part two, various instruments are played into a microphone, whose signal undergoes the same kind of analysis as the brainwaves.

[152] Rosenboom, *Extended Interface with the Human Nervous System,* 81–83.

[153] Ibid.

4.3.2. Performance Analysis

On February 12th, 1977, Rosenboom performed both parts of *On Being Invisible* at the Music Gallery in Toronto; the run-time of the two parts were 23:47 and 21:44. Several weeks later, Rosenboom's performance at the Western Front in Vancouver, BC on February 28th, 1978, parts one and two clocked in at 54:07 and 39:13, respectively. While from the time-stamp it may be clear that these versions are of different length, what might be unclear is that they are not simply longer and shorter versions of the same piece. See below two figures which offer waveforms which show the amplitude or loudness of the recordings in their entire length. What can be gleaned from this gross analysis is that the two performances, a mere sixteen days apart, offer entirely different dramas and energies, and *propose* entirely identities for the system.

A curt and more listen-centric analysis follows which allows a more fine differentiated of structural and timbral changes in each performance. As such, I describe below in detail my perception of some excerpts from key musical moments which demonstrate Rosenboom's system at work.

The Toronto recording is characterized by the ebb and flow of a kind of nervous, hectic energy. A furtive glance at the waveform above shows at least three such arch-like events in the first eight minutes. The activities of this autonomous machine begin slowly. A sporadic wobbling sound which meanders in frequency between about 200 and 400 hz, which is punctuated by a spike in sound with strong high partials embossed in reverb. As the sequence of events seems repeat and develop, the meandering sways between

accelerating and decelerating rhythmic phrases, and a fast, periodic, and aggressive stuttering. With almost every repeat of this phrase, its voices grow in number and becoming more timbrally complicated. This ten minute crescendo shows the intentionality of Rosenboom's system; its blend of new musical parameters into existing material showcase its orchestrational logic.

The Vancouver recording differs profoundly. In this recording, we might understand two distinct sections in the flow of events. The first thirty minutes of performance constitute the first part, which sustains a general growth of energy, followed by several similar but shorter movements from quiet to loud, sporadic to complex. First sounds of the piece introduce two voices with strong lower partials which subtly rise and fall in frequency in and out of sync with each other. These voices' presence forms a perceptual drone; their changes in timbre as driven by Rosenboom's system critically characterize the first thirty minutes.

A second group of voices enter at around the eighth minute; first only one synthesized tone with an irregular, fast warbling filter envelope. A second voice enters, undulating at first slower, creating a third voice by filtering the tone's partials, but soon matched in speed with its partner. At an eleventh minute, a sudden dip in frequency affects each of the voices, suggesting they system treating them as related to a common frequency-gestalt. The fluttering voices increase in amplitude and coalesce into the increasingly prominent drone texture.

Just before the seventeenth minute emerges a voice which is much freer in pitch, seemingly improvising in reference to the established drone texture in a mode and melodic style (melismatic passages, frequent scooping into pitch and microtonal glissandi) suggestive of South Indian Carnatic music. In the climactic, most texturally dense moment of the piece (twenty-sixth minute), the drone's frequency separate dramatically the first voice begins to rise and the second follows some time later, suggesting the system has decided to consider the voices independently in the realm of frequency. The improvising voice drops from the texture, and the drone constituent signals becomes increasingly noisy, becoming sort of whining, downward slides in frequency punctuated by spike of loud sound which reminds of the first movement.

It is hard to decipher which sounds are reactions to the mental signals of perception, though predictions can be made through listening. Perhaps with visual cues provided by the performer, such as the opening and closing of eyes to stop alpha wave production, might clue listeners in to how this performative relationship. It might be possible to link textures between these two; the twenty-seven minute mark in the Vancouver performance and the beginning of Toronto performance described above are contrapuntally similar in texture, but of a much different tone quality.

Just before the thirty-fifth minute, there is also a notable sound gesture which seems to be timbrally reminiscent of the very beginning of the Toronto recording; suggesting that at its feasible that some changes in the quality of sounds may recur in different performances. A more general similarity may be observed by comparative

listening to the two records: both pieces contain sounds suggestive of brainwave sonification in their envelop, duration, and consistency of texture over time. These frequent, almost periodic spikes in amplitude which pervade many sections of each performance may also be observed in the wave forms above.

FIVE. *ON BEING INVISIBLE* and THE BODY: CONCLUSIONS

There exists no proper score for *On Being Invisible,* and although Rosenboom has documented the system he built, it would be nothing less than painstaking to replicate. As a result, the piece has been and may only ever be performed by Rosenboom and the reflects his personal performance practice. As such, we can understand *On Being Invisible* as Rosenboom's last proposition regarding EEG music of the 1970s. What exactly then does *On Being Invisible* propose about the role of the body in the performance of EEG music?

In a 1972, Rosenboom wrote "there are those who say: 'Who wants to have a plug at the back of the head to produce music?' But would this be so different from teaching the fingers to play a piano? The problem is how to make a bio-feedback system that would permit a person to control the brainwave output for musical purposes."[154] *On Being Invisible* represents perhaps Rosenboom's most sophisticated answer to tis problem.

In this text, I have sought to assemble several concepts and ideas to speak to the Rosenboom's artistic experiments with EEG and the phenomenon as a whole. Gesture, musical interfacing and organology, Merleau-Ponty's embodiment, Don Ihde's technofantasy, cybernetics, cognitivism, Koestler's holarchy and Rosenboom's own propositional aesthetics – these perspectives meet at the body.

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[154] David Rosenboom, "Methods for Producing Sounds or Light Flashes with Alpha Brain Waves for Artistic Purposes," *Leonardo* 5, no. 2 (Spring 1972), 142.

Andy Clark puts forth the notion of *profound embodiment*, which is the third tier of various gradations of an entity's self-regulating autonomy. A descriptor applicable to both human and non-human entities, Clark writes that "humans are *profoundly embodied agents*: creatures for whom body, sensing, world, and technology are resources apt for recruitment in ways that yield a permeable and repeatedly reconfigurable agent/world boundary."[155] In this light, *On Being Invisible* comes close to allowing both the system and the performer to exist on this level of awareness of the world. The performer is encouraged to make entrances or exits with the starting and stopping of brainwave production and the system reconfigures its anticipations of how its sonic output will be perceived by the performer.

On Being Invisible's perceptual hearing model guiding the production of sounds in combination with the control mechanism analyzing EEG signals to confirm these predictions creates unique conditions for performance incredibly sensitive to the embodied acts of listening, perceiving, and producing brainwaves. In contrast to *Music for Solo Performer*'s dramaturgy of performer failure, *On Being Invisible* is driven by the opportunity of the performer to intentionally enter or exit the system – assuming the performer's competency and thus respecting their sense of agency.

This system seems to move towards realizing the kinds of technofantasies proposed in the 1971 by John Lennon, Chuck Berry, and Yoko Ono, however in a very

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[155] Andy Clark, "Re-Inventing Ourselves: The Plasticity of Embodiment, Sensing, and Mind," *Journal of Medicine and Philosophy* 32 (2007): 279.

different manner. Instead of tapping into and extracting vivid musical thought from the conscious or unconscious mind, Rosenboom developed a complex system with a robust sound vocabulary to be driven by an expert performer – representing one of the more deeply investigative and evolved EEG performance practices to date.

BIBLIOGRAPHY

Anderson, Christine. *Komponieren zwischen Reihe, Aleatorik und Improvisation: Franco Evangelistis Suche nach einer neuen Klangwelt.* Sinfonie 18. Hofheim: Wolke Verlag, 2013.

Arms, Jay M. Review of *Music 109: Notes on Experimental Music* by Alvin Lucier. *The Bulletin of the Society for American Music* 40, no. 2 (Spring 2014): 21–23.

Auslander, Philip. *Liveness: Performance in a Mediatized Culture.* London: Routledge, 2008.

——."Music as Performance: Living in the Immaterial World." *Theater Survey* 47, no. 2 (November 2006): 261–269.

Bailey, Derek. *Musical Improvisation: Its Nature and Practice in Music*. Englewood Cliffs, NJ: Da Capo, 1980.

Barzel, Tamar. "An Interrogation of Language: 'Radical Jewish Culture' on New York City's Downtown Music Scene." *Journal of the Society for American Music* 4, no. 2 (March/April 2010): 215–250.

Battcock, Gregory, ed. *Breaking the Sound Barrier: A Critical Anthology of New Music.* New York: E.P. Dutton, 1981.

Battier, Marc and Marcelo M. Wanderley eds. *Trends in Gestural Control of Music.* Originally published as CD-ROM (Paris: IRCAM, 2000).

Bellen, Martine and David Rosenboom. "Prolegomenon to *AH!: Opera No-Opera.*" Accessed January 1, 2015. http://www.davidrosenboom.com/sites/default/files/media/downloads/Prolegomenon%20to%20AH%21_0.pdf.

Benson, Bruce Ellis. *The Improvisation of Musical Dialogue: A Phenomenology of Music.* Cambridge: Cambridge University Press, 2003.

Bergstrom, Ilias, et al. "Using Music as a Signal for Biofeedback." *International Journal of Psychophysiology* 93 (2014): 140–149.

Bernard, Jonathan W. "Theory, Analysis, and the 'Problem' of Minimal Music." In *Concert Music, Rock, and Jazz Since 1945: Essays and Analytical Studies,* edited by Elizabeth West Marvin and Richard Hermann, 259–284. Rochester, NY: University of Rochester Press, 1995.

Bernstein, David W. ed. *The San Francisco Tape Music Center: 1960s Counterculture and the Avant-Garde.* Berkeley, CA: University of California Press, 2008.

——. "'Listening to the Sounds of the People': Frederic Rzewski and Musica Elettronica Viva (1966-1972)." *Contemporary Music Review* 29, no. 6 (December 2010) 535–550.

Bicknell, Stephen. "Organ Construction." In *The Cambridge Companion to the Organ*, edited by Nicholas Thistlethwaite and Geoffrey Webber. Cambridge, England: Cambridge University Press, 1998.

Bhagwati, Sandheep, David Rosenboom, Navid Navab, and Julian Stein. Posted June 12, 2012. "09 Native Alien with David Rosenboom." Vimeo video, 29:24. Accessed April 4, 2015. https://vimeo.com/43946733.

Black, Daniel. *Embodiment and Mechanization*. Burlington, VT: Ashgate, 2014.

Blum, Thom. Review of *Biofeedback and the Arts: Results of Early Experiments* edited by David Rosenboom. *Computer Music Journal* 13, no. 4 (Winter 1989): 86–88.

Born, Georgina. "On Musical Mediation: Ontology, Technology, and Creativity." *Twentieth-Century Music* 2, no. 1 (2005): 7–36.

Brinkmann, Reinhold, ed. *Improvisation und neue Musik.* Mainz, Germany: Schott, 1979.

Brouse, Andrew. "Petit guide de la musique des ondes cérébrales", *Horizon 0*, No. 15. Accessed December 3, 2014. http://www.horizonzero.ca.

Brown, Chris. "David Rosenboom's Future Travel." New York: New World Records. 2007. CD. Liner Notes.

Brown, Earle. "Notes on Some Works." *Contemporary Music Newsletter* 6, no. 1 (1972): 1–3.

Brown, Earle. "On December 1952." *American Music* 26, no. 1 (2008): 1–12

Burr, Anthony. "Between Composition and Phenomena: Interpreting 'In Memoriam John Higgins'." *Leonardo Music Journal* 22 (December 2012): 87.

Burns, Christopher. "Realizing Lucier and Stockhausen: Case Studies in the Performance Practice of Electroacoustic Music." *Journal of New Music Research* 31, no. 1 (March 2002): 59–68.

Buzsáki, Gyorgy. *Rhythms of the Brain.* Oxford: Oxford University Press, 2011.

Claude Cadoz and Marcelo M. Wanderley, "Gesture - Music." In *Trends in Gestural Control of Music,* eds. M.M. Wanderley and Michael Battier, 71–94. Paris: IRCAM Centre Pompidou, 2000.

Cameron, Catherine. *Dialectics in the Arts: The Rise of Experimentalism in American Music.* Westport, CT: Praeger, 1996.

Cascone, Kim."The Aesthetics of Failure: 'Post-Digital' Tendencies in Contemporary Computer Music." In *Audio Culture: Readings in Modern Music,* edited by Christoph Cox and Daniel Warner, 392–398. New York: Continuum Press, 2004.

Chadabe, Joel. *Electric Sound: the Past and Promise of Electronic Music.* Upper Saddle River, NJ: Prentice Hall, 1997.

Clark, Andy. *Being There: Putting the Brain, Body and World Together Again.* Cambridge, MA: MIT Press, 1997.

——. "Re-Inventing Ourselves: The Plasticity of Embodiment, Sensing, and Mind." *Journal of Medicine and Philosophy* 32 (2007): 263–282.

——. *Supersizing the Mind: Embodiment, Action and Cognitive Extension.* Oxford: Oxford University Press, 2008.

Clarkson, Austin. "'Structures of Fantasy and Fantasies of Structure': Engaging the Aesthetic Self." *Current Musicology* (2005): 67–94.

Cogan, Robert. *New Images of Musical Sound.* Cambridge: Harvard University Press, 1984.

Collins, Nicolas. "Resonance Comes Between Notes and Noise." *Leonardo Music Journal* 22 (December 2012): 87.

—— and Julio d'Escriván, eds. *The Cambridge Companion to Electronic Music.* Cambridge, England: Cambridge University Press, 2012.

——. "Nicholas Collins Talking About Alvin Lucier." YouTube video, 9:31, introduction to the Lucier festival produced by Dag in De Branding, The Hague (NL), May 29, 2010. Video by Viola Rusche, posted by "siliconluthier," December 14, 2011, https://www.youtube.com/watch?v=c1C-HNpRpMs8.

Computer Music Journal. “MF Concerts at the Chelsea Art Museum.” News Release. *Computer Music Journal* 27, no. 4 (Winter 2003): 11–12.

Computer Music Journal. “13th Annual Florida Electroacoustic Music Festival.” News Release. *Computer Music Journal* 28, no. 3 (Fall 2004): 9–10.

Cook, Nicholas. *Music, Performance, Meaning: Selected Essays.* Aldershot: Ashgate, 2007.

——. “Changing the Musical Object: Approaches to Performance Analysis.” In *Music’s Intellectual History: Founders, Followers and Fads,* edited by Zdravko Blazekovic and Barbara Dobbs Mackenzie, 775–790. New York: RILM, 2009.

——. and Richard Pettengill. *Taking it to the Bridge: Music as Performance.* Ann Arbor: University of Michigan Press, 2013.

Cook, Perry. “Principles for Designing Computer Music Controllers,” *New Interfaces for Musical Expression* (2001).

Chung, Becky. “10 Pieces of Music Created With Brainwaves.” *The Creators Project.* June 25, 2014. Accessed February 10, 2014. http://thecreatorsproject.vice.com/blog/10-pieces-of-music-created-by-brainwaves.

Cope, David. *New Directions in Music.* Long Grove, IL: Waveland Press, 2001.

Corness, Greg. “The Musical Experience Through the Lens of Embodiment.” *Leonardo Music Journal* 18 (2008): 21–24.

Cox, Christopher. “The Alien Voice: Alvin Lucier’s *North American Time Capsule 1967*.” In *Mainframe Experimentalism: Early Computing and the Foundations of the Digital Arts,* edited by Hannah B. Higgins and Douglas Kahn, 171–192. Berkeley: University of California Press, 2012.

Crawford, Tim and Loran Gibson, eds. *Modern Methods for Musicology: Prospects, Proposals, and Realities*. Burlington, VT: Ashgate, 2012.

Cumming, Naomi. *The Sonic Self: Musical Subjectivity and Signification.* Bloomington, IN: Indiana University Press, 2002.

Davis, Randal. “‘. . .And What They Do As They’re Doing. . .’: Sounding Space In the Work of Alvin Lucier.” *Organised Sound* 8, no. 2 (August 2003): 205–212.

Dean, Roger T. “Envisioning Improvisation in Future Computer Music.” In *The Oxford Handbook of Computer Music*, edited by Roger T. Dean, 133–150. New York: Oxford University Press, 2009.

DeLio, Thomas. “Avant-Garde Issues in Seventies Music.” In *Breaking the Sound Barrier*, edited by Gregory Battcock, 254, 267–269. New York: Dutton, 1981.

——. *Circumscribing the Open Universe: Essays on Cage, Feldman, Wolff, Ashley and Lucier.* Lanham, MD: University Press of America, 1985. 89–105.

——. “The Music of Alvin Lucier” *Journal of New Music Research* 10, no. 2 (1981): 137–146.

Demers, Joanna. *Listening Through the Noise: The Aesthetics of Experimental Electronic Music.* New York: Oxford University Press, 2010.

Dery, Mark. “The Arcane Experiments of Richard Teitelbaum.” *Keyboard* 15, no. 7 (1989): 74–88.

Dodge, Charles. *Earth’s Magnetic Field.* Nonesuch records, 1970, LP, liner notes.

Downey, Greg. “Listening to Capoeira: Phenomenology, Embodiment, and the Materiality of Music.” *Ethnomusicology* 46, no. 3 (Fall 2002): 487–509.

Drees, Stefan. “Körper Medien Musik: Körperdiskurse in der Musik nach 1950.” Hofheim, Germany: Wolke, 2011.

Dreyfus, Hubert L. “The Current Relevance of Merleau-Ponty’s Phenomenology of Embodiment.” *The Electronic Journal of Analytic Philosophy* 4 (Spring 1996). Accessed November 15, 2014. http://ejap.louisiana.edu/ejap/1996.spring/dreyfus.1996.spring.html.

Duckworth, William. *20/20: 20 New Sounds of the 20th Century.* New York: Schirmer Books, 1999.

——. *Virtual Music: How the Web Got Wired for Sound.* London: Routledge, 2005.

Duncan, Alexander. “EEG Pattern Classification for the Brain-Computer Musical Interface.” Ph.D. diss., Glasgow University, 2001.

Dunn, David. “A History of Electronic Music Pioneers.” In *Classic Essays on Twentieth-Century Music: A Continuing Symposium,* edited by Joseph Darby, Richard Kostelanetz, and Matthew Santa, 87–123. New York: Schirmer Books, 1996.

Dyson, Frances. *Sounding New Media: Immersion and Embodiment in the Arts and Culture.* Berkeley: University of California Press, 2009.

Eaton, Manford L. "Bio-potentials as Control Data for Spontaneous Music." ORCUS, Operational Research Company Universal Systems, technical bulletin no. 3001 (August, 1968).

——. *Bio-Music.* Barton: Something Else Press, 1974.

Emmerson, Simon. "Combing the Acoustic and the Digital: Music for Instruments and Computers or Prerecorded Sound." In *The Oxford Handbook of Computer Music,* edited by Roger T. Dean, 167–190. New York: Oxford University Press, 2009.

—— ed. *Music, Electronic Media, and Culture.* Burlington, VT: Ashgate, 2000.

——. *Living Electronic Music.* Burlington, VT: Ashgate, 2007.

Erickson, Robert. *Sound Structure in Music.* Berkeley, University of California Press, 1975.

Fels, Sidney. "Intimacy and embodiment: Implications for Art and Technology**."** *ACM Conference on Multimedia* (200): 13–16.

Ferrari, Giordano. "Franco Evangelisti." Grove Music Online, Oxford Music Online. Accessed September 21, 2014. http://www.oxfordmusiconline.com/subscriber/article/grove/music/09095.

Fraser, Mariam. "Making Music Matter." *Theory, Culture and Society* 22, no. 1 (2005): 173–189.

Gardiner, Michael, John Sakata, Binu Tulachan. "In Memory, Theory: Concluding Unscientific Postludes," *Current Musicology* 95 (Spring 2013): 118–161.

Gerlach, Julia. "Körpermusik: Körper in intermedialer Musik und Klangkunst." *Neue Zeitschrift für Musik* 167, no. 4 (July 2006): 22–25.

Gimbel, Allen. Review of "Sferics; Music for Solo Performer." *American Record Guide* 74, no. 3 (May 2011): 145.

Glover, Martin Kier. "The Drama of Harrison Birtwistle's 'The Triumph of Time'." *Tempo* 66 (262): 2–11.

Godlovitch, Stan. *Musical Performance: A Philosophical Study.* London: Routledge, 1998.

Goehr, Lydia. *Imaginary Museum of Musical Works.* Oxford: Oxford University Press, 2007.

——. "Explosive Experiments and the Fragility of the Experimental," *Elective Affinities: Musical Essays on the History of Aesthetic Theory,* 108–135. Columbia University Press: 2008.

Green, Thomas H. "Straight, No Chaser." *Mixmag* 237 (February 2011): 62–65.

Hackett, Paul G. *Theos Bernard, the White Lama: Tibet, Yoga, and American Religious Life.* New York: Columbia University Press, 2012.

Haskins, Rob. Review of *Music 109: Notes on Experimental Music,* by Alvin Lucier. *ARSC Journal* 44, no. 2 (Fall 2013): 21–23.

Hebdige, Dick. "Un-imagining Utopias," in *Sound Unbound: Sample Digital Music and Culture,* edited by Paul D. Miller, 83–89. Cambridge, MA: MIT Press, 2001.

Hermann, Thomas, Andy Hunt, John G. Neuhoff, eds. *The Sonification Handbook.* Logos Publishing House, Berlin: 2011.

Hiller, Lejaren. *Experimental Music: Composition with an Electronic Computer.* New York: McGraw-Hill, 1959.

Hoffman, Elizabeth. "On Performing Electroacoustic Musics: a Non-idiomatic Case Study for Adorno's Theory of Musical Reproduction." *Organised Sound* 18, special issue 1 (April 2013): 60–70.

Hoffman, Frank, ed. *Encyclopedia of Recorded Sound.* London: Routledge, 2004.

Holmes, Thom. *Electronic and Experimental Music.* 2nd edition. London: Routledge, 2002.

Howe, Blake. "The Allure of Dissolution: Bodies, Forces, and Cyclicity in Schubert's Final Mayrhofer Settings." *Journal of the American Musicological Society* 62, no. 2 (Summer 2009): 271–322.

Husserl, Edmund. *Ideen zu einer reinen Phänomenologie und phänomenologischen Philosophie: Allgemeine Einführung in die reine Phänomenologie.* Hamburg, DE: Meiner Felix Verlag, 2009.

Hsu, Sheng-Hsiou and Tim Mullen. “Online Recursive Independent Component Analysis for Real-time Source Separation of High-density EEG.” *Engineering in Medicine and Biology Society 36th Annual International Conference* (2014).

Ihde, Don. *Bodies in Technology.* Minneapolis: University of Minnesota Press, 2002.

——. *Embodied Technics.* Copenhagen, DK: Automatic Press, 2010.

——. *Listening and Voice: Phenomenologies of Sound,* second edition. New York: State University of New York Press, 2007.

Jantsch, Erich. *The Self Organizing Universe: Scientific and Human Implications of the Emerging Paradigm of Evolution.* Oxford: Pergamon Press, 1980.

Jensenius, Alexander Refsum, Rolf Inge Godøy, and Marcelo M. Wanderley. “Developing Tools for Studying Musical Gestures Within the Max/MSP/ Jitter Environment.” *Free Sound International Computer Music Conference* (2005): 282–285.

Jordà, Sergi.“Digital Lutherie: Crafting musical computers for new musics’ performance and improvisation.” Ph.D diss. UPF Barcelona, 2005.

Johnson, Tom. *The Voice of New Music: New York City, 1972-1982: A Collection of Articles Originally Published in the Village Voice.* Eindhoven, NL: Apollohuis, 1989. 31–31, 68–69, and 288–291.

Kahn, Douglas. *Noise, Water, Meat: A History of Sound in the Arts.* Cambridge: Massachusetts Institute of Technology Press, 1999.

——. *Earth Sound Earth Signal: Energies and Earth Magnitude in the Arts.* Berkeley: University of California Press, 2010.

Kim, Jin Hyun and Uwe Seifert. “Embodiment: The Body in Algorithmic Sound Generation.” *Contemporary Music Review* 25, no. 1/2 (February 2006): 139–149.

Laing, Ronald David. *The Politics of Experience.* New York: Penguin, 1990.

Landy, Leigh. *Experimental Music Notebooks*. London: Routledge, 1994.

——. *What’s the Matter with Today’s Experimental Music? Organized Sound Rarely Heard.* Chur: Harwood, 1991.

Latartara, John and Michael Gardiner. “Analysis, Performance, and Images of Music Sound: Surfaces, Cyclical Relationships, and the Musical Work.” *Current Musicology* 84 (Fall 2007): 53–59, 61–78, and 181–182.

de Laubier, Serge. “The Meta-Instrument.” *Computer Music Journal* 22, no. 1 (Spring 1998): 25.

Leder, Drew. *The Absent Body.* Chicago: The University of Chicago Press, 1990.

Leman, Marc. *Embodied Music Cognition and Mediation Technology.* Cambridge, MA: MIT Press, 2008.

——. “Musical Gestures and Embodied Cognition.” *Actes des Journées d’Informatique Musicale* (May 2012): 5–7.

Lewis, George E. “Interactivity and Improvisation.” In *The Oxford Handbook of Computer Music,* edited by Roger T. Dean, 457–466. Oxford: Oxford University Press, 1999.

Leslie, Grace and Tim Mullen. “MoodMixer: EEG-based Collaborative Sonification.” *New Interfaces for Musical Expression* (2011).

Lucier, Alvin. “Beats That Can Move Sugar.” Interview by Michael Parsons. *Resonance* 4, no. 10 (1995): 10–16.

—— and Douglas Simon. *Chambers.* Interviews by Douglas Simon. Middletown, CT: Wesleyan University Press, 1980.

——. “Fruits and Vegetables.” *Current Musicology* (Fall–Winter 1999): 253–268.

——. Interview by Walter Zimmerman. In *Desert plants: Conversations with 23 American Musicians,* edited by Walter Zimmerman, 137–148. Vancouver: Zimmermann Musikverlag, 1976.

——. *Music 109: Notes on Experimental Music.* Middletown: Wesleyan University Press, 2012.

——. “Origins of a Form: Acoustical Exploration, Science, and Incessancy.” *Leonardo Music Journal* 8 (1999): 5–12.

——. *Alvin Lucier: Reflections: Interviews, Scores, Writings 1965-1994.* Edition Musiktexte 3. Edited by Gisela Gronemeyer and Reinhard Oehlschlägel.

Translated by Markus Trunk, Gisela Gronemeyer, Frank Gertich, and Petra Cosby. Cologne, DE: Edition Musiktexte, 1995.

——. "Seesaw: a sound installation." In *Words and Spaces: An Anthology of Twentieth-Century Musical Experiments in Language*, edited by Thomas DeLio and Stuart Saunders Smith, 222–245. Lanham, MD: University Press of America, 1989.

——. "The Tools of My Trade." In *Contiguous Lines,* edited by Thomas DeLio, 143–160. Lanham, MD: University Press of America, 1985.

——, Mindy Lee, and Elie Siegmeister. "Three Points of View." *The Musical Quarterly* 65, no. 2 (April 1979): 281–295.

——. "Sitting in a Room with Alvin Lucier." Interview by Frank J. Oteri. *NewMusicBox* April 1, 2005. Accessed September 28, 2014. http://www.newmusicbox.org/articles/sitting-in-a-room-with-alvin-lucier-alvin-lucier/.

——. "Vespers: an Interview with Alvin Lucier." Interview by J.D. Simon. *Arts in Society* 9, no. 2 (1972): 277–285.

——. "What We Mean When We Say Music is Universal." *Sonus - A Journal of Investigations into Global Musical Possibilities* 32, no. 1 (Fall 2011): 1–6.

Manning, Peter. *Electronic and Computer Music.* New York: Oxford University Press, 2004.

Margolin, Arthur. "Conversations with Alvin Lucier." *Perspectives of New Music* 20, no. 1/2 (Fall/Winter-1982:Spring/Summer 1981): 50.

May, Andrew. Review of *Invisible Gold* by David Rosenboom. *Computer Music* 26, no. 2 (Summer 2002): 102–103.

Mcluhan, Marshall. "The Argentbite of Outwit" in *Marshall Mcluhan Essays,* edited by Michel A. Moos. Amsterdam, NL: G+B ARTS international, 121–125.

McMullen, Tracy. "Corpo-Realities: Keepin' It Real in "Music and Embodiment" Scholarship." *Current Musicology* (Fall 2006): 61–80.

Merleau-Ponty, Maurice. *Phenomenology of Perception.* Translated by Donald A. Landes. London: Routledge, 2014.

Miranda, Eduardo Reck. *Composing Music with Computers.* Oxford: Butterworth-Heinemann, 2001.

—. "Affective Jukebox: A Confirmatory Study of EEG Emotional Correlates in Response to Musical Stimuli." *Joint International Computer Music Conference / Sound and Music* (2014).

——. "Plymouth brain-computer music interfacing project: from EEG audio mixers to composition informed by cognitive neuroscience." *International Journal of Arts and Technology* 3, no. 2/3 (2010): 154–177.

—-. *Computer Sound Synthesis for the Electronic Musician.* Oxford: Butterworth-Heinemann, 1998.

—— and Julien Castet, eds. *Guide to Brain-Computer Music Interfacing.* Frankfurt: Springer Verlag, 2014.

——. and Alexander Duncan and Ken Sharman. "Mind the Music: Towards Thought-Controlled Music Systems." *XVIII Annual Congress of the Brazilian Symposium on Computer Music* (1998).

——. and Ken Sharman, Kerry Kilborn, and Alexander Duncan. "On Harnessing the Electroencephalogram for the Musical Braincap." *Computer Music Journal* 27, no. 2 (Summer 2003): 80–102.

——. and Marcelo M. Wanderley. *New Digital Musical Instruments: Control and Interaction Beyond the Keyboard.* Middleton, WI: A-R Editions, 2006.

——. and Andrew Brouse. "Toward Direct Brain-Computer Musical Interfaces." In *New Interfaces for Musical Expression, 2005.*

——. and Andrew Brouse. "Interfacing the Brain Directly with Musical Systems: On developing systems for making music with brain signals." *Leonardo* 38 , no. 4 (2005): 331–336.

Miller-Keller, Andrea, ed. *Alvin Lucier: A Celebration.* Middletown, CT: Wesleyan University Press, 2012.

Motte-Haber, Helga de la. "Embodiment – Klanggeste – Biofeedback: Rück- und Ausblick auf ein neues Thema der Musikwissenschaft." *Positionen: Texte zur aktuellen Musik* 83 (May 2010): 6–10.

——. “Extrem Schönes Donnern.” *Neue Zeitschrift für Musik* 160, no. 2 (March 1999): 10–15.

Müller, Hermann-Christoph. “Auf Der Grenze: Natur in der Amerikanischen Musik.” *Neue Zeitschrift für Musik* 165, no. 2 (March 2004): 38–41.

Mullen, Tim, Richard Warp, and Adam Jansch. “Minding the (Transatlanctic) Gap: An Internet-Enabled Acoustic Brain-Computer Music Interface.” *New Interfaces for Musical Expression* (2011).

Mulder, Axel. “Design of Virtual Three-dimensional instruments for Sound Control.” PhD diss., Simon Fraser University, 1998. ProQuest (NQ37736).

——. “Getting a Grip on Alternate Controllers: Addressing the Variability of Gesture Expression in Musical Instrument Design.” *Leonardo Music Journal* 66 (1996): 33.

——. “Virtual Musical Instruments: Accessing the Sound Synthesis Universe as a Performer.” *Simpósio Brasileiro de Computação e Música* (1994): 243–250.

——. “Human Movement Tracking Technology.” Report 94-1 of the Hand Centered Studies of Human Movement Project. Burnaby, British Columbia, Canada: Simon Fraser University, 1994. Accessed December 18th, 2014. http://www.xspasm.com/x/sfu/vmi/HMTT.pub.html.

Mumma, Gordon. “Alvin Lucier’s Music for Solo Performer (1965)” *Source* 2 (1968): 68–69.

——. “Live-electronic Music.” In *The Development and Practice of Electronic Music,* edited by Ronald C. Perera and Jon H. Appleton, 286–335. Englewood Cliffs, NJ: Prentice-Hall, 1975.

Norman, Katherine. “Real-World Music as Composed Listening.” *Contemporary Music Review* 15, no. 1/2 (1996): 1–28.

Novello, Alberto. “From Invisible to Visible: The EEG as a Tool for Music Creation and Control.” MA Thesis, Institute of Sonology, 2012. Accessed October 15, 2014. http://www.sonology.org/NL/thesis-pdf/Alberto%20Novello.pdf.

Nuzzo, Angelica. *Ideal Embodiment: Kant’s Theory of Sensibility.* Studies in Continental Thought. Bloomington: Indiana University Press, 2008.

Ojanen, Mikko, Jari Suominen, Titti Kallio, and Kai Lassfolk. "Design Principles and user interfaces of Errki Kurenniemi's Electronic Musical Instruments of the 1960's and 1970's." *New Interfaces for Musical Expression* (2007): 88–93

Oreskes, Naomi and John Krige, eds. *Science and Technology in the Global Cold War.* Cambridge, MA: MIT Press, 2014.

Ouzounian, Gascia. "Embodied Sound: Aural Architectures and the Body."*Contemporary Music Review* 25, no. 1/2 (February–April 2006): 69–79.

Overholt, Daniel James. "Musical Interface Technology: Multimodal Control of Multidimensional Parameter Spaces for Electroacoustic Music." PhD Diss., University of California, Irvine. 2007. ProQuest (3291442).

Paine, Garth. "Gesture and Morphology in Laptop Music Performance." In *The Oxford Handbook of Computer Music*, edited by Roger T. Dean, 214–232. New York: Oxford University Press, 2009.

——. "Interactivity: Where to from here?" *Organized Sound: An International Journal of Music Technology* 7, no. 3 (December 2002): 295–304.

Perera, Ronald C. and Jon H. Appleton, eds. *The Development and Practice of Electronic Music.* Englewood Cliffs, NJ: Prentice-Hall, 1975.

Perkis, Tim. Review of *Crossings* by Alvin Lucier and *Digital Music* by Emanuel Dimas de Melo Pimenta. *Leonardo Music Journal* 1, no. 1 (1991): 112

——. Review of Musica Elettronica Viva performance, featuring Frederic Rzewski, Alvin Curran, Richard Teitelbaum, and George Lewis at Mills College, Oakland, California, February 12th 1994. *Computer Music Journal* 18, no. 3 (Fall 1994): 66.

——. "Some Notes on my Electronic Improvisation Practice." In *The Oxford Handbook to Computer Music,* 161–166. Edited by Roger T. Dean. Oxford: Oxford University Press, 2009.

Piekut, Benjamin. *Experimentalism Otherwise: The New York Avant-Gade and its Limits.* Berkeley, CA: University of California Press, 2011.

Pinch, Trevor and Frank Trocco. *Analog Days: The Invention and Impact of the Moog Synthesizer.* Cambridge, MA: Harvard University Press, 2002.

Rafo Dewar, Andrew. “Handmade Sounds: The Sonic Arts Union and American Technoculture.” PhD diss., Wesleyan University, 2009. ProQuest (3362663).

Reich, Charles A. *The Greening of America: How the Youth Revolution is Trying to Make America Livable.* New York: Random House, 1970.

Reybrouck, Mark. “Musical Imagery between Sensory Processing and Ideomotor Simulation.” In *Musical Imagery,* edited by R.I. Godoy and H. Jogensesn, 117–136. New York: Taylor and Francis, 2001.

——. “Music Cognition and the Bodily Approach: Musical Instruments as Tools for Musical Semantics. *Contemporary Music Review* 25, no. 1/2 (February–April 2006): 59–68.

Riddell, Alistair, Bart Hopkin and Alec Bernstein. “Computer Control for Acoustic Instruments.” *Experimental Musical Instruments* 7, no. 1 (1991): 8–11.

Risset, Jean-Claude, and David L. Wessel. “Exploration of Timbre by Analysis and Synthesis.” In *The Psychology of Music,* edited by Diana Deutsch, 113–69. San Diego: Academic Press, 1999.

Reynolds, Roger. *Mind Models: New Forms of Musical Experience.* London: Routledge, 2005.

Rogalsky, Matthew. “‘Nature’ as an Organising Principle: Approaches to Chance and the Natural in the work of John Cage, David Tudor and Alvin Lucier.” *Organised Sound* 15, no. 2 (August 2010): 133-136.

Roszak, Theodore. *The Making of a Counter Culture: Reflections on the Technocratic Society and its Youthful Opposition.* Berkeley, CA: University of California Press, 1969.

Rowe, Robert. Review of *CDCM - Computer Music Series* volume 2 by Rick Baitz, Martin Bresnick, Scott Lindroth, Neil Rolnick, and Richard Teitelbaum. *Computer Music Journal* 13, no. 4 (Winter 1989).

——. *Interactive Music Systems : Machine Listening and Composing.* Cambridge, MA: MIT Press, 1993.

——. Review of *Systems of Judgement* by David Rosenboom. *Computer Music Journal* 14, no. 3 (Fall 1990): 84–85.

Rosenboom, David. “B. C.-A. D. and Two Lines: Two Ways of Making Music While Exploring Instability--In Tribute to Salvatore Martirano.” *Perspectives of New Music* 34, no. 1 (Winter 1996): 207–226.

——. *Collected Articles: A Selection of Previously Unpublished or Out of Print Writings by David Rosenboom 1968–1982.* Piedmont, CA: David Rosenboom Productions, 1984.

——.“New Musical Interfaces: The Performing Brain.” *Computer Music Journal* 14, no. 1 (Spring 1990): 48–66, 100.

——. *Extended Musical Interface with a Human Nervous System: Assessment and Prospectus.* Leonardo monograph 1. Berkeley: International Society for Arts, Sciences, and Technology, 1990.

——. “Interview with David Rosenboom.” Interview by Larry Polanski. *Computer Music Journal* 7, no. 4 (Winter 1983), 40–44.

——. “Propositional Music: On Emergent Properties in Morphogenesis and the Evolution of Music, Part I: Essays, Propositions and Commentaries.” *Leonardo* 30 no. 4 (1997): 291–297.

——. “Propositional Music: On Emergent Properties in Morphogenesis and the Evolution of Music, Part II: Imponderable Forms and Compositional Methods.” *Leonardo Music Journal* 7 (1997): 35–39.

——. “A Program for the Development of Performance-Oriented Electronic Music Instrumentation in the Coming Decades: “What You Conceive Is What You Get.” *Perspectives of New Music* 25, no. 1/2 (Winter–Summer 1987): 569–583.

—— and Richard Teitelbaum. “In Conversation: David Rosenboom and Richard Teitelbaum. *Musicworks: The Journal of Sound Exploration* 21 (Fall-Winter 1982): 12–14.

——, ed. *Biofeedback and the Arts: Results of Early Experiments.* Vancouver: Aesthetic Research Centre of Canada, 1975.

——. “Body Brain Performance.” Interview by David Paul. *Performing Arts Journal* 10, no. 2 (1986): 5, 12–16.

——. “How Important is the Scientific Aspect of your Work?” *NewMusicBox,* April 1, 2005. http://www.newmusicbox.org/articles/How-important-is-the-scientific-aspect-of-your-work-David-Rosenboom/. Accessed September 28, 2014.

——. “Active Imaginative Listening— a neuromusical critique.” *Frontiers in Neuroscience* 8, no. 251 (August 2014): 1–8.

——. “Method of Producing Sounds or Light Flashes with Alpha Brain Waves for Artistic Purposes.” *Leonardo* 5*,* no. 2 (Spring 1972), 141–145.

——. Interview with Dean Rosenthal. Accessed November 15, 2014. http://www.deanrosenthal.org/rosenboom.html.

Rzewski, Frederick. “Little Bangs: A Nihilist Theory of Improvisation.” *Current Musicology* 67/68 (2002): 377–386.

Sanders, Linda and Keith Moore. “Alvin Lucier” Grove Music Online, Oxford Music Online. Accessed September 21, 2014. http://www.oxfordmusiconline.com/subscriber/article/grove/music/47065.

Sanio, Sabine. “Ausdruckskonzepte in der Musik des 20. Jahrhunderts.” *Dissonanz/Dissonance* (December 2001): 4–9.

—-.“Ein Neues Verständnis von Musik.” *Neue Zeitschrift für Musik* 161, no. 5 (September 2000): 24–31.

Saunders, James ed. *The Ashgate Research Companion to Experimental Music.* Farnham: Ashgate, 2005.

Saunders, Frances Stonor. *The Cultural Cold War: The CIA and the World of Arts and Letters.* New York: The New Press, 2001.

Scharf, Robert H. “Whose Zen? Zen Nationalism Revisited.” In *Rude Awakenings: Zen, the Kyoto School, and the Question of Nationalism* (Nanzan Studies in Religion and Culture), edited by James W. Heisig and John Maraldo, 40–51. Honolulu: University of Hawai’i Press, 1995.

Serafin, Stefania and Matthew Burtner. “The Exbow MetaSax: Compositional Applications of Bowed String Physical Models Using Instrument Controller Substitution.” *Journal of New Music Research* 31, no. 2 (June 2002): 131–140.

Shaw, George Bernard. “Man and Superman.” In *George Bernard Shaw’s plays: Mrs Warren’s Profession, Pygmalion, Man and Superman, Major Barbara: contexts and criticism,* 483–474. New York: Dodd, Mead & Company, 1935.

Shaw, John C., ed. *The Brain’s Alpha Rhythms and the Mind: A Review of Classical and Modern Studies of the Alpha Rhythm Component of the*

Electroencephalogram with Commentaries on Associated Neuroscience and Neuropsychology. Amsterdam: Elsevie, 2003.

Siegel, Wayne and Jens Jacobsen. "The Challenges of Interactive Dance: An Overview and Case Study." *Computer Music Journal* 22, no. 4 (Winter 1998): 29–43.

Simanowski, Roberto. *Digital Art and Meaning: Reading Kinetic Poetry, Text Machines, Mapping Art, and Interactive Installations.* Minneapolis: University of Minnesota Press, 2011.

Simoni, Mary, ed. *Analytical Methods of Electroacoustic Music*. London: Routledge, 2006.

Solie, Ruth A. "When the Message Becomes the Medium: Text-Music Relationships in the Avant-Garde." *Ars Lyrica* 4 (1989): 7–18.

Smalley, Denis. "Spectro-morphology and Structuring Processes." In *The Language of Electroacoustic Music*, edited by Simon Emmerson. Hampshire, UK: MacMillan Press, 1984.

Straebel, Volker and Wilm Thoben. "Alvin Lucier's *Music for Solo Performer:* Experimental Music Beyond Sonification." *Organised Sound* 19, special issue 1 (April 2014): 17–29.

Swartz, Barbara E. "The advantages of digital over analog recording techniques." *Electroencephalography and Clinical Neurophysiology* 106, no. 2: 113–117.

Tanaka, Atau. "Sensor-Based Musical Instruments and Interactive Music." In *The Oxford Handbook of Computer Music*, edited by Roger T. Dean, 233–257. New York: Oxford University Press, 2009.

Teitelbaum, Richard. "Improvisation, Computers and the Unconscious Mind." *Contemporary Music Review* 25, no. 5/6 (October–December, 2006): 497–508.

——. "Intervalic Relations in Atonal Music." *Journal of Music Theory* 9, no. 1 (Spring 1965): 72–127.

——."In Tune: Some Early Experiments in Biofeedback Music." In *Biofeedback and the Arts: Results of Early Experiments,* edited by David Rosenboom, 35–56.Vancouver: Aesthetic Research Centre of Canada, 1976.

——. "Interview with Richard Teitelbaum." Interview by Astronauta Pingium. *Astronauta Pingium.* March 20, 2014. Accessed March 1, 2015. http://

astronautapinguim.blogspot.com/2014/03/interview-with-richard-teitelbaum.html.

Tick, Judith. “Because Time was in the Air (Part III)”. *The Bulletin of the Society for American Music* 34, no. 3 (Fall 2008): 53–56.

Tillery, Gary. “The Philosophy of John Lennon.” *Philosophy Now* 52 (August/September 2005): 26-28.

Todd, Peter M. and Garth D. Loy. *Music and Connectionism.* Cambridge, MIT Press, 1991.

Toliver, Brooks. “The Alps, Richard Strauss’s *Alpine Symphony* and Environmentalism.” *Green Letters* 15, no. 1 (October 2011): 8-21.

Trueman, Daniel et al. “PLOrk: The Princeton Laptop Orchestra, Year 1.” *International Computer Music Conference* (2006).

Tyranny, “Blue” Gene. Review of *Invisible Gold* by David Rosenboom. AllMusic.com. Accessed September 1, 2014. http://www.allmusic.com/album/david-rosenboom-invisible-gold-mw0001179426.

Varela, Francisco J., Evan Thompson, and Eleanor Rosch. *The Embodied Mind: Cognitive Science and Human Experience.* Cambridge, MA: MIT Press, 1991.

Vail, Mark. “Curtis ElectroMusic Specialities: Chips That Launched Dozens of Synths.” *Keyboard* 28, no. 9 (September 2002): 120.

Vickey, Lindsay. “The Western Edge: Some Recent Electronic Music from Western Australia.” *Organised Sound* 6, no. 1 (2001): 69–74.

Wanderley, Marcelo and Phillipe Depalle. “Gestural Control of Sound Synthesis.” *Institute of Electrical and Electronics Engineers* 92, no. 4 (April 2004): 632–644.

Wagner, Michael J. “The Effect of Music Stimuli and Biofeedback in the Production of Alpha Brainwave Rhythms and Verbal Reports of Musicians and Non-musicians.” PhD diss., The Florida State University. ProQuest (7330299).

Wagner, Thorsten. *Franco Evangelisti und die Improvisationsgruppe Nuova Consonanza. Zum Phänomen Improvisation in der neuen Musik der sechziger Jahre.* Saarbrücken, DE: Pfau, 2004.

Warde, Anne. Review of "Alvin Lucier — 40 Rooms." *Computer Music Journal* 24, no. 2 (Summer 2000): 110–111.

Wessel, David and Matthew Wright. "Problems and Prospects for Intimate Musical Control of Computers." *New Interfaces for Musical Expression* (2001).

Wiener, Norbert. *Cybernetics: or Control and Communication in the Animal and the Machine.* Cambridge, MA: MIT Press, 1961.

Winkler, Todd. *Composing Interactive Music: Techniques and Ideas using Max.* Cambridge, MA: MIT Press, 1998.

Wiskus, Jessica. *The Rhythm of Thought: Arts, Literature, and Music after Merleau-Ponty.* Chicago: University of Chicago Press, 2013.

Woodruff, Jeremy. "Music for Solo Performer by Alvin Lucier in an Investigation of Current Trends in Brainwave Sonification." https://www.academia.edu/2591068Music_for_Solo_Performer_by_Alvin_Lucier_in_an_Investigation_of_Current_Trends_in_Brainwave_Sonification, accessed December 1, 2014.

Worrall, David. "An Introduction to Data Sonifcation." In *The Oxford Handbook of Computer Music*, edited by Roger T. Dean, 312–333. New York: Oxford University Press, 2009.

Yadlowsky, Peter M. Review of Hierarchical Musical Specification Language (HMSL software) by Phil Burk, Larry Polanski, and David Rosenboom. *Leonardo Music Journal* 1 (1991): 119.

Young, Samson. "I am thinking in a room different from the one you are hearing in now (homage to Alvin Lucier) (2011) - Trailer." Vimeo video. 2:57. Posted by "Samson Young." Accessed September 13, 2014. https://vimeo.com/27901896.

Zibowski, Lawrence M. *Conceptualizing Music: Cognitive Structure, Theory, and Analysis.* Oxford: Oxford University Press, 2002.

DISCOGRAPHY

Braxton, Anthony. *Five Compositions (Quartet) 1986.* Black Saint. 1986. CD.

Hassel, John. *Vernal Equinox.* Lovely Musics. 1990. CD. Originally released in 1977.

Eleven Musicians and HMSL. *Hallways.* Frog Peak Music. 1993. CD.

Jarrett, Keith. *Hymns/Spheres.* ECM Records. 1976. LP.

Lucier, Alvin. *Theme.* Lovely Musics. 1999. CD.

——. *Sferics / Music for Solo Performer (1965).* Lovely Music. 2010. CD.

——. *Vespers and Other Early Works.* New World Records. 2002. CD.

——. "Music For Alpha Waves, Assorted Percussion, and Automated Coded Relays." *Imaginary Landscapes.* Nonesuch. 1989. CD.

Musica Elettronica Viva. *MEV 40.* New World Records. 2008. 4-disk CD.

Riley, Terry. *In C.* Sony Classics. 2009. CD. Originally released in 1968.

Rosenboom, David. *Invisible Gold.* Pogus Music. 2001. CD.

——. *A Live Electro-Acoustic Music Retrospective.* Slowscan. 1987. CD.

——. *Brainwave Music.* Arts Research Centre of Canada. 1975. LP.

——. *Future Travel.* New World Records. 2007. CD.

——. *How Much Better if Plymouth Rock had Landed on the Pilgrims.* New World Records. 2009. CD.

—— and Jacqueline Humbert. "Distant Space." Distributed with *The Wire* (November 2013). *The Wire Tapper* 33. CD

—— and Anthony Braxton. *Two Lines.* Lovely Music. 1996. CD.

—— and Don Buchla. *Collaboration in Performance.* 1750 Arch. 1978. LP.

——. *Predictions, Confirmations & Disconfirmations.* On *In Celebration of the 50th Anniversary of the Experimental Music Studios at the University of Illinois.* School of Music at the University of Illinois at Urbana-Champaign. 2008. 4-disk CD.

——. *Systems of Judgement.* CRC. 1991. CD.

——. Consortium to Distribute Computer Music, Vol. 30. Contains selections from *Music from-On Being Invisible II (Hypatia Speaks to Jefferson in a Dream)*. Centaur Records. 2000. CD.

VIDEOGRAPHY

Ashley, Robert. *Music with Roots in the Aether.* Lovely Music. 2005. DVD. Originally released in 1976.

Rosenboom, David. "Brain Music for John and Yoko: John Lennon, Yoko Ono & Chuck Berry with David Rosenboom." *The Mike Douglas Show*. Performance, interview, and discussions. Originally aired on CBS, Philadelphia, PA, 1972. Re-released by Los Angeles, Rhino Home Video VHS 1998.

Rusche, Viola and Hauke Harder. *No Ideas But in Things: The Composer Alvin Lucier* (Mainz, Germany: Wergo, 2014) DVD.

WEBSITES

"About." David Rosenboom. http://www.davidrosenboom.com/about

"David Rosenboom." CalArts. Accessed March 23, 2015. https://directory.calarts.edu/directory/david-rosenboom.

"David Rosenboom." Lovely Music. http://www.lovely.com/bios/rosenboom.html

"HMSL homepage." Phil Burk. Accessed April 3, 2015, www.softsynth.com/hmsl.

"Marian Zazeela." The Mela Foundation. Accessed February 15, 2015. http://www.melafoundation.org/liteperf.htm

"Native Alien Project." MatraLab. Accessed February 10, 2015. http://matralab.hexagram.ca/projects/native-alien/.

"On Being Invisible." Western Front Archive. Accessed December 15th, 2015. http://front.bc.ca/events/on-being-invisible/

"Pogus Records." Accessed March 13, 2015. http://www.pogus.com/

"Signal Path I: Homage to Alvin Lucier." *This Music is False: Samson Young*. Accessed September 13, 2014. http://www.thismusicisfalse.com/Signal-Path-I-Homage-to-Alvin-Lucier.

APPENDIX

TEXT SCORE BY EDWARD DEWAN FOR ALVIN LUCIER'S *MUSIC FOR SOLO PERFORMER*

The alpha rhythm of the brain has a range of from 8 to 12 hz, and, if amplified enormously and channeled through an appropriate transducer, can be made audible. It can be blocked by visual attention with the eyes open or mental activity with the eyes closed. No part of the motor system is involved in any way. Control of the alpha consists simply of alteration of thought content – for example, a shifting back and forth from a state of visual imagery to one of relaxed resting.

Place an EEG scalp electrode on each hemisphere of the occipital, frontal, or other appropriate region of the performer's head. Attach a reference electrode to an ear, finger, or other location suitable for cutting down electrical noise. Tout the signal through an appropriate amplifier and mixer to any number of amplifiers and loudspeakers directly couple to percussion instruments, include large gongs, cymbals, tympani, metal ashcans, cardboard boxes, bass and snare drums (small loudspeakers face down on them), and to switches, sensitive to alpha, which activate one of more tape recorders upon which are stored pre-recorded, sped-up alpha.

Set free and black alpha in bursts and phrases of any length, the sounds of which, as they emanate from the loudspeakers, cause the percussion instruments to vibrate sympathetically. An assistant may channel the signal to any or all of the loudspeakers in any combination at any volume, and, from time to time, engage the switches to the tape recorders. Performances may be of any length.
Experiment with electrodes on other parts of the head in an attempt to pick up other waves of different frequencies and to create stereo effects.

Use alpha to activate radios, television sets, lights, alarms, and the audio-visual devices. Design automate systems, with or without coded relays, with which the performer may perform the piece without the aid of an assistant.[1]

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[1] Alvin Lucier, "*Music for Solo Performer* (1965)," interview by Douglas Simon, in *Chambers* by Alvin Lucier and Douglas Simon, 69 (Middletown, CT: Wesleyan University Press, 1980)