Elements of Electroacoustic Music Improvisation and Performance

A Pedagogical Toolkit

LUIS ALEJANDRO OLARTE

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Luis Alejandro Olarte

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Supervisors:
Professor Andrew Bentley – Music Technology Department, Sibelius Academy, University of the Arts Helsinki
Jean-François Charles – Assistant Professor in Composition and Digital Arts University of Iowa, School of Music Iowa City

Pre-examiners:
Professor Per Anders Nilsson – Academy of Music and Drama at University of Gothenburg
Jean-François Charles – Assistant Professor in Composition and Digital Arts University of Iowa, School of Music Iowa City

Chair / Custos:
Professor Andrew Bentley

Examiner:
Professor Per Anders Nilsson

Sibelius Academy, University of the Arts Helsinki
MuTri Doctoral School
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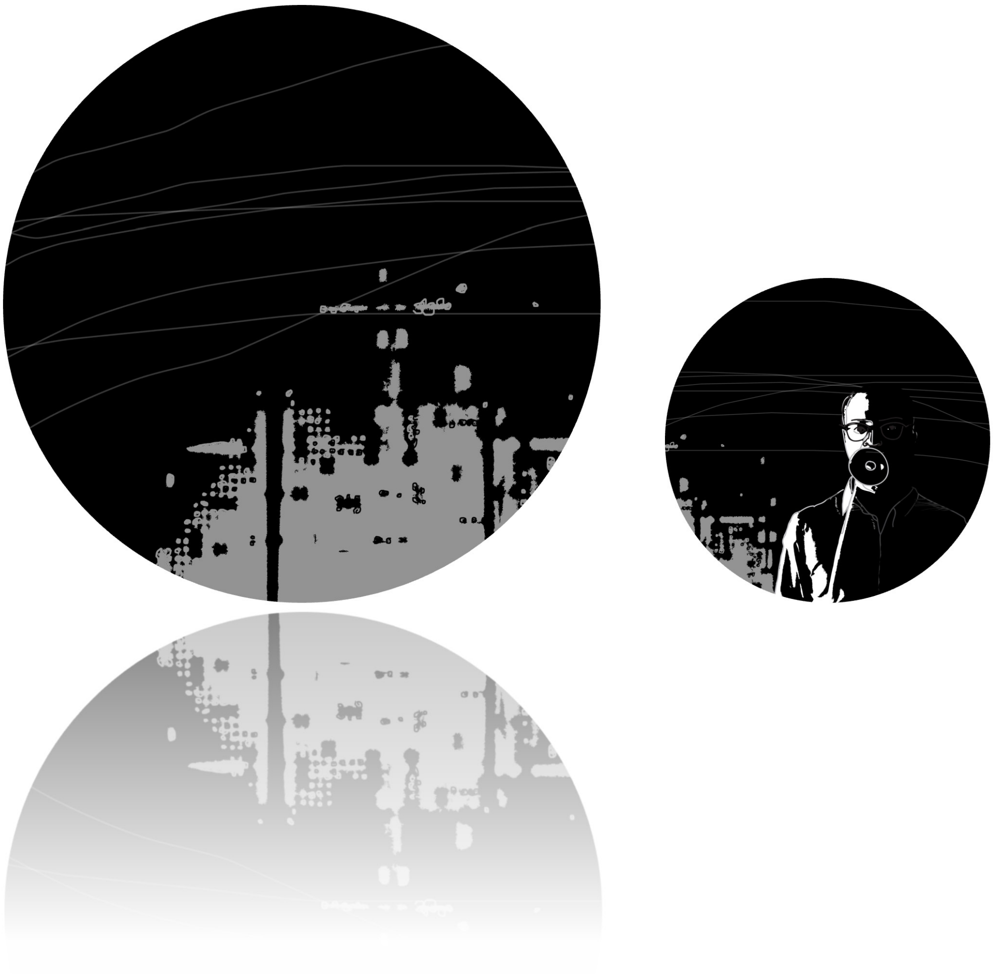

Foreword

`Abstract:` *The core application of my research project is a pedagogical package or toolkit for studying and teaching electroacoustic music performance and improvisation. The package consists of a series of units, each of which investigates fundamental concepts or elements of electroacoustic music, sound theory and its performance aspects through improvisational strategies. The two disciplines of electroacoustic music performance and improvisation, have been considered in a combined and holistic manner. Each unit includes musical exercises, performance situations, theoretical discussions and suggested developments designed to systematically address the essential questions of becoming a sound performer integrating electrical means with musical expression. The toolkit is presented within a theoretical framework where the main aspects of the discipline have been studied: listening and improvisation, the contributions of the electroacoustic genre to modern musicianship and a collection of electronic instruments as tools for performance.*

The toolkit has been developed using a process of qualitative inquiry and action research methodology based on fieldwork with university student groups during more than one thousand hours of workshops over the past five years. The final result is thus a fully integrated skill set compiled in a book. This research is a response to the modern challenges of designing pedagogical content towards the development of performance skills with electronic instruments and audio technology.

The main research question leading this work project has been: *What are the methods, materials, resources, and strategies required to develop skills in the discipline of Electroacoustic Music Performance and Improvisation?*

I approached this question by following a combined methodology of action research and deductive-inductive analysis. The deductive-inductive methodology was applied in the following way: an initial hypothetical content of sonic concepts, performance ideas, musical situations and electroacoustic themes was investigated with music students at third-level education (University of the Arts

Helsinki) in a series of workshops. Evaluating a hypothesis through fieldwork entailed a deductive process. Accordingly, the research findings were recorded via a process of data collection, which included audiovisual recordings, working notes, personal observations, and verbal or written feedback from the participants. This data was then analyzed and evaluated through a triangulation process with my supervisors, leading to the reformulation of the toolkit's contents. In contrast, the process of inferring the theory and contents of the electroacoustic music performance and improvisation discipline from the collected data was an inductive process. The new contents were then further tested on the field and analyzed until reaching the form presented in this document: twenty one units organized into four sections researching the sonic, electroacoustic, musical and performative foremost aspects or *elements* of the discipline; a discussion on the related values of improvised sonic performance and three chapters establishing the theoretical framework.

The results of this research offer the opportunity to acquire knowledge and understanding of electroacoustic music by performing with the tools of the genre while simultaneously developing improvisation skills through the manipulation of sound technology concepts. Playing with electroacoustic tools must impose no obstacle to the flow of the performer's intuition and musical thinking, and the development of a proper dexterity should be considered a fundamental part of modern musicianship. Whereas performance, improvisation and electroacoustic music are too often treated as distinct disciplines, in this work, these topics are developed and explored in an entirely unified manner. This approach allows the development of a fully integrated skill set in a single, cohesive discipline: *Electroacoustic Music Performance and Improvisation.* This pedagogical toolkit will grant new generations of students of electroacoustic improvisation access and insight into a unified method and discipline; one might further hope for it to spark new relationships between musicians and technology, or even to stimulate further research in domains such as psychoacoustics, acoustics, electroacoustic lutherie or the philosophy of music education.

Alejandro Olarte
January 14, 2019

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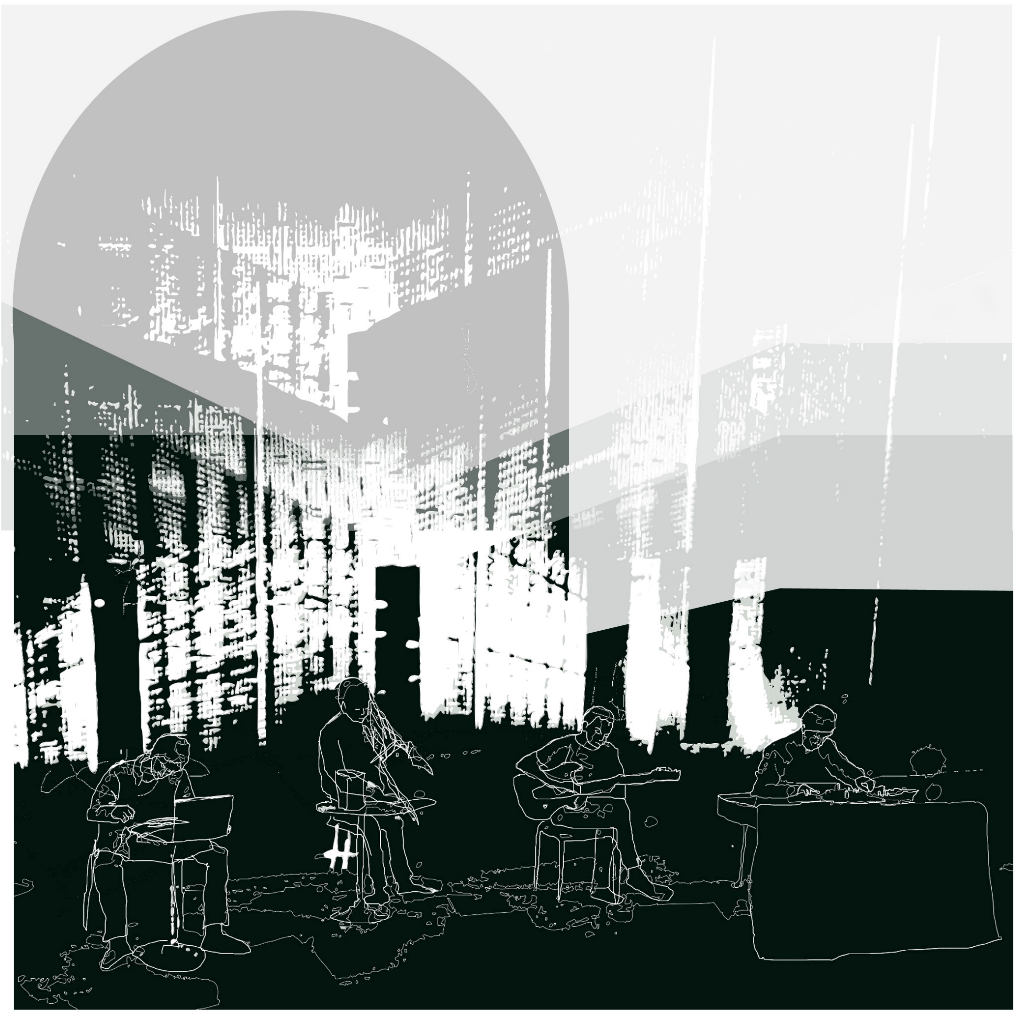

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Introduction

When I was a child, I used to play in a living room with many interesting objects, including a couple of musical instruments that easily sparked the imagination and playfulness. The one object that piqued my interest and fascination over time was an old radio that belonged to my grandmother. It was an enormous piece of wood furniture kept with special care and turned on only on important occasions, such as somebody's birthday or New Year's celebrations (For everyday use, we had smaller radios around the house). That *radiola* had a small screen, letters and numbers and several locks including one protecting a vinyl player. Once when I was looking for a toy that "accidentally" ended up under that marvelous treasure box, I had to use all the power of a five year old to push the radiola forward to be able to grab the toy, and what I discovered was not an unhappy little car behind the radiola; it was an incredible and stunning world: an amazing number of electronic components, colorful little boxes arranged like a small city with corridors, streets, buildings, houses, a fair amount of dust, a very particular smell, vacuum tubes that looked like perfect rockets and pieces of a deserted town of the future.

That revealing incident raised some questions that took me several years to put into words: How did a magic music box get its voice from a forgotten, hidden dusty miniature town from the future? How were the sounds produced with all those fascinating electronic components? Why did turning the front panel dial change the sounds coming from the box, and how were that knob and its needle related to the rope and the cylinder of gears on the back? – Wait, there's music coming out of there! No, now it's noise!

Today I recognize that same fascination and questioning in people's voices when they come to join me in a workshop or in performing with electronic instruments. It is then that I understand that my work is to make them fall in love even more with those natural powers of transducing electricity into sounds and with the act of driving and revealing those sounds as music. Of course there is a science behind it; of course there are skills and techniques to be mastered, and of course there is a listening quality to be cultivated and developed, but I believe the purpose of keeping alive and expanding the enchantment with electric sounds is to unveil paths for building artistic identity and to look for answers and questions about our own inner and outer natures.

The work presented here is about electroacoustic music performance, improvisation and pedagogy. It focuses on developing a set of units and contents for learning and teaching performance with electroacoustic instruments through improvisation. This work is an effort to contribute to the understanding and integration of such contents, tools and techniques into the educational programs at the university level and is targeted to instrumentalists, vocalists, composers, sound artists and musical pedagogues. It can be used as teaching material for an electroacoustic improvisation class or as a source of inspiration for composition exercises including an electroacoustic dimension or as a guide for individual or band training based on improvisation techniques and including electronic instruments, or even (and here, I am showing the reaches of my ambition) to support a curriculum in a dedicated major for electroacoustic performance.

I started this research from a personal need in my work as a pedagogue. After my studies at the National Conservatory in Paris with Alan Savouret in "Generative Improvisation", I started giving workshops for musicians on the performance with electronic and electroacoustic instruments. I chose a hands-on approach that makes it easier to experiment, research and learn about sound synthesis, sound processing and electroacoustic concepts rather than a pure theoretical approach. In that sense improvisation appeared to be a great tool to simultaneously investigate a conceptual framework while enjoying the opportunity to make music. Consequently, I began to organize sessions around a central concept combining dedicated exercises and free playing, exposing techniques and offering experiments with electroacoustic music tools, listening and discovering recordings of the genre and perhaps, the most important sharing and debating thoughts and ideas. These became the main ingredients of my method of work and the seeds of the research.

In the following paragraphs, I will discuss the essential terminology, scope, and situatedness of this work. Then I will expose my methods and methodologies used to carry out the research and how these methods led me to the contents of this book. I will explain how the text is structured into two parts and the logic behind them. By way of advancing a few conclusions or findings, I will cogitate on the contribution of this research to the contemporary music education area.

Electroacoustic music (EAM) is a keyword in this text and should be understood as a term composed of two ideas. From a technical perspective, it refers to music done with the technology of "converting acoustic energy into electrical energy and vice versa"[1] and from the aesthetic point of view, it relates to the genre of music developed in Europe, Japan and the Americas from the 1950s. The evolution of the genre was facilitated thanks to the advances and possibilities offered to musicians to manipulate and experiment with high quality audio recordings on magnetic tape and integrate electronic devices into musical performances.[2]

EAM is said to have two main subgenres: *Acousmatic Music* and *Live Electronic Music*. The first one refers to a form of studio composition, which exists only in a recorded format and is intended to be played over a set of loudspeakers.[3] In the second one "the technology is used to generate, transform or trigger sounds during the act of performance."[4] However, subsequent practices evolving from the capabilities of portable computer systems to calculate and process audio in real-time, along with practice-based artistic research, have blurred these categories.[5] The grey area between studio composition and performance includes understanding the studio as an instrument, bringing the studio tools or prepared material from the studio to the stage and using indistinctly improvisation and performance techniques in both scenarios. Of course, there are still practices that clearly take one or the other. For example, a complete acousmatic work with all the spatial information encoded in a multichannel file will imply very little performance in a concert presentation or a fully notated score mixing acoustic and electronic instruments will not require as many improvisation skills as in an improvised performance. On the other hand, an Electroacoustic Improvisation set may not

[1] "Electroacoustics, N." OED Online. Oxford University Press. Accessed December 20, 2017.

[2] Emmerson, Simon, and Denis Smalley. Electro-Acoustic Music. Oxford University Press, 2001.

[3] The term *Acousmatic Music* is used in this text in its most recent accepted use: music on a fixed medium. See for example: Bayle, François. Musique Acousmatique Propositions–Positions, 1993.
However, it is essential to note that in a historical perspective the term has had other uses such as the one discussed by Jérôme Peignot in 1960. Peignot discuss the term *acousmatique* to define the listening experience of musique concrète: "*...acousmatique se dit déjà d'un bruit que l'on entend sans en connaître l'origine.*" (...acousmatic is said of a noise that we hear without identifying its origin.) Source: Peignot, Jérôme. "De la musique concrète à l'acousmatique." in Esprit, No. 280. Paris, 1960. Page 116. Under this definition, it will be possible to imagine a piece of "live acousmatic music", where sources are invisible and unidentifiable to the audience, but the creation and manipulation of the sound happen at the time of the performance.
For further discussion see: Battier, Marc. "What the GRM Brought to Music: From Musique Concrète to Acousmatic Music." Organised Sound 12, no. 3 (December 2007): 189–202.

[4] Emmerson 2001

[5] Tremblay, Pierre Alexandre. "Mixing the Immiscible: Improvisation within Fixed-Media Composition." In Proceedings of the Electroacoustic Music Studies Conference Meaning and Meaningfulness in Electroacoustic Music, Stockholm, June 2012;
Wishart, Trevor. "Beyond Notation." British Journal of Music Education 2, no. 3 (1985): 311–326.

include at all sounds, presets or configurations prepared in advance at the studio, focusing on the creation and performance of all materials and sounds *from scratch*, or *on the spot*. In tune with this line of thoughts, I have chosen the term *Electroacoustic Music Improvisation* over the historical term *Live Electronics*.

Improvisation in the context of this book is used as a term to incorporate a set of practices related to *inventing and creating music at the time of its performance*. The spontaneous invention of music *in situ* implies a variety of degrees of freedom to alter, change, decide, shape, initiate and conclude collectively or individually the musical outcome at any point during its performance. This can range from not having a predetermined agreement on how to start or how to conclude or how long the performance should last, and not deciding on any working or performing rules up to the use of text-based or graphic scores, a set of instructions, suggestive themes, prepared sound files, and many others steps in between before the fully scored performance.

For pedagogical purposes, I propose to use the terms *free improvisation* and *guided improvisation* to make a difference in the intention of improvising music. In the situation of free improvisation, the only agreement is to play music together; all the exchange, confrontation and argumentation of ideas, emotions and feelings should happen in the realm of the musical moment, so eluding or reducing pre- and post-verbalization as much as possible. On the other hand, guided improvisations have one or more working rules, limits, goals, objectives, and can be "evaluated" in the sense of how accurate was the performance of the original set of rules or plans. In the situation of guided improvisation it is very important to discuss as much as necessary in order to clarify the rules or working principle, as well as to develop critical judgments, analytic tools and vocabulary with which to talk about the performance situation retrospectively. It is possible to find a balance between the two situations. I suggest, for example, starting and ending the session with free play while allocating and dedicating time for guided improvisations proposed by any member of the ensemble. I found it very important to explain the role of the moderator of the session in order to clarify whether the moderator is part of the performance or not. The balance between freedom and framework allows developing skills to perform and improvise and enable the structuring of the sessions over a longer period of time.

The **Electroacoustic Improvisation (EAI)** community can accurately be described as having been born from the encounter of the tradition of improvisation with the tools of electroacoustic music. To further situate this research I would like to mention key figures in the development of the genre from whom I have taken inspiration. These include Keith Rowe; "Musica Elettronica Viva" (MEV ensemble); John Cage; David Tudor and his works with "Composers inside electronics"; the "Sonic Arts Union" — Robert Ashley, David Behrman, Alvin Lucier, Gordon Mumma; Nicolas Collins; Morton Subotnick; Sergi Jordà; Laetitia Sonami; Eliane Radigue; Suzanne Ciani; Michel Waisvisz; Derek Bailey; Christian Marclay; John Zorn; Vinko Globokar; Mauricio Kagel; the "New Phonic Art" ensemble; the "Opus N" ensemble with Alain Savouret and Christian Clozier; the trio "GRM-Plus" founded by Denis Dufour; the ensemble "K und K" with Dieter Kaufmann and Gunda König; "The Gentle Fire" ensemble with Graham Hearn, Hugh Davies, Michael Robinson, Richard Bernas, Richard Orton, Stuart Jones; "Sol Sonoro"– Roberto García Piedrahita, Luis Boyra and Ricardo. Arias; Kalev Tiits, Shinji Kanki, Juhani Liimatainen and Andrew Bentley.

Further influences. From the pedagogical perspective of improvisation and technology, this research has taken as a starting point existing research and proposals by Christopher D. Azzara, Edward Sarath, Peter Webster, and David Elliott. Specific touchstones include Azzara's argument for the practice of improvisation as an essential component of general music pedagogy,[6] Sarath's extension of improvisation pedagogy and technique to include broader mental and methodological concepts,[7] Webster's emphasis in the cognitive aspects of technology and creativity,[8] and Elliott's argument for a praxial music education: *knowing-in-action.*[9]

Of particular importance for construction of the underlying conceptual framework of the research that leads to this text are Alain Savouret and his practical applications and extensions of the electroacoustic music research to the musical improvisation, as well as his pedagogical approach based on *aurality*;[10] Leigh Landy and his pedagogical passion and commitment – reflected in most of his publications and work;[11] John Sloboda and Jeff Pressing with their systematic investigations from a perspective of cognitive psychology;[12] Andrew Brown and Andrew Hugill with their contribution to the understanding of digital musician-

[6] Azzara, Christopher D. "Improvisation." In The New Handbook of Research on Music Teaching and Learning: A Project of the Music Educators National Conference, 171–187. Oxford University Press, 2002.

[7] Sarath, Edward W. "Improvisation for Global Musicianship: Improvisation Integrates Many Aspects of Music Learning. Edward W. Sarath Looks Specifically at How Improvisation and Multiculturalism Work Together." Music Educators Journal 80, no. 2 (1993): 23–26.

[8] Webster, Peter. "Historical Perspectives on Technology and Music." Music Educators Journal 89, no. 1 (2002): 38–43;
Webster, Peter R. "Creativity as Creative Thinking." Music Educators Journal 76, no. 9 (1990): 22–28.

[9] Elliott, David J. Praxial Music Education: Reflections and Dialogues. Oxford University Press, 2009.

[10] Savouret, Alain. Introduction à Un Solfège de l'audible: L'improvisation Libre Comme Outil Pratique, 2010.

[11] Landy, Leigh. Understanding the Art of Sound Organization. MIT Press, 2007;
Landy, Leigh. "The ElectroAcoustic Resource Site (EARS)." Journal of Music, Technology & Education 1, no. 1 (2007): 69–81.

[12] Sloboda, John A. Generative Processes in Music: The Psychology of Performance, Improvisation, and Composition. Clarendon Press/Oxford University Press, 1988.

ship;[13] Bruno Nettl and his enquiry for a broader understanding of improvisation from an ethnographic point of view;[14] Curtis Roads and Trevor Wishart with their views from within the practice, as well as their carefully knitting together of systemic thinking.[15]

Finally, there is the figure of Cornelius Cardew who inspired me to struggle to elevate the ideas of Improvised performance with electroacoustic tools to a dimension that touches the human soul beyond the technical issues of the machines.[16]

Research method. After identifying my research as a development process of a pedagogical package for electroacoustic performance and improvisation, it was possible to implement the research using different methods. In the following lines, I will discuss why Action Research was the chosen method and what this choice implies.

The investigation could have been based on quantitative methods, for example by fixing a series of exercises and determining a success rate in some measurable unit then iterating the exercises package to different groups, and concluded by letting the statistics speak for themselves. Eventually, some of the exercises would have been less successful and discarded, while others would have make it to the top. The final package would have refined itself over time. I did not choose this approach for a number of reasons which I find difficult to argue. First, imposing the idea of a person holding the right answers in their notebook and checking the performance of *test subjects* would have created very strong hierarchical and power relationships unproductive for a pedagogical process (or human process in general). It would have spoiled all the pleasure of the social aspects connected with the group improvisation practice. While some of the performance tasks and exercises have clear pedagogical goals, the accomplishment and success of them cannot be estimated in one or even a few sessions, or even not at all: as explained in chapter two, the expertise of an improviser partly resides in carefully turning sonic and musical knowledge into subconscious processes. Even allowing for the absence of a scale of measurement and a definitive threshold for success, it became clear that quantitative research was simply not an appropriate approach to address the questions of how to improve skills in a highly subjective and

[13] Brown, Andrew R. Sound Musicianship: Understanding the Crafts of Music. Vol. 4. Cambridge Scholars Publishing, 2012;
Hugill, Andrew. The Digital Musician. Routledge, 2012.

[14] Nettl, Bruno, and Melinda Russell. In the Course of Performance: Studies in the World of Musical Improvisation. University of Chicago Press, 1998.

[15] Roads, Curtis. Composing Electronic Music: A New Aesthetic. Oxford University Press, 2015;
Wishart, Trevor. On Sonic Art. Routledge, 2016;
Wishart, Trevor. Audible Design: A Plain and Easy Introduction to Practical Sound Composition. Orpheus the Pantomime, 1994.

[16] Cardew, Cornelius. "Towards an Ethic of Improvisation." Treatise Handbook, 1971, 17–20.

creative discipline. The investigation that I was designing could not fit these methods.

In the qualitative research field, many methods were more appealing and could elucidate and to a certain extent promote understanding of the dimensions and details of the questions at the heart of the research.

Ethnography: ethnographic research brings to the fore the reality of the participants and accommodates the researcher's full immersion and interaction in that reality. This idea helped me to narrow down my target groups (university students at the third level of education) and to clarify the situatedness of my work (a study in one university of arts in the capital of a European Nordic country in the second decade of the twenty-first century). However, I did not enter into more details than that since I did not want to focus on any particular narrow group. My intention was to produce a pedagogical toolkit that could be useful beyond the national borders of the place where I was working.

Phenomenology has provided an invaluable input to the field of electroacoustic music through the work of Pierre Schaeffer and his research team. Some aspects of the *écoute réduite* or *reduced listening* will be discussed in chapter two. Although it will be naive to pretend to cover in a few lines the potential contribution of phenomenology to the filed under study, I can say that the underlining of the importance and primacy of the subjective consciousness proposed by phenomenology is a crucial tool to uncover the hermetic nature of spontaneous electroacoustic music creation. I acknowledge also how the unveiling of mechanisms in the psychology of aural perception can bring light on the pedagogy of the field in question, and how advancements in this area could be made through phenomenological methodologies. I did not adopt phenomenological inquiry as a main method mainly because of the amount of human resources that this approach would have required. This would have required a very competent multidisciplinary team with expertises in electronics, audio technology, music improvisation, pedagogy, cognitive psychology and an acute familiarity with phenomenology.

From grounded theory research I identified the need to develop a theory instead of trying to fit into an existing one. The specific inductive method for this type of research requires that the theory emerges from the data rather than precedes it. In my case, this would have meant leaving aside the theoretical background that I was already developing prior to the beginning of the work. The starting point I had was pre-built theories based on personal intuition, experience, and hypothetical assumptions. This preliminary development was due in part to university protocols that required a detailed description of the theoretical framework and speculation on the findings of the research, even before being accepted to carry out the research. This previous construction is not possible for ground theory research, which requires that the entire process starts from the data collection process before any theoretical formulation, therefore, been incompatible with the administrative procedures of my host institution.

Artistic research: my study could have been an artistic investigation by focusing on producing knowledge through art practice within the discipline under consideration. In this context, a pedagogical content would have been a secondary outcome. Although the research was planned to include artworks, concerts demonstrations and eventually music scores, the main preoccupation was undoubtedly to create a didactic package to foster the creativity and research of the electroacoustic music performance and improvisation discipline inside the university. Therefore my research method needed to be appropiate to music education, and *Action Research* was the most appealing since the values grounding this method were in perfect tune with my own aims in artistic and academic excellence.

Action Research as defined by Stephen Kemmis, Robin McTaggart, Rhonda Nixon and Liora Bresler is:

> an approach to improving education by changing it and learning from the consequences of change; a participatory process in which people work towards the improvement of their own educational practices; collaborative and aims to involve all those responsible for action in the improvement process; and aims to establish critical communities of people participating and collaborating in all phases of the research process and committed to enlightening themselves about the relationship between circumstance, action and consequence in their own situations.[17]

The more resonant points between the action research methodology and the development that I was planning to do were the commitment to educational improvement and educational action that is informed, committed and intentional.[18] As explained by Jean McNiff and Jack Whitehead educational improvement does not necessary means that something needs fixing or is malfunctioning but a struggle for the highest possible quality.[19] The idea of improvement in my case came as the need to consolidate a discipline within a theoretical and practical framework. The improvement could only be made by investigating and questioning my own pedagogical practices and by struggling to learn as much as I could about performing with electronics, ensuring that pedagogical action ensued from my own commitment and motivation.

I identified with Bresler's pedagogical views and her emphasis on the importance of a pragmatic and self-critical pedagogical approach. "If the central point of ethnography is culture and the central point of phenomenology is lived experience, action research is based on the close interaction between practice, theory and

[17] Kemmis, Stephen, Robin McTaggart, and Rhonda Nixon. The Action Research Planner: Doing Critical Participatory Action Research. Springer Science & Business Media, 2013.

[18] McNiff, Jean, and Whitehead Jack. You and Your Action Research Project. 3rd ed. Routledge, 2009.

[19] Ibid.

change ... one major difference between action research and other qualitative approaches is its pragmatic, practice-oriented emphasis as a primary motivation for the research".[20]

The action research methodology was a key component to allow a permanent self-evaluation during the process, to integrate an experimental attitude and to emphasize research through practice; in this case an intensive practice of improvisation, performance and electroacoustic music in visceral symbiosis with teaching activities.

To implement the action research process, I organized teaching activities with workshops, yearly courses, performance laboratories, and jam sessions. I built electronic and digital instruments and helped people to build their own; I organized concerts and public performances with the participants of the workshops. Each group spent copious hours improvising, playing, experimenting, musicking and tinkering with the concepts presented in this text. I worked hard on studying, filtering, and clarifying the fundamental elements of the discipline while eagerly keeping my artistic practice a high level by engaging in different collaborations with peer artists. The close relation with Andrew Bentley, my supervisor, helped me to keep on track with the work, to re-think and re-write the toolkit several times. This triangulation process was as important as the work done in the laboratories of performance. The result of this research *in and through practice* is this book.

Data collection and ethics. The research initially required a process of data collection from the workshops in order to carry on the analysis and identify the relevant concepts to be considered in the pedagogical package. I started by using Audiovisual recordings to document the workshops, the teaching process, the transmission and communication of performance tasks and the interaction with the participants debating about the introduced themes. This approach made it obvious that image and sounds could reveal the identity of a participant. Therefore, to respect privacy standards the consent and a full understanding for the participants of what were the audiovisual documents for and who will use them was required. In the struggle of clarity, integrity, and respect of the confidentiality of the material produced in the classroom I developed a note of consent to be signed at the start of the workshop. The note of consent it included an introduction to the research where it was clearly stated the research purposes and my sole access to the data since I was the one who was to analyze it and handle it.

This form of documentation started to have its problems. A camera and microphone are objects loaded with meanings and expectations, and lead to trepidation, extraneous thoughts, self-consciousness and doubt about where the recording material will end up. The trust established with the participants enabled us to

[20] Bresler, Liora. "Zooming in on the Qualitative Paradigm in Art Education: Educational Criticism, Ethnography, and Action Research." Visual Arts Research, 1994, 1–19.

discuss the recordings and we decided together to leave it aside. The main data of the project became my personal notes on the field and the verbal feedback given by participants along with the observations of my supervisors. Audio recordings were only made under special circumstances and by the musicians themselves as material for analysis. I am confident today I took the right decision based on the premise of non to use personal data of little relevance to the research.

After the research process, there remain one unsolved issue for which I could not find a satisfactory answer, that waits upon further action and research: the development, use, and promotion of sustainable environmental tools for electroacoustic performance. From such a contemporary debate the almost "no comment" or reaction from the musical industry and manufacturers of audio technology is alarming. Audio technology has to address the issue of producing environmentally friendly gear, as well as committing to international agreements on ethical human labor. Every performer should engage in spreading consciousness regarding energy consumption and natural resources and the attempt to impact the market by taking these aspects into consideration.

Changes of direction and scope. The research has also involved turns from the original plan. For example, initially I wanted to include a form of hardware or machine to accompany the text. I gradually left the idea behind, because I noticed how people experience great satisfaction in designing, building, improving, fine-tuning and adjusting their own performance sets in detail (as well as enjoying the possibility to choose among the thousands of available audio devices). The Do It Yourself (DIY) tradition in EAM grants uniqueness to each performance set and reflects the attitude of experimental research at the heart of the discipline. There are excellent resources available to introduce musicians to the world of electronics – some of those about electronic instruments are reported in chapter four – but there are fewer that address the performance issues and the building of a technique in improvised electroacoustic music.

Hence, I understood, the research could not be done by focusing on one machine or on the machines. What people needed was not an extra-portable-voltage-controlled-VSTi, but guidance on how to use the technological tools for musical purposes and a space to play and explore these sound machines. Instead of demanding audio devices to play, the musicians participating in the process wanted a space for performing and ideas on how to improve their musicianship with technology. People repeatedly praised (in direct communications and personal feedback) the value of having space to experiment and be systematically introduced to concepts through practice freely. The value of the work of what I was doing was to harvest and entertain a space to perform with electronic instruments within the university. My contribution became clear then: structuring and compiling a corpus of knowledge based on aural practices, where music is made by ear, and the knowledge is transmitted aurally.

Aurality. The aural culture, or *phonoculture*, to use the term of Alain Savouret, is characteristic to EAM because EAM is based on *aural* practices. The EAM is done by questioning and going beyond the category of *musical notes*. Sound, silences, noises and their performance in the broader possible understanding are the main ingredients of expression. They resist notation and they become a form of notation in themselves. There are alternatives to notate the sounds afterwards (spectrograms, sonograms, plots), and prescriptive notations (given instructions on how to make the sounds), but the quantity, diversity, and volatility of the electronic devices used to perform the sounds of electronic music make it difficult, if not unrealistic, to pretend to condense the technique of the instruments as has been done with acoustic instruments (i.e., the Chopin and Liszt études for piano).

The pedagogical compilation that I was writing, based on aural transmission and reception of knowledge, had to pass to higher levels of abstraction when identifying the fundamental aspects or *elements* of the discipline – while keeping the concrete and practical characteristics. The result is the pedagogical toolkit proposed here.

Concerts and public performances have been milestones on the research process. Organizing a concert has been the final step on the workshops every time. Moving out from the rehearsing studio and the laboratory of performance to the stage works as an incentive and stimulus for the participants, increases the commitments of the regular meetings and unites the group in a collective creative process. For me, it was the opportunity to have a perspective of the work done in each cycle, evaluate the methods and contents of the sessions and expose the research to a broader audience. The role of the audience during the process has a clear importance in a pedagogical and performative context.

There is always an audience that can take different forms: the performers themselves when everybody in the room is part of the performance; an expert listener when one or more members of the ensemble or a moderator are not part of the performance situation; a casual audience when informal guests, friends or visitors are allowed to attend the sessions; a spectator audience when the rehearsal is open to anyone; an audience when the situation has been prepared and explicitly set for a concert presentation or even an imaginary one. In each of these cases, the listener becomes the third ear of the musician allowing them to listen to the music within a unique context created with the presence of each person in that place at that moment. The listening experience with the third ear creates all sort of memories and emotional responses that shape the experience of performing. A public musical sharing moment also fulfills the social duties of the artists with their communities. Based on empirical observations, it must be acknowledged that the presence of a listener influences the performance, for example, by affecting the generation of ideas or the initiatives of performers to assume roles and risks or even the duration of improvisations. These observations seem to echo the idea of the observer effect.[21] Consequently, it is essential to organize a public concert or to open the sessions to larger audiences. Simultaneously, the private-individual-audience-solo-jamming or the closed-doors-band-rehearsal have their functions and equally fundamental values for the experimentation, refinement, and improvement of skills. There should also be times even without the moderator, who should recognize when to leave the room and let the situation reach its ultimate consequences.

Above I exposed how *action research* was implemented in my work as “research undertaken by practitioners into their own practice, in order to improve it”.[22] The action research method was applied through a cycling process of deductive-inductive analysis, interpretation, planning, and conceptual re-formulation of the pedagogical package presented in the final form of this written work.

Organization of the text. The corpus of the text is divided into two main parts: a theoretical framework and the toolkit itself. The aim of the first one is to unveil the roots of the EAI discipline, while the goal of the second one is to present a set of practical units systematically covering the multiple dimensions of performing and improvising EAM.

The first part *context* is composed of three chapters. The first one, which is marked chapter two in the index – following this introduction, is an analysis of how listening can be understood as the key aspect of performing improvisation in the context of a sonic/aural based discipline articulated by a praxial philosophy of music education.[23] The listening modes are presented and studied under cognitive, socio-political and metaphysical considerations.

In the following chapter three, I address the contribution of EAM to modern musicianship. What is the impact of audio technology and EAM developments, and how has it affected the understanding of musicianship? Six aspects were identified as having an influence and challenging the performer of EAM: sound amplification, sound recording, sound synthesis, sound spatialization, audio broadcasting and cybernetics. Each of these innovations extends and transforms the way we perform music and reveals the differences between performing acoustic instruments and performing electronic instruments.

The closing chapter four of this section is a study, through a compact review, of the electronic instruments for EAI. Fourteen electronic instruments/tools were

[21] “The observer effect is the fact that observing a situation or phenomenon necessarily changes it.” For a detailed explanation and examples see:
Baclawski, K. “The Observer Effect.” In 2018 IEEE Conference on Cognitive and Computational Aspects of Situation Management (CogSIMA), 83–89, 2018.

[22] Elliott, John. Action Research for Educational Change. Milton Keynes: Open University Press., 1991.

[23] Martin, Jeffrey. “Composing and Improvising.” Praxial Music Education: Reflections and Dialogues, 2005, 165–176

chosen to examine the process of experimenting, performing and learning about EAM by manipulating the tools of the genre. Experimentation is stressed as the attitude to explore the performance possibilities of each device or their combination. The incompleteness of the list is in that sense a quality because its purpose is not to sum up the *state of the art* of electronic organology but to invite the performer to explore and experiment, to have an open ear and eye to any device that could be integrated in a performance set, what could be called the *egg slicer* paradigm. An egg slicer is not by definition intended to be an electronic instrument. However, when amplified the egg slicer can take the form of an incredibly expressive instrument. These three chapters consolidate a working framework for the second part, which deals with the practical implementations.

The structure of the second part is inspired by the *Elements* of Euclid and his ability to capture the mathematical essence of geometry through the identification of a set of fundamental axioms. Although the text does not suggest any parallel to what will be an axiomatic system on EAM, it presents the contents organized into four elementary aspects to be considered and separately studied: sonic elements, electroacoustic elements, musical elements and performance elements.

Each of these four sections is subdivided into chapters or units that break down each topic. There are twenty-one chapters in the four sections, all have the same structure: an explanation of the learning goals or objectives, a description of the proposed activity, some possible variations, a discussion of the relevant concepts, and suggestions for implementing the ideas in performance tools. The title of each chapter introduces the topic and gives a hint about the proposed activity. The activities take the form of exercises, musical tasks or performance situations that address specific concepts of EAM and EAI.

There is a logical progression in the toolkit; however, it is meant to be used in a flexible way, for example, by accessing units from different chapters in a non-linear order. The duration, focus and intensity of the work on each chapter should be adapted to the level of each group. The toolkit is intended for university students, but the backgrounds and education either as performers or as technologists may vary widely, so for some groups the elements of sounds can be covered over a couple of sessions, while the elements of electroacoustic sound may take months. It will also be possible to use only a fragment of it for a short focused workshop or to develop a one or two-year course to cover it all. I would like to clarify that the toolkit should be seen as an opening, and it should be expanded and extended with permanent contributions coming from the participants. The function of the toolkit is to support an ensemble or a band to reach a certain level of creative autonomy to invent their own creative and working systems and their own conceptual universe, at that point the toolkit is no longer necessary and should be left aside. While mainly focused on group performance in most cases it is possible to adapt the units for individual or solo performance.[24]

Closing the second part, there is a chapter (nine) on the values and ethics of the EAI. It is in a different form and style than previous chapters. It does not include any particular performing challenge, and it is written in a very subjective way. However, it is included in this part as a catalyst of ideas as well as covering all the elements with elementary questions of a possible system of ethics. What would a set of pedagogical tools be without an invitation to transcend its contents and bring the knowledge that it conveys to a broader perspective of human issues? That last chapter may feel at times very opinionated, but in the overall structure it balances the intention of the previous sections, where an objective analysis of the fundamental components of the EAI is attempted.

An afterword at the end of the document includes the final comments, a series of annexes that illustrate the secondary outcomes of the research (three scores for ensembles using improvisation, links to artistic projects in which I have collaborated with other members of the doctoral school and a Code Repository with Digital synthesis Projects in SuperCollider), the reference of the works cited in the thesis, and a thematic bibliography suggesting additional readings.

The main contribution of this research is an effort to integrate into the area of contemporary music higher education a tradition and a practice of an aural-based discipline that has evolved from the middle of the twentieth century, influencing academic and popular musics, generating aesthetic challenges, inspiring technological advancements and revealing aspects of our systems of perception and understanding of realities. EAI is a musical practice that stresses the inter-subjective interactions, giving clues of possible functioning modes of a society eager for change.

[24] To avoid overlap some performance activities, musical tasks, and improvisation situations did not make it into the final version of the toolkit. This made it possible to maintain the content of the units and chapters in its more essential form. I will mention some of the discarded exercises as tips for development (this is the intended use of the toolkit: be conceived as a starting point). Among the units that did not make it to the toolkit there are *Viacruxis* or a progressive crescendo; *Rondo* working on repetitions; *Chant responsorial* about solo-group relationship; *Interpolation* about building transitions; *Sample obbligato* about sound processing; *The errors* about memory; *Affects* about role-playing and performance; *Steal a sound* about group interaction; *Moving musicians* about body and space; *Occam's razor* about focus listening.

Part I

Context

2

Sonic Improvisation and Listening Modes

In this chapter I will discuss how sonic improvisation can be understood as a research tool through specific modes of listening. I identified for the purposes of this study three different modes: structural, holistic and transcendental listening. These modes resonate with the ideas of praxial music education, in which the accent is placed on the development of musicianship by reflecting-in-action and reflecting-on-action.[1] Therefore, the main implication of this analysis is a conception of active-creative-listening that can be applied in the context of contemporary music education at the university level as a tool to investigate the sonic world: our understanding, perception and relation to it.

The text starts with an analysis of the work of Jeff Pressing, who has methodically approached the issues of music improvisation from a cognitive perspective, building a detailed theory based on the analysis of complex interactions between memory and knowledge. Pressing's perspective will allow me to bring into focus the concept of structural listening which, despite being very attractive as a rationalization tool with several consequences in the pedagogical domain, leaves important aspects of the contextual realms of improvisation activity in the shadows.

On the other hand, social and contextual aspects are special touchstones in George Lewis' ideas and understanding of improvisation. His views include a historical and political background related to freedom and equality in our society. By including this perspective of improvisation as a tool for sociological investigations, the cognitive view can be enhanced, and the idea of a holistic listening can be introduced. The understanding of a holistic listening illuminates another set of skills that will be necessary to expand the conceptual framework of improvisation as a research tool. If a larger and more complete picture of sonic improvisation as a research tool emerges when expanding the cognitive ideas to an awareness

[1] Schön, Donald A. "Knowing-in-Action: The New Scholarship Requires a New Epistemology." Change: The Magazine of Higher Learning 27, no. 6 (1995): 27–34.

of the socio-political context, there is a danger of politicization of culture that should be transcended. I have to admit that other dimensions of the practice of improvisation seem to escape under the veil of a hermetic irrationalism.

In an endeavor to grasp those elusive aspects, I will reflect on the work of Cornelius Cardew, a fully engaged musician who, in an illuminating article “Towards an Ethic of Improvisation,” delivers a reflection touching on the boundaries of mysticism.[2] By facing the metaphysical level of Cardew’s discussion, a concept of transcendental listening emerges and helps to complete my argumentation, which I consider is an answer to the questions of why it is important to cultivate, support and encourage sonic improvisation inside the university, and how this support contributes to contemporary music development.

2.1 Sonic improvisation vs. music improvisation

Before getting into the main discussion of this chapter, I should clarify the use of the terms sonic and music improvisation. The term music improvisation includes a large colorful set of practices, including a number of genres such as jazz, traditional music, world music, early music, electronic music. This is why it is a good practice in the interest of clarity to accompany the term improvisation with a qualification. For example, tonal improvisation, modal improvisation, Persian classical improvisation, carnatic improvisation, electroacoustic improvisation, and so forth. Then, music improvisation is a larger concept that includes a variety of forms and genres. Sonic improvisation is consequently a superset of music improvisation, whose more salient characteristics include a systematic use of: extended instrumental techniques, non-traditional instruments such as electronic devices or everyday objects, undetermined pitches, absence or blurring of rhythmical pulse, noise textures and complex spectral sounds. However, if a steady pulse in a major key or a modal melody are present in sonic improvisation, they are generally used as reference, texture or anecdotal comments, but the focus of the improvisation is on extending the instrumental and gestural vocabulary beyond the “classical-tonal” or “modal” techniques. Hence, in this text when I speak about music improvisation, I am making reference to a larger set of practices, and when I talk about sonic improvisation, the reader should have in mind a subset or genre of practices closer to the language and ideas of musicians and ensembles such as “Musica Elettronica Viva”, “Composers inside electronics”, “Gruppo di Improvvisazione Nuova Consonanza”, the “New Phonic Art” ensemble, “Gentle Fire”, the “Sonic Arts Union”, “AMM”, Sergi Jordà, Michel Waisvisz, Evan Parker, Keith Rowe, Christian Marclay, Suzanne Ciani.

[2] Cardew, Cornelius. “Towards an Ethic of Improvisation.” Treatise Handbook Including Bun No. 2 [and] Volo Solo. London; New York: Edition Peters, 1971. 17–20.

The concept of music improvisation (also improvisation in a larger sense) has been studied and defined by several scholars and from a number of disciplines, including: cognitive psychology,[3] neuroscience,[4] music therapy,[5] sociology,[6] ethnography,[7] musicology,[8] philosophy,[9] pedagogy,[10] computer music,[11] and of course from the artist's own perspectives.[12] Those definitions often take into account concepts like spontaneity, creativity, intuition, freedom, framework, constraints, openness, extemporaneity, among others, and up to a point are presented in contrast to notated or composed music. As explained by Alperson, in general terms, those definitions reveal a tension between two ontological understandings of the concept:[13]

- the understanding of music improvisation as a verb focusing on action or activity. i.e. "The process of creative interaction (in private or in public; consciously or unconsciously) between the performing musician and a musical model which may be more or less fixed."[14]

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[3] Sloboda, John A. Generative Processes in Music: The Psychology of Performance, Improvisation, and Composition. Clarendon Press/Oxford University Press, 1988;
Berkowitz, A. L. The Improvising Mind: Cognition and Creativity in the Musical Moment. New York, NY, US: Oxford University Press, 2010.

[4] Beaty, Roger E. "The Neuroscience of Musical Improvisation." Neuroscience & Biobehavioral Reviews 51 (2015): 108–117;
Jung, Rex E., and Oshin Vartanian. The Cambridge Handbook of the Neuroscience of Creativity. Cambridge University Press, 2018.

[5] Wigram, Tony. Improvisation: Methods and Techniques for Music Therapy Clinicians, Educators, and Students. Jessica Kingsley Publishers, 2004.

[6] Lewis, George, and Benjamin Piekut. The Oxford Handbook of Critical Improvisation Studies. Oxford University Press, 2016.

[7] Lortat-Jacob, Bernard. L'Improvisation dans les musiques de tradition orale: ouvrage collectif. Peeters Publishers, 1987;
Nettl, Bruno, and Melinda Russell. In the Course of Performance: Studies in the World of Musical Improvisation. University of Chicago Press, 1998.

[8] Borgo, David. "The Complex Dynamics of Improvisation." In Springer Handbook of Systematic Musicology, 1017–1027. Springer, 2018.

[9] Peters, Gary. The Philosophy of Improvisation. University of Chicago Press, 2009.

[10] Sarath, Ed. Music Theory Through Improvisation: A New Approach to Musicianship Training. Routledge, 2009.

[11] Dean, Roger. Hyperimprovisation: Computer-Interactive Sound Improvisation. A-R Editions, Inc., 2003.

[12] Nachmanovitch, Stephen. Free Play: Improvisation in Life and Art. Penguin, 1991;
Prévost, Eddie. No Sound Is Innocent: AMM and the Practice of Self-Invention, Meta-Musical Narratives, Essays. Copula, 1995.

[13] Alperson, Philip. "On Musical Improvisation." The Journal of Aesthetics and Art Criticism 43, no. 1 (1984): 17–29.

[14] Micheál O'Suilleabhain in Lortat-Jacob, Bernard. L'Improvisation dans les musiques de tradition orale: ouvrage collectif. Peeters Publishers, 1987.

- the understanding of music improvisation as a noun focusing on the art work resulting from the activity, i.e. "The creation of a musical work, or the final form of a musical work as it is being performed."[15]

In the scope of this study, I will use a definition of music improvisation framed as a verb: *the creation of music in the course of performance.*

2.2 The cognitive perspective and structural listening

In the cognitive perspective, improvisation is understood as a complex cognitive activity shaped from severe constraints on human information-processing and action. The main research question postulated by cognitivism and improvisation is: How is improvisation carried out? Therefore, the core notion in a cognitive discussion is *constraint*, "the scarcity of resources in real time that humans can utilize for making music when they are not following a predetermined plan of action."[16]

A pioneer of this research who has become a reference for the clarity, discipline and refinement of his theories is Jeff Pressing. Parallel to his activities as pianist, composer and performer, he pursued a career as a research scientist in cognitive psychology. In his study on music improvisation, he analyzes and deconstructs step-by-step the complex chain of cognitive operations observed during the activity of improvisation.

> The improviser must effect real-time sensory and perceptual coding, optimal attention allocation, event interpretation, decision-making, prediction (of the actions of the others), memory storage and recall, error correction, and movement control, and further, must integrate these processes into an optimally seamless set of musical statements that reflect both a personal perspective on musical organization and a capacity to affect the listener. Both speed and capacity constraints apply.[17]

This conception is very close to the information theory paradigm, in which the process of information can be decomposed into three levels: input, central process-

[15] Nettl, Bruno, Rob C. Wegman, Imogene Horsley, Michael Collins, Stewart A. Carter, Greer Garden, Robert E. Seletsky, et al. Improvisation. Oxford University Press, 2001.

[16] Ashley, Richard. "Musical Improvisation." The Oxford Handbook of Music Psychology, 2009, 413–420.

[17] Pressing, Jeff. "Psychological Constraints on Improvisational Expertise and Communication." In Collected Work: In the Course of Performance: Studies in the World of Musical Improvisation. Series: Chicago Studies in Ethnomusicology, Published by: Chicago, IL, USA: University of Chicago Press, 1998. 47-67.

ing and response.[18] In musical terms, these correspond to an acoustic stimulus, a cognitive musical representation of the sounds, including their eventually developmental possibilities and a physical response, incorporating a physical movement, timing of muscular actions, proprioception, touch, spatial perception, and central monitoring of efference.[19] Pressing's model also considers a cognitive loop of operations of feedback and feed-forward to monitor the acoustic input and the movement response. To optimally achieve the operations of sensing, data processing, action, reaction and control, the improviser should develop a set of cognitive tools.

In Pressing's analysis these tools include *the referent, the knowledge base and a specialist memory*. The referent in this context is "a set of cognitive, perceptual, or emotional structures (constraints) that guide and aid in the production of musical materials".[20]

The concept of referent is very stimulating for research as well as an excellent pedagogical and creative tool because designing, performing and studying the referent or the implied constraints, frameworks and cognitive structures liberates the musician from the need to generate the rules on-the-go and facilitates the starting point for an improvisation. The referent concept allows the performer to isolate research questions such as developmental techniques or problem-based improvisations. The referent is also a key concept in understanding and clarifying the discussions about the differences between free or total improvisation and improvisation with constraints; however, many argue that an improviser cannot create ex-nihilo or without the setting of any referent or frame of references.[21] In Pressing's understanding, when there is no referent or when it is devised in real-time, it is common to speak of *free* or *absolute* improvisation, though "this is much rarer than referent-guided or relative improvisation".[22]

Developing an expertise requires motivation to assume an intensive and disciplined practice. This motivation is influenced by personal and environmental factors and allows the musician to work with the referents and develop a special memory (procedural and declarative) that will enrich and maintain what Pressing calls the "knowledge base".

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[18] Pierce, John R. An Introduction to Information Theory: Symbols, Signals and Noise. Courier Corporation, 2012.

[19] Pressing, Jeff. "Improvisation: Methods and Models." In Collected Work: Generative Processes in Music: The Psychology of Performance, Improvisation and Composition. Published by: Oxford, United Kingdom: Clarendon Press, 1988. 129-178.

[20] Pressing, "Psychological Constraints on Improvisational Expertise and Communication." 47-67.

[21] Alperson, "On Musical Improvisation." 17.

[22] Pressing, Jeff. "Cognitive Processes in Improvisation." In Collected Work: Cognitive Processes in the Perception of Art. Series: Advances in Psychology, No. 19 Published by: Amsterdam, Netherlands: North-Holland, 1984.; Published by: New York, NY: North-Holland, 1984. 345-363.

> The distinguished expert has materials that are known in intimate detail, and from differing perspectives, and the various materials or modules are cross-linked by connections at various levels of the hierarchical knowledge structure. Part of the effect of improvisational practice is to make motorically transparent by overlearning what has been conceptually mastered.[23]

The knowledge base is also informed by other musical activities such as composing, reading, selective listening and analysis. The construction of the knowledge base is then strongly determined by personal choices and predilections. The knowledge base should be accessible to the performer at any time. This process of integration and reaction is facilitated by the development of specialist memory. In Pressing's view, this memory can be of two sorts: either the performers memorize musical gestures, producing an *object memory* or they memorize process of compositional problem-solving, developing a *process memory.* For example, variation techniques, developments, interpolations and juxtapositions.[24]

This conception of memory has evolved in Pressing's later works through the ideas of declarative and procedural memory, sometimes referred to as *knowing that* and *knowing how.* In an endeavor to clarify the picture and the understanding of memory, he goes on to analyze the degree of consciousness applied to memory by introducing the concepts of *implicit* and *explicit* memory, in other words, memory that depends (or not) on a conscious process of recollection.

By analyzing the different aspects of the knowledge base, the activity of improvisation can be carefully and progressively studied in an increasing progression in an academic context. Pedagogically speaking, sonic improvisation is a tool to learn and investigate music by handling and being exposed to music concepts and sound properties in a performative situation. Sonic improvisation is a method to build a knowledge base about music, acoustics and musical performance by interiorizing complex cognitive operations in our process of sensing, collecting and manipulating acoustic data to formulate sonic and temporal structures.

But what are the philosophical assumptions behind this understanding of music improvisation? It can be argued that it is the assumption of learning something about the world, that there is a musical intelligence that can be developed, and that this process of learning gives us insights about ourselves, about our perceptual and cognitive processes, about the way we use our memories and the mechanisms we use to learn. This perspective could be criticized for relying too strongly on the knowledge gained by intense rehearsals and repetitions of a collection of formulas, gestures, tricks, trades and models by which the musician is brought to rely on a repertoire of *clichés* and prefabricated traits ready to be combined in all directions, somehow betraying the spontaneity and invention

[23] Pressing, "Psychological Constraints on Improvisational Expertise and Communication." 47-67.

[24] Pressing, "Cognitive Processes in Improvisation." 345-363.

on the spur of the moment, which is central to the idea of improvisation. This kind of formulaic composition makes the design of musical form and structure an isolated collection of events.[25]

Pressing is aware of the problem, but he argues that massive training eventually drives the performers "to a liberation and a process of transcendence and consciousness of unperceived repetitive aspects of their music and through an improvement of stale musical design".[26] He illustrates the situation through a comment by Miles Davis about how "his sidemen only really got loose in the last set of the night, after they had used up all their well-learned tricks".[27]

Another good example of focused intensive rehearsal and the *tricks* becoming a transcendental practice is saxophonist Evan Parker. When one listens to his use of circular breathing, multiphonics techniques, tonal range, polyphonic thinking, and speed, we can only imagine the thousands of practicing hours. Anyone can recognize his playing after a few seconds, even if it is based on improvisation. Why? Because he has transcended the superficiality of the *tricks* with intensive practice time and integration of an instrumental and acoustic knowledge that elevates his extended techniques to a superior dimension.

By cultivating a cognitive approach to music improvisation, I argue that a **structural way of listening** is developed, because it draws the attention to the internal structure of the activity, aiming for an expertise in "perceptual vigilance, muscular strength, memory, hand-eye coordination, reaction speed, logical fluency, spatial perception, speed and depth of associative thinking".[28] As a consequence, the most salient feature in this approach is an over-estimation of the individual. From inside this theory, it is not easy to explain how improvisers respond and act in a social context, how the cultural codes articulate the creative process, how a group can be understood not as a collection of isolated cognitive bubbles but as a natural ecosystem intertwined with commonalities of historical and cultural background.

2.3 The sociopolitical perspective and holistic listening

An awareness of the social constraints can help us to develop the concept of a **holistic listening**. In this concept, the activity of improvisation involves a

[25] Dahlhaus, Carl, and Hans Hildenbrand. "Composition et Improvisation." In Collected Work: Essais Sur La Nouvelle Musique. Published by: Genève, Switzerland: Contrechamps, 2004. 191-199.

[26] Pressing, "Improvisation: Methods and Models." 129-178.

[27] Carr, Ian, and Leonard Lyons. Miles Davis: A Critical Biography. London: Quartet Books, 1982.

[28] Ericsson, K. Anders, and Neil Charness. "Expert Performance." American Psychologist 49, no. 8 (August 1994): 725.

process of awareness, understanding and criticism of the socio-political and historical context, where and when the performing act is taking place. Where are we playing?; to whom?; which historical facts and artistic developments emerge from the play?; which political and philosophical ideologies are underlined in the techniques and performing practices?. When I am part of an improvisation, I am not only experimenting with my cognitive powers or stimulating my perception with the sensuality of acoustic impulses, I am in a specific space and time, in a room of a building, in a city that has a history and connotations. My technique is the result of a long process of absorption, digestion and processing of Western culture. From this perspective it could be argued that if one is interested in improvisation, it is not only to stimulate some brain activity, but also to engage in an ideological struggle for the re-evaluation of musical values and the social modes of organization. Therefore, engagement with improvisation is an active criticism of musical activities in the social context and a reconsideration of music actors' roles with regard to institutions and policies of control, access and distribution of music.

The social awareness and the understanding of music as an inter-subjective activity creating culture resonates with the ideas of Christopher Small and what he calls "musicking"

> Musicking is part of that iconic, gestural process of giving and receiving information about relationships which unite the living world, and it is in fact a ritual by means of which the participants not only learn about, but directly experience, their concepts of how they relate, and how they ought to relate, to other human beings and to the rest of the world.[29]

Small's thinking goes one step further to embrace all musical activity as a verb, keeping the awareness of the social aspects of music to let us focus on how this vision applies to sonic improvisation.

American composer and scholar George Lewis has dedicated an important effort in his work bringing to the attention of academic and musical circles the social and historical context that has produced the emergence of groups, bands and soloists fully dedicated to music improvisation activity. Taking inspiration from his writings, one might be tempted to suggest that we are facing a situation parallel to the triggering of the free jazz movement in the second half of the twentieth century, as the interest in improvisation increasingly occupies academic discourses due to the critical state of the economic and social paradigms of our times.

A glance at Lewis's extensive list of publications reveals the direction of his thinking, through titles like: "Americanist Musicology and Nomadic Noise", "When Im-

[29] Small, Christopher. "Musicking—the Meanings of Performing and Listening. A Lecture." Music Education Research 1, no. 1 (1999): 9–22.

provisers Speak, Where Do Their Words Go?", "Review of Freedom Sounds: Civil Rights Call Out to Jazz and Africa", "Foreword: After Afrofuturism", "Improvisation and Pedagogy: Background and Focus of Inquiry", "Improvising Tomorrow's Bodies: The Politics of Transduction", "The AACM In Paris. Black Renaissance Noire", "Gittin' to Know Y'all: Improvised Music, Interculturalism and the Racial Imagination", "Improvised Music After 1950: Afrological and Eurological Perspectives", "Experimental Music in Black and White: The AACM in New York, 1970-1985", "Purposive Patterning: Jeff Donaldson, Muhal Richard Abrams and the Multidominance of consciousness", "The old people speak of sound: Personality, empathy, community".[30]

Lewis has dedicated careful attention to the relationships between music improvisation and the socio-political context in which the artistic activity is carried out. By advancing and taking forward Lewis' ideas reflected in his writing, improvisation becomes a socio-political act in the quest for freedom, equality, civil rights, empowerment of the minorities, independence of thinking and political emancipation;[31] an inclusive, inter-cultural activity in which individuals seek the expression of a rebellion against oppression by old-rooted economic powers. The understanding of context is fundamental to the understanding of the activity of musical improvisation; music has to go beyond the concert halls and face society, stimulate collective creative practices and self-questioning disciplines. By inducing creative thinking through social contact, music practices may renew themselves from the inside and be reborn in an informed and aware state of society's realities.

In fact, sonic improvisation challenges musical structures and vocabularies; it generates a possibility to rethink the hierarchies and roles strictly defined by traditions established by societies that have disappeared or mutated. By confronting the paradigm of written practices, sonic improvisation facilitates research inside the language itself, and by a conscious socio-political contextual activity, this research illuminates spots that otherwise would pass under sociologically silent and unquestioned agreements. This is revealed in any improvisation session when all the social rules become evident. To generate a dynamic, controversial attitude in the playing of a musician whose main education is based on classic canons requires a pedagogical effort. For example, developing musical and sonic attitudes in an electroacoustic ensemble such as argumentative, controversial, polemic, provocative, ironic, even impolite and not thoughtlessly melting in a warm, always comfortable music of middle register, mezzo-forte, moderato, endless, shy, where nothing interesting happens for hours, is a long process of argumentation and debate.

[30] "George E. Lewis." Columbia University Department of Music, April 22, 2016. `https://music.columbia.edu/bios/george-e-lewis`.
[31] Lewis, George E. A Power Stronger than Itself: The AACM and American Experimental Music. University of Chicago Press, 2008.

According to Gary Peters, we need to understand improvisation not as something created out of nothing, but as a *reappropriation*, an affiliation with previous cultural forms, a question asked from the present to the past: a *re-novation* model.[32] From this model and from an analysis of the *demands of the work* and the struggle of the artist to fulfill such demands, Peters proposes a re-reading of Adorno's conditions necessary to any composition, and therefore improvisation: *disobedience*, *independence* and *spontaneity*.[33]

However, is it really possible to teach disobedience, independence and spontaneity inside the academic world? I would be curious to see how many directors and program coordinators would react to such a proposal of pedagogical contents. As a Latin-American educated in public universities, I cannot avoid seeing the irony and utopia of such a situation. In Latin-America, as in many other places (and times) in the world, any connection made by academic programs to ideas instigating political, social, or even aesthetic disobedience in the populus have been brutally condemned by the old-well-armed powers, involving even the literal extermination of individuals. Consequently, after the deception of witnessing repeated overturns of social struggles, and after contemplating the lethargic and slow reactivity in our contemporary Europe when dealing with important aspects of society calling for a change, I am growing more skeptical and critical towards the real scope of the socio-political powers in the activity of improvisation.

How much of utopia and idealistic thinking lives in the guts of an understanding of a musical and sonic practice of improvisation? To what extent can a more or less marginal artistic practice such as sonic improvisation really affect the political scene, without becoming a pamphlet? To which measure improvised-sonic-performance can interfere with economic models and develop new paradigms of social structures? What is the real sociological impact on people's minds when they take part in an improvisation-based performance? Is the everyday life of the *minorities* and lowest levels of society who struggle for survival through a conventional system of work, salaries, taxes and social services affected by the sound explorations of a cluster of artists? The reader will probably agree with me that modesty is an important attitude with which to face these questions.

In his article "Composition and Improvisation", Carl Dahlhaus tries to temper the *romanticism* implicit in such views of improvisation.

> Whether the expectations which attached to improvisation and aleatoric technique, expectations which revolved around emphatic ideas of spontaneity, newness and revolutionary content, were real or imaginary is difficult to decide at present. It is true of music, as of politics, that the present conceals itself to the same extent as it presses itself on our attention. The

[32] Peters, 18-20

[33] Adorno, Theodor W., Wesley V. Blomster, and Anne G. Mitchell. Philosophy of Modern Music. New York: Continuum, 2003. 36–37

> significance of what is happening at the moment may be grasped directly in an emotional way, but the forging of concepts which are not to be mere slogans in party strife presupposes distance. It is difficult to speak of the present without becoming incoherent.[34]

Sonic improvisation, like any other artistic discipline, has a social responsibility to actively participate in a pedagogical process of building bridges between researchers, artists and audiences. As a research tool, it can be used to study the behavior inside an improvisation group, to question and illuminate our understanding of social codes and interactions articulated in the sonic work. Sonic improvisation can be used also to investigate the concert practices, spaces for performance and channels of delivery of public art. A holistic listening embraces not only the cognitive aspects of sound perception and production but also encourages in the listener an awareness of where, when and why the sound playing is actually happening.

In the wake of this attempt to build a more integrated (holistic) view of the activity of sonic improvisation as a research tool, I have observed that other aspects of the artistic practice were more hermetic and elusive. Many musicians know that there are *those things* that are not easy to speak about or communicate in words, and that not everybody thinks that is important to do so. Some celebrities in the music world are well known for having written thousands of music lines in scores or performed innumerable concerts without leaving substantial texts about their practices, not even questions or topics for meditation. These are after all implicit in the sonic worlds of such artists. Consequently, despite the logical fallacy, it could be argued that sonic improvisation is research about sonic improvisation and that the reasoning process through sonic improvisation is the practice itself. However, I claim here to take on this discussion and to try to elucidate some of these almost mystical and hermetical aspects of the discipline by discussing the concepts expressed by a key figure on the sonic improvisation community: Cornelius Cardew.

2.4 The metaphysical perspective and transcendental listening

Cornelius Cardew is probably one of the best examples to illustrate the limits and the dangers when the activities of music and socio-political engagement become indistinguishable, because of the suspicious circumstances in which he died in 1981. At that time Cardew was totally committed to socialism, deeply

[34] Dahlhaus, Carl. Schoenberg and the New Music: Essays by Carl Dahlhaus. Cambridge University Press, 1987.

studying the Marxist classics, and engaged in serious political activities, "composing, performing, touring (e.g. in Ireland in support of the Republican cause), organizing, lecturing, analyzing and discussing with comrades, and demonstrating on the streets (for which he was arrested and imprisoned) against fascism and racism."[35] Cardew was part of "AMM", an experimental group in the UK dedicated to sonic improvisation which has had a strong influence on subsequent generations of musicians, as much for its aesthetic aspects as for its ideology of the discipline.

In the text *Treatise Handbook* (published in 1971), Cardew included an article "Towards an Ethic of Improvisation" that contains a very personal and deep reflection on the "various different kinds of virtue or strength that can be developed by the musician".[36] From the very outset of the article, he reveals a praxial understanding of music and improvisation; when he confesses to having some difficulties in writing the article because "action is a stronger virtue than conversation", his reasoning leads him to conclude, in a more abstract definition, that "when you play the music, you are the music".

In this text, Cardew analyses the impossibility of rehearsing improvisation, the pointlessness of recording an improvisation, the attitude towards our sound world marked by technology and the practice of including those sounds as part of the musician's vocabulary, the inclusion of other objects as sound sources or as tools to extend instrumental techniques, and the strong influence of the space and environment on the improvisation. In all these points, the author unfolds little by little his oriental philosophical influences and personal beliefs, for example, when he discusses the idea that *music is erotic* or argues about the innocence required in the interpretations of alternative graphic or textual notations for guided improvisations, for which it is probably better to be a non-musician. (He carried out an experiment of mixing a large number of professionals and amateurs in the improvisation project called *The Scratch Orchestra*).

In the text's final paragraph, Cardew presents a set of seven virtues to be developed by the improviser. Here, in my opinion, Cardew raises certain points that open a window to another understanding of sonic improvisation as a research tool. His analysis takes us to another dimension of the practice of improvisation, to use Gary Peters' words, "not by going beyond the known, but by entering into it again and again".[37] I will comment now on each of these seven virtues, and by questioning them, I aim to suggest the way they can be related to a broader idea of listening, which I identify as **transcendental listening**.

1. Simplicity: Reaching a level of musicianship where any single sound can be produced, perceived and understood in a simple way is a laborious task,

[35] Tilbury, John. Cardew, Cornelius. Oxford University Press, 2001.
[36] Cardew, 17.
[37] Peters, 115

maybe not for children but certainly for adults. Why? Because of the tendency to overload the creative process of listening by playing with layers of mental and physical operations that end up hiding the acoustic phenomenon itself. It could be argued that a process of elaborated intellectualization or high levels of abstraction can also bring the mind beyond its own limits. Historically, musical interest seems to oscillate between phases of complexity and simplicity. However, as we can appreciate in many mathematical realizations, complex concepts can be expressed in simple sets of components or condensed equations: they are simple to read, but can be difficult to understand. Simplicity should not be confused with laziness. There is a necessary effort to do and chase the *ghosts* and fears that surround us and isolate us from the contemplation and production of sounds. A necessary element for creating an improvisation culture is the letting go of fear. Nachmanovitch writes of "five fears" the buddhists describe that are obstacles to our freedom to create: "1) fear of loss of life, 2) fear of loss of livelihood, 3) fear of loss of reputation, 4) fear of unusual states of mind, and 5) fear of speaking in public."[38] Fear of public speaking is taken to mean *stage fright*, or fear of performing. "Fear of performing is profoundly related to fear of foolishness, which has two parts: fear of being thought a fool (loss of reputation) and fear of actually being a fool (fear of unusual states of mind)".[39] To these fears Nachmanovitch adds the fear of ghosts, that is, being overcome by teachers, authorities, parents, or great masters. Werner also discusses the aspect of fear — fear-based practicing, fear-based teaching, fear-based listening, and fear-based composing. He writes that "improvisation and self-expression require the taming of the mind, the dissolution of the ego, and the letting go of all fears."[40]

2. Integrity: "What we do in the actual event is important–not only what we have in mind. Often what we do is what tells us what we have in mind. The difference between making the sound and being the sound".[41] *Being the sound* is one of those concepts easier to say than to understand. Are we talking here about a form of body resonance that accompanies the production and perception of sound? Could we understand ourselves as vibratory entities moving and inhabiting a vibratory space? The identification between the work being created and the artist has been treated ad investigated by Csikszentmihalyi in his research on *Flow Theory*.[42]

3. Selflessness: how could we divert the obsessive care about the "I" that has been so strongly developed in our culture, the idolization and worship of our subjective, personal, private worlds? We have reached the limits of democ-

[38] Nachmanovitch, Stephen. Free Play: Improvisation in Life and Art. Penguin, 1990.
[39] Ibid.
[40] Werner, K. "Effortless Mastery: Liberating The Master Musician Within (New Albany, IN, Jamey Aebersold)," 1996.
[41] Cardew, 20.
[42] Csikszentmihalyi, Mihaly. "Happiness and Creativity: Going with the Flow." Futurist 31, no. 5 (October 9, 1997): 8.

racy; there are things that should not be said not for the sake of censorship but for the sake of respect to the integrity and lives of others. How can a sonic activity of playful creativity help us to demystify the self? My answer is *by listening*. By striving to listen actively to the world beyond the all-pervasive "me". We cannot exist without our bodies; we cannot think without neurons, but we cannot pretend to absorb the universe and reduce it to our bodily experience. There may be someone or something outside ourselves.[43]

4. Forbearance: Can we renounce hyperactivity without falling into the bad habit of procrastination? Can a non-interventional attitude teach us something about the sounds that come out of our instruments and tools? Is there such a thing as sonic mistakes that are intolerable in improvisation research?

5. Preparedness: Can we accept that any eventuality may occur at any moment? Can we humbly accept that our capacity for predicting the future is rather limited? How much can our capacity for awareness be extended and improved through training to be awake and ready?

> Anything can, and does, happen at any time. At the same time, things happen in predictable chains, according to predetermined conditions and agreed-upon conventions. These chains are constantly being broken, according to changes in conditions. Our expectations of what must or will happen also change. At any moment, my activity or inactivity may influence, actively or passively, the state of the whole. At the same time, my perception of this state may influence my activity. A circular causality may exist between present and future, so that not only does the present influence the future, but the future influences the present. Likewise, the past determines the present, but the present also constantly changes the past (something which, according to Augustine, even God cannot do).[44]

6. Identification with nature. Drifting through life: With this idea Cardew is trying to bring our attention to the musical/sonic composition of common reality. In this way we may enter a permanent state of awareness, like a continuous contemplative meditation. Nature is continuously sounding and singing, and when we play, our voice melts with this infinite drone. Our digital

[43] This resonates with Murray Schafer and Brian Dennis ideas on *acoustic ecology* and a music pedagogy based on listening.
Schafer, R. Murray. Ear Cleaning: Notes for an Experimental Music Course. Don Mills: BMI Canada, 1967;
Dennis, Brian. Experimental Music in Schools: Towards a New World of Sound. 2. London: Oxford University Press, 1970.

[44] Rzewski, Frederic. "Little Bangs: A Nihilist Theory of Improvisation." Collected Work: Current Musicology. LXVII–LXVIII (Fall–Winter 1999): Composers. Published by: New York, NY, USA: Columbia University (Department of Music), 1999. no. 67–68 (1999): 377–86.

tools and computers are made with stones, minerals and metals whose voices we should reveal as we do with the wood and copper of musical instruments: they amalgamate with our fingers, they are nature.

7. Acceptance of Death.

> From a certain point of view, improvisation is the highest mode of musical activity, for it is based on the acceptance of music's fatal weakness and essential and most beautiful characteristic-its transience. The desire always to be right is an ignoble taskmaster, as is the desire for immortality. The performance of any vital action brings us closer to death; if it didn't it would lack vitality. Life is a force to be used and if necessary used up. "Death is the virtue in us going to its destination" (Lieh Tzu).[45]

Through this idea, Cardew seems to reach a new stage concerning the ethics of improvisation, its ontological foundations, its goals and its meanings, to which he is addressing a new set of questions. If by improvising with sounds we can return to the fundamental question of life and death, then improvisation is definitely a tool to inquire and investigate our understanding, perception and relation to the world. Trascendental listening expands Sonic improvisation to another dimension, as a tool to question our beliefs and to strive to illuminate the truth. When I play music as if it were the last time before disappearing forever, my playing is totally different. I feel the power of all those vibrations going into the air telling everybody around me my most secret and deep thoughts, ideas, emotions and dreams. I cannot leave this world before playing my last note!

By commenting on Cardew's ideas of improvisation, I wanted to illustrate how the understanding of improvisation and listening can be enhanced by including metaphysical questions of our beings, our environment and our *raison d'être. Transcendental listening* implies comprehending sonic improvisation as an instrument for self-discovery through self-observation and self-criticism, an active learning experience that can bridge and bring us closer to our humanness and soul.

2.5 Conclusions

In this chapter, I have proposed to analyze sonic improvisation via three modes of listening that change the perspective or focus the interest on different aspects of improvisation. My analysis, without pretending to be exhaustive, included three approaches. The first of these was the cognitive view with its structural listening

[45] Cardew, 20.

in which the main preoccupation is how the creative process of improvisation is carried out and the set of cognitive operations to process the perceptual stimulus and ideas in a spontaneous sonic creative situation. This view reveals important aspects and understanding of the way improvisers work and generate ideas but remains silent on the meanings that musicians attach to their activity in social contexts. The second, the socio-political view with its holistic listening, calls our attention to historical frameworks and the importance of improvisation as a tool to research human behaviors and social interactions. This view must be tempered to not be confused or amalgamated with politics. The third view, the metaphysical perspective combined with transcendental listening, is an attempt to elucidate aspects of improvisation that seem to capriciously escape the rational and analytical mind.

Other theorizations on listening modes underline and stress differently the dimensions suggested here. For example, the *ecological acoustics* developed by Eric Clarke as an effort to apply James Gibson's ecological perceptual theory to music with the listening experience as the pivotal piece informed/informing the environment can be seen as a form of holistic listening. Also, the *ear cleaning* of Murray Schafer, a practice that strives to raise consciousness of the surrounding sounds and ultimately of all sounds. The ideas advanced by Schafer resonate with the proposal above of listening as an active experience to study reality. Starting from a subjective silence and centering the listening act as the working tool, Schafer promotes active participation, experimentation, improvisation and analysis.

The concept of *reduced listening* as explained by Michel Chion is the name given by Pierre Schaeffer "to the listening mode that focuses on the traits of the sound itself, independent of its cause and of its meaning" in contrast to *casual listening* and *semantic listening*.[46] The reduced listening is a clear cognitive effort to understand the nature, perception and sensuality of the sounds, a journey into the intimacy of the sonic matter. It will relate, then, to the structural listening proposed above. In the same vein, Denis Smalley uses the term *spectromorphology* as a tool for describing and analyzing listening experience. "Spectro-morphology is an approach to sound materials and musical structures which concentrates on the spectrum of available pitches and their shaping in time".[47] A profound analysis of the objective and subjective properties of sounds.

Building on the phenomenological bases of Pierre Schaeffer's reduced listening Lasse Thoresen has developed a method of analysis called *Aural Sonology*.[48] In this method through a process of repeated listening combined with provisional

[46] Chion, Michel. Audio-Vision: Sound on Screen. Columbia University Press, 1994.
[47] Smalley, Denis. "Spectro-Morphology and Structuring Processes." In Collected Work: The Language of Electroacoustic Music. Published by: New York, NY: Harwood, 1986. 61-93.
[48] Thoresen, Lasse, and Andreas Hedman. Emergent Musical Forms: Aural Explorations. Department of Music Research and Composition, Don Wright Faculty of Music, University of Western Ontario, 2015.

analyses steps, the listener builds a comprehensive representation of the whole music piece under analysis, from the sound objects, through patterns descriptions and identification of forms. Thoresen argues that this method avoid a reductionist perspective elucidating structuralist and semiotic information embedded in the logical relationships within musical elements. *Aural Sonology* can potentially be an excellent tool for the analysis of recorded improvisations to extract and relate sonic qualities to formal traits either to be further studied by setting up more guided improvisations or by keeping track of reaching the desired outcome, for example achieving formal thinking while improvising or revealing the individual and common listening intentions.[49]

Finally, Pauline Oliveros, in an approach influenced by Asian contemplative practices, coined the term *deep listening*. Deep listening is a practice rooted in *sonic meditations* or "systematically working to train attention in both mindfulness and awareness" though sound.[50] The purpose of this practice is "to heighten and expand consciousness of sound in as many dimensions of awareness and attentional dynamics as humanly possible". Oliveros developed her technique into a teaching, creative and improvisation method that includes listening exercises while asleep and dreaming. Deep listening is reported by the practitioners as a tool for *revelation and transformation*.[51] Because of the confrontation with metaphysical aspects of the listening experience, deep listening can, to a certain extent, be identified with the ideas of transcendental listening exposed in this chapter.

These three approaches and understandings of sonic improvisation as a research tool reveal why the discipline should be supported, cultivated and promoted in universities and academies to contribute to the development of contemporary music and musicianship.

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[49] Thoresen, Lasse. "Exosemantic Analysis Analysis Of Music-As-Heard." The Electroacoustic Music Studies Conference, Stockholm, 2012

[50] Oliveros, Pauline. "Deep Listening: A Composer's Sound Practice." Edited by Lance W. (Reviewer) Brunner. Notes: Quarterly Journal of the Music Library Association 62, no. 3 (2006): 715–18

[51] Ibid.

3

Musicianship and Electroacoustic Music Performance

In this chapter, I view the concept of musicianship through the lens of electroacoustic music performance. Traditional views of musical expertise and musicianship can be expanded through a rethinking of the skills and values necessary to perform and improvise in settings involving electronic instruments. After reviewing some of the basic ideas and views about musicianship in the context of western music, I will attempt a definition of musicianship that embraces contributions from electroacoustic music. I argue that sound amplification, recording, synthesis, spatialization, broadcasting and cybernetics can be considered fundamental ingredients in the development of contemporary electroacoustic musicianship; I also argue that they form a conceptual core integrating a variety of performance practices in electroacoustic music.

3.1 Musical expertise and music making

The concept of musicianship has been at the center of a variety of philosophical inquiries, interpretations and traditions. Either addressed directly or as a consequence of ontological considerations about the nature of music, the question of what makes a musician a musician has occupied many thinkers, philosophers, musicologists and ethnomusicologists over the centuries.

The goal of this chapter is not to report on the richness, diversity and depth of views on *global* musicianship. My intention here is rather to elucidate the contributions of electroacoustic musical practices as part of a musician's expertise. As a starting point, a working definition of musicianship can be expressed as *the set of skills and virtues to make and appreciate music and to deepen one's identity as a musician.* The *savoir faire* of the musician, his or her expertise, cannot be a conclusive definition since it should be in tune with philosophical, ethical, moral and spiritual trends that shape and guide society. Therefore, it should undergo permanent evaluation, reconsideration and redefinition.

To examine the input of audio technology and electroacoustic music in the *know-how* and *know-what* of the professional contemporary musician set of skills, let us first look at some influential ideas of musicianship in the scope of the western-European tradition. In Boethius' chief work *De Institutione Musica*, which summarizes ancient Greek thoughts on music, the concept of musicianship emerges from the division of work in Boethius's distinction between the intellectual, or knowing, musician, the creator and the maker.[1] If not a direct link to the modern roles of critic, composer and performer, this idea is nevertheless related to the different activities and skills of judging, imagining, combining and producing sounds for musical purposes.

Over time, this idea of the division of labor in the musical field has fostered the development of highly specialized musicians and has favored training programs that support and facilitate apprentices to concentrate on distinct aspects of musical activity: performing an instrument, writing music, analyzing art works, etc. However, *Comprehensive Musicianship* emerged as an alternative to the specialized approach within the MENC (National Association for Music Education, formerly known as the Music Educators National Conference) over the second half of the twentieth century in North America. Comprehensive Musicianship is a concept that has developed from the query of integrating diverse musical activities, such as composition, analysis, performance, improvisation, history, theory and listening skills, in a unified curriculum for music education.[2]

The underlying idea of Comprehensive Musicianship is to communicate through the educational process a holistic view of musical practice. How successfully this can be done has been hotly debated. The criticisms basically expose the difficulties of allocating and concentrating resources in a very condensed manner to cover very broad and time-demanding musical issues, such as analysis, history, composition and interpretation.[3] From another point of view, widening the agenda of musical training in a multidimensional perspective has as a positive outcome the demystification of activities of composition and analysis for performers or conversely, the practice of improvisation and performance for composers and the-

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1 Anicius Manlius Severinus Boethius (Rome, 480-524/525). De institutione arithmetica libri duo, De institutione musica libri quinque. B. G. Teubner, Leipzig, 1867. Book I chapter 34. `http://archive.org/details/DeInstitutioneArithmeticaLibriDuoDeInstitutioneMusicaLibriQuinque`.

2 Choksy, Lois, Robert Abramson, Avon Gillespie, and David Woods. "Comprehensive Musicianship: An American Technique and Philosophy for Teaching Music." Teaching Music in the Twenty First Century, 2001, 115–123.

3 Grashel, John. "An Integrated Approach Comprehensive Musicianship: John Grashel Explains How Comprehensive Musicianship, Too Long Ignored by Instrumental Educators, Can Be Used to Advantage in the Rehearsal Room." Music Educators Journal 79, no. 8 (1993): 38–41.

oreticians. Very often I have encountered the *panic of the white page*, when music performance students were asked to perform composition or improvisation tasks. However, in many of those cases, a tolerant and supporting framework of spaces for experimentation generated a liberating experience, enabling students to show their great creative potential. I am aware, however, that these experiences cannot replace the proper allocation of time and effort to develop composition or instrumental skills.

Either by dissociating the musician's tasks and skills, as in Boethius's views, or by unifying them, as in the Comprehensive Musicianship project, we seem to be facing an understanding of musicianship that includes three aspects of musical practice: performance, composition, and theory. In contrast with other cultures outside the western-European tradition, this triumvirate seems very focused on the craft of music-making. For example, in the candombe and santeria traditions, the musicianship is related to the ability to interact with the supra- and infra-worlds and their deities in a query often related with supernatural, magical powers for healing.[4] In these contexts, beyond physical or mental dexterity, musicianship assumes a larger set of qualities involving more spiritual and mystical competencies.

In certain European traditions, the capacity to convey and arouse emotions in the audience and/or to alter mental states has also been considered part of the musical skill set (see for example the Italian tarantella, or the movement of *Sturm und Drang* in the eighteen century). It is probably not a coincidence that some sub-genres of popular electronic music make allusion to trance and other altered states of mind relating to electronic sounds, dance, performance and some aspects of musicianship.[5] However, much work and interdisciplinary analysis remains to be done in order to gain an understanding of the aspects of spirituality and religiosity and the crossing borders of academic and non-academic electronic music. I am personally fascinated by the ideas of driving fundamental forces such as electromagnetism through music and sound, and have experienced some sort of mystical empowerment through performance. Furthermore, while working with circuits and soldering copper and tin to move electrons around to generate and modulate audio signals, I have tasted flavors of what could be called an alchemic enthusiasm. But all of these remain in the domain of anecdotical experiences; more rigorous philosophical and psychological analysis is needed to provide frameworks and analytical tools to grasp the depth of power of electroacoustic music and musicians over the human soul.

In the chapter "Defining the Musical Identity of Non-Musicians," Nikki Richard and Tanchyuan Chin analyze the inconsistency in classifying musicianship on the

[4] Rouget, Gilbert. Musique et La Transe. Vol. 66. Gallimard Paris, 1980.
[5] John, Graham St. "Electronic Dance Music Culture and Religion: An Overview." Culture and Religion 7, no. 1 (March 1, 2006): 1–25.

basis of formal musical training.[6] They propose by quoting Sloboda,[7] and Elliott,[8] to expand the concept of musicianship in order to include in parallel to the *productive* musical expertise a *receptive* musical expertise, giving to music-listening the same status as music-making. Richard and Chin's argument challenges assumptions of formal musical training and intensive practice starting at an early age as the sole means of reaching musical expertise. Their reasoning stresses the benefits of long exposure to music and motivated and engaged listening as an alternative path towards musical expertise. This query of broadening the conceptual framework of musicianship is in tune with some of the observations about electroacoustic music that I will develop below, for example, the shifting of listening modes.

Another effort to widen the perspectives of musicianship is reflected in the work of Philip Alperson, who argues in "Robust Praxialism and the Anti-Aesthetic Turn" for a holistic view of praxialism in musical education. Alperson attempts to integrate aesthetic views (derived from a philosophy of aesthetic formalism with enhanced cognitive aspects tracing back to Kant) and praxial philosophy as developed by thinkers such as David Elliott and Thomas Regelski. In the holistic view of Alperson, musical processes and experiences are purposeful, contextual and socially-embedded.[9]

> The praxial view, on my understanding of it, calls into question the hard distinction between intrinsic and instrumental values of music, arguing that the philosophy of music should take as its subject not only the specifically aesthetic values of music deriving from the sensuous, structural, expressive, and referential aspects of music, but also those artistic values pertaining to the larger personal, cultural, and social significance of music that have been a part of musical practice since antiquity, including the possibility that music may play a role in the construction of *Bildung*, or (very roughly) spiritual formation.[10]

Although an inclusive approach, *Robust Praxialism* gives an extended framework to think about and elaborate on the different aspects and contributions of electroacoustic music to the concept of musicianship. In the next section, I focus on how performing with electronic instruments can be considered and integrated within the larger concept of musicianship.

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[6] MacDonald, Raymond, David J. Hargreaves, and Dorothy Miell. Handbook of Musical Identities. Oxford University Press, 2017.

[7] Sloboda, John. Exploring the Musical Mind: Cognition, Emotion, Ability, Function. OUP Oxford, 2005.

[8] Elliott, David J. Music Matters: A New Philosophy of Music Education. New York: Oxford University Press, 1995.

[9] Alperson, Philip. "Robust Praxialism and the Anti-Aesthetic Turn." Philosophy of Music Education Review 18, no. 2 (January 1, 2010): 171–93.

[10] Ibid.

3.2 Electroacoustic music contribution

In his book *Sound Musicianship*, Andrew Brown analyzes the concept of musicianship from different angles, including contemporary practices of sound and performance, thereby offering an updated picture.[11] One important contribution of Brown's work is his inclusion of a technological perspective to complement the cognitive, embodied, cultural and educational aspects of musical activity. For example, the *sound as data* concept can be seen as a natural extension of the musical notation propitiated by technological means. Sound is a signal that can be converted and transferred in various types of transmission formats: electrical, digital, optical, magnetic, mechanical. Thus, the musician must be familiar with and aware of these formats and consequently with the processing, representation and manipulation of that data.

Composing, improvising, performing, analyzing and distributing music requires the contemporary musician to grasp and grab the research carried out in fields such as Analog and Digital Signal Processing, Acoustics and Psychoacoustics. Such knowledge can be accessed and appropriated through practice. Improvising, performing, manipulating and making music with an algorithm is one way to grasp, analyze, understand and illuminate the hermetic appearance of a cryptically coded computer process while revealing the musical potential of that particular sound processing.

During the twentieth century the musical field experienced deep transformations facilitated by developments of sound amplification, sound recording, sound synthesis, music robotics and cybernetics, computer science and telecommunications technologies. Our everyday relation to music and consequently the concept of musicianship has been altered at the root level, and musical education must reflect those transforming processes. Andrew Hugill, who has engaged the process of rationalizing and integrating the digital era into musical education, explains it in a clear manner.

> A digital musician is one who has embraced the possibilities opened up by new technologies, in particular the potential of the computer for exploring, storing, manipulating and processing sound, and the development of numerous other digital tools and devices which enable musical invention and discovery. This is a starting point for creativity of a kind that is unlike previously established musical practice in certain respects. It also requires a different attitude of mind. These musicians will be concerned not only with how to do what they do, nor what to do, but also with why to make music. A digital musician, therefore, has a certain curiosity, a questioning and critical engagement that goes with the territory.[12]

[11] Brown, Andrew R. Sound Musicianship: Understanding the Crafts of Music. Vol. 4. Cambridge Scholars Publishing, 2012.

[12] Hugill, Andrew. The Digital Musician. Routledge, 2012.

Performing an electroacoustic instrument demands a different set of skills than performing with an acoustic instrument. The physical ability to play fast and loud, for example, as a trait of virtuosity which was heavily pursued in previous times has been left behind by the electric power of amplification and by precision of very accurate digital clocks. The improvement of electrically and digitally controlled acoustic mechanical systems has opened up perspectives on music robotics and cybernetics, challenging musicians by exceeding or surpassing human dexterity.[13] Musical memory is also called into question by recording technologies that have made sampling techniques and instant recall of extremely detailed sonic gestures an option for live performance. The extensions of sound qualities induced by the analysis and synthesis of sounds by electrical and digital means has also spurred questions and research as well as raising issues of user interface to control and perform these sound synthesis processes during performance. Using loudspeakers as the primary medium of transmission for the performance of sounds has opened possibilities to create, explore and experiment with different placements, configurations and loudspeakers setups, creating original listening spaces an environments. Spatializing sounds requires particular skills for the design, adjustments and creative use of these listening spaces. Finally, the codification and transmission of sound over digital networks and through the Internet have opened the door to forms of performance in which the physicality and presence of the musicians is not a definitive requirement but rather an option.

These six aspects of electroacoustic music and audio technology: sound amplification, recording, synthesis/analysis, spatialization, broadcasting and cybernetics, have deeply influenced all aspects of musicianship: aural, cognitive, physical, contextual, social, intersubjective and pedagogical skills for perceiving, integrating, analyzing, imaging, composing, assessing, judging, transmitting and expressing musical thoughts with sounds. Using electroacoustic methods and techniques has blossomed in a multitude of aesthetic contexts which will be crucial to the development of artistic identity in generations to come. In the second part of this thesis, I propose a package of activities, tasks, exercises, situations and musical ideas to explore the interaction and relationship between aspects of musicianship and electroacoustic music resources.

Considering the contributions of electroacoustic music mentioned above, the concept of musicianship can be updated and described as *the capacity to think sonically as a mental and physical activity based on the appropriation of a body of knowledge about sound*. Knowledge about sound involves many dimensions, including procedural and declarative knowledge grounded in memory, types of perceptions, and experiences with sounds.[14] The knowledge base involves know-

[13] Valle, Andrea. “Making Acoustic Computer Music: The Rumentarium Project.” Collected Work: Music and the Moving Image. XVIII/3 (December 2013): Re-Wiring Electronic Music. Published by: Champaign, IL, United States: University of Illinois Press, 2013. 18, no. 3 (2013): 242–54.

[14] Pressing, Jeff. “Psychological Constraints on Improvisational Expertise and Communication.” In Collected Work: In the Course of Performance: Studies in the World

ing about sounds and how to work with them. Building the knowledge base is a process that involves awareness of the physicality of sounds, their propagation in the environment and their quantitative and qualitative characteristics, as well as the life of sounds in perceptual and mental human systems, the interpretation of sounds in a cultural context and the appreciation and judgment of artistic potential of sounds. Cultivating and expanding knowledge about sound is an active engagement that involves its direct manipulation with combinatorial, logical and procedural transformations and operations that can be applied to convey different forms of meaning, emotions, ideas and insights into inner and outer life. In terms of cognitive psychology, it can be described as building *an embodied knowledge of sound*.

I want to underline here how thinking with sounds can be described as a mental activity. This means that mental processes such as free associations, problem solving, imagination, as well as deduction-induction when using sounds can happen in the absence of physical acoustic vibrations. Silent singing in reading a score or imagining melodies is an old and well-known practice of many performers.[15] Sounds can be understood as a physical phenomenon but should also be considered as a mental process as well as a sociological or cultural commonality, and even beyond that, as a way of climbing the heights of spiritual life or descending deep into the caves of the sub-conscious. Thinking of the world and its essence through sounds can enlighten us to the way we understand, teach and transmit musical knowledge.

3.3 Performer skills

Performing a musical instrument involves specialized motor and aural skills. Mastering the loop of perception-action and control mechanisms involving the adjustment of different aspects of sound is a carefully crafted developmental process of a set of mental and physical skills. These processes and skills are deeply rooted in the musician's body and mind. Cognitive neuroscience research has enlightened relationships between acquisition and maintenance of musical skills and re-shaping capacities of the brain thanks to its neuroplastic qualities.[16] Intense practice, repetitive rehearsing and focus or goal-oriented work are methods to master technical challenges of performing musical instruments. However, as a very popular assumption among musicians reminds us: technical mastery is not enough to perform music. What else does a musician need in order to cultivate and to evolve in his or her quest for musicality and musicianship? When asking this

of Musical Improvisation. Series: Chicago Studies in Ethnomusicology, Published by: Chicago, IL, USA: University of Chicago Press, 1998. 47-67.

[15] Agustín, San. Confessions: XXVII, 36. Oxford: Clarendon Press, 1992.

[16] Gaser, Christian, and Gottfried Schlaug. "Brain Structures Differ between Musicians and Non-Musicians." Journal of Neuroscience 23, no. 27 (2003): 9240–9245.

question to professionals or experienced musicians, one may find a variety of answers and beliefs that range from poetic abstraction to emotional expressiveness, intellectual virtuosity and socio-political engagements or even forms of spiritual contemplation. These extra layers that complement and give sense to technical skills, regardless of their hermetical nature, are very present in the pedagogical moment of knowledge and artistic transmission.

I believe that a fully engaged and active experimentation of musical possibilities of an instrument through individual and group practice supported by an environment in which social categories have been flattened out and where an encouraging atmosphere of trust has been established are fundamental requirements for the acquisition, development and expansion of all dimensions of musical performing skills. Acquiring performing skills can be seen as a journey along the path of building an artistic identity, gaining independent thinking in musical creativity and reinventing by experimenting with the knowledge of performing music. Integrating and expanding the learning process with electroacoustic means entails thinking in detail about aspects of performance skills. Let us now take a closer look at these aspects.

3.3.1 Amplification

Electricity liberates musicians from the need to deliver energy to excite the resonant modes of an instrument on a moment-to-moment basis. Relaying the production of acoustic energy to an electric power source has allowed musicians to become members of the audience at will, or to slightly shift their role from actor to spectator. The shifting of listening perspectives has opened the development of concert forms and interactive pieces that intersect with forms issued from visual arts, such as concert-installations and automatic systems that may eventually bypass the performer altogether. Freeing the hands and body of the preoccupation of supplying energy into the acoustic system allows the performer to redirect these resources into intensifying the listening experience and to deeply concentrating on sound details.

In acoustic instruments, the relay or decoupling of energies between sound generation and sound control was known well before the discovery of electricity. In instruments such as the organ, the air supply for blowing the pipes is ensured by a mechanical system. However, even if the source of power in the organ is not dependent on the musician, its control is fully in the hands of the performer. In an electronic context, the source of power is electricity, and the musician can either articulate the moment-to-moment sounds or trigger automatic processes controlling sound parameters.

What makes electroacoustic performance special in this context is the combination of both acoustic energy supplied by a third component, non-directly from the musician, and automatization or *programmed* control during performance. As a consequence, the physicality of performing with electroacoustic instruments is on another level compared to acoustic instrumental performance, perhaps closer to the orchestra conductor, to whom musical gestures are intended to drive the musical power of an ensemble of musicians instead of furnishing acoustic energy or directly controlling the production of sound.[17]

Even when acoustic components are integrated with electroacoustic instruments through amplification, the musical performance requires a different approach. Minimal sounds can be maximized, and sonic details at the proximity of the source are easily revealed and can be musically exploited. Electroacoustic musicians must take full advantage of these resources (sound amplification and acoustic energy relay) and deeply integrate them with their other performance skills.

3.3.2 Recording and sampling

Recording and recalling sounds at the studio, on the stage or anywhere that a microphone can reach has expanded the musician's resources to include, manipulate and work with sounds that are dislocated in time and space. The musical mind has to assimilate every sound event or sound environment as a potential resource for the musical discourse. Musical performance using recorded sounds requires skills to contextualize and organize sounds and sonic material, for example by playing with revealing and hiding the origin of the material, or by morphing their spectral content creating hybrid or *fantastic* sonic entities. Using recorded material allows performers to transpose, impose or combine different acoustic environments and therefore to play with *spaces within the spaces.*[18] If the source of an acoustic event is invisible, a full layer of musical discourse and structure can be built around the identification or origin of sounds. The potential of recorded sound has been at the heart of musical genres such as *musique concrète, acousmatic music*, tape music, soundscape compositions but also in real-time performance of samples.[19] Electronic musicians have to cultivate the capacity and intuition to juxtapose, combine and recall sounds from pre-recorded libraries or in situ recordings, mastering the microphone, editing, processing and mixing samples in real-time or preparing material at the studio, navigating between different past moments and judging the musical qualities and potential of acoustic scenes that can eventually be integrated into a performance.

[17] Genevois, Hugues, and Raphaël De Vivo. Les Nouveaux Gestes de La Musique. Parenthèses, 1999.
[18] Andean, James. "Space Within Space: Report on a Concert," 2009.
[19] Russ, Martin. Sound synthesis and Sampling. New York: Focal Press, 2013;
Davies, Hugh. "A History of Sampling." Organised Sound 1, no. 1 (1996): 3–11;
Kane, Brian. Improvising Tape Music. Spark, 2006.

3.3.3 Spatialization

Another aspect to be developed by the electroacoustic music performer is the delivery of sounds through a set of loudspeakers. Sound spatialization and sound diffusion are very important aspects of electroacoustic music and have been a focus of intensive research from the origins of music played through loudspeakers.[20] If the recording of sounds can be analyzed as a dislocation of time, the projection of sounds through loudspeakers can be seen as a dislocation of space. This could be called the *double dislocation paradigm of electroacoustic music*. An array of loudspeakers placed in a room and controlled by a central unit allows performing with localization, motion, trajectories and diffusion of sound sources. [21] Working with and handling space narratives and sonic space design must be addressed by the performer, either by creating and following scores, instructions, intuitive improvisation or free creative will. Different systems and platforms are available for the performer to build, learn and integrate the projection of sound sources with loudspeakers. The *choreography of sound* and the *spatial thinking* are essential skills which must be learned and practiced.[22]

3.3.4 Synthesis and analysis

Musicians are constantly occupied with the tuning and maintaining of their instruments. This is also the case for electroacoustic musicians for whom the idea is taken almost to the extreme of constantly re-inventing the instrument. Adding an extra string to the piano or a few more centimeters to the cello is a hazardous task that requires a lot of work from the musician, for example. On the other hand, redesigning an electroacoustic instrument by restructuring its components, altering its topology or changing the mapping of controls and functions is a much more common practice in electroacoustic music.[23] As a consequence, a deeper knowledge of acoustics, analogue and digital signal processing is required from

[20] Zvonar, R. A History of Spatial Music (2006), n.d;
Macedo, Frederico. "Investigating Sound in Space: Five Meanings of Space in Music and Sound Art." Organised Sound; Cambridge 20, no. 2 (August 2015): 241–48;
Truax, Barry. "Composition and Diffusion: Space in Sound in Space." Organised Sound 3, no. 2 (1998): 141–146.

[21] Bayle, François, Éric Daubresse, Pierre-Alain Jaffrennou, François Nicolas, and Jean-Claude Risset. "L'espace et l'électroacoustique." Collected Work: L'espace: Musique/Philosophie. Series: Musique et Musicologie: Les Dialogues, Published by: Paris, France: L'Harmattan, 1998. 372-390.

[22] Eckel, Gerhard, Martin Rumori, David Pirro, and Ramón González-Arroyo. "A Framework for the Choreography of Sound." In ICMC, 2012;
Godøy, Rolf Inge. "Gestural Affordances of Musical Sound." In Musical Gestures, 115–137. Routledge, 2010.

[23] Jordà, Sergi. "Improvising with Computers: A Personal Survey (1989-2001)." Journal of New Music Research 31, no. 1 (2002): 1–10.

the musician. Even without engaging in the mutation of the instrument itself, electroacoustic music requires the skills of representing a sound, a set of sounds or a sonic event as a block diagram of unit generators, an interconnected patch of sonic modules or an abstract function to be rendered as a sound.

Performing, manipulating, activating, transforming or driving sound synthesis analogically or digitally is mostly a mental skill that requires high levels of abstraction. These skills are built in a slow process of learning about the theories of sound synthesis and by familiarization with techniques and instruments. The skill of sound synthesis lies in the ability to abstract sound operations and to define sonic events and processes in electronic digital and analogue terms. Virtuosity here is about creating and imagining clever and elegant inter-connections and combinations of sound functions, modules and synthesis units.

3.3.5 Broadcasting

Thanks to the constant improvement of streaming and broadcasting audio, the possibilities and developments of telematic performances, online jam sessions and other forms or collaborative distant music practices are more common every day.[24] The principle of playing with non-physically present musicians to a virtual audience has existed since the days of radio broadcasting and will certainly develop in the near future as new forms of virtual reality concerts and live music sharing evolve.[25]

Setting up an audio streaming system for musical performance is a complex task mainly because the necessary control of latency and stability of data transmission depends on many factors not obvious to manage without technical knowledge. However, more and more tools are becoming available for musicians, facilitating the access and setting up of networked performances.[26] Similar to sound amplification, recording and synthesis, sound performances over a network extend beyond the aesthetics and ideas of electroacoustic music.[27] These tools and ideas are used and explored in an ever-growing number of musical genres. Performing with non-physical musicians may feel awkward at the beginning, but if the video

[24] Whalley, Ian. "Developing Telematic Electroacoustic Music: Complex Networks, Machine Intelligence and Affective Data Stream Sonification." Organised Sound 20, no. 1 (April 2015): 90–98.

[25] Oliveros, Pauline, Sarah Weaver, Mark Dresser, Jefferson Pitcher, Jonas Braasch, and Chris Chafe. "Telematic Music: Six Perspectives." Leonardo Music Journal 19, no. 1 (2009): 95–96.

[26] Carôt, Alexander, Pedro Rebelo, and Alain Renaud. "Networked Music Performance: State of the Art." In Audio Engineering Society Conference: 30th International Conference: Intelligent Audio Environments. Audio Engineering Society, 2007.

[27] Mills, R. H. "Tele-Improvisation: A Multimodal Analysis of Intercultural Improvisation in Networked Music Performance," 2014.

image is bypassed, it is actually a liberating experience that invites one to fully focus on the sound of a performer. Making full abstraction of body language and visual cues forces the development of the means of expression and communication necessary for performing and improvising in a group. Therefore, another set of skills for networking performance has to be developed in the context of contemporary music performance using electroacoustic means.

3.3.6 Cybernetics and Robotics

Artificial intelligent musical agents driving electroacoustic or electromechanical audio devices are becoming common partners and complementary units in an electroacoustic music performance context[28] If amplification and automation has taken away from the performer the responsibility of providing energy to maintain and acoustic event, artificial intelligence may liberate performers of cognitive tasks to allow them to focus and explore other dimensions of musical expression. Interacting with non-human musicians demands openness, tolerance, and experimentation in order to widen aesthetic perspectives and to conquer new territories of expression. Instead of being afraid of robots taking over musicians' work (a similar affair surrounded the beginning of recording technologies), performers should welcome the opportunity to explore and gain deeper knowledge of humans' musical expressive nature. At the same time it is important that contemporary performers assume a clear position with respect of ethical issues related to the embodiment of nano-technologies, bio-technologies and telecommunications metamorphosing the human body under sonic expression arguments.

3.4 Conclusions

Musical and sonic ideas can be generated from widely varied processes, for example, handling and sonically investigating instruments, objects and materials as well as mental images, emotional or psychological states or meditation routines, stimuli from social and cultural life and from many other activities and sources in the private and personal spheres. This still mostly applies to generating musical ideas that include electroacoustic resources. However, the advancement and understanding of transducing processes of acoustic energies into electric ones has opened perspectives for different listening attitudes and creative tools, leading performers to develop, master and integrate a diversity of skills broadening their musicianship.

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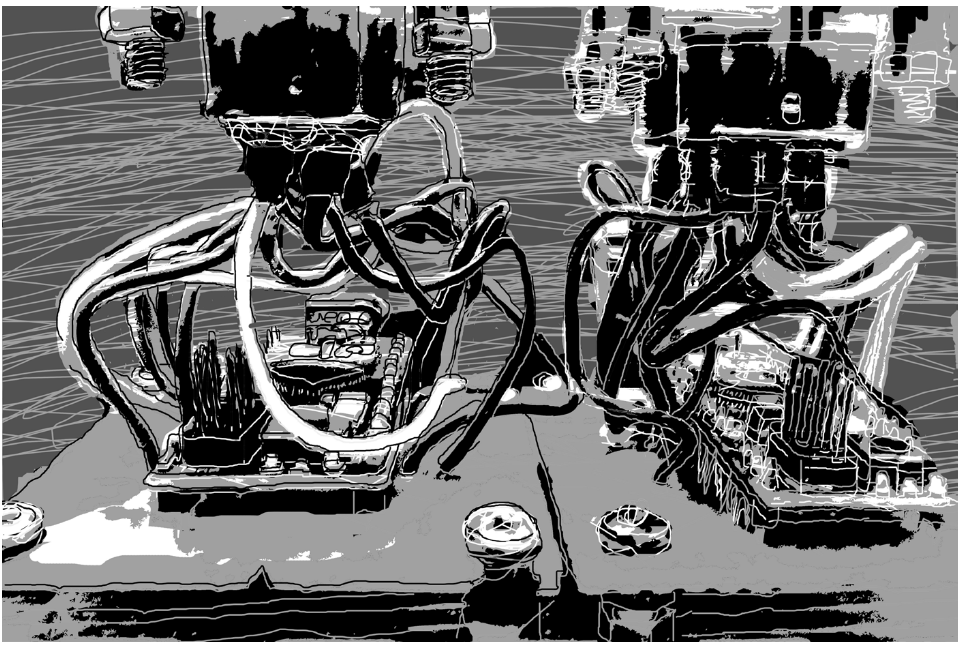
[28] Sobh, Tarek M., Bei Wang, and Kurt W. Coble. "Experimental Robot Musicians." Journal of Intelligent and Robotic Systems 38, no. 2 (2003): 197–212;
Miranda, Eduardo Reck. Readings in Music and Artificial Intelligence. Vol. 20. Routledge, 2013.

Observed through the lens of electroacoustic music, the concept of musicianship is expanding beyond traditional skills of performing acoustic instruments to include aspects of extended listening and instrumental perspectives. For example, *microscopic* listening reveals details of the sound made possible by amplification; relaying the production of acoustic energy with electricity allows for the shifting of roles from actor to audience and eases the performer into contemplative states *vis-à-vis* the sonic performance; translating mental operations and mental representations of sound processes into interconnected hardware and software requires an inner ear based not on mechanical properties of instruments but on high-level representations of signal flows. By dislocating sound from its source in time and space thanks to recording, sampling and spatialization techniques, the performer gains access to a large gamut of possibilities around memories, references and sonic traces. By using broadcasting techniques, interaction between performers takes on different forms in which the non-physical presence of musicians or audience concentrates the attention through communicating solely thorough the sonic material. Finally, by integrating and interacting with artificial intelligent environments and systems, performers can access deeper dimensions of musical activity.

In this chapter, I have highlighted the relevance and importance of silent features of electroacoustic music practices and audio technology developments. These have opened doors and perspectives that expand the ideas and concepts inherent to a musician's skills and musicianship. The concept of musicianship is central to the discussion and arguments developed in this book. Contemporary music performers can benefit greatly from integrating into their discipline and practice the knowledge and tools offered by the research and developments of electroacoustic music.



4

Electronic Instruments for Performance and Improvisation

In this chapter I will discuss a set of musical instruments used for electroacoustic performance and improvisation from a didactic and pedagogical perspective. The purpose of the chapter is to invite performers to experiment, research, rebuild, enhance, analyze and rethink their own electroacoustic performance environments. To do so, I will break down and survey a selected series of electroacoustic tools and instruments through the lenses of performance practices. The set of electronic instruments were chosen for their relevance in the Electroacoustic Music field through the history of the genre and their recognition among practitioners. The list is of course incomplete, but it has been of great utility for the pedagogical purposes of the research exposed in this work. I will briefly discuss for a matter of clarity the definition and classification of Electronic Instruments, but a detailed musicological presentation or an in-depth discussion on the classification and taxonomy of Electronic Instruments is outside the scope of this chapter. To complement the presentation of the instruments, in the following paragraphs, I will explain my views on the relations between experimenting, building, performing and learning Electronic Music Instruments. This chapter wraps around the conceptual framework for the pedagogical toolkit of the second part, so it can be seen as a resource of materials to refer to when implementing the performance exercises, tasks and dynamics presented in the toolkit.

4.1 Terminology and definitions

Hugh Davies in "Electronic Instruments" in the Grove Music Online discusses the meaning and usage of terms related with musical instruments in the field of electronic and electroacoustic music, including electric(al), electronic, electroacoustic, electromagnetic, electrotonic, electrogenic, radio-electric, ether-wave, electrophonic, synthetic, electron music, electromusic.[1] According to Davies, "to-

[1] Davies, Hugh. Electronic Instruments. Oxford University Press, 2001.

day 'electroacoustic' and 'electronic' are the most widely used terms for the large area of music generated or modified by electric and electronic instruments and associated equipment". He also argues that "common usage dictates 'electronic instruments' rather than 'electric (or electroacoustic) instruments' as the generic term for all instruments in which vibrations are amplified and heard as sound through a loudspeaker, whether the sound-generating system is electroacoustic or electronic". In this text, I follow Davies's proposal of understanding Electronic Instruments as the large set embracing a diversity of instruments, devices and machines of different natures (electroacoustic, electromechanical, electronic, digital) for the purpose of performing electroacoustic music. Although the term *Electronic Instruments* while referring to *Electroacoustic Music* practices may sound unclear, it is the more accurate terminology. The musical aesthetics implied in this work are positioned and related to the Electroacoustic Music and Live Electronics tradition enveloping experimentation and research with sounds, electricity, and technology in different forms. The Electroacoustic Music genre has been developing from the middle of the twentieth century along with the advancements of instruments, synthesizers and audio equipment, better described and identified under the umbrella concept of Electronic Music Instruments as explained above.

In Davies's analysis, the main point to distinguish among electric and electronic instruments is based on the principles of sound generation.

> The term 'electric' is comprises two types of instruments: electroacoustic instruments, which produce sounds, albeit often virtually inaudible, by acoustic methods, and which incorporate built-in microphones, pickups or transducers by means of which these vibrations are amplified; and electromechanical instruments, in which the mechanism itself produces no sound but creates a regular fluctuation in an electrical circuit which can be converted into an audio signal. The term 'electronic' is used for instruments in which the sound is generated by means of electronic oscillators or digital circuitry.[2]

The instruments involved in performance and improvisation of Electroacoustic Music should include as many definitions, variations and combinations as possible, and there should not be restrictions to integrate any device in a session, regardless of their means of sound generation or underlying technology. I have gone one step further in some of the tasks proposed in later sections of this work and suggest performance without amplification, or without electricity – or even only with the body – in a fully acoustic way, for the purpose of focusing either on the listening experience or on the performance attitude or to clarify a musical-sonic concept.[3] The electronic instrument's construction, analysis or classification

[2] Ibid.

[3] In this regard, I would like to cite the saxophonist Marc Vilanova, an active participant of the live electronics workshop in 2013, as an outstanding performer who

are not the ultimate goal of the discussion exposed in this book. This being said, it is essential to understand that the study of electroacoustic devices and instruments, their signal flow, specs, capabilities and limits is a crucial part of the development of performative and creative sound skills. Exploring and expanding the performers' electroacoustic sonic vocabulary can be done by simultaneously training performance skills and listening attitudes and by mastering the tools and components of the electroacoustic signal chain. Hence, fluency and dexterity of electroacoustic music performance is a continuous process of interaction between the performer's musicianship and understanding of idiosyncrasies of electroacoustic tools.

One important clarification of terminology is to distinguish the concept of *interface or controller* from the *sound generating system*. In *New Digital Musical Instruments*, Miranda and Wanderley state the difference by observing the decoupling of physical interface or *control device* from the *sound engine* or *sound generating system* with a mapping layer interconnecting sensed parameters from the controller with parameters of the synthesis engine.[4] There is a considerable amount of research on controlling devices for sound synthesis or sound processing systems, probably related with the access to sensor technology and the popularization and decreasing costs of microcontrollers.[5] This decoupling controller/-source is not only a quality of digital instruments as demonstrated for analog, voltage controller devices, where some experiments have taken the risk of abandoning the keyboard paradigm as performance controller to explore different alternatives. For example, the sliding ring in a ribbon controller of the *trautonium* and *ondes martenot*,[6] a joystick as in the EMS VCS3 synthesizer,[7] touch-sensitive plates in the Buchla 112,[8] and many others such as performing wheels, antennas and photoresistors. Even beyond electronic instruments, the organ presents the same feature of using keyboards, soft knobs, drawbars and pedals to control the air flowing through pipes.

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has integrated into his acoustic playing techniques listening attitudes, sonorities, and qualities proper to the electronic music.

"Marc Vilanova." Accessed December 2, 2018. `https://web.archive.org/web/20180815212529/https://www.marcvilanova.com`.

4 Miranda, Eduardo Reck, and Marcelo M. Wanderley. New Digital Musical Instruments: Control and Interaction beyond the Keyboard. Vol. 21. AR Editions, Inc., 2006;

Bovermann, Till, Alberto de Campo, Sarah-Indriyati Hardjowirogo, and Stefan Weinzierl. Musical Instruments in the 21st Century. Springer, 2017.

5 See for example the proceedings of New Interfaces Musical Expression conference from 2001. "NIME | Archive of NIME Proceedings." Accessed December 20, 2018. `http://www.nime.org/archives/`.

6 Roads, Curtis. Composing Electronic Music: A New Aesthetic. Oxford University Press, 2015.

7 Gardner, James. "The Don Banks Music Box to The Putney: The Genesis and Development of the VCS3 Synthesiser." Organised Sound 22, no. 2 (August 2017): 217–27.

8 Dalgleish, Mat. "The Modular Synthesizer Divided," n.d.

This chapter is mostly concerned about sound generator systems, while performance controllers are mentioned when needed but without pretending to establish a focused study on them, mostly because there is already considerable literature available on this topic and because most of the non-popular performance interfaces have been built in small batches and are difficult to submit to a direct test and critical judgment.

4.2 On the classification of electronic instruments

There are several sources that discuss the classification and taxonomy of Electronic and Electroacoustic Music Instruments, and several approaches to doing so. For example, Bakan et al. discuss in detail possibilities of extending the classification system of musical instruments proposed by Erich von Hornbostel and Curt Sachs in 1914.[9] Their proposal is to add a fifth category to the typology with *electronophones*. This category includes instruments which produce sound by purely electronic means; in contrast, other electrified or amplified instruments remain in their own original categories but are classified using a special nomenclature of suffixes.

Other approaches for classification and categorization of Electronic Instruments involve identifying pertinent qualities and singularities of electronic instruments and interfaces as the core of the classification paradigm. For example, after conducting a survey (Taxonomy of Interfaces for Electronic Music Performance) in a research program called "Performance Practice in New Interfaces for Realtime Electronic Music Performance", Garth Paine remarks that recent attempts for classification of Digital Music Instruments "have focused on the sensor types used, the nature of the interface, the way gestures are captured and the mappings between interface and sound generating functions."[10] Slightly different attempts on the classification cited by Paine include: the master's thesis of Pringer, who compared Digital Music Instruments with respect to expressivity, immersion and feedback,[11] and the multidimensional approach of Birnbaum et al, where the role of sound, required expertise, music control, degrees of freedom, feedback modal-

[9] Bakan, Michael B., Wanda Bryant, and Guangming Li. "Demystifying and Classifying Electronic Music Instruments." Collected Work: Selected Reports in Ethnomusicology. VIII (1990): Issues in Organology. Published by: Los Angeles, CA, USA: University of California (Department of Ethnomusicology and Systematic Musicology), 1990. 8 (January 1, 1990): 37–64.

[10] Paine, Garth. "Towards a Taxonomy of Realtime Interfaces for Electronic Music Performance." In NIME, 436–439, 2010.

[11] Piringer, Jörg. Elektronische Musik Und Interaktivität: Prinzipien, Konzepte, Anwendungen. na, 2001.

ities, inter-actors and distribution in space are identified as relevant dimensions for a plausible taxonomy.[12]

Conscious of the challenges and issues of dealing with an ever-expanding and multifaceted corpus of electronic-digital-electromechanical-analog-electroacoustic instruments, Thor Magnusson has advanced the idea of *musical organics* "as a methodological approach for studying and classifying instruments, including DMIs" (Digital Musical Instruments): "The notion of musical organics is then proposed as an approach benefiting the organology of new digital instruments. This is not a classification system designed with considerations of physical space or printed books: it is rather a philosophical concept, engaging with the problems of classifying DMIs, and proposing a dynamic architectural information-space applying modern media technologies, where classifications of musical instruments can be built on-the-fly using a flexible information retrieval system".[13]

Studying these classification and taxonomy systems can be a way to explore the landscape of possible and impossible instruments, to investigate how musicians and engineers have set up and implemented different categories and combinations and even to imagine new ones. For example, while examining the document "Revision of the Hornbostel-Sachs Classification of Musical Instruments by the MIMO (Musical Instrument Museums Online) Consortium" one can find categories such as "Electromechanical sound processing devices" including spring reverberators and tape echo, but is it possible to imagine and build other devices for this category?[14] What about "Electroacoustic aerophones" or "Photoelectric electromechanical instruments"? Could these categories be further expanded with new implementations? The classification finishes at Software, but it is clear that there is still some research in digital synthesis not implemented yet in specialized hardware such as DSP chips (SHARC, FPGA and similars). See for example the synthesis techniques reported by Stelios Manousakis "Non-Standard Sound Synthesis with L-Systems" that exist so far only as Unit Generators for Supercollider. Self-contained Instruments could be built around it.[15]

[12] Birnbaum, David, Rebecca Fiebrink, Joseph Malloch, and Marcelo M. Wanderley. "Towards a Dimension Space for Musical Devices." In Proceedings of the 2005 Conference on New Interfaces for Musical Expression, 192–195. National University of Singapore, 2005.

[13] Magnusson, Thor. "Musical Organics: A Heterarchical Approach to Digital Organology." Journal of New Music Research 46, no. 3 (July 3, 2017): 286–303.

[14] Consortium, MIMO. Revision of the Hornbostel-Sachs Classification of Musical Instruments by the MIMO Consortium, 2011;
Dolan, Emily I. "Review: MIMO: Musical Instrument Museums Online." Journal of the American Musicological Society 70, no. 2 (August 1, 2017): 555–65.

[15] Manousakis, Stelios. "Non-Standard Sound Synthesis with L-Systems." Leonardo Music Journal, 2009, 85–94.

4.3 Between experimenting, performing and learning

In this thesis, I usually refer to an electronic or electroacoustic *set* instead of an electronic or electroacoustic instrument, because in practice a performer often uses a collection of interconnected devices as an instrument. Thus, instead of a cohesive, self-contained unit, the instrument is a bundle of sound generators, sound processors, sensors, transducers, gestural controllers and audio devices. These may include a large variety of items and equipment: from electrified and amplified acoustic instruments, passing by self-built electronic gizmos and all sorts of electronic machines deconstructed, customized or solely used as sound generators, processors or controllers (i.e. a fan, a drill, a blender or as in the *circuit bending* tradition of manipulating low-powered electronic devices for sonic purposes), up to high quality audio equipment designed and built by engineers, including synthesizers, pickups, amplifiers, loudspeakers, mixers, software, analog and digital converters.

Traditionally, performing electroacoustic music involves many degrees of actively participating in building, programming and modifying the performing tools. From programming the presets of a synthesizer, passing by the coding of software and DSP units (or even entire programs), soldering guitar pedals and synthesizer modules to the designing and building of complete instruments are common practices among performers of electroacoustic music and live electronics. DIY culture is still very strong and supported by on-line communities and forums discussing open software and hardware projects. Since every performance set is unique in the sense that it represents a very specific combination of devices and their eventual programming, it would be a quixotic task to pretend to index all of the reported inventions of the previous and current centuries. Instead I propose here an entrance gate for initiation to experimental practice with relatively accessible electronic instruments and audio devices.[16]

[16] The research and development of electroacoustic instruments is a very active and expanding field in the industry and in the academic world as confirmed by conferences, fairs, magazines, online publications, blogs and DIY communities. The Music Technology Group (MTG) of the Universitat Pompeu Fabra in Barcelona entertains a list available at `https://github.com/MTG/conferences` with more than 50 entries for conferences and 12 journal calls in 2018, including development and research on the Electroacoustic, Electronic and Digital Music Instruments field, for example, NIME, ICMC and SMC conferences. The music industry and companies also organize worldwide fairs, show trades and meetings such as NAMM – National Association of Music Merchants (NAMM) `https://www.namm.org/` and Frankfurt Musikmesse: `https://musik.messefrankfurt.com/frankfurt/en.html` The online activity through Forums and mailing lists have as well facilitated the exchange of circuit designs and implementations for building electronic music instruments by amateurs and professionals. See for example forums such as `http://electro-music.com/` and the popularity of *youtubers* creating user guides and *how-to-do* content.

The modular nature of electronic instruments requires a permanent exercise of experimenting with interconnecting, patching, mapping signals, adjusting levels, matching impedances and re-programming that large variety of devices. Though there are of course some self-contained, fully stand-alone instruments that can be just switched on, ready to fire sounds, such as a synthesizer with built-in loudspeakers, there are many instruments and devices that do not include the amplification system, leaving the user to handle the connections. Other devices require a connection to a controller interface or to other equipment, and many times the strength of an audio device conceived for performance resides in its re-programmability or reconfiguration features. Experimenting in this context entails creating inventive connections and preparing signal paths combining elements and devices to spark the sonic curiosity and instigate the music. Investigating and familiarizing oneself with a piece of equipment is done by systematically exploring the sonic, electrical and acoustic properties of the machine, driving the gear to produce the sounds and results conceived by the musical mind but also letting the instruments themselves talk and guide the musician's hand and ear to the unexplored territories of sonic expression.

Ultimately, it is about being in tune with the machines to allow the musical stream of ideas to freely flow in the circuit between the brain, the ear and the hand. The constant re-building and re-designing of electroacoustic instruments can be thought of as a parallel idea of tuning and maintaining an acoustic instrument.

The diversity of devices and the ever-changing, ever-evolving and unfinished nature of electroacoustic music sets for improvisation and performance can be perceived as a pedagogical challenge. Imagine for example having individual music lessons where the apprentice comes with a new instrument every week or for every session the instrument experiences deep structural changes: an extra string in the violin or a bigger resonant case for the guitar or a flute with a different, larger body. Although it may sound fascinating for some, it raises questions about the possibilities of developing musicianship or building an instrumental knowledge of gestures and sounds.

I argue that dexterity with electronic instruments is a matter of balancing the activities of experimenting, researching, learning and performing. It can be very easy with electronic instruments to invest considerable amounts of time in the experimentation process configuring or building the instrument without allocating enough time to perform it, or spending hours browsing the presets of a synthesizer or plugin without putting together a musical moment, or poring over endless catalogues of audio gear and musical devices looking for the ever-missing part to complete a performance set. At the other extreme, definitely fixing a performance set can turn into a monotonous activity that loses the freshness, risk, questioning and critical learning characteristics of the experimental and research attitudes. Therefore, it is in the balancing of research and creation, experimentation and practice that musicianship can be most fostered. I am not saying of course that it should always happen in that way. Not everybody wants to be, or ends up being, a musician performer. Experimenting with electronics, coding and programming can be the gateway to a professional development of an instrument builder or to expertise about specs, and evolving critical judgments on audio devices can be an opening for a career as an entrepreneur in the audio industry and market. The pedagogical moment of researching, experimenting, performing and discussing is then the best arena to support personal initiatives of development in relation to the Electroacoustic Music Instrumentarium.

4.4 Exploring the electronic instrumentarium

Contact microphones

Contact microphones are a versatile tool for amplifying and exploring acoustic properties of all sort of objects. Though there are different typologies of contact microphones available in music stores such as condenser (AKG 411 pp),[17] dynamic (Schertler Dyn-Uni-P48),[18], the most popular are the piezoelectric disks. Ceramic piezoelectric disc elements are inexpensive and can be easily fit, embedded and attached to ready-made objects or to self-built structures combining plates, springs, sticks, bars, pipes, or any acoustic path where vibrations can be picked up through mechanical contact. The efficiency of sound amplification with piezo disks is dependent to their placement and attachment: if attached too strongly, the piezo element cannot vibrate and therefore the sound will be weak; if too loose, the piezo element will not pick up enough vibrations and may move, producing scratches and loud, unexpected sounds. The robustness and relative low cost of piezo discs make them a great tool for experimental recordings and amplification. If adequately protected, they can withstand low temperatures and humidity and can be used, for example, to amplify the process of ice melting by freezing the contact mic inside a bag of water, or for underwater listening, to mention only two classic examples for triggering the sonic imagination.

Due to the very high impedance of piezo discs, to improve the signals when connecting to other audio devices, it is important to match the impedance with a transformer, a buffer circuit or a dedicated preamplifier for piezo mics.[19] It is important to notice as well that piezo discs can be wired and used as loudspeakers,

[17] "C411 PP | High-Performance Miniature Condenser Vibration Pickup." Accessed November 17, 2018.
`https://fi.akg.com/C411PP.html?dwvar_C411PP_color=Black-GLOBAL-Current`.

[18] "Schertler Group – Pickups – DYN-UNI-P48." Accessed November 17, 2018. `https://www.schertler.com/en_IT/shop/pickups/dyn-uni-p48`.

[19] "PZ-Pre – Radial Engineering," November 8, 2018.
`https://web.archive.org/web/20181108223541/http://www.radialeng.com/product/pz-pre`.

so a feedback battery-powered based instrument can be relatively easy to build and a practical tool for experimenting.

On the legacy of John Cage's experimentations in manipulating phono cartridges, replacing the needle with other objects to amplify a world of microsounds,[20] Richard Lerman and Hugh Davies have created a series of instruments based on the piezoelectric effect to amplify strings, wires, springs excited by bowing, and plucking techniques.[21] In the same vein than Hugh Davies' *Shozyg* instrument, an interesting and inspiring example of using piezo discs as microphones for integrating a variety of resonating objects in a self-contained unit is the *Springboard* by Eric Leonardson.[22] As remarked by Leonardson, "Nearly any material and object in the everyday environment has the physical ability to vibrate in the audible frequency range. Once amplified, its potential for art-making is just a matter of the time required to become familiar with the range of behavior of the sound."[23] The springboard consists of springs, coils, metal grill, eye-bolts, wood sticks, plastic combs and auxiliary objects attached or superposed to the structure such as rubber bands and balls, music boxes, chains, friction mallets, strings, bows, everything incorporated in an aluminum walker and a wooden base. There are hundreds of other examples of this practice: mechanically attaching objects and picking up their vibrations with contact microphones. See for example the chapter "Piezo music" by Nicolas Collins, which gives an exquisite list of examples.[24] Contact microphones are then an invitation to research microsounds, to extend the listening experience into the inside of the materials and to creatively invent, compose, arrange, rediscover objects as performance instruments through amplification. In the words of Leonardson:

> Part of the beauty of the piezo contact mic lies in its ability to allow the sound explorer a way to get around the engineering and design challenges that a "proper" acoustic instrument presents, the interrelated material properties of resonance, impedance, mass, etc. Once one has a mixer, amplifier and loudspeakers, the price of a piezo contact mic is negligible, and its ability to act as an aural microscope into unknown sonic yet

[20] Cage, John, Earle Brown, David Tudor, Kenji Kobayashi, Howard Hillyer, Matthew Raimondi, Walter Trampler, David Soyer, Earle Brown, and Kenji Kobayashi. Cartridge Music. Wergo, 1965.

[21] Mooney, JR. "Hugh Davies's Self-Built Instruments and Their Relation to Present-Day Electronic and Digital Instrument-Building Practices: Towards Common Themes." In International Festival for Innovations in Music Production and Composition. The University of Leeds, 2015.

[22] Leonardson, Eric. "The Springboard: The Joy of Piezo Disk Pickups for Amplified Coil Springs." Leonardo Music Journal 17 (November 15, 2007): 17–20.

[23] Ibid.

[24] Collins, Nicolas. Handmade Electronic Music: The Art of Hardware Hacking. 2 edition. New York: Routledge, 2009. 41-44.

> entirely physical aspects of any object or material is truly exciting, if not amazing.[25]

Contact microphones and by extension other microphones in the electroacoustic music performance can be considered as a performance tool. Dynamically altering the distance between source and microphone, playing with displacements and movements, for example, introduces noticeable changes to timbre and volume, converting the static well-placed microphone in a lively sound processor.

Transducers and alternative loudspeakers

The amplification chain microphone-amplifier-loudspeaker is fundamental to music performance that integrates electronic means (along with synthesis, sampling, broadcasting and cybernetics). A microphone is a tool for researching the sonic realm, capturing sounds, expanding the ears limits, revealing the microphonic world. Though a microphone could be coupled to headphones to become an individual personal experience (unless the signal is shared and distributed among an audience all wearing headphones), the use of loudspeakers allows one to research the counterpart of capturing sounds: conveying sounds back to the acoustic world. The process of listening to the acoustic reality through a microphone and reproducing the captured sounds through loudspeakers is not transparent. There is always a modification; even the most up-to-date high-fidelity audio system cannot ignore the fact that construction and position of microphones, frequency response and total harmonic distortion of devices, room acoustics and psychoacoustic phenomena play a significant role in the amplification process, leaving clear traces and marks on the sounds. Therefore, to ease the tension of the unattainable task of *rebuilding* our auditive system with machines, we can walk in the other direction: stressing and underlying imperfections, colorations, modifications and filtering of the microphonic process. In Electroacoustic Music Performance, amplifying an instrument or miking a sound object is a process of integrating and unifying the acoustic properties of the object with the electronic and electric properties of the devices used for it. Filtering and even distortions produced by the placement or active motion of the mics should be welcomed as a part of the musical and sonic expression.

Accepting the imperfections of any microphone, amplifier, and loudspeaker becomes an invitation to experiment with alternative amplification systems. Amplifying sounds, live captured, prerecorded or synthesized, through objects with the goal of acoustically filtering them and highlight the physic-acoustic-mechanical properties of resonant objects can be achieved with *structure-borne drivers* (referred in many industry catalogues as exciters and transducers). The process and

[25] Leonardson, Eric. "The Springboard: The Joy of Piezo Disk Pickups for Amplified Coil Springs." Leonardo Music Journal 17 (November 15, 2007): 17–20.

technique of building one of these devices is described in Popular Mechanics Magazine from June 1966, under the title: "Build a Fantastic Coneless Loudpseaker".[26] The technique of transducing the electrical signals into acoustic vibrations by activating, exciting, driving objects, most commonly with an electromagnetic device similar to the ones driving the cone in a conventional loudspeaker, was known, developed and admirably implemented by David Tudor and the group of sound artists around him in the collective *Composers Inside Electronics*. John Driscoll and Matt Rogalsky in their article about the work *Rainforest* by David Tudor and the chronological assessment of all its versions gives a clear perspective on how the collaborative development (technically and aesthetically) of Tudor's ideas make the integration of objects as sound sources and as acoustic filters in an electroacoustic/sound art context one key aspect of the work itself.[27]

Rainforest can be seen as an invitation to experiment and learn about acoustic properties of objects when used as devices projecting the sounds in space. Because the loudspeaker is a crucial part of the electroacoustic instrument I suggest to experiment with preparations, attaching objects to the elements; building all sorts of resonant cases; using transducers to drive everyday life objects, conventional music instruments, plates, springs, pipes, surfaces, or any other available object; connecting piezo elements as loudspeakers.[28] For these experiments, a power amplifier should be either built, borrowed or acquired. The specifications of the amplifier should match as closely as possible the ones from the loudspeaker or element used, with special attention to the impedance and to the power limits (Small amplifiers/loudspeakers can be battery-powered and used as mobile instruments).[29]

Non-input mixers

Mixing signals is a whole art in itself, often related with sound recording arts or sound reinforcement in public amplification; live mixing is as well a fundamental skill for the electroacoustic performer. Using a smaller mixer for creating

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[26] "Popular Mechanics 1966." Accessed November 22, 2018. `https://archive.org/stream/PopularMechanics1966/Popular/mechanics-06-1966`.

[27] Driscoll, John, and Matt Rogalsky. "David Tudor's Rainforest: An Evolving Exploration of Resonance." Leonardo Music Journal, 2004, 25–30.

[28] see Nicolas Collins for a technique of matching impedance using a power transformer when connecting a piezo element to an amplifier.
Collins, Nicolas. Handmade Electronic Music.45-48

[29] From my own artistic personal practice, the collaboration with Marianne Decoster-Taivalkoski and Alejandro Montes de Oca in the *Aquatrio* ensemble has focused over the years into developing custom sound systems from scratch, integrating organic and electronic elements.
"Aquatrio Plays Aquarmonio." Vimeo. Accessed December 2, 2018. `https://vimeo.com/184912956`.

and controlling sub-mixes before sending signals to the main sound desk of the hall/rehearsal space is a convenient practice. With a small mixer as part of the electronic performance set, it is possible to integrate a variety of sound sources such as microphones, synthesizers, noise makers, effects processors, stomp boxes, pedals, recording devices, and monitoring loudspeakers among others. Other than the main function of mixing signals, a mixer can be driven into self-oscillation by creating feedback paths, for example, through auxiliary channels or effect send busses feeding back to channel inputs. This configuration or *missuses* of a mixer turns it into a sound generator device. The practice is known as *non-input mixer* and has been greatly explored and mastered by many musicians, including Toshimaru Nakamura, Masami Akita, Goh Lee Kwang, Marko Ciciliani and Christian Carrière among others.[30]

The non-input mixer as an electronic instrument has a lot of potential for improvisation and performance. The sonic world can be significantly extended by integrating effects in the signal chain. Because of non-linearities of the feedback system, the non-input mixer can feel non-fully controllable or unpredictable. These can be seen as musical challenges and as a potential for musical interaction investigations.[31] Further possible experimentations on the same working principle are possible by including several simultaneous feedback paths from and towards the mixer and by including all sort of devices in the feedback loop. For that purpose, a mixer with enough inputs and outputs and routing capabilities should be used. A mixer allowing these configurations is known as a matrix mixer. A simple matrix mixer allowing the distribution of signals based on amplitude control can be built around a few operational amplifiers. In the DIY pages, the company *Doepfer* provides the schematics and indications on how to build one.[32]

Radios

A radio receiver is a very useful device for electroacoustic performance. Most of the radio receivers integrate a loudspeaker, making them self-contained and movable/portable if battery powered. The radio receivers can work as noise generators; they can provide random access to radio broadcasting material for direct playback or further sampling. Depending on the model, radio receivers can be

[30] As a musical example, see for example Nakamura's albums: *No-input mixing board 1-3* (2000-2003)

[31] Bengler, Ben. The Audio Mixer as Creative Tool in Musical Composition and Performance. Institut fur Elektronische Musik und Akustik (IEM), Universitat für Musik und darstellende Kunst Graz (KUG), 2011;
Aufermann, Knut F. "Feedback Processes: An Investigation into Non-Linear Electronic Music." Unpublished Master's Thesis. Middlesex University, London, 2002.

[32] "A-100 Do It Yourself Page." Accessed November 24, 2018. `http://www.doepfer.de/DIY/a100_diy.htm`.

hacked and converted into noise machines or driven into self-oscillation by touching or accessing the circuitry (in battery powered devices). Pairing with radio transmitters, radio receivers will do a great job for local or small scale broadcasting of material, towards (or from) the audience for example, and to trigger experimentation on networking performances (regulations have to be double checked in every venue and rehearsal space).

The relationship between radio technology (controlling and deploying electromagnetic fields for telecommunications) and musical instruments is an intricate and old one, dating back to early experiments at the beginning of the twentieth century up to recent days. Among the early pioneers experimenting with electromagnetic waves and music instruments is Leon Theremin, who developed an instrument known by his own name *the Theremin*. In the Theremin, the sounds are created through the interactions of a couple of radio frequency oscillators and the changes of capacitance produced by the proximity of objects, i.e. the human body.[33] In the area of radio as musical instruments, one should note the use of radio receivers as random or unpredictable source material as in John Cage Imaginary Landscape No. 4 (1951), Jean Tinguely's radio Sculptures (1962) or in Stockhausen's compositions from 1968-1970 (Kurzwellen, Spiral, Pole, and Expo) using the short-wave radio as a musical instrument and as a source for musical imitation and motivic development.

Live sampling of media content broadcasting live is a common practice among modern electronic musicians, reflected in commercial synthesizers such as the *teenage engineering synthesizer op-1*, which includes a built-in fm receiver and a four-track recorder or through software plugins integrating Software Defined radio, such as the *Plugin's boutique radio VST*.[34]

Anna Friz in her on-line article "Radio as Instrument" analyses the live set of Tetsuo Kogawa *fm feedback* using fm transmitters and receivers (as well as other works including the author's own).[35] Friz explains how Kogawa's work reflects a *molecular* politics and aesthetic choice, "identifying the minimum unit of diversity needed to create change". The radiophonic circuitry in this context, says Friz, is not an apparatus for communication for sharing information and broadcasting but "as an anarchic and noisy system that expresses basic relations of proximity and distance, where distances are not overcome but differentiated".[36] Exploring the electromagnetic spectrum with short-wave radio receivers, electromagnetic pickups, germanium diodes, custom antennas or coils is an *ear opening*

[33] Ssergejewitsch, Theremin Leo. Method of and apparatus for the generation of sounds. United States US1661058A, filed December 5, 1925, and issued February 28, 1928. `https://patents.google.com/patent/US1661058A/en`.

[34] "Plugin Boutique Radio Review – Find Your Frequency." MusicTech, March 21, 2018. `https://www.musictech.net/2018/03/plugin-boutique-radio-review/`.

[35] Friz, Anna. "Radio As Instrument." Wi: Journal of Mobile Media, 2009.

[36] Ibid.

experience that can potentially be integrated in performance.[37] There will be an interminable list of examples of sound artists and musicians who include radio devices in their projects, compositions, improvisations and performances, but making such a list is not the point here. Nevertheless, I cannot close this section without mentioning Keith Rowe, who includes in his performance set radio receivers among other electronic devices. Listen, for example, to the record *The World Turned Upside Down* by Keith Rowe, Günter Müller, Taku Sugimoto, released 31 March 2000 in Erstwhile Records as an illustration of the dexterity and mastering of the possibilities offered by incorporating a short wave radio receiver in the performance set.

This short section should be seen as an invitation to dive into the world of the electromagnetic spectrum, radio waves, radio transmission, radio devices, analog, digital or software radios and their potential in an electroacoustic music performance context.

Turntables

Turntables have been involved in the development of electroacoustic music (language and tools) from the experiments carried out by Pierre Schaeffer and his team in the 1950s. As reported by Peter Manning in his article "The Influence of Recording Technologies on the Early Development of Electroacoustic Music", previous observations on the subjective effects of playing gramophone recordings at different speeds were made during the 1920s by Paul Hindemith, Darius Milhaud, Ernst Toch and Percy Grainger and "the work of the Bauhaus artists László Moholy-Nagy, Oskar Fischinger and Paul Arma during the early 1930s, seeking in the first instance to modify the physical contents of the record groove".[38] It was the team working at the RTF (Radiodiffusion Télévision Française), which had at their disposal gramophones and magnetic recordings that pushed experimentation and research resulting in *musique concrète*. With or without modifying the physical content of recordings, these early investigations with turntables included experimentations with the direction of playback: forward, backward, and speed playback, creating loops and juxtaposing sounds. All of these techniques pioneered later practices, although with very different aesthetic goals, of DJs, hip-hop music and turntablism from the 1970s onwards.

In the inception of live electronic music performance, there is the *Imaginary Landscape N°1* (1939) by John Cage, scored for piano, large Chinese cymbal and two turntables equipped with records of test tones. "Cage asked the performers to manipulate the pitch and rhythm of the tones by changing turntable speed,

[37] Kubisch, Christina. Electrical Walks: Electromagnetic Investigations in the City, 2004.

[38] Manning, Peter. "The Influence of Recording Technologies on the Early Development of Electroacoustic Music." Leonardo Music Journal, 2003, 5–10.

spinning the platter by hand, and dropping and lifting the needle."[39] Cage's work is a clear invitation to experimentation with the performance capabilities of turntables by direct manipulations of the records, a practice that has been deeply explored in DJ culture.

Turntablism, "commonly understood as a subset of DJ culture, privileges active and extensive sound manipulation, distinct from other practices (as in the post-disco lineage of house, techno, and trance), where the DJ often favors the more straightforward playback of sound recordings".[40] Turntablism uses techniques invented by the hip-hop culture and builds on them. The most relevant performance techniques linked to the hip-hop culture and later developed by the turntablism are *breakbeat* and *scratching. Breakbeat* (also called Merry-Go-Round) is attributed to Clive Campbell, better known as *DJ Kool Herc* or the *Father of Hip-Hop*, the technique consists of using two turntables and a two-channel mixer to alternate and switch between two copies of the same record allowing the performer to indefinitely extend the break of a song, a measure with only drums and percussion; *scratching* credited to Theodore Livingston, better known as *Grand Wizzard Theodore* (also famous for mastering the *needle drops* techniques) consists of rubbing the record back and forth producing new rhythmical figures.[41]

Further advanced techniques included: *transformer scratch*: simultaneously flipping the crossfader back and forth on the mixer at the same time as scratching the records; *crab scratch*: quickly moving the crossfader using four fingers to produce morphing sounds and many other variations establishing personal signatures for each turntablist.[42] *Beat Juggling* is probably the most popular technique, consisting of fast switching between two identical records, looping, re-combining different sounds to produce new beats and sounds.[43] While these techniques are closely related with the *hip-hop* music genre, they can be a source of inspiration to integrate with vinyl players and turntables in an electroacoustic music context.

The mechanical features of the turntable can also be exploited for sonic purposes. The turntable becomes then a device producing rotary motion with an integrated pickup. This family of techniques can extend from introducing materials such as

[39] Collins, Nicolas. "Live Electronic Music." Chapter. In The Cambridge Companion to Electronic Music, edited by Nick Collins and Julio d'Escrivan, 2nd ed., 40–57. Cambridge Companions to Music. Cambridge: Cambridge University Press, 2017

[40] Chapman, Dale E. Turntablism. Oxford University Press, 2012.

[41] Williams, Justin. "Historicizing the Breakbeat: Hip-Hop's Origins and Authenticity." Lied Und Populäre Kultur / Song and Popular Culture 56 (2011): 133–67.

[42] Miyakawa, Felicia M. "Turntablature: Notation, Legitimization, and the Art of the Hip-Hop DJ." In From Soul to Hip Hop, 59–83. Routledge, 2017.

[43] Hansen, Kjetil Falkenberg. "The Acoustics and Performance of DJ Scratching." PhD Diss., KTH Royal Institute of Technology, 2010, 1–74;
D'Errico, Michael A. "Behind the Beat: Technical and Practical Aspects of Instrumental Hip-Hop Composition." PhD Thesis, Tufts University., 2011.

sticky tape on the vinyl or rubber bands to force the needle to jump to more dramatic vinyl transformations, such as cutting and pasting pieces of different vinyls together, or even more, to deconstruct the turntable by adding extra needles, or extra layers of rotating discs, etc. The Danish duo *Vinyl terror and horror* with Camilla Sørensen and Greta Christensen has pushed artistic and sonic research focusing on the use, deconstruction, hacking and bending of turntables and vinyl discs. The duo physically manipulate records and record players creating sonic sculptures and a powerful sound experience with reminiscences of Milan Knížák's or Christian Marclay's works.[44] Another source of inspiration for experimenting with performance possibilities offered by the turntables are illustrated in the work of *Institut fuer Feinmotorik (IFF)*. According to their website, the group describes itself as having some "reputation for their acoustic work with prepared turntables (turntablismtheorism) and their reductionist set-up called Octogrammoticum: 8 turntables, 4 DJ mixers + end-mixer, which is served by the group members. Anything (except records) which somehow fits between turntables and pick-up cartridges (household-rubber-bands, paper-stickers, rubber-gums, handicraft-tools among others) may be played."[45] The IFF music is refined and very well crafted. The enactment of the turntables reveals a mastering and a great sensibility for the mechanical and electric sounds manipulated in live performance.

According to the New York Times, turntables outsold electric guitars in 1999.[46] Without arguing about the actual primacy of which instrument has the record of units sold today, this article reveals the importance of turntables in popular culture and electronic music production. Turntables are a great tool for sonic adventures and to connect with the ideas that generate and spark research in electroacoustic music. As a derivative line of research, CD players and DJ controller interfaces should be explored as well. Their digital nature will bring glitches and hisses to sonic experimentation and research.[47]

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44 WeissenBrunner, Karin. "Experimental Turntablism-Live Performances with Second Hand Technology: Analysis and Methodological Considerations." PhD Thesis, City, Universtiy of London, 2017.

45 "...:::INSTITUT FUER FEINMOTORIK:::..." Accessed December 6, 2018. `http://www.institut-fuer-feinmotorik.net/info.html`.

46 Herz, J. C. "GAME THEORY; Making Music Without the Instruments." The New York Times, January 20, 2000, sec. Technology.
`https://www.nytimes.com/2000/01/20/technology/game-theory-making-music-without-the-instruments.html`

47 Straebel, Volker. "From Reproduction to Performance: Media-Specific Music for Compact Disc." Leonardo Music Journal, 2009, 23–30;
Cascone, Kim. "The Aesthetics of Failure:'Post-Digital' Tendencies in Contemporary Computer Music." Computer Music Journal 24, no. 4 (2000): 12–18.

Tapes and cassettes

Tape machines are probably more common in a studio context than on stage; however, the live manipulation of tapes either with tape machines, cassette players, dictaphones, or directly with hand-held magnetic playback heads is a convincing expression tool. For example, in a world of digital synthesis and digital tools, where the noise produced by the controllers or the interaction with the instruments is minimal, all the parasite noises of operating a tape machine become an acoustic treasure to be pursued. The resulting sounds from forwarding, rewinding, stopping or advancing the tape by hand are charged of a certain nostalgia and can be very evocative of a time gone by (for some generations). A performance of live editing of tape, slicing, splicing, cutting, pasting, looping, and stressing all the resulting noises produced by the interaction with the tape machine and the tape will make a great performance by itself.

There are a couple of examples of using tape in a performance context, for example, the *Tape Bow Violin* developed by Laurie Anderson in collaboration with Bob Bielecki from 1977.[48]

> (The Tape Bow Violin) is a violin with a tape playback head mounted on the bridge, and a bow that has pre-recorded lengths of audio tape instead of hairs. The bow is drawn across the head, which plays back the recorded sounds; the performer controls the speed and intensity of the bow stroke, and decides which sections of the recording to play back and in which direction. Anderson used the same idea in a work for string orchestra first performed in 1979; all the instruments were fitted with playback heads and each player had several tape bows in addition to a normal one.[49]

Another interesting use of tape and tape heads is *Random Access* by Nam June Paik. "For his first solo show, at a gallery in Wuppertal, Germany, Paik tacked fifty-odd strips of prerecorded audiotape to the wall and invited visitors to run a handheld playback head wired to speakers along the strips at whatever speed or direction they desired."[50]

Importing techniques from the experimental studio to the stage, Robert Fripp in collaboration with Brian Eno exploited the tape-loop effect obtained by chaining

[48] Jestrovic, Silvija. "The Performer and the Machine: Some Aspects of Laurie Anderson's Stage Work." Body, Space, & Technology Journal 1, no. 1 (2000).

[49] Davies, Hugh, and Susan McClary. Anderson, Laurie. Oxford University Press, 2014.

[50] Ippolito, Jon. "Ten Myths of Internet Art." Leonardo 35, no. 5 (December 2002): 485–98.

two tape machines set to record and playing back guitar improvisations, resulting in a multilayering sonic texture. The technique is known as *Frippertronics*.[51]

Tape delays such as the *RE-201 Space Echo, Binson Echorec 2 T5E, Echoplex EP-3, Echolette E51, Evans vocal echo, Dynacord, Watkins copycat* and many other similar tape devices, are still in use and found in second hand markets. A new wave of hardware tape delays have introduced new models, for example: *Fulltone Tube Tape Echo, Fulltone SSTE, T-Rex Replicator, T-Rex Echorec.* These devices convey a very organic sound made out of micro imperfections on the playback, bandwidth and frequency response of the devices; a few of them will let the performer experiment with manually interacting with the tape or altering the playback/recording speed, and in some cases manipulating/moving the playback head positions. *Multitrack cassettes* and even *Dictaphones* are great tools for layering and looping sounds in a live situation, definitely something to experiment with.

Samplers

In a nutshell, a sampler is a device for playing back pre-recorded and pre-edited sound material using an interface (hardware, software or a MIDI controller) for triggering, sequencing and further manipulating samples. The sampling process could be done live as well, meaning that an audio signal is captured on the spot, time and frequency adjusted, trimmed, edited and assigned to a key, pad or a slot ready to be triggered. From a historical perspective, the concepts of sampling were present in the early *musique concrète* through the operations and manipulations of magnetic tape as discussed in the previous sections. As musical instruments, there are few examples of samplers preceding their digital counterparts. The *Mellotron*(Mk1 dating from 1963) is described as an *Analog Sampler* by Hugh Davies, which uses "a series of parallel lengths of pre-recorded magnetic tape that are individually controlled by keys on the keyboard".[52] Preceded by the *Chamberlin* (patented in 1949 by Harry Chamberlin), they share the same functional idea, which consisted of recording on separate tapes, one for each key, a sound of an instrument or later of sound effects. When one key was activated, the associated tape was pulled into contact with a play head and when released, the tape came back to initial position, preserving the attack but having limited duration. Different later versions of the mellotron have improved the mechanical and playback issues and have struggled to make a portable and musician friendly device. However, with the advent of digital storage memories, the production and popularity of analog samplers went into the shadows. For an extensive and detailed review of the history of sampling, including photoelectric instruments

[51] Parra Cancino, Juan Arturo. "Multiple Paths. Towards a Performance Practice in Computer Music," 2014.

[52] Davies, Hugh. Mellotron. Oxford University Press, 2001.

and early analog samplers, see Hugh Davies' article "A History of Sampling" in Organised Sound.[53]

After the very expensive early digital music machines such as Computer Music Melodian (1976) by Harry Mendell and the Fairlight CMI (Computer Musical Instrument) (1979) by Tony Furse and with the decreasing cost of digital chips, CPUs and processing power, many other companies released their own versions of samplers from the 1980s (Alesis, Casio, Clavia, Tascam, E-mu Systems, Korg, Kurzweil, Yamaha, Roland, and Akai, among many others). On the other hand, the development of DAW (Digital Audio Workstations) and VST (Virtual Studio Technology) opened the expansion and implementation of pure software samplerssampler: "the early era included Nemesys Gigasampler (1998), Emagic EXS24 (2000), Native Instruments Kontakt (2002) and Steinberg Halion (2002)".[54]

Whether computer-based or hardware machines, the sampler requires a user interface for performance. Though they can be programmed and sequenced with a built-in or external software, here we are interested in their built-in performance aspects. The more common user interface in modern commercially available samplers are the keyboard and the two dimensional matrix of pads. The latter was made popular by Akai's MPC (Music Production Center) series of instruments (1988) designed by Roger Linn and emphasizing the performance, sequence and manipulations of drum samples (though of course any sound could be sampled and loaded in the instrument). The user interface of pads, also known as *Drum Pads or Sample Pads*, became a central (but not exclusive) part of drum machines, grooveboxes and beatboxes.[55] The concept of a grid-matrix as an interface to control digital audio processors has been taken in many directions and many implementations are still open for development. Jared Dunne, for instance, reviewed the *Monome* eleven years ago and praised the reconfigurable sixty-four pads of the machine and all its assignable connectivity with software. An important point in the *monome* was that the production company left the door open to commissions that involved customized designs, which eventually attracted the attention of the DIY communities.[56]

Performing with pads requires dexterity, rhythmical precision and reflex, as demonstrated by hip-hop artists instrumental virtuosity can be achieved (to mention only one in the ever growing list, see for example Abraham Orellana (1989) known by his stage name AraabMuzik). Other than triggering samples, working with sample-based instruments requires skills in editing, looping, mixing, filtering,

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[53] Davies, Hugh. "A History of Sampling." Organised Sound 1, no. 1 (1996): 3–11.

[54] Vuolevi, Aleksi. "Replicant Orchestra: Creating Virtual Instruments with Software Samplers," 2018.

[55] Burczyk, Steven C. Groovebox. Oxford University Press, 2016;
Davies, Hugh. Electronic Percussion. Oxford University Press, 2001.

[56] Dunne, Jared. "Monome 40h Multi-Purpose Hardware Controller." Computer Music Journal 31, no. 3 (Fall 2007): 92–94.

modulating and adding effects to the sounds as well as familiarity programming sequencers.

The interface controlling the playback of samples is a great territory for research in instrument design. For example, the sophistication of Michel Waisvisz's control system *The Hands* "has also permitted him in The Voice Catcher from Steim (1994) to process in real time sounds recorded from members of an audience in less formal situations".[57] Closer to me, Hugh Sheehan, a participant of my workshops, has developed a clever system repurposing *gametrak* controllers for the playback of samples, allowing him to craft a clear gesture notation and a visual enhancement of electronic performance.[58] The NIME (New Interfaces for Musical Expression) conference proceedings return several entries under the keyword search for "sampler". To mention only one as an example of alternative controllers for samplers, see for example *The Slidepipe*, which consists of a horizontal pipe as a metaphor for a timeline by Mark Argo at the New York University (2004).[59] Another interesting example of performing with samplers is Sachiko Matsubara (Sashiko M), which uses an Akai S20 without any input. Sachiko has made the center of her performance the sine test tone of the sampler machine.[60] Inventing creative ways to perform samplers and samples is a task that every electronic musician should address at one point in their career.

Synthesizers

There is not a standard form for the synthesizer, and different realizations make the look of it very diverse, ranging from rack units, modular systems, software and code, plugins, mobile applications, keyboards and keyboard-less desktop units. The technology behind the synthesizer has evolved and changed with the technology, and many instruments have become an iconic signature of each epoch. Today one can still find in the market instances of almost every technological development in a synthesizer. For example, the rare vacuum tubes still find their way into synthesizer models: the *knifonium* by Knifaudio,[61] *S-2000* by Metasonix[62] or the *Fusion Drone System* by Erica Synths.[63] For discrete electronics

[57] Davies, Hugh. "A History of Sampling." 3–11.

[58] "Acts of Discovery – Hughsheehan.Com." Accessed December 9, 2018. https://hughsheehan.com/Acts-of-Discovery.

[59] Argo, Mark. "The Slidepipe: A Timeline-Based Controller for Real-Time Sample Manipulation." In the Proceedings of the International Conference on New Interfaces for Musical Expression, 189–192. Hamamatsu, Japan, 2004.

[60] Pereira, Carlos Arthur Avezum. "O Silêncio Como Afeto Ou a Escuta Corporal Na Recente Música Experimental." PhD Thesis, Universidade de São Paulo, 2017.

[61] "Knifaudio." Accessed December 10, 2018. http://knifaudio.com/knifonium/.

[62] "S-2000 Synthesizer." Accessed December 10, 2018. http://www.metasonix.com/index.php/s-2000-synthesizer.

[63] "EricaSynths – Fusion Drone System." Accessed December 10, 2018. https://www.ericasynths.lv/shop/eurorack-systems/fusion-drone-system/.

with some transistor-based synthesizers, see for example the *SunSyn* by JoMoX,[64] and the more and more popular hybrid analog/digital synthesizers such as the Elektron *Analog Four*, with analog voices digitally controlled, or the other way, digital core with analog control.[65] At the other end of the spectrum there are of course the pure digital synthesizers, such as *scsynth* and *kronos*, which exists only as a source code to be compiled for different processor architectures.[66]

In any of its forms, whether modular, desktop unit, rack mounted, or software, the synthesizer requires a control interface. From the familiar keyboard, fingerboard, ribbon controllers, touchpads, wind controllers, guitar-style interfaces, drum pads, sequencers, theremins, wheels, footpedals, breath controllers, photoresistors, joysticks, multitouch interfaces, tangible controllers (reactable or audiocubes), patch panels to more exotic interfaces such as gloves,[67] wearables,[68] virtual reality interfaces,[69] brain controllers,[70] and even living neurons.[71] With any of the controller interfaces as in the sampler case, the dexterity of performing the synthesizer must be attained through conscious practice and discipline, looking for high levels of control to drive the synthesizer or the music without obstacles. Even in the case of an artificial intelligent component, the system must *learn* to play and interact with other performers. But mastering the performance interface is only one side of the coin; the other one is to program the synthesizer.

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[64] "JoMoX SunSyn | Vintage Synth Explorer." Accessed December 10, 2018. `http://www.vintagesynth.com/misc/sunsyn.php`.

[65] "Monome." Accessed December 10, 2018. `https://monome.org/norns/`.

[66] Bencina, Ross. 2011. "Inside scsynth." In Collected Work: The Super Collider Book, 721–740. Published by: London, United Kingdom: MIT Press, 2011;
Norilo, Vesa. "Kronos: A Declarative Metaprogramming Language for Digital Signal Processing." Computer Music Journal 39, no. 4 (2015): 30–48.

[67] Costantini, Giovanni, Massimiliano Todisco, and Giovanni Saggio. "A Wireless Glove to Perform Music in Real Time." In 8th WSEAS International Conference on Applied Electromagnetics, Wireless And Optical Communications, Penang, Malaysia, 2010.

[68] Kapur, Ajay, Eric L. Yang, Adam R. Tindale, and Peter F. Driessen. "Wearable Sensors for Real-Time Musical Signal Processing." In Communications, Computers and Signal Processing, 2005. PACRIM. 2005 IEEE Pacific Rim Conference On, 424–427. IEEE, 2005.

[69] "MuX | Build Sound." Accessed December 10, 2018. `http://www.playmux.com/`.

[70] Miranda, Eduardo Reck, 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.

[71] Moore, Darren, Guy Ben-Ary, Andrew Fitch, Nathan Thompson, Douglas Bakkum, Stuart Hodgetts, and Amanda Morris. "CellF: A Neuron-Driven Music Synthesiser for Real-Time Performance." International Journal of Performance Arts and Digital Media 12, no. 1 (2016): 31–43;
Miranda, Eduardo R., Larry Bull, François Gueguen, and Ivan S. Uroukov. "Computer Music Meets Unconventional Computing: Towards Sound Synthesis with in Vitro Neuronal Networks." Computer Music Journal 33, no. 1 (2009): 9–18.

From the advent of digital memories, it has been possible to recall and store patches, interconnections, programs or presets within a synthesizer. This makes life easier for the performer who needs to rapidly react to the changes in the music direction during a live situation. However, as argued by Nicolas Collins while reflecting about the Yamaha DX7, the presets may have slowed down the research of programming and grasping the architecture of the synth, "many users been just happy browsing through the presets offered on the front panel without further explorations."[72] I tend to agree with this statement since the number of presets (sometimes on the order of thousands) in a digital synthesizer can be overwhelming and can hide all the programmability options. Popular advice on many online forums for programming synthesizers includes "start by erasing all the presets". Presets can be a way to learn to program, according to the synthesizer. Some synthesizers will unveil all the settings and interconnections used in each preset. I have found an excellent practice to *copy* or reproduce the presets from one synthesizer to another by studying them and deconstructing them, or even better, to use only aural information. Programming a synthesizer requires familiarity with the architecture and the synthesis technique implemented in each instrument. Let us have a look at the synthesis techniques.

The following list collects the synthesis techniques described by Jeff Pressing in *Synthesizer Performance and Real-Time Techniques*,[73] and Curtis Roads in *The Computer Music Tutorial*.[74] The title is accompanied with music, relevant dates and names, with a published document or a synthesizer commercially distributed.

- Additive synthesis (1906) Telharmonium – combining tones, typically harmonics of varying amplitudes.
- Subtractive synthesis (1930) Trautonium – filtering of complex sounds to shape harmonic spectrum, typically starting with geometric waves.[75]
- Vocoding (1936) Homer Dudley – Vocoder (Voice Operated reCorDER) – using a series of narrow band filters and noise generators to analyze and synthesize the human voice.
- Sampling (1940s) Pierre Schaeffer – (1949) Chamberlin – using recorded sounds as sound sources subject to modification.

[72] Teboul, Ezra J. "Silicon Luthiers: Contemporary Practices In Electronic Music Hardware." A.M., Dartmouth College, 2015. 138-140
[73] Pressing, Jeff. Synthesizer Performance and Real-Time Techniques. Oxford: Oxford University Press, 1992.
[74] Roads, Curtis, and John Strawn. The Computer Music Tutorial. MIT press, 1996.
[75] Butterworth, Stephen. "On the Theory of Filter Amplifiers." Wireless Engineer 7, no. 6 (1930): 536–541.

- Amplitude Modulation – (1963) Paul Ketoff Syn-Ket[76] – changes in an audio signal's loudness under manual or automated control.
- Granular synthesis (1959) Iannis Xenakis – Gabor – (1963) Tempophon, Springer[77] – combining of several small sound segments into a new sound
- Fast Fourier Transforming (FFT) – (1979) Fairlight CMI (Series I – III).[78]
- Frequency Modulation/Phase Modulation (1973) John Chowning[79] – (1983) DX7 Yamaha – modulating a carrier wave with one or more operators
- Wavetable Synthesis (1979) Wolfgang Palm – PPG Wave Computer 360 – Wavetables are a set of one-cycle waveforms that can be smoothly switched / interpolated by scanning though them via a modulation source.[80]
- Waveshaping Synthesis (1978-1979) Daniel Afirb, Marc Le Brun[81] – intentional distortion of a signal to produce a modified result
- Phase Distortion – (1984) Casio CZ series – altering speed of waveforms stored in wavetables during playback
- Vector Synthesis – (1986) Sequential Circuits Prophet VS- technique for fading between any number of different sound sources
- Physical Modelling – (1993) Yamaha VL1/ VP1 – mathematical equations of acoustic characteristics of sound
- Scanned Synthesis – (1998) Max Mathews, Bill Verplank, Rob Shaw
- Composite Synthesis – (1999) Alesis QS6.1 – using artificial and sampled sounds to establish resulting *new* sound

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[76] Black, H. Modulation Theory. Bell Telephone Laboratories Series. Van Nostrand, 1953.

[77] Nottoli, Giorgio, Giovanni Costantini, Andrea Angelini, M. Todisco, and D. Casali. "Texture: A Granular Synthesizer for Real-Time Sound Generation." WSEAS Transactions on Signal Processing 10 (2014): 601–610.

[78] Cooley, James W., and John W. Tukey. "An Algorithm for the Machine Calculation of Complex Fourier Series." Mathematics of Computation 19, no. 90 (1965): 297–301.

[79] Chowning, John M. "The Synthesis of Complex Audio Spectra by Means of Frequency Modulation." Journal of the Audio Engineering Society 21, no. 7 (1973): 526–534.

[80] Andresen, Uwe. "A New Way in Sound Synthesis." Audio Engineering Society, 1979.

[81] Arfib, Daniel. "Digital Synthesis of Complex Spectra by Means of Multiplication of Non Linear Distorted Sine Waves." In Audio Engineering Society Convention 59. Audio Engineering Society, 1978;
Le Brun, Marc. "Digital Waveshaping Synthesis." Journal of the Audio Engineering Society 27, no. 4 (1979): 250–266.

- Resynthesis – (1977) Synclavier – modification of digitally sampled sounds before playback
- Direct Digital Synthesis – computer modification of generated waveforms
- Wave Sequencing – (1990-1994) Korg Wavestation – linear combinations of several small segments to create a new sound
- Wave Terrain Synthesis (WTS) – extends the principle of wavetable lookup to the scanning of three-dimensional surfaces.[82]

The above list can be expanded with Julius Smith's "Taxonomy of Digital Synthesis Techniques" which analytically present four categories for digital synthesis (detailed description in the cited paper).[83]

- Processed Recording
  Concrète, Wavetable T(time domain), Sampling, Vector, Granular, Principal-components T(time domain), Wavelet T(time domain)
- Spectral Model
  Wavetable F(frequency domain), Additive, Phase Vocoder, PARSHL, Sines+Noise (Serra) Principal-components F(frequency domain), Chant, VOSIM, Risset FM Brass, Chowning FM Voice, Subtractive, Linear Predictive Coding, Inverse FFT, Xenakis Line Clusters
- Physical Model
  Ruiz Strings, Karplus-Strong extensions, Waveguide, Modal, Cordis-Anima, Mosaic
- Abstract Algorithm
  VCO, VCA, VCF, Some Music V, Original FM, Feedback FM, Waveshaping, Phase Distortion, Karplus-Strong

Finally, there is a considerable amount of work in sound synthesis in the digital domain that so far exists only in software form, either as unit generators, objects or classes for different languages. Stelios Manousakis contributes to the list of synthesis techniques with his paper on "Non-Standard Sound Synthesis with L-Systems ."[84]

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[82] Mitsuhashi, Yasuhiro. "Audio Signal Synthesis by Functions of Two Variables." Journal of the Audio Engineering Society 30, no. 10 (1982): 701–706.

[83] Smith, Julius O. "Viewpoints on the History of Digital Synthesis." In Proceedings of the International Computer Music Conference, 1–1. International Computer Music Accociation, 1991.

[84] Manousakis, "Non-Standard Sound Synthesis with L-Systems." 85–94.

- Stochastic models (Xenakis' GENDY)
- rule-based systems, (Koenig, Brün, Berg)
- fractal interpolation (Monro, Dashow, Yadegari)
- waveform segmentation algorithms
- non-linear oscillators and feedback-based techniques (FitzHugh Nagumo, Double Well, Weakly non-Linear, Gravity Grid, KmeansToBPSet1, Wave Terrain and VMScan2D).[85]

The performer of synthesizers must approach the study of the instrument from a physical and intellectual perspectives. Aiming for precision and reactivity while studying the physical gesture interaction and from a cognitive perspective, imagining, combining and understanding the settings for each instrument. The *virtuosism* of performing synthesizers is then a two-sided coin: imagining and creating connections resulting in sound processes and physically interacting with them. One may prefer each of the sides and performing in a moment-to-moment fashion like a traditional acoustic instrument or with a less *interventionist* attitude, setting up generative sonic processes for listening contemplation.

There is still a lot of ground for research in the domain of sound synthesis, from the lists above for example, experimenting with artificial intelligence and innovative sensors to create interfaces for control. Further research must be carried out into electronic implementations such as memristors and nano-technologies for eventually embedding the algorithms in standalone instruments and making them suitable for performance, but there is not only a hurry for new instruments or new synthesis techniques; the *old ones* are also fruitful sources of inspiration waiting to be rediscovered everyday under the lights of electroacoustic improvisation.

Noise Machines and DIY

This section is about noise machines. The reader may agree how difficult if not impossible it is to put boundaries looking for a definition of what a noise machine is. In this context, I am thinking of all the self-made *musical instruments* resulting from experimentation with electronics (hardware and software), self-contained units, built or hacked that can generate or process electrical signals to be heard and to be used in a performance context. From the millions of available examples, the archetype of what I am calling noise machines can be illustrated

[85] Collins, Nick. "Errant Sound Synthesis." In ICMC, 2008.

from the following instances:[86] The *Crackle box* by Michel Waisvisz,[87] the *Sudophone* by John Richards,[88] the *Postcard Weevil* by Tom Bugs,[89] the *Benjolin* by Rob Hordijk,[90] the *Litle Boy Blue* by Jessica Rylan,[91] the *WolfTone SoundBox* by Derek Holzer,[92] the *Victorian synthesizer* by John Bowers,[93] the *noise Toaster* and the *Weird Sound Generator* by Ray Wilson,[94] the *Sled Dog* by Nicolas Collins[95] as well as digital machines integrating software and hardware such as the *Synclooper* or the *Walking Machine* by Per Anders Nilsson,[96] the *ixi lang* by Thor Magnusson,[97] and the *Spectral DJ* by Jean-François Charles.[98] The list

[86] The instruments/noise machines listed here were chosen because I have had direct or indirect contact with the artists and creators and because in most cases schematics, code or resources are available or shared as open source material from the artist themselves or through community forums, making it possible to reproduce and rebuild them.
"Electro-Music.Com-Links (DIY Synths and Electronics)." Accessed December 10, 2018. `http://electro-music.com/forum/links.php?id=28`;
"Online Resources – Synth DIY Wiki." Accessed December 10, 2018.
`https://sdiy.info/wiki/Online_resources`.

[87] "The Hands: A Set of Remote MIDI-Controllers." International Computer Music Conference Proceedings 1985.

[88] Richards, John. "Getting the Hands Dirty." Leonardo Music Journal, 2008, 25–31.

[89] Richards, John. "Beyond DIY in Electronic Music." Organised Sound 18, no. 03 (December 2013): 274–81.

[90] Edwards, Peter. "Collaborating with Circuits. Music, Invention and Electricty." The Insitute of Sonology & STEIM, 2014.

[91] "Flower Electronics." Accessed December 10, 2018.
`http://www.flowerelectronics.com/`;
Blasser, Peter. "Stores at the Mall," 2015.

[92] "Macumbista.Net." Accessed December 10, 2018. `http://macumbista.net/`;
Flood, Lauren. Building and Becoming: DIY Music Technology in New York and Berlin. Columbia University, 2016.

[93] Bowers, John, and Phil Archer. "Not Hyper, Not Meta, Not Cyber but Infra-Instruments." In Proceedings of the 2005 Conference on New Interfaces for Musical Expression, 5–10. National University of Singapore, 2005.

[94] Wilson, Ray. Make: Analog Synthesizers: Make Electronic Sounds the Synth-DIY Way. Maker Media, Inc., 2013;
"Music From Outer Space Your Synth-DIY Headquarters." Music From Outer Space Your Synth-DIY Headquarters. Accessed December 10, 2018.
`http://www.musicfromouterspace.com`.

[95] Collins, Nicolas. "A Solder's Tale: Putting The "Lead" Back In "Lead Users"." IEEE Pervasive Computing 7, no. 3 (2008): 32–38.

[96] Nilsson, Per Anders. A Field of Possibilities: Designing and Playing Digital Musical Instruments. Academy of Music and Drama; Högskolan för scen och musik, 2011.

[97] Magnusson, Thor. "Affordances and Constraints in Screen-Based Musical Instruments." In Proceedings of the 4th Nordic Conference on Human-Computer Interaction: Changing Roles, 441–444. ACM, 2006.

[98] "Spectral DJ." Accessed December 10, 2018. `https://www.spectraldj.com/`;
Charles, Jean-François. "A Tutorial on Spectral Sound Processing Using Max/MSP and Jitter." Computer Music Journal 32, no. 3 (2008): 87–102.

could keep going for many pages because the tradition of *getting the hands dirty* (as John Richards said so well) with electronics and code is more than alive; it is at the core of the discipline of electroacoustic performance.

Do-it-yourself, hacking, bending, building, deconstructing, opening, abusing, improving, extending, deforming, prototyping, soldering, de-soldering, breadboarding, inventing, re-discovering, understanding, non-understanding, copying, plugin-in, plugin-out. All these verbs and actions seem to be related when thinking about the practice of electronics and electroacoustic musicianship. In fact, most of the time it feels like a natural path for a performer or musician moving towards the aesthetics of *live electronics*. In an interview between Ezra Teboul and Nicolas Collins, Collins makes allusion to the evolution of the Korean electronic scene, a path that I can relate to as a teacher and that I have seen in many musicians.

> (...) And you see this evolution: let's start a band, then let's add the effects, then it gets noisier and noisier, and then they say let's disconnect the instruments and use only the effects. You go from Otomo to Japan noise... then you get to the point where they say let's open up the effects, let's see what's inside, let's do a piece with just the one transistor we pulled out from the pedal... let's just do something with dirty contacts. It's this funny kind of arc that's represented very well in the Korean scene. I've seen this post-effect pedal stuff happen. It's really interesting.[99]

The path of getting inside the electronics, *composing inside electronics* (this was the name taken by one of David Tudor's ensembles) is one that opens up from the moment of making the first connection between devices. Connecting the microphone of my voice or instrument to what? Why that machine and no other? This machine is not doing what I want or what I need, so should I get another machine, should I build one, should I modify it? In my case, I answer these common questions from musicians starting their electronic journey with a welcoming attitude: "Come to experiment; you will find out by yourself"; it is the beginning of the electric odyssey. Some may want to go deeper and deeper, becoming *Silicon Luthiers*;[100] others take a more radical approach, refusing to play anything that has not been built or coded by themselves and eventually some will keep it at the level of changing batteries and connecting to the mixer. There is no unequivocal relation between experimental electronics and electronic music, and becoming an instrument designer competing with the musical industry is a challenging dream (in the state of our economic practices today, it is always cheaper to buy than to build).

[99] Teboul, 140

[100] Collins, Nicolas. "Composing Inside Electronics." PhD Thesis, University of East Anglia. 2007.

However, the learning process of deconstruction and building has no equal and sometimes it merges with the act of creation. Did I just build a circuit or did I compose a piece? Did I just make a Max patch or an instrument or a performance score?[101] From the pedagogical perspective, the question is not irrelevant. The learning process is what matters, and it is important sometimes to sit down and write the code, solder, disassemble, think and create with an experimental spirit and with the artistic humbleness of facing failure and reaching the limits of technical knowledge. In my own learning process, each of my mentors has exposed me to their own self-built instruments, patches and original ideas: Andrew Bentley through his charism of permanently studying and designing circuits and patches for performance,[102] Kalev Tiits with his creative approach to analog electronics and electromechanical thinking,[103] Roberto Garcia Piedrahita via his technical curiosity and the spontaneity of his critical listening,[104] Alain Savouret with his profound attitude towards inventiveness,[105] and Charles Besnainou through his engineering discipline.[106] From each of them I have taken great emotion and desire to learn and continue with the experimentation and creation of DIY electronic music instruments.

Because of the strong idiosyncrasy of the instruments discussed here, one may be tempted to call them at times *site-specific*; they can be built for a special occasion or for a place, however the common scenario is that the noise machines are not only specific to a space or a situation. The performance dimension of *noise Machines* should be centered on listening and intuition. If many of these include potentiometers, buttons, sockets, encoders, switches, faders and connectors, others may not and instead may challenge the performer to invent performance gestures or to develop performance techniques. Even in certain cases, the *Noise Machines* may resist any performance action and playing the instrument may consist only of letting the machines live their own sonic life in an autonomous and serene way.

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[101] Ibid.

[102] Bentley Andrew, "Simple Equipment for Electronic Music Making" in Orton, Richard. Electronic Music for Schools. New York: Cambridge University Press, 1981, 107-131

[103] Lähdeoja, Otso. “Composing the Context: Considerations on Materially Mediated Electronic Musicianship.” Organised Sound 23, no. 1 (April 2018): 61–70.

[104] Acosta, Rodolfo. “Musica Academica Contemporanea En Colombia Desde El Final de Los Ochenta.” Circulo Colombiano de Musica Contemporanea, 2007.

[105] Savouret, Alain. Introduction à Un Solfège de l’audible: L’improvisation Libre Comme Outil Pratique, 2010.

[106] Boutin, Henri, Charles Besnainou, and LAM IJLRDA. “Physical Parameters of an oscillator Changed by Active Control: Application to a Xylophone Bar.” In Proceedings of the 11th International Conference on Digital Audio Effects, 1–4, 2008.

Microcontrollers and Microcomputers, DIYDSP

In thirty years of computer music oriented hardware development since the IRCAM Signal Processing Workstation (ISPW)(late 1980s) to the BELA board (2016) many things have changed, others remain.

The ISPW used two Intel i860 RISC (reduced instruction set computers) with up to 32 Mbytes of local RAM and a CPU clock rate of 40-50 MHz, plus a Motorola 56001 DSP chip as I/O processor supporting four bidirectional channels of serial digital audio at 44.1Khz sampling rate and RS-422 serial port for MIDI, the whole implemented as a plugin coprocessor board for the NeXT computer with a custom CPOS/FTS operating system (CoProcessor Operating System/Faster Than Sound) and having a size of about 30cm in a cube-shaped black case.[107]

Computational power has dramatically increased, while the physical size and the costs of CPUs have exponentially decreased. As an illustrative comparison to the ISPW, the ARM cortex-A8 at the core of a beaglebone black with the *BELA cape* (2016) is the size of a credit card with all the connectivity (USB ports, Ethernet, microSD card), it will run at 1Ghz and will have 512Mbytes of RAM.[108] The BELA "runs a custom Linux audio environment that gives buffer sizes as small as two samples, producing latency as low as 1 millisecond from audio in to audio out, or even down to 100 microseconds from analogue in to analogue out."[109]

The programming platforms have also been improved, making it possible to relay languages in high level synthesis thanks to compilers, cross compilers and tools available for many platforms, leaving behind the need of writing tedious machine code. The *BELA* platform can be programmed in SuperCollider or PureData, two open source user customizable synthesis languages or through its own web-browser interface. It can accept sensor data through the many available ports, and it can write analog data (other than audio) for example voltage control, or data controlling actuators, solenoids, motors and other transducers. It also

[107] Lindemann, Eric, François Dechelle, Bennett Smith, and Michel Starkier. "The Architecture of the IRCAM Musical Workstation." Computer Music Journal 15, no. 3 (1991): 41–49;
Puckette, Miller. "Combining Event and Signal Processing in the MAX Graphical Programming Environment." Computer Music Journal 15, no. 3 (1991): 68–77;
Puckette, Miller. "FTS: A Real-Time Monitor for Multiprocessor Music Synthesis." Computer Music Journal 15, no. 3 (1991): 58–67;
Viara, Eric. "CPOS: A Real-Time Operating System for the IRCAM Musical Workstation." Computer Music Journal 15, no. 3 (1991): 50–57.

[108] McPherson, Andrew. "Bela: An Embedded Platform for Low-Latency Feedback Control of Sound." The Journal of the Acoustical Society of America 141, no. 5 (2017): 3618–3618.

[109] Moro, Giulio, Astrid Bin, Robert H. Jack, Christian Heinrichs, and Andrew P. McPherson. "Making High-Performance Embedded Instruments with Bela and Pure Data," 2016.

has the old MIDI interfacing. The research team at the Centre for Digital Music, Queen Mary University of London, UK led by Andrew P. McPherson successfully launched the project in a kickstart campaign in 2016, and it has been the platform for a great variety of embedded digital instruments and projects.[110] I have also worked intensively in a modular synthesizer implementation with the platform running SuperCollider patches.[111]

The BELA is a highpoint in the expanding land of microcontrollers and single-board computers for audio and electronic musical instrument development, at least today in 2018. Since the launch of the Arduino boards in 2005, an avalanche of small computer boards have hit the hobbyist market.[112] For example, the Arduino Uno board is a microcontroller based on the ATmega328 (8-bit AVR RISC) by Atmel, it can perform audio operations in the form of Pulse Width Modulation and even drive an external Digital to Analog Converter (DAC) for better Audio quality. On top of that, it can handle sensor data and stream audio files from external SD cards.[113] The *ArduinoSynth* is an umbrella of projects for 8-bit sound synthesis, direct sound synthesis and a tinkering tool for learning about analog and digital conversions.

A smaller and faster cousin of the Arduino Uno board is the Teensy board, which surpasses almost all of its cousin's features. The teensy 3.2 board (2015) developed by Paul Stoffgen has microcontrollers with ARM Cortex M-series CPUs 72Mhz clock, 34 digital pins, 21 analog inputs, 1 built-in DAC, USB client port, 3 serial ports, 1 SPI, I2C and CAN bus for digital connections, and even more interesting from an audio perspective, an audio shield has been developed to integrate audio signals in and out. The "Cortex-M4 DSP instructions provide plenty of computational power for real-time FFT (spectrum analysis)." and advance synthesis operations.[114] The teensy can be used for different kinds of projects, from standalone synthesizers to external sound cards (and can stream audio in and out from a computer host). Yasmeen Sultana has worked in the code for an audio driver to integrate a multichannel sound card for the teensy, which expands the features of the audio library initially released by Paul Stoffgen.[115]

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[110] "Bela: An Embedded Platform for Low-Latency Interactive Audio." Kickstarter. Accessed December 11, 2018. `https://www.kickstarter.com/projects/423153472/bela-an-embedded-platform-for-low-latency-interact`.

[111] Olarte, Alejandro. `https://github.com/Hyppasus/supercollider-eurobela`.

[112] Barrett, Steven F. Arduino Microcontroller Processing for Everyone! Morgan and Claypool Publishers, 2010.

[113] Bianchi, André Jucovsky, and Marcelo Queiroz. "Real Time Digital Audio Processing Using Arduino." In the Proceedings of the Sound and Music Computing Conference, Stockholm, Sweden, 30:538–545, 2012.

[114] "PJRC Store." Accessed December 11, 2018. `https://www.pjrc.com/store/teensy3_audio.html`.

[115] Sultana, Yasmeen. "Open-Source Audio Platform for Embedded Systems." PhD Thesis, University Of Applied Sciences Kiel, 2018.

In the same family of 32-bit ARM processors, the STM32F4 family of microcontrollers by STMElectronics has given birth to an incredible audio tool for musicians: the *Axoloti* (2015) developed by Johannes Taelman. The Axoloti offers the basic audio and MIDI connections, plus a microSD card for local storage.[116] With fine audio codecs delivering good audio quality and an incredible software/patcher to edit and program the board. The Axoloti has stimulated a very lively community around it, sharing patches, integrating synthesis ideas and as a pedagogical platform.[117] The "32-bit ARM microcontrollers have begun to approach the processing power that was previously only available through the use of dedicated DSP ICs. They enable very low latency and deterministic run-time control while providing enough overhead for useful audio calculations".[118] With the great effort of the developer and the community writing code, it has become very friendly and accessible.

In a similar evolutionary path, using the same processor ARM Cortex-M4, the crowdfunding system, a community user-based forum for sharing and exchanging code, an open source and open hardware design, the *OWL* (2013) by Thomas Webster, Guillaume LeNost, and Martin Klang, is a programmable digital guitar effect pedal.[119] Contributing to the success of the project are the tools for compiling the code made available. It can run compiled patches made in PureData, Max/Gen, an online simulator and be controlled over USB via MIDI. Through a company based in England (Rebel Technology), the same team released a eurorack module version of the Owl with the added features of accepting voltage control.

When I first saw in the NIME (New Interfaces for Musical Expression) conference in 2011 the microcomputer Beagleboard Xm running the CCRMA satellite software platform coupled to an Arduino nano,[120] I immediately fell in-love with embedded digital synthesizers. I could foresee their potential. Integrating high level DSP in the form of supercollider and PureData patches in an acoustic instrument with all the electronics physically integrated in the body of the

[116] "Axoloti Core | Axoloti." Accessed December 11, 2018. `http://www.axoloti.com/product/axoloti-core/`.

[117] Charles, Jean-François, Carlos Cotallo Solares, Andrew Willette, and Carlos Toro Tobon. "Using the Axoloti Embedded Sound Processing Platform to Foster Experimentation and Creativity." In Proceedings of the International Conference on New Interfaces for Musical Expression, Blacksburg, Virginia, USA, 204–205, 2018.

[118] Mulshine, Michael, and Jeff Snyder. "Oops: An Audio synthesis Library in c for Embedded (and Other) Applications." In Proceedings of the International Conference on New Interfaces for Musical Expression, Copenhagen, Denmark, 460–463, 2017.

[119] Webster, Thomas, Guillaume LeNost, and Martin Klang. "The OWL Programmable Stage Effects Pedal: Revising the Concept of the on-Stage Computer for Live Music Performance." In Proceedings of the International Conference on New Interfaces for Musical Expression, London, United Kingdom, 621–624, 2014.

[120] Berdahl, Edgar, and Wendy Ju. "2011: Satellite CCRMA: A Musical Interaction and Sound Synthesis Platform." In A NIME Reader, 373–389. Springer, 2017.

instrument, including electrodynamic transducers, leaving behind thick cables of controlling data, MIDI, computer and sound interfaces, that was a very appealing idea. From that moment I started to follow all the projects of microcomputers for audio that surfaced in conferences and forums. The *Sonic Pi* developed by Sam Aaron is an excellent example of the use of microcomputers as pedagogical tools for audio.[121] Sonic Pi is a software dedicated to live coding and a performance environment, among its design challenges is to be able to run in a Raspberry Pi. Other representatives of this movement include: the *PiSound* project, managed by Pranciškus Jansas from 2017, is an Audio and MIDI Interface for the Raspberry Pi.[122] PiSound is another project in the same vein as the previous ones presented above, with all the ingredients for what can be accurately called DIYDSP (Do It Yourself Digital Signal Processing).[123]. There are many other appealing projects for the development of electronic instruments frequently emerging such as the *MozziByte* an "Arduino Mini Sensor Sonification Sound Synth" or the *Percussa Super Signal Processor Eurorack Module* showing the value of the community funded projects.[124] Moreover, The reprogrammability of more and more commercially available audio devices for synthesis and sampling based on microcomputers with a very small footprint has opened the way to develop two forms of instruments: one based on complex parallel processing to exchange signals with other microcomputers through external hardware connections, the other as a centralized *monolithic*, *in the box* or hub, standalone unit.[125]

The number of available tools to start the adventure of programming microcomputers and microcontrollers is continually decreasing the technical requirements needed. There are platforms targeting young users, such as the BBC micro:bit and the sonicPi, which aim to increase computer literacy in children and young

121 Aaron, Samuel, Alan F. Blackwell, and Pamela Burnard. "The Development of Sonic Pi and Its Use in Educational Partnerships: Co-Creating Pedagogies for Learning Computer Programming." Journal of Music, Technology & Education 9, no. 1 (May 2016): 75–94.

122 "Pisound – Audio & MIDI Interface for Raspberry Pi." Indiegogo. Accessed December 11, 2018. `https://www.indiegogo.com/projects/1983605`.

123 There is a blog that carries that name run by Noah Vawter which is dedicated to electronic musical instruments based on open platforms

124 "MozziByte Mozzi Arduino Mini Sensor Sonification Sound Synth." Kickstarter. Accessed December 2, 2018.
`https://www.kickstarter.com/projects/mozzibyte/mozzibyte-mozzi-arduino-mini-sensor-sonification-s`.
"Percussa Super Signal Processor Eurorack Module." Kickstarter. Accessed December 2, 2018. `https://www.kickstarter.com/projects/percussa/percussa-super-signal-processor-eurorack-module`.

125 The eurorack module emphER-301 `http://www.orthogonaldevices.com/er-301` by orthogonal devices can be compared, as an example of the two approaches with the *Noorns*, which is more a self-contained voltage controlled microcomputer by the "Monome Company". Both using microcomputers

(as well as in some adults).[126] The alternative DIYDSP path for coding and creating electronic instruments provides the opportunity to tailor the electronic instruments to the needs (and capriciousness) of each performer, to the point that a big company like Korg has been taken in the momentum and released an API (Application Programming Interface), SDK (Software Development Kit) and dedicated development tools to create custom oscillators and modulation effects for their *Prologue* synthesizer.[127] This must be a door for a new wave of programming engineers who may want to take the steeper road of programming DSP chips and eventually renewing the practices in the audio industry, such as: FPGA, SHARC, Blackfin, dsPIC; or to contribute with the efforts to embed high level programming languages in dedicated microchips; embedding python and java are done, others are just in progress (LISP, PERL).[128] Another possible path to raise the fever of coding for systems on a chip is to enter the land of the mobile devices SDK audio programming with tools such as JUCE and FAUST.[129]

At the beginning of this section, I mentioned that there are a few things that have not changed between the ISPW times and the BELA days. These are essential to performing musical instruments. Microcomputers have gotten smaller, faster and cheaper, but our body still has two hands, two legs, two ears, one mouth, consequently the physical interaction with computers still has the same challenges than thirty years ago. If a computer is extended with performance interfaces, it falls back to a physical/mechanical problem. The sensing technology may change, while our limits of perception and reaction, our time tolerance to muscle effort or our dexterity on fast motions may not change much, even if computers may help us improve those. When designing a digital electronic instrument and choosing the sensing and interaction mechanisms, the ergonomic aspects have to be at the center of the design. How does one perform the instrument? Which movements, gestures? Which amount, range and rate? The question of our mechanical fine motor control while performing computers is even more pertinent if we consider how electronics are fused and embedded within our bodies.

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[126] Schmidt, Albrecht. "Increasing Computer Literacy with the BBC Micro: Bit." IEEE Pervasive Computing 15, no. 2 (2016): 5–7.

[127] "Prologue SDK | Prologue – Polyphonic Analogue Synthesizer | Korg (USA)." Korg Global. Accessed December 11, 2018.
`https://www.korg.com/us/products/synthesizers/prologue/sdk.php`.

[128] George, Damien. MicroPython Python for Microcontrollers, 2016;
Schoeberl, Martin. "A Java Processor Architecture for Embedded Real-Time Systems." Journal of Systems Architecture 54, no. 1–2 (2008): 265–286.

[129] "Tutorials | JUCE." Accessed December 11, 2018.
`https://juce.com/learn/tutorials`;
Michon, Romain, Julius Smith, Chris Chafe, Stéphane Letz, and Yann Orlarey. "Faust2api: A Comprehensive API Generator for Android and IOS."
In Proceedings of the Linux Audio Conference (LAC-17), Saint-Etienne, France, 18–21, 2017.

> With the radical miniaturization of electronics, sensors and actuators combined with bio- and nano-technologies and global digital networks, information is more than ever before directly embedded into everything imaginable. The bonds between human and computer are merging in ways that were previously only the dreams of science fiction.[130]

Another aspect that seems to evolve at a slower pace than the decreasing size of transistors is the advancement of synthesis techniques. Programming microcomputers should facilitate experimentation with digital sound synthesis; there was a glance of non-classic sound synthesis techniques in the previous sections waiting to be investigated. Even if another VA (Virtual Analog) subtractive synthesizer with a big knob for the cutoff frequency is a good step for learning, the next step of programming should not be avoided. What else can be developed in a computer for sound synthesis purposes? The permanent effort to get digital synthesizers to sound as close as possible to their analog counterparts reminds me of the warning statement by John Cage about electrical musical instruments' attempts to imitate eighteenth- and nineteenth-century instruments, by performing masterpieces from the past and by searching to reproduce the sounds of old instruments.[131] Even bare metal programming must be tried out, and the digital voice of the microprocessors revealed just in case an alternative sound synthesis techniques are waiting under those silicon cakes.

When the BELA is compared to the microcomputers of the future in forty years, I only can hope that the big issues of computers will finally be addressed. These issues, as we all know at the time of this writing, do not related to the size or speed of processors, but to an administration of natural resources involved in their manufacturing process. Will the computers of the future be made in a sustainable way that respects the environment? Will the future computers be made of biodegradable electronic components? Will recyclable processors be an option when designing a computer based electronic instrument? Will those computers be produced and distributed with fair commercial accords without human labor oppression? Will those devices be the sign of a civilized life harmonious with nature? Will the electric power of those digital instruments be optimized and built with no obsolete parts? I hope that in forty years we will not be making computer musical instruments with stones because of an environmental catastrophe, but rather with some form of ultra-modern lithophones as glorified pieces of technology.

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[130] Flanagan, Patricia J. "Haptic Interface Aesthetics–'Feedback Loops, Live Coding and How to Harness the Potential of Embodied Estrangement in Artistic Practices and Aesthetic Theories within Interface Culture.'" In International Conference of Design, User Experience, and Usability, 58–67. Springer, 2013.

[131] Cage, John. "The Future of Music: Credo." Audio Culture: Readings in Modern Music. New York: Continuum, 1937.

Live Coding

From time to time I encounter the argument that "a computer is not a musical instrument",[132] and though I tend to agree that if trying to play a Chopin prelude using the qwerty keyboard mapped as MIDI notes is not necessarily irrefutable proof of the instrumental potential of the computer, it actually is one of the preferred interfaces for certain performance practices such as live coding, other options being systems to translate incoming data, audio or control to alphanumeric or graphic instructions for the synthesis algorithm or to affect the rules governing it. As expressed in the TOPLAP (Transdimensional Organisation for the Purity of Live Algorithm Programming) manifesto, live coding is "a new direction in electronic music and video: live coders expose and rewire the innards of software while it generates improvised music and/or visuals. All code manipulation is projected for your pleasure"(Hamburgh 2004).[133] However, the heterogeneous forms of events and performances named by the practitioners as *live coding* make it hard to define. Let us consider some commonalities and aspects of the practice in the following paragraphs.

Live coding is a form of computer music performance (*Laptop music*), though concerts and public shows are not the only forms of presentation. Live coding can happen as well over networks, in chat rooms or even in the confined space of a solo performance with headphones. Performing with a computer can take the form of connecting controllers and interfaces to the host computer and driving a synthesizer, triggering samples and sound files, and processing audio signals. What makes the difference with the live coding practice is the ability to edit, alter and modify the structure of the signal graph of a running audio patch or program. This can be achieved with some hardware synthesizers where the routing, mapping and modulation matrix are exposed to the user. It is for example the panacea of modular synthesizers (these, however, can be used in a preset manner by pre-programming different voices that enter, change and leave the musical flow without structural modifications or re-patching). Therefore, live coding exploits the flexibility of dynamic programming languages by interacting with algorithms, rewriting them, generating processes, programming on the spot, manipulating the code, changing the rules during the execution of the program. "Usually, the programming is carried out within some sort of arts programming environment, such that the program output affects audio and visuals and the operator projects his/her screen during performances to make the process (in principle) transparent."[134] Extending this idea beyond audiovisual and digital data, some rule-based performance acts, dance and theater also fit the live coding definition.

[132] Fels, Sidney, and Michael Lyons. "How to Design and Build New Musical Interfaces." In Human-Computer Interaction – INTERACT 2015, edited by Julio Abascal, Simone Barbosa, Mirko Fetter, Tom Gross, Philippe Palanque, and Marco Winckler, 642–43. Lecture Notes in Computer Science. Springer International Publishing, 2015.

[133] "Toplap." Accessed December 11, 2018. `https://toplap.org/wiki/Main_Page`.

[134] Collins, Nick. "Live Coding of Consequence." Leonardo 44, no. 3 (2011): 207–211.

The need for *transparency* by projecting the screen and revealing the code or a graphical visualization of it is a reaction to the "laptop-performer-stuck-behind-the-laptop dilemma".[135] Revealing the code by projecting it has consequences on the look and appeal of the running program. It may be a cultural construct,[136] but there seems to be a tendency to prefer text-based and script languages over graphical patching interfaces. Blackwell and Collins argue that there are flexibility and structural reasons (algorithmic maneuverability, customization, openness of mapping, abstraction level).[137] When debating over why a user may choose a scripting language over a graphical environment such as Ableton Live, Blackwell and Collins state:

> An aesthetic response would be to embrace the challenge of live coding; the virtuosity of the required cognitive load, the error-proneness, the diffuseness, all of these play-up the live coder as a modern concerto artist. But a key concern remains the representational paucity of programs like Ableton, which are biased towards fixed audio products in established stylistic modes, rather than experimental algorithmic music which requires the exploratory design possibilities of full programming languages.[138]

However, there seem to be different levels of preferred graphical environments for live coding. The software Max and PureData, that allow for re-structuration of the data flow graph by altering connections between boxes (building blocks of dynamically linked libraries) with *wires* in a *patcher* canvas, are taken as a different category with more approval than other software based on the graphic control of the synthesis parameters such as *Ableton Live.*[139] This hierarchy of programming languages now seems a tad artificial since one can argue as well that some live coding sessions are only about adjusting a few parameters on code snippets in scripting languages or limiting the interaction with the code to trigger rhythmical events with text-based interfaces. On the other hand, the integration of *Max for Live* allows more complex routing as well as deconstruction of synthesis architectures.[140] Magnusson will reply that there are *strong and weak* definitions of live coding. The strong form is the one where the algorithm is written or

[135] Collins, Nick, Alex McLean, Julian Rohrhuber, and Adrian Ward. "Live Coding in Laptop Performance." Organized Sound 8, no. 3 (2003): 321–330.
[136] Bell, Renick. "Towards Useful Aesthetic Evaluations of Live Coding." In ICMC, 2013.
[137] Blackwell, Alan F., and Nick Collins. "The Programming Language as a Musical Instrument." In PPIG, 11, 2005.
[138] Ibid.
[139] Magnusson, Thor. "Herding Cats: Observing Live Coding in the Wild." Computer Music Journal 38, no. 1 (2014): 8–16.
[140] Roberts, Charles, and Graham Wakefield. "Live Coding the Digital Audio Workstation." In the Proceedings of the 2nd International Conference on Live Coding, 2016.

modified during the execution of the program; the weak form is the other cases when there is only manipulation of prewritten code.[141]

> Rules must be explicit. We may be inventing and changing rules all the time in our heads, but unless those rules are written down and modified while they are being followed by a computer (or other agent), that is not live coding.[142]

How much of the code is actually written in real-time is definitely another illustration of the diversity of practices. Writing a language from scratch, or rewriting everything like audio drivers and DSP engine, recompiling the operating system or even uncovering the assembly code or the machine code in front of an audience is definitely a possibility. It may be the *hard* way to go, perhaps a stronger performance act than a musical one but a virtuoso performance from the point of view of the *strong* kind of live coding for sure. A step further would involve preparing the language and libraries to be used during the performance, memorizing it and starting from an empty page. More preparations can be done before performance, for example, preparing routines, events, processes, code snippets, shortcuts, abstractions or even notes in a safety document close at hand, just in case the panic or stress of the white page hits at the wrong moment or to avoid annoying acoustic accidents due to the risk of working with untested code. Even if these preliminary preparations are classified as a *weak* live coding practice, I definitely sympathize with the player from the performance point of view.

The complexity of the exposed code is then a matter of choice and taste and may vary and change from performance to performance or even inside the same performance. Some may prefer a cryptic *low-level* language, where the commands are not understandable to a non-computer informed person. This choice may reinforce the allure of a scientific (or hacking) activity, demonstrating high skills of programming and manipulating computers.[143] Others may advocate for a more *human-like* readable *high-language*, with the purpose of giving semantic cues from the commands and engaging with the audience. For example, using descriptive names for functions, variables and routines such as _ *nowAnExplosiveSoundWillCome*_ to trigger processes that will sonically correspond to the execution of the code creates a more direct and inclusive communication with the audience. This choice of bringing the programming language close to everyday language may potentially diverge in poetry, jokes, quotations or dialectic-rhetoric kinds of performance.[144] When collective performances are set, blurring comprehensibility

[141] Magnusson, Thor. “The Threnoscope: A Musical Work for Live Coding Performance.” In ICSE. Live 2013, 2013.

[142] McLean, Alex. “Live Coding for Free.” Floss+Art. London: OpenMute, 2008, 224–231.

[143] “Hacking Perl in Nightclubs.” Accessed December 12, 2018. `https://www.perl.com/pub/2004/08/31/livecode.html/`.

[144] Lee, Sang Won, Georg Essl, and Mari Martinez. “Live Writing: Writing as a Real-Time Audiovisual Performance.” Ann Arbor 1001 (2016): 48109–2121.

of the code in favor of a more audiovisual experience can be another choice, for example, superimposing many screen projections on one surface.[145] Of course, using other types of visualization will take the performance to different levels of abstraction.[146] In any case, visually sharing with the audience the screen makes all the graphic and visual elements part of the instrument-performance, for example, colors, fonts and formatting for the text (or graphics), tabulation, use of blank spaces, including a console or a post window, backgrounds, transparencies, number of windows or tabs and any other parameter that will be shown.

Group performance of live coding reveals the issues of *who is contributing what.* It is easy and understandable that a parallel mass of audiovisual information, several audio layers with screen projection, can cause *traffic jams*, resulting in a loss of clarity. The density of the performance can be a quality or can be a disturbance for the performers. Bands have creatively found some alternatives when clarity of performance becomes an issue. For example, the band *Powerbooks unplugged* places the performers within the audience and uses only the built-in speakers of the laptop, challenging the standards of traditional concert settings.[147] Sharing or collaborative coding, passing the code around and taking turns modifying it or playing with it, or restricting the coding material or the language functions are other alternatives to lower the feelings of entropy. Nick Collins makes allusion to the “renaissance mathematical competitions (lasting 40-50 days)” as a metaphor of a group interacting with the same code.[148] The idea of sharing and competition, suggests Nick Collins, can eventually be taken to the extreme of hacking each other’s computers.[149]

Laptop performance as a form of improvised electroacoustic music takes the erudition of writing code to the required levels of mastering a performance practice for public enactment. Creating digital content through arbitrarily complex changes of structure at the performance time of algorithms, considering that there is no debugging or testing available, requires a deep knowledge of the tools and computer music expertise.[150] Using the idea of malleable on-the-fly changing of rules is a performance concept that can be exported and experimented with in cross-disciplinary contexts as exposed by Rymer Jess.[151] Furthermore, live coding is an opportunity to challenge the relationship between music and the computer.

[145] “Slub (Band).” Wikipedia, September 11, 2017. `https://en.wikipedia.org/w/index.php?title=Slub_(band)&oldid=800184496`.
[146] McLean, Alex, Dave Griffiths, Nick Collins, and Geraint A. Wiggins. “Visualisation of Live Code.” In EVA, 2010.
[147] Rohrhuber, Julian, Alberto de Campo, Renate Wieser, Jan-Kees van Kampen, Echo Ho, and Hannes Hölzl. “Purloined Letters and Distributed Persons.” In Music in the Global Village Conference (Budapest), 2007.
[148] Collins, Nick. “Live Coding of Consequence.” 207–211.
[149] Ibid.
[150] Collins, et al. “Live Coding in Laptop Performance.” 321–330.
[151] Rymer, Jess. “An Argument for Investigation into Collaborative, Choreomusical Relationships within Contemporary Performance: A Practical and Theoretical Enquiry

For example, Bill Thompson in his piece *dismantle for laptop (solo)* “slowly destroyed a laptop while accompanied by three junkyard percussionists as part of the Scrapclub events in London.”[152] Other examples of where the bending of the concepts of live coding can take the artist are the collective *Loud Objects* that perform *live soldering* acts while projecting the shadows from the worktable, or in a similar way, the *Breadboard Band* that “takes a prototypical approach to constructing circuits in performance”.[153]

Electronic Music Performance Networks

In a broad sense, a network is an “arrangement of intersecting lines”.[154] In the context of electronic musical instruments, the lines can be understood as signals, the intersection as connection points and the arrangement as a system of multiple components. Accordingly, an *Electronic Music Performance Network* (EMPN) has a collection of interconnected units sharing signals. This definition is so large that it is almost useless for the purpose of this chapter, since audio signals are shared across discrete components inside many pieces of audio equipment (mixers, computers, signal processors among others), all of which fall into the same category. To start narrowing the definition, a first step is to consider the *components* of the network as discrete, isolated, electronic performance sets. Zooming out from each device that encloses a local network of signals, to a performance set of interconnected electronic devices allows to clarify the definition of what EMPN means. In this process of encapsulating the components used by one performer, it is crucial to the definition of network to allow the faculty of receiving and sending signals from inside and outside the performance set.

Acknowledging that each performance set is different and for the purpose of illustration, let us take the following configuration as an example of a performance set: a microphone, a preamplifier, a mixer, a couple of processing units such as pedal effects, a couple of extra sound sources such as a synthesizer, a hacked radio and an active loudspeaker. This performance set is a self-contained unit that can play as solo or in a group without requiring any further external connection. To integrate this set in a network, at least one signal input and one signal output should be exposed and available to other performances sets. Some

into the Distinct Contributions of a Collaborative, Co-Creative Approach.” Avant 8 (2017): 181–191.

152 Thompson, Bill. “CEC — EContact! 12.3 — Scrapyard Aesthetics and the Swansong of the Inspiron by Bill Thompson.” CEC | Canadian Electroacoustic Community. Accessed December 12, 2018. `https://econtact.ca/12_3/thompson_dismantle.html`.

153 Richards, John. “The Music of Things.” Journal of the Japanese Society for Sonic Arts 9, no. 2 (2017): 16–20.

154 “Network | Definition of Network in English by Oxford Dictionaries.” Oxford Dictionaries | English. Accessed December 13, 2018. `https://en.oxforddictionaries.com/definition/network`.

electronic instruments have network capabilities by nature. For example, a modular synthesizer is a collection of modules with inputs and outputs that can be arranged across many cases or cabinets; likewise, the *scsynth* synthesis engine of Supercollider program can receive and send signals to one or many clients.

The requirement of having at least one signal input and output pushes the definition of the EMPN even further. What is the nature of signals going in and coming out of the performance set? It can be analog signals, such as audio or voltage control; it can be digital signals, such as MIDI, OSC,[155] or digital audio; or text and graphics for performance instructions and score sharing; it could be radio signals encoding and decoding audio with AM or FM techniques, or light signals by using lasers beams and phototransistors for transmitting and receiving audio signals.[156] One of the least common but of course possible types of signals in this context is electromechanical signals: using relays and actuators to send, receive and process motion producing acoustic vibrations and sounds. Therefore, according to the type of signal shared, it is plausible to add one more qualification to the Electronic Music Performance networks.

- analog,
- digital,
- electromagnetic,
- radio,
- optical,
- electromechanical and,
- complex (including different types of shared signals).[157]

Once the signals are made available in and out of each performance set to other performers, there appears another question to consider: to where, from where and how are the signals shared? Theoretically, there is no limit to where each per-

[155] Wright, Matthew. "Open Sound Control: An Enabling Technology for Musical networking." Organised Sound 10, no. 3 (2005): 193–200.

[156] "Build a Laser Communication System." Accessed December 13, 2018. `https://www.allaboutcircuits.com/projects/build-a-laser-communication-system/`.

[157] As a trivial sidenote, while looking at this list, there is of course the family of *acoustic network instruments*, but that is only a fancy name for a group of sonic performances as old as humanity, where the acoustic signals are shared in a group that receives through the ears and sends signals with the body or extensions of it (musical instruments). A pure mechanical network instrument based on hydraulic pumps, gears, pipes and plates is also imaginable but outside the scope of this research

former should be physically located. It would take some engineering efforts, but it could be anywhere in the world (or even beyond!), with an adequate relay system and carefully finetuning the receivers and senders to entertain the signals over long distances. Somehow geographical space is transcended. This also means that there will always be a delay time associated with the transmission medium, the data rate and bandwidth available.[158] Eventually, quantum internet will fix that. This may or may not have consequences in the musical output, either because the delay time is negligible for audio purposes or because aesthetic choices of temporal asynchronicities are seen as a quality. In contexts where time accuracy is required, the time latency of signals between performers can spoil the musical outcome and the performance. The time inaccuracies can also reflect in micro (or macro) fluctuations changes in the signal producing sonic perceptual artifacts. Again, one can choose to be constantly frustrated about it and dream and wait for the great telecommunication protocol and connectivity with zero loss, high fidelity, high speed, extensive bandwidth or *live with it* and integrate it in the performance. As the composer Georg Hajdu observes when talking about these audio issues, "the Internet thus gives birth to its own aesthetic".[159]

But performance sets do not necessarily have to be at the other side of the planet to set up a EMPN; they can be in the same room. Sharing data is the crucial point, but a difference can be made from the performance perspective whether or not the performers are physically in the same space. Roger Mills from the University of Technology Sydney, has written a very succinct doctoral thesis (2014) on the topic of "Improvisation in Networked Music Performance". He proposes naming a *co-located* situation when musicians share the same physical space using a system for data sharing and a *telematic* situation when they are dislocated acoustically and visually.[160] The same logic could be applied for the audience. Are the listeners in the same space as the performers; are they monitoring the experience close by one of the dislocated performers? Are they in a totally different space accessing the performance individually via a web browser or collectively through a broadcasting setting in a concert hall? Even more, the listening space could be created through headphones and thanks to the advancements of webaudio, more interactive tools are available to offer to listeners a more active listening experience.[161] Using mobile devices and web servers can give members of the audience a participatory role during an electroacoustic performance. For example, by accessing controllers on a webpage where the band is streaming discrete

[158] Cerqueira, Mark. "Synchronization over Networks for Live Laptop Music Performance." Master's Thesis, Department of Computer Science, Princeton University, 2010.

[159] Hajdu, Georg. "Quintet. Net: An Environment for Composing and Performing Music on the Internet." Leonardo 38, no. 1 (2005): 23–30.

[160] Mills, R. H. "Tele-Improvisation: A Multimodal Analysis of Intercultural Improvisation in Networked Music Performance," 2014.

[161] Choi, Hongchan, and Jonathan Berger. "WAAX: Web Audio API EXtension." In Proceedings of the International Conference on New Interfaces for Musical Expression, Daejeon, Republic of Korea, 499–502, 2013.

channels and creating personalized mixes to be heard with headphones or even contributing with sounds from an on-line synthesizer. However, the sharing of data among performers in a co-located situation does not necessarily have to be communicated to the audience; it can be another tool or working mechanism for the band.

After considering the performance set as the *cell* of the network ecosystem, the different nature of signals shared, and the performance and listening space, there is still one aspect to consider: the inclusion or not of a centralized distribution system. For example, in an analog context with three or more performers sharing audio signals, there are two possibilities. Centralize the signal to a mixer with enough channel inputs and sends or sub-mixes (at least one for each performer, but if the mixer is big enough with physical channels, more signals from and to each performer can be distributed) or use local bypasses to forward signals as a multichannel block so that there is only a connection from one musician to the next, avoiding the central device. Other variations of the non-centralized setting can be imagined where one musician passes only one signal to the next, as limited resource sharing. In one of my workshops, Kaj Mäki-Ullakko set up a performance situation where each performer passed an audio channel to the next and a control channel to the previous in a side-chain fashion. The loop of signals was closed so that the last performer passed the audio to the first and received the control from the first. The result was a very complex and enjoyable, interconnected instrument requiring the full attention of the performers with the ability to open and close signals by playing.

Both architectures (point-to-point connections or a central server) have wonderful creative applications as well as qualities and challenges, but there is no reason not to experiment and develop tools for each. Passing signals from one point to other can deteriorate the original signal over several iterations from a communication theory perspective, but this could be the exact point of an art performance. On the other hand, for example, using a central convergent point for all signals facilitates the monitoring, recording and appreciation of the whole. This idea can be applied to the synthesis too by running a synthesizer in a server and having many performer clients sending instructions to it or the other way around, having one performer sending instructions to a network of de-localized synthesizers.

If going telematic for setting up an Electronic Music Performance Network over the internet, there are a few steps to consider. Once the sounds are in a digital format and access to a reliably good internet connection with administrator rights has been found (which may be needed for opening ports, allowing security checks and the considerable streaming data traffic uploading and downloading), then a software tool for streaming and interfacing is needed. There are some dedicated available tools for audio streaming: JackTrip by CCRMA,[162] NINJAM by

[162] Cáceres, Juan-Pablo, and Chris Chafe. "JackTrip: Under the Hood of an Engine for Network Audio." Journal of New Music Research 39, no. 3 (2010): 183–187.

Cockos,[163] and eJamming.[164] Though many improvements on speed and bandwidth are constantly done and the software tools use inventive solutions to counterbalance the connection issues (peer-to-peer connections, delay compensation, buffering techniques), real-time audio over the internet is still under *construction*.

Other than the skills to properly adjust and play with delayed audio signals when using the internet, the performance aspects to consider in an EMPN relate to intersubjectivity, human *presence* and *sharing* information. It cannot be only about how it is different to play with the audio signal of a dislocated musician. In our century people are experiencing telecommunications even from before birth, and talking on the phone or in video-conferences from one side of the planet to the other is helping us to train how to extract all the emotional and cognitive information embedded in the signals of a non-present person. I have often felt even more connected and a deeper, realer presence over a phone line than with the person sitting next to me on a public bus. The differences are the commonalities, a common history, a shared past, a collective memory, common plans, identification and recognition of the other, support and complicity and all the things that love entails. I do not necessarily have those commonalities with the person sitting next to me on the bus, so it is normal that they are less present. Apply this to our dislocated musician, and it can be the same. If music is more than sounds, as I argued in the previous pages, it is not only about the moment where we meet on-line to play together, nor is it about the delayed signals or even the signals themselves. It is about all the common past and future pieces of life that make the performance-network-meeting strong. The need to have a breathing body close by can be overcome by an act of trust. I have been in many spontaneous musical meetings where the music just flowed from people who have never met before; I see that skill as a sharp sense of intuition. The way that a musician offers the first seconds or fraction of seconds of their music can tell many things about their education, social background, aesthetic inclinations, all of which can be false predictions and precipitated conclusions of course, but then there is time to meet and the music unfolds according to that encounter of worlds. I can see how those on-line spontaneous encounters are even more difficult since there are the masks of anonymity, or the virtual-made persona – avatars. However, moving in that cyberspace and handling the relations with cyber-musicians of the future is just another skill that many probably have as an innate quality.

The sharing of data among performers suggests incredible possibilities. A couple of years ago Andrew Bentley suggested to our local improvisation group in the Sibelius Academy that we should develop a system to collectively plan and communicate the future actions and events to come during a running improvisation. It is an exciting idea that deserves more investigation. The few experiments that

[163] "Cockos Incorporated | NINJAM." Accessed December 13, 2018. `https://www.cockos.com/ninjam/`.

[164] "EJAMMING AUDiiO – The Collaborative Network for Musicians Creating Together Online in Real Time." Accessed December 13, 2018. `http://www.ejamming.com/`.

we did started to teach us about *playing in the future*. The actual present sound was only the materialization of the actions or processes set by the performers some time earlier. The whole group was struggling to make music in the future without acoustic sound guidance. The act of sharing our intentions of where the music should go through a kind of instant message system brought up the question of what the appropriated codes to communicate were: words, symbols, cues? Accessing and scheduling parameters of a shared patch? Imagine for a second how the timeline of the performance can become more intricate in a *large* present if, while *playing in a future situation*, somebody happens to sample the actual audio output and to record the present actions so that the whole present will be recalled and played back later on, overlapping present, past and future actions. If we cannot improve the latency in a communication chain, let us use it as a buffer to *thicken*, broaden, the present.

We have seen how the whole story of sharing data raises some ethical concerns. Without going in a straight analogy of what has happened in the social media world and the violation of the individual right to privacy in our context of electroacoustic performance, sharing data also has ethical concerns to be aware of. What do I do with the signals that you are giving me? Ignoring them is a possibility, but then what is the point of sharing? Is there a point when processing the data can be respectful? Think for example of a situation of sharing controls over a network for handling the volume parameter of a synthesis process. If performer A processes performer B's control data by constantly inverting it, B can overwrite performer A's intentions: when A goes high, the inverting process takes the values down; then A notices it and starts to play in the other direction, but then performer B changes the inverting mapping again. Ultimately, performer A has been suppressed by performer B. Is that fair? No worries – it's just improv! (replies performer B). Well, I agree with Tim Perkis and John Bischoff from "The League of Automatic Music Composers":

> We approached the computer network as one large, interactive musical instrument made up of independently programmed automatic music machines.[165]

Therefore, when sharing signals and data, the goal is to drive that one single extended instrument, so the signals and data must be treated as coming from a single extended performer, not as a competing and colliding set of instructions. In Mills thesis,[166] Alexander Carôt and Pedro Rebelo's articles,[167], and Geil

[165] Perkis, Tim, John Bischoff, Jim Horton, Rich Gold, Paul DeMarinis, and David Behrman. The League of Automatic Music Composers, 1978-1983. New World Records, 2007.
[166] Mills, "Tele-Improvisation".
[167] Carôt, Alexander, Pedro Rebelo, and Alain Renaud. "Networked Music Performance: State of the Art." In Audio Engineering Society Conference: 30th International Conference: Intelligent Audio Environments. Audio Engineering Society, 2007.

Weinberg's articles,[168] there are comprehensive presentations and analysis of the state of art as well as historical overviews of many projects done in the area of Network Musical Performance. I invite the reader to consult these sources and all those that they quote as inspiration for further artistic works with the Electronic Music Performance Networks.

Music robots

Music robots, artificial intelligent musical agents, automatic DSP systems with learning algorithms, self-coding algorithmic audio machines, virtual reality automatons performers, self-driven electromechanical improvisers, autonomous sound installations, all are part of the electronic instrumentarium. Mostly because the future seems to be heading in that direction driven by nano-technologies, big data analysis, machine learning and artificial intelligence developments. Also because all the seeds for these ideas have been planted (and some are already blooming) by electroacoustic musicians in previous generations.

Inspired by readings on *Musical Robotics*, *Embedded Cognition* and *Human Robot Interaction* I suggest to classify music robots according to degree of autonomy, decision-making capabilities and musical cognition capabilities.[169]

- In a first level there are the electromechanical machines that perform actions given by humans or are triggered by a pre-programmed sequencers or governed by algorithmic process. The main characteristic in this group is that machines cannot change, stop, restart or modify their program without human intervention. Once the pre-programmed sequence is running, it will run until the end or it will turn in a loop according to the list of instructions.

- In an intermediate level there are enhanced computers with sensors and data processing capabilities for analyzing the environment or human actions or

168 Weinberg, Gil. "The Aesthetics, History and Future Challenges of Interconnected Music Networks." In ICMC, 2002.

169 Bretan, Mason, and Gil Weinberg. "Integrating the Cognitive with the Physical: Musical Path Planning for an Improvising Robot." In AAAI, 4371–4377, 2017;
Camurri, Antonio. "On the Role of Artificial Intelligence in Music Research." Journal of New Music Research 19, no. 2–3 (1990): 219–248;
Scholtz, Jean C. "Human-Robot Interactions: Creating Synergistic Cyber Forces." In Multi-Robot Systems: From Swarms to Intelligent Automata, 177–184. Springer, 2002;
Yanco, Holly A., and Jill L. Drury. "A Taxonomy for Human-Robot Interaction." In Proceedings of the AAAI Fall Symposium on Human-Robot Interaction, 111–119, 2002;
Whalley, Ian. "Software Agents in Music and Sound Art Research/Creative Work: Current State and a Possible Direction." Organised Sound 14, no. 2 (2009): 156–167.

other machines and with the particularity of being able to alter or adjust their outputs. These machines can be considered a step further towards autonomy.

- At the top there are algorithms that are able to learn styles and more abstract concepts from interaction with the sonic and musical environment and ultimately re-write or reprogram themselves according to spontaneous decision-making.

In all cases, their sonic output can be electromechanically or electronically generated.

There are many examples in the first category, which is very close to sonic electromagnetic or electromechanical sculptures and includes many of the early works of mechatronics artists-engineers-inventors who have built autonomous sonic machines. These machines use solenoids, motors, pumps, gears, actuators and are programmed with microcontrollers. They act on plates, strings, percussions, pipes, and many other surfaces and materials, including loudspeakers. A Disklavier playing back a MIDI sequence or reproducing a live performance done in another Disklavier will fit this category. Also the automatic machines of the Tsukuba series by Maywa Denki,[170] or the "Z machines robot band".[171] I also include in this category a configuration with an audio input such as a microphone and an acoustic instrument, an algorithm hosted in a computer analyzing the signal and inferring MIDI notes from a fundamental frequency estimation and a playback system such as a sampler. If there is no input, there is no output.

The second category expands on the previous one by improving decision-making in the governing software based on analysis of sensing external data, music and sonic input. The machine can stop and decide when to restart; in a musical context, it can make musical proposals or take the initiative of triggering events. It is more an interactive dialogue than a question-answer scenario. This became possible when programmers gained access to sophisticated languages and to the refinement in the sensor industry as well as advancements in multidisciplinary work and research on *musical robotics and machine listening and learning*. The work of Gil Weinberg in designing *Haile* a robotic percussionist that "listens to live human players, analyzes perceptual aspects of their playing in real time, and uses the product of this analysis to play along in a collaborative and improvisatory manner".[172] Or Francois Pachet with his continuator software: "The resulting system is able to learn and generate music in any style, either in standalone

[170] Kapur, Ajay. "A History of Robotic Musical Instruments." In ICMC. Citeseer, 2005.
[171] Long, Jason, Jim W. Murphy, Ajay Kapur, and Dale Anthony Carnegie. "A Comparative Evaluation of Percussion Mechanisms for Musical Robotics Applications." In Automation, Robotics and Applications (ICARA), 2015 6th International Conference On, 173–178. IEEE, 2015.
[172] Weinberg, Gil, and Scott Driscoll. "Toward Robotic Musicianship." Computer Music Journal 30, no. 4 (2006): 28–45.

mode, as continuations of musician's input, or as interactive improvisation back up."[173] There are many other works implementing different statistical techniques to make decisions and methods to create databases based on machine listening and from the Music Information Retrieval research field.

The third category is the more fresh one, but there are researchers who are committed to it. Creating an algorithm that can re-write itself and has high levels of autonomy is a difficult task (well beyond musical interests). Michael Young calls them *Live Algorithms.* A Live Algorithm "is the function of an ideal autonomous system able to engage in performance with abilities analogous (if not identical) to a human musician, and produce a living computer music."[174] He also gives the following properties for an autonomous machine improvisation: "adaptability, empowerment, immersion, opacity, and the unimagined."[175] The last one is particularly interesting; it is about giving imaginative capacities to the machine/robot/algorithm, suggesting that "computers might extend, not copy, human behaviour through autonomous and prosthetic capabilities".[176] More works should appear based on research on deep learning techniques and neural networks and will eventually permeate the experimental electronic music scene as performers, guests and improvisers.

Each system involving some form of musical robotics and artificial intelligence needs also to be learned from human performers. It is different to lead a system that is fully dependent on the input; it requires a very different musical attitude compared to playing along with a system that reacts to the incoming impulses and adjusts itself to the surroundings and it is definitely distinctive to perform with an autonomous robot partner that can enter states of flow trying to solve the unresolvable problem and the open-ended questions of musical improvisation, maybe by bringing more questions to consider for us, human agents.

Loudspeaker orchestra and multichannel systems

I would like to close this chapter of exploring the electronic music instrumentarium with what represents the end of the electroacoustic chain: the loudspeaker. Expanding what was said in the section on transducers and loudspeakers, I will

[173] Pachet, Francois. "The Continuator: Musical Interaction with Style." Journal of New Music Research 32, no. 3 (2003): 333–341

[174] Blackwell, Tim, Oliver Bown, and Michael Young. "Live Algorithms: Towards Autonomous Computer Improvisers." In Computers and Creativity, 147–174. Springer, 2012;
Young, Michael. "NN Music: Improvising with a 'Living'Computer." In International Symposium on Computer Music Modeling and Retrieval, 337–350. Springer, 2007.

[175] Young, Michael. "Au (or) a: Exploring Attributes of a Live Algorithm." EMS: Electroacoustic Music Studies Network De Montfort/Leicester, 2007.

[176] Ibid.

address here the configurations of multiple sources. The reason to have a separate section for multichannel systems is because the systems have to be addressed from a performance point of view in a different way than a single loudspeaker. As an analogy, let us take the difference between performing on one pipe as a sonic object and performing on five hundred pipes as in a church organ. Multiplication of sources requires creative strategies to keep things under control.

Shifting from using a monophonic configuration towards a dual loudspeaker arrangement contains on a small scale all the issues, challenges and potentialities of performing with larger multichannel systems. Let us consider that paradigm shift in more detail. Adding a second loudspeaker raises questions such as:

- Should the two loudspeakers be similar, matching each other's physical, electrical and sonic properties, or should the second loudspeaker be different, bringing its *own voice* in counterpoint to the other one?
- Where should the two loudspeakers be positioned? Close to each other? Side by side? In a line? Behind one another? One on top of the other? At the opposite ends of the room? On the ceiling and floor? In a random position chosen by chance operations?
- Are the loudspeakers in a fixed position? Do they move? Who moves them? Do they swing or rotate?
- Which signal should be directed towards each loudspeaker? The same for both loudspeakers? The same one with different levels or slightly delayed in time? Or totally different signals?
- Is there any dynamic change in the signals sent to each loudspeaker? If so, are there other performer(s) sharing the spatialization task or is it done by the same performer as the one producing the sounds?
- If there is any panoramic motion, How does the controller for panning look like and how the performer interacts with it? Is it for example, by turning knobs, faders, joysticks, pedals, infrared sensors or any other custom controllers including motion tracking devices, or by mapping automatic processes such as a low frequency oscillators, sequencers, function generators or by programming an algorithm distributing the spectral content of one signal over the two loudspeakers, or by any other means of deciding which signal goes to each loudspeaker?
- What parameters should be available to distribute the signals among the two loudspeakers? Only dynamic level? Equalization? Time delay? Reverberation?

- Is the performer generating the sounds monitoring their performance from the same loudspeakers as the second performer (if any) or from a supposed audience (if any) or using headphones or other loudspeakers reproducing the same signals but in the near listening field to the performance set?
- Does the process that originates the sound simultaneously produce *spatial* information to be mapped to the loudspeakers?

Obviously, these questions have been addressed by many performers, musicians, engineers and researchers over the decades of electroacoustic tool development and research in spatial audio. For example, as noted by Nils Peters in his dissertation, similar questions must have been faced with the advent of multichannel microphone techniques as developed by "Blumlein (1931), (coincident microphone techniques) and Steinberg and Snow (1934) (spaced microphone techniques)".[177] Elaborating on the ideas of spatialization controllers presented by Andreas Pysiewicz and Stefan Weinzierl in the review of "Instruments for Spatial Sound Control in Real Time Music Performances" the above questions could be organized under different categories: the role of the performer, the number of performers, the loudspeaker setup, the controller type/interface, the controlled spatial parameters, the scope of control and the technique of spatialization.[178] From a practical pedagogical approach targeting improvised performance, I propose to isolate the loudspeaker setups, the interface for performing and the division of roles between generating sounds and their spatialization.

Zooming into the loudspeaker setup, there seem to be at least three possible scenarios: one with the maximum possible homogeneity among the loudspeakers (frequency response, dynamic response, total harmonic distortion); another where each loudspeaker is treated as a different timbre source with its own specificities; and a mixed system combining similar and heterogeneous loudspeakers. The homogeneity of the loudspeakers facilitates the rendering of *sound field synthesis*, such as *wave field synthesis* or *high order ambisonics*, and it is suitable to reproduce audio signals in stereo, quadraphonic, octophonic configurations and beyond. Relatively recent two-dimensional and three-dimensional arrangements proposed in the Atmos-Dolby setups recommend as well to match as much as possible the timbre of separate loudspeakers, including overheads and ear level loudspeakers.[179]

In the second scenario, the search for diversity of sound quality and timbre of each loudspeaker has resulted in *loudspeaker orchestra* configurations. In the sense of

177 Peters, Nils. "Sweet [Re] Production." PhD Thesis, McGill University, 2010.

178 Pysiewicz, Andreas, and Stefan Weinzierl. "Instruments for Spatial Sound Control in Real Time Music Performances. A Review." In Musical Instruments in the 21st Century, 273–296. Springer, 2017.

179 "Dolby Atmos 9.1.2 Speaker Setup." Accessed December 20, 2018. /us/en/guide/dolby-atmos-speaker-setup/9-1-2-setups.html.

Acousmonium-type of systems[180] and not in the sense of a *Virtual Symphony Orchestra* playing back through a set of loudspeakers arranged on stage simulating the symphony orchestra.[181] In this arrangement, the same signal sent to different loudspeakers definitely sounds different. In the tradition of electroacoustic music, this configuration is often played by hand in a mixing desk and consists of direct manipulation of spatial parameters, control over location and trajectories of sound sources, and relies on "the timbral characteristics of the different speakers interacting with the performance space."[182]

Neither system is exclusive. For example, different loudspeakers can be calibrated to match each other's timbral qualities through carefully measuring and adjusting the equalization and gain of each loudspeaker, making it possible to perform sound field synthesis rendering on a non-matching system. On the other hand, by judiciously working on the timbre of each channel a loudspeaker orchestra can be built from an array or similar units. Two loudspeakers of the same brand and same model can end up sounding totally different. It is also important to notice that the configuration of loudspeakers does not exclusively imply one technique of spatialization so that an octophonic ring can be used for ambisonics, or for amplitude-based panning, or for singular monophonic sources, or as a diffusion system for stereo materials.

The third scenario is a hybrid between the two previous: including matched loudspeakers in three dimensional or two dimensional geometrical configurations extended with loudspeakers with a lot of character, such as tweeters trees, subwoofers, directional loudspeakers, sound bars, rotating systems, prepared or enhanced loudspeakers typical from the loudspeaker orchestra.

Considering any of the loudspeaker setups discussed, I suggest experimenting with at least four performance interfaces because of their chance to be available in the framework of an electroacoustic improvisation workshop: a mixing desk, a multitouch tablet, a hacked or repurposed videogame controller such as a joystick, a Kinect (eventually a video-camera with a motion tracking algorithm) and an alphanumeric keyboard for entering the spatialization parameters in the form of live coding. A comprehensive and historical list of controllers for spatialization has been compiled by Pysiewicz and Weinzierl, including more than thirty different devices used in the context of sound spatialization. The list offer an informative overview of many creative solutions for controlling sound spatialization.[183]

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[180] Desantos, Sandra, Curtis Roads, and François Bayle. "Acousmatic Morphology: An Interview with François Bayle." Computer Music Journal, 1997, 11–19.

[181] Pätynen, Jukka, and Tapio Lokki. "Evaluation of Concert Hall Auralization with Virtual Symphony Orchestra." Building Acoustics 18, no. 3–4 (2011): 349–366.

[182] Austin, Larry. "Sound Diffusion in Composition and Performance Practice II: An Interview with Ambrose Field." Computer Music Journal 25, no. 4 (2001): 21–30.

[183] Pysiewicz, and Weinzierl. "Instruments for Spatial Sound Control in Real Time Music Performances. A Review." 273–296.

The mixing desk: the source signal can be duplicated either by analog or digital means and routed to available input channels, then using direct outs, auxiliary buses or submix outputs (eventually insert points), routing as many available channels for amplification and loudspeakers as possible, so that the faders or knobs from the mixer controls the level of each loudspeaker (multichannel sources are of course possible, but it is wise to grow in complexity one step at the time until suitable fluency with the system is reached). Annette Vande Gorne has extensively worked on and systematized the performance gestures at the mixing desk.[184] Her techniques include carefully use of the *mutes/solos* buttons, grouping faders and organizing the layout of the mixer for smoothly making transitions between different configurations as well as fast dramatic changes, rapid accentuation of loudspeakers, repetitive oscillations between groups, sudden jumps, accumulating planes and layers and different trajectories: circular, spiral, front-back, back-front, in-out. Vande Gorne's approach requires practice, dexterity and familiarity with the mixer and its components. Her compilation of gestures is an excellent start point for further experimentation and developing of personal techniques at the mixing desk.

A multitouch tablet can be programmed with a graphical interface that sends messages via Open Sound Control or MIDI protocol to a host machine (some mixers will support either one or the other) or to a dedicated host computer with a multichannel audio interface. The mapping could implement direct mapping on trajectories, levels and mutes in an amplitude-based panning algorithm, for example. The interface can be designed to have different modes, such as moving sound sources among the speakers, spreading the signal by growing the graphical representation of the source, or drawing trajectories that repeat recording and play-back gestures. The graphical interface can be inspired on a physical mixing desk or represent the physical space of sound diffusion or even create an abstract allegory of the listening space.

Using video game controllers requires the performer to program a layer of mapping space parameters to the available data from the controller. For example, affecting the position of a joystick or a target object (motion tracking/kinect) can result in affecting the azimuth, distance and elevation of a spatialization algorithm.[185] The correlation between performance gesture with video game controllers and resulting sound movement should be investigated further. For example, by inverting the mappings or by measuring the amount of movement, or

[184] Gorne, Annette Vande. "L'interprétation Spatiale. Essai de Formalisation Méthodologique'." Démeter, 2002.

[185] My colleague Dom Schlienger has developed a system for "spatially interactive audio applications" based on acoustic localisation. His system work as an alternative to visual tracking solutions and facilitate the integration of acoustic instruments/sources into the control paradigms of spatialization.
Schlienger, Dominik. "Acoustic Localisation for Spatial Reproduction of Moving Sound Source: Application Scenarios & Proof of Concept." In International Conference on New Interfaces for Musical Interaction, 2016.

by creating instructions that result in movements such as moving the controller back and forth, and left and right can result in a centrifugal sound motion. Creating mappings of physical gestures to sonic trajectories requires inventiveness and clever solutions to optimize the accuracy and reliance of the system.

Finally, the use of live code techniques to generate scripts allows direct interaction with the spatialization algorithm, for example, to enter very precise values for the parameters and schedule tasks with extremely accurate precision.

From the experiments suggested above, it is obvious that it is not an easy task to control the spatialization while generating sound material. Splitting or sharing spatialization tasks is a formidable way to develop coordination, understanding and intuition to pair musical intentions among the sound generator musician(s) and the one(s) taking care of the distribution of sound in the space. All the possible configurations are full of potential; one musician performing the sounds and one performing the space or many performing sounds and one taking care of the spatial parameters or even more, one producing sounds and many creating a spatial choreographies, and of course many producing sounds and many others playing with the space. In the case of a solo performance, the solution could be perhaps to use preprogramed trajectories to be triggered by similar gestures to the ones creating the sounds or to integrate the spatial dimension in the sound synthesis process, for example, a polyphonic multichannel granular synthesizer with a parameter to spread, center and rotate the grains in an array of loudspeakers.

Mapping strategies

When designing instruments for electroacoustic improvisation the mapping strategy between the exposed controls at the user interface (also known as the input device, gestural controller, control surface, hardware interface) and the synthesis engine can bring new perspectives on performance but can as well turn an exciting concept of an instrument into a very musically uninteresting or dull interface. Therefore, particular attention should be placed on the mapping system. Mapping strategies can be very different, and it is essential for the designer and the performer to be aware of the choices. In the article “Mapping performer parameters to synthesis engines” Andy Hunt and Marcelo Wanderley, while reviewing the literature on mapping strategies, isolate two main directions: explicitly defined mappings and dynamically or generative created mappings.[186]

Considering two data sets of gesture control and synthesis parameters, explicitly defined mappings take different forms: one-to-one, one-to-many (divergent map-

[186] Hunt, Andy, and Marcelo M. Wanderley. “Mapping Performer Parameters to Synthesis Engines.” Organised Sound 7, no. 2 (2002): 97–108.

ping), many-to-one (convergent mapping), many-to-many.[187] After relating the two data sets, it is necessary to choose as well the type of interpolation, range and the function to map values from one domain to the other. For example, a linear slider affecting the volume could map MIDI values from 0-127 with an exponential interpolation into the loudness range of -60db to -20db. Experiments carried out by Hunt and Wanderley revealed how depending on the performer experience, and expectations different mappings strategies from complex to obvious were preferred and how a pedagogical dimension appeared by coupling different gesture parameters or deconstructing the mapping. [188]

A dynamic mapping system means that the instrument can adapt, change and mutate its behavior according to an algorithm, state, pre-programmed progression or by stochastical means. Dynamic mappings can be very well thought for example by demanding more physical resources from the performer while reaching complexity levels, so generating emotional reactions on the performer. It can be as well a refreshing way to rediscover an instrument or a set. Hunt and Wanderley described three different application using neural networks to drive the mapping of three distinct instruments that could be used as an inspiration to develop or implement these fascinating ideas.[189]

Mapping is then a crucial point to consider while developing a performance set, and there is a lot of fine-tuning, research and experimentation to be done by the musicians and designers to cover the possibilities and affordances offered or hidden in each controller and synthesis engine.

Conclusions

In this overview of Electronic Instruments for Performance and Improvisation, I have presented performers with a pool of possibilities and ideas for experimenting, exploring and expanding their performance set. By introducing a selection of instruments from the ever-expanding electroacoustic instrumentarium, I have sought to cover the fundamentals of approaching the electroacoustic discipline with a fresh regard of the tools of the genre. Finally, in the tradition of *getting your hands dirty* and building your own set, I have tried to communicate my deep love for the performance practices of researching the potential performance

[187] Rovan, Joseph Butch, Marcelo M. Wanderley, Shlomo Dubnov, and Philippe Depalle. "Instrumental Gestural Mapping Strategies as Expressivity Determinants in Computer Music Performance." In Kansei, The Technology of Emotion. Proceedings of the AIMI International Workshop, 68–73. Citeseer, 1997.

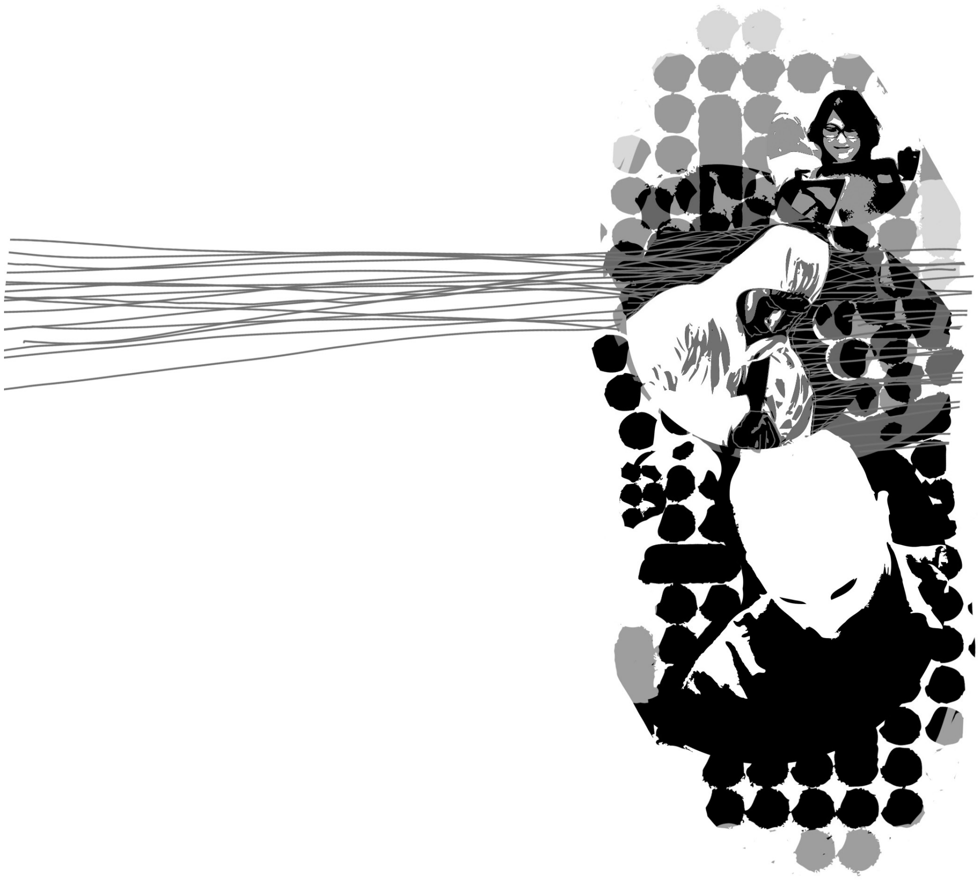
[188] Hunt, Andy, Marcelo M. Wanderley, and Matthew Paradis. "The Importance of Parameter Mapping in Electronic Instrument Design." Journal of New Music Research 32, no. 4 (2003): 429–440.

[189] Hunt, Andy, and Marcelo M. Wanderley, 2002.

aspects of electronic devices, coding Digital Signal Processing and exposing ourselves as musicians to the fascinating world of electronic experimentation.

Part II

Toolkit Units



5

Sonic Elements

5.1 The Canvas – Silence

A performance exercise to create awareness of the potentialities of very low sound levels to create a silence canvas, an acoustic space for a listening experience.

5.1.1 Tags

Loudness, dynamics, silence.

5.1.2 Goal

This task is intended to enhance the listening in a collective playing situation by forcing both overall and individual sound levels to be as low as possible. Performing at the softest possible volume enables the listener-performer to appreciate and focus on the details of each musician's performance. The detailed listening will reveal aspects of the sound of the group as a whole and will stimulate forbearance in each performer, simultaneously allowing the creation of sonic and performative spaces where music and sounds can live comfortably without struggling to be heard. A consequence of this task should be a deeper understanding of the dynamic control and possibilities of the instruments; each instrument should be adjusted to be able to play at the low energy end of the sound level. If this is not possible, the instrument is not suitable for the task.

5.1.3 Description

All the musicians start an improvisation playing pianissimo simultaneously; when one of the musicians notices that he or she is playing louder than somebody else, he or she must decrease the volume below the other person's level and continue performing while permanently adjusting the level to avoid playing louder than anyone else in the group.

Obviously, the music should gravitate towards silence since each musician is trying to play under the volume of the others. However, total silence is not the goal. Instead, a subtle crystal pianissimo like a *Silence Canvas* should emerge from the performance.

5.1.4 Variations

The silence canvas concept can be explored by imposing restrictions on the sonic material used. For example, continuous sounds, granular textures, bursts of attacks, inharmonic sounds, noises or pure tones will produce completely different results. Experimenting with the sonic material and intensifying the listening of the quiet volume and soft sound levels may suggest turning off the amplifiers and continuing with acoustic and mechanical sources or even taking the sources away and reducing the experiment to the performer's body sounds, how far could we go? listening to each other's blinking eyes? Does the listening focus change if the amplifiers are switched on again?

Another area of possible exploration consists of reducing the focus of attention on the whole group (i.e. trying to never play louder than anybody else) to fixing the attention on a single member of the band (i.e. never playing louder than x or y performer). In this manner, it is possible to investigate the subtle shift in perception that occurs when moving from a listening experience of the band as a whole to a more discriminating and selective listening experience.

Exploring the location of the musicians and the sound sources in the room will introduce new challenges and aspects to experiment. While proximity may help to build in the subtleties of the task, spreading the sound sources in the room and keeping the individual and overall volume low will be more demanding and will require extra concentration. Another step could be to invite some persons to be the public, which will inevitably increase the noise floor and could potentially make it more difficult to listen to the other members of the band.

5.1.5 Discussion

After the task proposed in this chapter, some concepts can be studied and discussed. Let us start with Signal-to-noise Ratio (SNR). SNR is defined as “the logarithmic power ratio of the signal and noise and typically expressed in dB.”[1] SNR informs us about the amount of noise introduced or presented in a system. Every electronic instrument has a noise level; it can range from very noisy devices such as amplifiers built around vacuum tubes to very silent high fidelity systems. That system’s noise can be revealed by turning up the gain while injecting no or very little input signal. Beyond the electronics, it is also possible to experience the noise floor of a room by focusing on it. Even further, as the exercise suggests, focusing on our inner being, guiding our inner listening, may also help us to learn about the “system noise” present in our body and mind. In the idea of the silence canvas, I propose to explore the proportion of audible signals just above the inherent noise of electronic instruments.

Another concept that naturally arises from this discussion is *Dynamic Range* (DR or DNR), which is another ratio measured in decibels, this time between the largest and smallest values of a variable quantity, such as sound.[2] In musical terms, this is a very well-known and studied parameter. Musicians master a large dynamic range from the very subtle pianissimo to the impetuous fortissimo. The dynamic range has been pushed in both directions (quietness and loudness), making popular standard notations such as “pppp” or “pppppp” and “ffff” or “fffff” (pianississississimo and fortississississimo). In electroacoustic music, the dynamic range is not limited by the physical capacities of the musician but by the dynamic qualities of the system and by sharp, critical and sensitive listening. Adjusting the levels and controlling the dynamics while performing electronic instruments may feel as simple as turning a knob or a fader. However, a well-balanced mix and subtle volume management require focused listening and the acquaintance with the sound qualities of amplifiers, speakers, mixers, converters, microphones and all parts of the electroacoustic chain.

The Dynamic Range for human hearing is very large and depends on different particular and subject-dependent conditions such as health, listening environment, motivation, nature and features of the stimulus: semantic, lexical, syntactic, and emotional.[3] In a broad sense, for the purpose of establishing a loose reference, it can be said the Human Dynamic Range extends from the hearing threshold (around -9dB SPL at 3 kHz) up to the pain threshold (from 120–140dB SPL , without protection), Approximately 100dB range (frequency dependent) in nor-

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[1] “ADC and DAC Glossary – Tutorial – Maxim.” Accessed August 15, 2018. `https://www.maximintegrated.com/en/app-notes/index.mvp/id/641`.

[2] Ibid.

[3] Gelfand, Stanley A. Hearing: An Introduction to Psychological and Physiological Acoustics. CRC Press, 2017.

mal conditions.[4] One can appreciate how the development of technology throughout history has expanded the useful Dynamic Range in electroacoustic equipment. For example, magnetic tapes from the 1950s had a useful range of 60dB. Today, 24-bit digital audio calculates to a 144 dB dynamic range, and computers process audio with a 64-bit floating point resolution that has increased that range considerably. These values mean that electronic instruments can dynamically cover the full range of human hearing; as a consequence, the study of the Dynamic Range in electronic instruments should focus on crafting the subtleties and mastering critical listening instead of trying to expand the limits. That is the purpose of the task introduced in this subsection: to create a listening attitude towards the details while demanding full concentration and decision-making on the handling of individual and overall volumes.

This chapter can be seen as an invitation for performers to experiment with the concepts of *Just Noticeable Difference* in sound level and thresholds of perception. "The Difference Threshold (or 'Just Noticeable Difference') is the minimum amount by which stimulus intensity must be changed in order to produce a noticeable variation in sensory experience."[5] As John Sloboda remarked, factors such as the focus of attention in a musical context can challenge the relevance of experiments attempting to define Just Noticeable Difference values of general validity.[6] Therefore, experimental and empirical research should eventually produce practical, useful and applicable results in the context of sound performance. Other aspects of the Dynamic Range will be explored and discussed in section 6.1

5.1.6 Implementations

A fantastic device to work within the context of this chapter is an analog comparator. A comparator can be used as a level crossing detector, allowing for triggering and gating events on the basis of instantaneous analysis of signal levels. I suggest to either build one or integrate one in a synthesizer patch.

> An analog comparator is basically an amplifier without feedback and thus has very high gain.[...]Typically an analog comparator compares voltage levels on two inputs and gives digital output based on the comparison.

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4 Sherlock, LaGuinn P., and Craig Formby. "Estimates of Loudness, Loudness Discomfort, and the Auditory Dynamic Range: Normative Estimates, Comparison of Procedures, and Test-Retest Reliability." Journal of the American Academy of Audiology 16, no. 2 (2005): 85–100.

5 "Weber's Law of Just Noticeable Difference." Accessed August 15, 2018. `http://apps.usd.edu/coglab/WebersLaw.html`.

6 Sloboda, John A. The Musical Mind: The Cognitive Psychology of Music. Oxford University Press, 1985. 151-156

When the voltage on the positive input (Vin0) is greater than the voltage on the negative input (Vin1) then the output voltage (VOUT) is saturated to its positive supply (+VSUPPLY), otherwise the output is saturated to is negative supply (-VSUPPLY). In microcontrollers, since there is no negative supply voltage, GND (ground level) is taken as –VSUPPLY and VCC level is taken as +VSUPPLY. [7]

† Build or program an instrument using the ideas of Noise Gate and sound compression according to the concepts presented in this chapter. Eventually, mapping thresholds, limits and ratios to exposed controls or automatic transformations to produce or process sounds. Imagine an instrument that changes its behavior according to the input levels. Often a noise Gate is used to automatically close a line or a microphone when the signal is below a certain level, but how could this idea be reversed and used as the basis of an instrument?

† Write a program that analyzes the amplitude of an incoming signal and applies a subtraction to this value of 1, 2 or 3 dB and a delay of 1 or 2 sec. Then, map this new value to control the amplitude of a noise generator, synthesizer or sample player. Explore the responsiveness and the accuracy of the software while always aiming to play below the output level of the program.

† Write a program that plays two different sounds that react to the level of an incoming signal. The two sounds are mapped to the upper or lower level of a hand-adjusted limit. For example, on a scale of 0-1, determine the boundaries of 0.2 and 0.8. Playing sounds under 0.2 will play a different sound than sound at 0.9. If the goal is to keep the program silent, explore reducing the boundaries and moving towards the lower end. How much compression can you handle on your dynamic range? Are 0.01 and 0.1 achievable limits?

[7] "AN_42473 AT11480: Analog Comparator Application Examples | Application Notes | Microchip Technology Inc."
Accessed August 15, 2018.
www.microchip.com/wwwAppNotes/AppNotes.aspx?appnote=en590888.

5.2 The Point – Transients

Performing a single sonic point as a whole composition.

5.2.1 Tags

Attacks, transients, attentional blink.

5.2.2 Goal

The goals of this task are: to develop techniques of fast dynamic control, to reflect on performance issues such as reactivity, synchronicity, the use of silence as a means of expression and forbearance as an improvisation value. The exercise can be used as well as a tool to encourage the study and appreciation of transient sounds and to approach the matter of the thickness of the present.

5.2.3 Description

The performers are required to play only one attack type of sound within a predetermined or undefined duration. When choosing a fixed duration framework, the length of the task can range from one to several minutes; alternatively, when working within an undefined duration, the exercise ends when every performer has played. The minimum recommended duration of the exercise is one minute.

Particular attention should be placed on focusing on and sensing the right moment to play. The task can be understood as a musical piece made out of a few exquisite sounds collectively composed.

5.2.4 Variations

With a group, it is fascinating to study two different versions of the task: looking for simultaneity or not. The attack sound may or may not be performed at the same time by all the members of the group. For the first case, synchronicity requires a mental state of alertness, concentration and sufficient dexterity with the instrument to be able to react as quickly as possible to play when any of the other members of the group has decided to play. Instantaneously playing an attack together might require a strategy. Visual contact, through visual cues and reading body language may come as an intuitive approach to deal with the task; however, fixing the attention and the concentration on someone else's visual prompts can possibly detract from the listening concentration. To find alternative strategies it can be proposed to perform the whole task with eyes closed.

In the second case, when performing the attack-sound without aiming to play simultaneously with other members of the band, the performer can concentrate on choosing carefully the appropriate moment to perform. This attitude should result in a very silent and sonically empty performance. Sometimes the absence of sound for extended periods of time may cause feelings of distress among musicians who are eager to play. A discussion around the concept of *forbearance* can then be introduced. Self-control and patience are precious qualities that can help musicians identify and support the arrival of a solo or a subgroup moment during an improvisation. Practicing with short sounds will also provide tools and inspiration to find performance alternatives to the never-ending droning sounds typical of electronic instruments.

Choosing the right moment to play is, of course, a very subjective decision that requires attention and concentration in the situation. By repeating the exercise, the performer can explore different mental states that occur when the decision to play arrives too fast or too late; for instance, the sound can be played immediately at the beginning of the task followed by a deep resonance in silence (mentally prolonging the sound) until the end, or the sound can be played towards the conclusion by preparing with a very long anacrusis. These mental states can involve some form of shifting in the listening mode between a contemplative and a performative one. After identifying different listening modes, it is worth experimenting with keeping one throughout the exercise.

Another possible interpretation of the sonic point is to consider it as a source point of sound, so that only one loudspeaker reproduces and diffuses the sounds of the whole band. All instruments must be mixed down to a mono signal and routed to a single channel of amplification. It is interesting to experiment for example with free improvisation material. Many observations can be made about sharing the *electrical space* of one loudspeaker. Do performers manage to hear each other? Is it possible to overcome the feeling of frustration of losing the autonomy and power of individual amplification? To what extent can the loudspeaker render with acceptable fidelity the details of the information transmitted to it? Where should that single source be: in the center, in front of the band, pointing towards the ceiling, moving, bouncing?

5.2.5 Discussion

> The geometric point is an invisible thing. Therefore, it must be defined as an incorporeal thing. Considered in terms of substance, it equals zero.

> Hidden in this zero, however, are various attributes which are 'human' in nature. We think of this zero—the geometric point—in relation to the greatest possible brevity, i.e., to the highest degree of restraint which, nevertheless, speaks. Thus we look upon the geometric point as the ultimate and most singular union of silence and speech. [. . .] The sound of that silence customarily connected with the point is so emphatic that it overshadows the other characteristics.[8]

A point in geometry is a location, it has no width, no length, no depth, is a zero dimensional mathematical object.[9] A point is a primitive notion, an abstract concept of mathematics difficult to visualize.[10] It is not extended in space or time, therefore it cannot contain anything. Euclid originally defined the point as 'σημειον εστιν, ου μερος ουθεν' "that which has no part."[11] This abstract geometrical-mathematical notion with non-physicality other than our consciousness is the foundation of Euclidean geometry. However, in physics a point must be understood as a non-non-zero charge or mass. For example, in classical electromagnetism, electrons are idealized as points with non-zero charge. This duality of abstract concept and physicality should be reflected though the exercise proposed here exploring the notion of a *Sonic Point*.

A Sonic Point can be understood as well as an abstract concept, which is projected in the physical world by the intentions of the performer as mechanical waves in the forms of clicks and impulses. The materialization of the sonic point as a perceptual stimulus involves performing extremely fast, sharp and short sounds. As a mental object, the Sonic Point is free of the constraints of chronological time but is trapped by the consciousness which is thinking it. As a perceived element, the Sonic Point has an infinitesimal duration bounded within the flow of time. How short that duration can be is a matter of experiment, practice (to perform and to perceive it), instrument-tuning and the equipment for automatic or hand triggering: in all cases there is a threshold in our perception system.

Let us consider for example the Unit Impulse. In Signal Processing, the Unit Impulse is an analogy of the geometrical point "the Dirac delta function, or δ (singular) function, is a generalized function, on the real number line that is zero everywhere except at zero, with an integral of one over the entire real line. The delta function is sometimes thought of as an infinitely high, infinitely thin spike

[8] Kandinsky, Wassily. "Point and Line to Plane (1926)." Kandinsky: Complete Writings on Art, 1947, 527–699.

[9] Walling, Peter T., and Kenneth N. Hicks. Consciousness: Anatomy of the Soul. AuthorHouse, 2009.

[10] Huleihil, Mahmoud, and Huriya Huleihil. "Digital Text Based Activity: Teaching Geometrical Entities at the Kindergarten." In Intelligent Interactive Multimedia Systems and Services, 99–112. Springer, 2011.

[11] Heath, Sir Thomas L. The Thirteen Books of Euclid's Elements: Translated from the Text of Heiberg with Introduction and Commentary. University Press Cambridge, 1908.

at the origin, with a total area of one under the spike, and physically represents the density of an idealized point mass or point charge".[12] In an analogy of such "improper function",[13] if a software writes a sample at the maximum amplitude in an audio buffer zeroing all the other samples, the Digital to Analog Converter circuitry will produce a signal presenting *ringing artifacts*: amplitude lobes due to the hysteresis of electronic components and other analog signal processing factors.[14] Every loudspeaker with its own sonic qualities and physical properties will react differently to the *one sample* at maximum amplitude (Unity Impulse) experiment, revealing its own frequency response.

Performing with those single-sample signals will eventually drive the experimenter to accept the clicks as attacks of a non-resonating sound object involving a slightly longer lifetime. There is an incredible universe of possibilities exploring the qualities of such extremely short sounds, and the task to perform one sonic point should be as precise as the sword of a Samurai. Think of how many variations of the universe could exist if the qualities of the Big Bang were affected!

While crafting extremely short sounds of an infinitesimal duration questions about the definition and perception of the *present* can be raised. In theory, a very sharp and narrow sonic event can be programmed in a modern Digital to Analog Converter exceeding the *zero time* of perception or the threshold in our human neurophysiological perceptual system. Such a sound event should be inaudible to our ears.[15]

Minimal temporal acuity cannot be expressed in a definitive and unequivocal number. Researchers such as David Green have concluded that the shortest time interval within which the ear can detect, discriminate and discern the order of auditory events, is about one or two milliseconds.[16] While reviewing the literature and research of *microtemporal auditory acuity* Roads points out that events in the order of microseconds "can be distinguished on the basis of amplitude,

[12] Li, C. K. "The Powers of the Dirac Delta Function By Caputo Fractional Derivatives." Journal of Fractional Calculus and Applications 7, no. 1 (2016): 12–23.

[13] Bueno, Otávio. "Dirac and the Dispensability of Mathematics." Studies In History and Philosophy of Science Part B: Studies In History and Philosophy of Modern Physics 36, no. 3 (2005): 465–490

[14] Hewitt, Edwin, and Robert E. Hewitt. "The Gibbs-Wilbraham Phenomenon: An Episode in Fourier Analysis." Archive for History of Exact Sciences 21, no. 2 (1979): 129–60.

[15] For example, the DAC AK4493EQ performing at a sample rate of 768Khz will have a duration per sample of about one microsecond) (Asahi Kasei Microdevices Corporation) "AK4493EQ | Product | AKM – Asahi Kasei Microdevices." Accessed October 11, 2018. `https://www.akm.com/akm/en/product/datasheet1/?partno=AK4493EQ/&link_id=link5020`.

[16] Green, David M. "Temporal Auditory Acuity." Psychological Review 78, no. 6 (November 1971): 540–51.

spectrum, and spatial position".[17] In an electroacoustic music studio with average modern tools, it is difficult or even impossible to carry out such experiments due to the physical limitations of audio equipment. Consider for example the attempt to play one-and-only-one sample at the sample rate of 192Khz, which is about 5.2 microseconds. Sending such a signal to the loudspeakers will make it acoustically vibrate and resonate at its own resonant frequencies, producing an impulse response of the loudspeaker that at certain frequencies will expose longer durations of the order of tenths of milliseconds and even beyond. Not a 5.2 microsecond sound event.

Even if it is impossible or unrealistic to transgress the limit of temporal acuity in the perceptual system, the concept of *now* or instantaneousness or present can be researched more in depth through electroacoustic performance. For example, considering psychological, conscious and unconscious processes with social and intersubjective interactions, the notion of *thick present* falls at the center of this discussion. Poli Roberto considers this notion in his article "Steps Toward an Explicit Ontology of the Future."

> The present can no longer be considered a kind of durationless interface between the past and the future, as an infinitely thin boundary between what has been and what will be. On the contrary, the idea is gaining acceptance that the present has both some duration and some depth – and therefore a rich and multifariously complex series of structures.[18]

The present includes immediate and remote pasts, living memories of what has happened and projections, expectations, protentions of a future anticipating what is going to happen. This multidimensional time structure is what gives depth to the present, as explained by Merleau-Ponty "time is not a line, but a network of intentionalities."[19]

Performing infinitesimal time is an opportunity to reflect, research and observe our temporal consciousness, developing the training of attention and preparing the subconscious reflex to hold the past and to foresee the future, to expand the thickness of an expanding present that can be sliced at any moment by a sonic point.

Iannis Xenakis is credited by Curtis Roads to be the first to explicate a compositional theory for grains of sound. Xenakis began by adopting the following lemma: "All sound, even continuous musical variation, is conceived as an assemblage of a large number of elementary sounds adequately disposed in time. In

[17] Roads, Curtis. "The Perception of Microsound and Its Musical Implications." Annals of the New York Academy of Sciences 999, no. 1 (November 1, 2003): 272–81.
[18] Poli, Roberto. "Steps toward an Explicit Ontology of the Future." Journal of Futures Studies 16, no. 1 (2011): 67–78.
[19] Merleau-Ponty, Maurice. Phenomenology of Perception. Routledge, 2013. Pp. 417

the attack, body, and decline of a complex sound, thousands of pure sounds appear in a more or less short interval of time."[20] Xenakis created granular sounds using analog tone generators and tape splicing. These appear in the composition Analogique A-B for string orchestra and tape (1959).[21] Curtis Roads has extensively worked at programming, analyzing and composing with *Sonic Grains* or *Microsonic Particles*.[22] In his article "The Perception of Microsound and Its Musical Implications", Roads studies the perceptual qualities of microsounds, he writes:

> Sound particles or microsounds last only a few milliseconds, near the threshold of auditory perception. We can easily analyze the physical properties of sound particles either individually or in masses. However, correlating these properties with human perception remains complicated. One cannot speak of a single time frame, or a 'time constant' for the auditory system. The hearing mechanism involves many different agents, each of which operates on its own timescale. [...] The perception of microsounds in a musical context is intertwined with cognitive functions, both rational and emotional, that resist understanding from a scientific point of view.[23]

From Roads's research, several relevant observations emerge.

First, a threshold of perception seems to appear around durations of 1 ms. This limit was also observed by Gabor while defining what he called *Sound Quanta* or sound particles of a time scale of the order of 1-100ms. According to Roads "for events that last less than about 1ms, many mechanisms of sound recognition break down, relegating these events to subsymbolic status" Microevents shorter than 2ms "as heard as click" but timbre variations are still recognizable (Auditory Acuity).

Second, for the limits of temporal perception, the measurements are complicated since changing the duration of a sound simultaneously changes its spectrum. Nonetheless, stimuli lasting less than 200 ms involve a different mode of hearing, affecting intensity, fusion/fission and pitch. "short sounds must be much greater in intensity than larger sounds in order to be perceptible". *Forward masking* is a phenomenon where a second onset will be masked by a former one if they are followed by less than 200 ms, "when the onsets are spaced by less than 50ms (rate of 20Hz), human perception reaches 'attentional limits' and groups the successive events". "The time needed to recognize the pitch of a tone is dependent on the

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20 Xenakis, Iannis. Formalized Music: Thought and Mathematics in Composition. 6. Pendragon Press, 1992.

21 Roads, Curtis, and John Strawn. The Computer Music Tutorial. MIT press, 1996.

22 Roads, Curtis. Microsound. MIT press, 2004.

23 Roads, Curtis. "The Perception of Microsound and Its Musical Implications." 272–81.

tone's frequency", the range between 1000Hz and 2000Hz are where the pitch sensitivity is the greatest.[24]

Third, microtemporal localization: "for brief Gaussian tonebursts, the horizontal localization blur is in the range of 0.8° to 3.3° depending of the frequency of the signals". The last point is about the idea of *Subliminal Perception* of stimuli that are beyond the limits of perception but cause reactions in the nervous system.[25]

These points can give the performer ideas of how to perform one and only one sonic micro event. The function enveloping the sound, the exact duration, intensity, spatial localization, spectral content and the microstructure are extremely co-dependent factors contributing to the perceived sonic quality of the event and should be mastered through experimentation.

Performing the Silence

By temporally isolating the sounds, this exercise reveals the durations and qualitites of silence. The task can lead to research on various attitudes during the silence, thereby introducing a reflection and discussion about the potentialities and qualities of performing silence, such as by focusing on closing the eyes, which is a powerful performance tool to induce the audience to concentrate on listening, or by fixing the view into an invisible spot (think of the regard of the opera singer). Other performance attitudes can relate to curiosity, for example, by doing sharp short head movements, such as by some animals in a state of attentiveness to danger, or anxiousness by self-imposed tics or even boredom by overstaying a resting position. Exploring body language in a silent performance increases the awareness of how much emotion and meaning can be communicated by the performer beyond the sound. Thinking and discussing the performers' body and the performance of silence could eventually bring the listening experience of the performer to unexplored or unconscious territories.

Sonic developments

The suggested type of sound for this activity is a very short attack with or without resonance, the purpose of which is to avoid discursiveness and to stimulate the forbearance of the musician and the research into the short sounds. However, many other interesting results will drive the performance while taking liberties in the sound typology. Starting from the extreme: reducing the attack to its shortest possible temporal existence brings up ideas about synchronicity and simultaneity. Experience has shown that with enough work, synchronicity in a

[24] Ibid.
[25] Ibid.

small group could be achieved without visual cues. Expanding the sustain and release envelope on the sounds opens up issues about micro-formal and micro-structural analysis. While staying in the realm of microsounds, it is possible to *compose* the inner structure of the microsound with micro-phrases or micro-sequences, out of short bursts of spikes or different stages of clicks, clacks or ticks. How far to go? I recommend for the *Sonic Point* activity to limit the sounds between the *one-sample* sound to a maximum of a single short sonic gesture that does not exceed a breathing cycle in duration: inhale-exhale-apnea associated with prepare-attack-resonance-silence. The morphology of the gesture should reduce to the minimum progressions, changes or developments so as to focus all the attention on the qualities of a microscopic, infinitesimal time.

Taking freedom in the temporal interpretation of the *sonic point* by increasing the number of attacks and diversifying their temporal relations among them will take us close to the work of John Stevens in his *Click Piece*, where every musician performs short repeated sounds in their own rhythm. *Click Piece* feels like a natural development from the *sonic point.* Different in intention from the experiment initially suggested here the *Click Piece* shifts the attention from performing a unique sound into performing a more dynamic and organic crackling texture.[26]

5.2.6 Implementations

† Code: Using transient detection, write a program that reacts to attacks by playing a short sonic event, and if the silence goes beyond a certain threshold, the program can decide to play another attack to which the performer should play synchronously.

† Circuits: Experimental research can be carried out as well with digital pins in a microcontroller. The threshold when the pin is "HIGH" and "LOW" can be carefully set and controlled to create an impulse. That time between the two states can be of the order of microseconds (one millionth of a second) and will produce a sharp attack and release. The resulting sound sharpness is determined by the analog components of the circuitry behind the microcontroller to convert the electric impulse to audible sound. This digitally generated impulse can be used to trigger other circuits like for example resonant low pass gates. Developing different times for the rising and falling of the amplitude and the curve of the function varying the amplitude levels has led to experiment with function generators in the analog domain or with digital to analog converters in the digital domain. I suggest experimenting as well with capacitors and logic gates as a way of triggering asynchronous rhythmic events significantly spaced in time to develop a training instrument (or patch) to practice synchronicity with a non-human agent.

[26] Stevens, John, Julia Doyle, and Ollie Crooke. Search and Reflect: A Music Workshop Handbook. Rockschool, 2007.

5.3 The Line – Monophony

A performance task of musical and sonic continuity, performing a collective monophonic electroacoustic instrument.

5.3.1 Tags

Monophony, continuity, discontinuity

5.3.2 Goal

The goal with the task proposed in this chapter is to train players on how to entertain a musical and sonic line, for example, carefully avoiding overlaps, reducing gaps, and ensuring musical and sonic continuity. This task should improve the attentiveness and focused listening of the performers to follow a musical intention and sonic material, as well as develop reflexes to continue a solo initiated by somebody else at any moment. Decisions about when to start, interrupt, shift or stop should be taken without hesitation, which increases the sense of confidence among the players.

5.3.3 Description

One performer starts playing a solo and continues improvising until another performer decides to start playing in the same musical and sonic spirit. As soon as the new solo begins, the previous performer should immediately stop, avoiding any overlap. If two players start at the same time, one of them has to drop out in a fast, intuitive negotiation process. If the first soloist decides to stop, one of the other members of the group must jump in and continue the improvisation, avoiding musical and sonic gaps.

The activity should be understood as a collective performance of a sonic line with a joint monophonic instrument that maintains the continuity of the sonic material from one performer to another. silences, breaks, ruptures, and rests have to be treated so as not to disturb the musical and sonic flow. The activity ends when all the members of the group have played once or when a predefined time has been reached. Other than reading the musical intentions, it is essential for each performer to carefully follow the development of sonic material during each solo to keep the continuity. Choosing the right moment and the suitable material to join must allow the performers to shift from one solo to the next.

5.3.4 Variations

Experiments can be carried by addressing the rate of change: How often can a new solo start? Is it a regular process? How to create irregularities without breaking the line? Can randomness and surprises be intentionally increased? By increasing the speed of the task and keeping the rule of sonic continuity and timbre-bending, the performers have to prepare, adapt and react to changes in the sonic material in a quicker way, training dexterity with the instruments. The order of interventions can be fixed or predefined, allowing them to focus on the goal of gradually increasing/decreasing the speed of change.

The content and the materials of each solo can be explored to introduce different issues that come with the complexity of the material. For example, an experiment can be done to try to carry one sound with the minimum possible variations through the different instruments; thus limitations are imposed on the vocabulary of the solos but the morphing between instruments is facilitated. Other versions can involve contrasts or opposition in the sonic material and musical intentions from performer to performer, for example, joining by opposing.

When performing only with electronic instruments, a variation of the task will consist in distributing all the band signals into an array of loudspeakers placed in a continuous straight line in front of the band. Either a straight line or a semicircular, concentric or eccentric curve, surrounding or pointing towards the performers. Four loudspeakers will do it, but the optimal is to assign one loudspeaker per performer. Playing in front of a line of loudspeakers can create interesting situations and raise questions about the dislocation of sources and signals in space, while simultaneously raising the issues of how and where a potential audience should be placed. Do performers use a system of stage monitors (wedges)? Should the loudspeakers used as reinforcement for public amplification be the same than the musicians' monitoring system? How is the listening experience with respect to clarity and identification of who is doing what within this placement?

5.3.5 Discussion

A line is another primitive object in Euclidean Geometry: 'γραμμὴ, δὲ μῆκος ἀπλατές'"A line is a breadthless length".[27] From the mathworld website source: "A line is a straight one-dimensional figure having no thickness and extending infinitely

[27] Heath, Sir Thomas L. The Thirteen Books of Euclid's Elements: Translated from the Text of Heiberg with Introduction and Commentary. University Press Cambridge, 1908

in both directions".[28] For another Greek mathematician, Sextus Empiricus the line is generated by the motion of a point 'ῥύσις σημείου'.[29]

The idea of a geometrical line can be put in relation to other concepts in the sonic domain. For example, monophony, continuity, sustained pitch, drone. If a "Sonic Point" is linked to the attack of a sound or to an instantaneous unity amplitude, the "Sonic Line" will be an infinitely expanding and unfolding sound in the time dimension. In the physical realm of sound, we must acknowledge an infinitesimal duration to the sonic point because a zero-time would confine the notion to the mental world in a subjective experience. In the same way, the sonic line extending infinitely in both directions over time is an abstract concept difficult to grasp and to use in performance because acoustic sounds have a beginning and end. Sounds are time-bound and have a finite lifespan. Nonetheless, having never had a physical experience of true, absolute silence (including repeated visits to anechoic chambers, using high quality damping earphones and dreams), I can conceive of this musical experience as a kind of temporal bubble emerging from the continuous infinite *hum*.

The ideal sonic line coming from the eternal past and extending into an eternal future in which musical moments surface is a concept that can be linked to improvisation practices and movements from the late 1990s and the first decade of the 21st century, for example, Onkyō in Tokyo, Berlin reductionism, the new London silence and Helsinki silent room. According to Lorraine Plourde, "Onkyō has been explained by musicians and music critics in Japan as a style in which the primary emphasis has shifted from producing or performing sound to that of concentrated and attentive listening. 'Non-intentional' sounds during quiet or 'silent' parts of performances have a significant role in the music as a whole, and performers and audience alike concentrate on many of these sounds as intently as they do to the intentional, performed sounds." [30] This listening practice cultivated in Tokyo in venues such as the (now closed) *Off site* and promoted by performers such as Otomo Yoshihide and Sachiko M, reveals, among other things, an extreme attention to each sound and a continuity between the surrounding sounds of the environment and the sounds of the performance. That continuity is then the link to the idea of a sonic line.

Similar notions are at the heart of the *Echtzeitmusik* movement (literally *realtime music*) in the *post-wall* Berlin. Christopher Williams in his review of *echtzeitmusik berlin: selbstbestimmung einer szene/self-defining a scene* explains the term reductionism as "a style characterized by quiet unstable sounds, subdued group interaction, renunciation of gesture, and structural uses of silence adopted by

[28] Weisstein, Eric W. "Line." Text. Accessed August 24, 2018. `http://mathworld.wolfram.com/Line.html`.

[29] Algra, Keimpe, and Katerina Ierodiakonou. Sextus Empiricus and Ancient Physics. Cambridge University Press, 2015.

[30] Plourde, Lorraine. "Disciplined Listening in Tokyo: Onkyō and Non-Intentional Sounds." Ethnomusicology 52, no. 2 (2008): 270–95.

younger improvisers in the mid- 1990s."[31] The expansion of the aesthetics of the softness, the sonic details and quiet noises, *acoustic microscopy*, reducing dynamic ranges, material development and performative gestures is understood by the practitioners as a listening experience equating listeners and performers. The goal according to Robin Hayward is to reorient "performers and listeners to otherwise marginalized elements of their musical and acoustic environment."[32] The awareness of the environment is stressed and illustrated by the advice of some seasoned improvisers like Axel Dörner, Keith Rowe or Eddie Prevost, who in their public workshops recommend that performers should "let the music emerge from the environmental sounds".[33] Focusing on the environmental and surrounding sounds, acoustic properties of the room, purposeless and accidental sounds, and the details of the *inaudible* allows the performers to create a transparent sonic world where every sound naturally surfaces from a continuous stream of sounds.

The ideas of the Echtzeitmusik and Onkyō mouvements arguably have precedents and parallels in the works of John Cage, Keith Rowe and Nuova Consonaza and have been spreading and influencing the musical scene around Europe and beyond, including Finland, through the meetings organized by Marko Timlin: under the title of "a.silent.room" and Visa Kuoppala in the "Svamp" sessions. The ideas have also sparked enthusiasm and interest in a more academic perspective.[34]

For the task proposed in this chapter, of collectively entertaining a sonic line, the abstract infinite line should be projected in performance-time as a series of consecutive segments, a line segment is a part of a line that is bounded by two distinct end points,[35] played by different musicians. Performing these line-segments while aiming to preserve continuity requires clever critical judgments

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[31] Williams, Christopher. "Echtzeitmusik Berlin: Selbstbestimmung Einer Szene | Self-Defining a Scene." Critical Studies in Improvisation / Études Critiques En Improvisation 7, no. 2 (December 7, 2011).

[32] Ibid.

[33] Workshops that I attended in 2006 and reported on in Chase, Stephen Timothy. "Improvised Experimental Music and the Construction of a Collaborative Aesthetic." PhD Thesis, University of Sheffield, 2007.

[34] Arthurs, Thomas. "Secret Gardeners: An Ethnography of Improvised Music in Berlin (2012-13)," 2016;
Blažanović, Marta. "Berlin Reductionism–An Extreme Approach to Improvisation Developed in the Berlin Echtzeitmusik-Scene." In Beyond the Centres: Musical Avant Gardes Since 1950. Conference Proceedings. Available on `http://Btc.Web.Auth.Gr/_assets/_papers/BLAZANOVIC.Pdf`, Accessed February, 11:2012, 2010;
Blažanović, Marta. "Echtzeitmusik: The Social and Discursive Contexts of a Contemporary Music Scene." Diss., Humboldt-Universität Zu Berlin, 2012;
Cassidy, Aaron, and Aaron Einbond. Noise in and as Music. University of Huddersfield Press, 2013;
Novak, David. "Playing Off Site: The Untranslation of Onkyō" Asian Music 41, no. 1 (2010): 36–59.

[35] Weisstein, Eric W. "Line Segment." Text. Accessed August 24, 2018. `http://mathworld.wolfram.com/LineSegment.html`.

on the sound qualities and dexterity with the instruments. In my opinion, the best way to achieve continuity is through repeated rehearsal with acute ear training and honest self-criticism. However, cognitive psychology and musical analysis provide tools to understand the cognitive and musical process of creating, perceiving and understanding sonic and musical continuity and can stimulate the sonic imagination to explore the concepts and frameworks.

Scott Barton wrote his Doctoral thesis about musical *(dis)continuity*, he analyzes musical works and provide a discussion on terms such as *sameness, simplicity, regularity, naturalness, directionality*, the thesis includes a study on models of similarity: *spatial, featured, structural representations, synthesis-structural transformations* and an examination of multiple hierarchical levels in structure and form.[36] The apparent intention in Barton's work is to provide conceptual tools for composers by considering a set of musical works and extracting the concepts and ideas through observation and analysis. Barton's contribution is to address a musical problem from the music itself, so transgressing the limits of reduced sonic material often used in the past to support music perception experiments. John Sloboda, as well, points out recent developments on the study of real listening conditions in the developments of cognitive psychology research.

> The second major development of recent years has been the attempt to study cognitive skills in situations more closely resembling those in which people would normally employ them outside the laboratory. Thus, concern has focused on how people deal with extended and meaningful material rather than on fragmented, meaningless stimuli. This movement has brought in its train an increased interest in developmental aspects of cognition, and cultural variance.[37]

From Barton's work we see how important subjective judgments are to framing the context and defining continuity in a musical situation. For example, the notion of *sameness* is identified in the musical domain as *sufficient similarity* because in the simple case of a continuous tone, it cannot be said that two fragments of 100 milliseconds at different moments of a sustained tone are the same. Even in a digitally generated oscillator, where each cycle can be mathematically generated from only one equation, two portions of a sustained tone will be perceptually different since they are heard at different moments. Changes in the context, either environmental or psychological, are time dependent and will affect perception. However, most listeners may agree on the similarity of the two segments extracted from the continuous pitch. Therefore, the notion of sameness must integrate a degree of flexibility, or, what Barton calls sufficient similarity or sharing sonic properties (e.g. volume, spectral content, direction) among sound entities.

[36] Barton, Scott Donald. Understanding Musical Discontinuity. University of Virginia, 2012.

[37] Sloboda, John A. The Musical Mind: The Cognitive Psychology of Music. Oxford University Press, 1986. 9-10

> Musical discontinuity is typically defined in terms of breaks/gaps (which can be created by tacets, juxtaposed contrast, surprise and change) and the negation or lack of continuity. Continuity then, describes an entity whose parts are connected without interruption or breaks. We can perceive such entities as continuous, as having no breaks or interstices, when the notion of sameness, or sufficient similarity, characterizes our perception at every point along a scale relative to other points (i.e. uninterrupted continuity). These conclusions of 'sameness' result from judgments of difference. Because we are able to perceive difference within unbroken wholes, cases of judged identity are better described as similarity comparisons that satisfy the appropriate property-sharing requirements. When (dis)similarity comparisons do not satisfy the appropriate property-sharing requirements, we perceive discontinuity. It follows that (dis)similarity comparisons significantly influence whether we perceive continuity or discontinuity within whole entities[38].

Barton also discusses connections and relations between distinct sonic entities resulting in the perception of continuity. For example, the author gives the *continuity illusion*, produced by involving "a softer sound that is interrupted by a louder sound (often a noise burst)". The relation of loudness can perceptually create a connection of continuity of type ABA, in which sound A *passes* through B. This type of interrupted continuity can be perceived, according to Barton, not only through dynamic *intermediaries* but also through temporal, higher-level organizations and context. This idea can be used to achieve continuity while elaborating a musically improvised discourse.

Gestalt theory has examined and pointed out some perceptual principles based on organization, grouping and segmentation of stimuli that are relevant to this discussion. Essentially, the law of *good continuation* which is based on observations that "parts often group in particular ways to form coherent wholes".[39] In Koffka's influential work on the principles of Gestalt theory, he states: "A straight line will continue as a straight line. We may generalize thus: any curve will proceed in its own natural way, a circle as a circle, an ellipse as an ellipse, and so forth."[40] I associate the idea of *natural continuation* with a *performing inertia*: once a process is set in motion by an intention, it can keep going until a new intention stops or changes it. The relation with motion can be associated as well with the Gestalt principle of *common fate*. "The common fate principle states that elements tend to be perceived as grouped together if they move together".[41] The grouping

[38] Barton, 59

[39] Ben-Shahar, Ohad, and Steven Zucker. "General Geometric Good Continuation: From Taylor to Laplace via Level Sets." International Journal of Computer Vision 86, no. 1 (January 2010): 48–71

[40] K. Koffka. Principles Of Gestalt Psychology, 1935

[41] Todorovic, Dejan. "Gestalt Principles." Scholarpedia 3, no. 12 (December 22, 2008): 5345.

of elements creates a wholistic perceptual entity. This common motion can be associated in the sonic domain with directionality on space (spatialization), temporal density (increasing, decreasing or keeping time intervals constant), dynamic progressions (crescendos and decrescendos) persistent, or spectral evolutions (filtering, stretching, compressing, gradual spreading or contracting of the frequency ratios, among others). Consequently, for the task proposed here, carefully observing the motion and direction of the pertinent sonic parameters can be a strategy to efficiently join and shift the performers, thus achieving an *unbroken line.*

In his study on Gestalt theory, Shelia Guberman, a researcher in physics and artificial intelligence, points out the importance of intention and imitation in the perception process.

> When we see in an image something that we describe as 'a circle', it is never a circle in the mathematical sense of the word. It is always a 'bagel', and very often it is not a closed line at all (e.g. in the handwritten characters 'a', 'o', 'g' and so on). In fact, when we describe the pattern as a 'circle', we describe not what we see, but what we think the author's intention was.[42]

Commenting on the good continuation principle, Guberman supports his thesis of imitation as the underlying process with the *mirror neurons* phenomenon.[43] He states that the good continuation principle "assumes that perception of a drawing includes the imaginable process of recreating (or imitating) the drawing."[44] Guberman explains that the good continuation feature "is possible only because we imitate a human person who possesses the same basic knowledge and similar real-life experiences, and who uses a writing tool with some mass and inertia."[45] In our context, the idea of redrawing can be expressed as *recreating the performance of a sonic gesture in the listener's mind.* The pedagogical strategy is to allow the maximum focus of attention by avoiding parallel threads of information until it becomes possible to keep the concentration on the other's stream of sound while performing.

This chapter cannot be closed without mentioning the work of La Monte Young. Young's music and ideas have been very influential in the development of minimalism and *electronic drone music.*[46] Young explores the feature of holding and

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[42] Guberman, Shelia. "On Gestalt Theory Principles." Gestalt Theory 37, no. 1 (2015): 25–44.

[43] Guberman, Shelia. "Gestalt Psychology, Mirror Neurons, and Body-Mind Problem." GESTALT THEORY 38, no. 2/3 (2016).

[44] Guberman, Shelia. "Gestalt Theory Rearranged: Back to Wertheimer." Frontiers in Psychology 8 (2017): 1782.

[45] Guberman, "On Gestalt Theory Principles." 25–44.

[46] Grimshaw, Jeremy. "The Tabula (Not so) Rasa: La Monte Young's Serial Works and the Beginnings of Minimalism, 1956-58," n.d;

sustaining musical notes throughout a whole piece or "for a long time". For example, his work "Composition 1960 #7" is an *event score* which consists of a perfect fifth B-F#, and the instruction: "to be held for a long time". The key words *long time* involve a shift of perception from a linear (as in successions of events) performing time towards a static and contemplative mind-state. Continuity is also stressed and sought in other works such as "Composition 1960 #10 to Bob Morris: Draw a straight line and follow it". Analyzing this work from the perspective of site-related art works on the 1960s in North America, McFadden notes: "For Young, the form of the line served as the minimal unit of action, or an event – what he termed the 'singular event.' The event for Young was the conceptual apparatus through which he structured activities over time and in space. The singular form of the line as event in turn expands into complex possibilities for experience. In each drawing, each following".[47]

The common point between these two of Young's works and the reflection presented here is the use of a visual element such as a line to illustrate, induce and guide the research of a sonic state in which continuity and duration will seem to escape the arrow of time. A difference, however, resides in the enactment of the polyphonic texture: though open to many interpretations, Young's work does not prevent several performers from simultaneously engaging in the music. On the other hand, the experiment proposed here should keep the monophonic texture at all times as an inter-subjective singular voice.

5.3.6 Implementations

† Develop an interactive system that will *listen* and analyze an audio input, then generate sounds when there is silence or refrain from playing when there are sounds in the input.

† In a modular or virtual synthesizer, recreate the above behavior by patching an envelope follower to a signal inverter then to a Voltage-Controlled Amplifier (VCA) modulating a sequence. Experiment with sensibility thresholds.

† Build a drone machine inspired for example by the Weird Sound Generator by Ray Wilson.[48]

Grimshaw, Jeremy. The Ideology of the Drone: La Monte Young the Mystic. Oxford University Press, 2011.

[47] McFadden, Jane. "Toward Site." Grey Room, no. 27 (2007): 36–57.

[48] "Music From Outer Space Your Synth-DIY Headquarters." Music From Outer Space Your Synth-DIY Headquarters. Accessed December 10, 2018. `https://web.archive.org/web/20161125185740/http://musicfromouterspace.com/`.

† Research, perform and set up additional experiments based on John Stevens *Sustain Piece* in which the performer inhales as deeply as possible then sustains a note for as long as possible on the exhale.[49]

[49] Stevens, John, Julia Doyle, and Ollie Crooke. Search and Reflect: A Music Workshop Handbook. Rockschool, 2007.

5.4 The Plane – Polyphony

A performance task to work and meditate on the possibilities of controlled and self-organized sonic polyphony

5.4.1 Tags

Polyphony, awareness, parallel listening, instant negotiation.

5.4.2 Goal

With this exercise, the goal is to provoke a group dynamic in which each performer is taken into account either as a player or a potential performer ready to act. The objective is to maintain a trio performance in which the members shift freely inside and outside the group.

5.4.3 Description

For more than three performers using electroacoustic instruments. The task starts in silence. When one performer plays the first sound he or she should continue improvising and other two players must immediately join. The improvisation will continue with the following rules:

- If one, two or three players from the current trio stop or decide to end their intervention, one, two or three players from the rest of the band must join the improvisation in order to keep the improvised trio format going.
- If one, two or three players from the band decide to join the trio, one, two or three players from the trio should respectively stop and become potential players again.

It is important to understand the state of *actual* player, improvising as a member of the trio in contrast to the *potential* performer ready and alert to join at any moment either by subjective decision or by reacting to one of the trio performers leaving the improvisation.

The duration of the task must be set in advance, and the end should be called by a moderator or by an external *timekeeper*. A recommended duration for the task is 10 to 20 minutes.

5.4.4 Variations

The task can be performed with any number of players, from two to a maximum size of the group minus one, resulting in different levels of polyphony. I have found the trio to be a good compromise between polyphonic complexity and group dynamics.

The task can be performed avoiding visual contact, for example, by sitting in a circle and facing outwards. The purpose of this is to focus on listening.

Another variation involves experimenting with the positioning of the loudspeakers, for example surrounding the musicians with a quadraphonic setting and panning the signals with an algorithm based on amplitude panning like VBAP or DBAP.[50] The main idea is to reproduce the concept of a plane with the spatialization of sound sources in a two-dimensional space. If the signal sources are panned but do not move, some experiments can be carried out by exploring the relationship between the performer's placement and their sounds coming from different points, for example how it affects to listen from the closer speaker somebody's else sounds instead that their own? Does it facilitate the task of creating a sonic plane or does it become more complex?

5.4.5 Discussion

Continuing with the metaphor of the geometric elements in the sonic realm in which the canvas is silence, a point an attack, a line a sound unfolding over time, the plane introduces the dimension of parallel sound voices or polyphony. The two-dimensional sonic plane has as axes the unfolding time and the density of coexistent voices or simultaneously-produced audio streams. From a group performance perspective, the new dimension opens the possibility of sharing not only silence or the consecutive creation of sounds but also the superimposition of parallel times. Performing several sonic lines at the same time presents to the listener a sonic ecosystem where the ear can freely shift from a wholistic contemplation through an individual thread following until a diving focusing or zooming microphonic experience. The new dimension of parallel times raises endless possibilities to experiment. From building a common quantizable time to which each voice refers in a synchronous or asynchronous relationship, dividing and multiplying temporal rational units, to poly-temporal systems where each voice has its own rate coexisting in a non-quantifiable irrational time. Multiple experiments and performance tasks can be imagined to study the range of possibilities between a

[50] Pulkki, Ville. "Generic Panning Tools for MAX/MSP." In ICMC, 2000;
Lossius, Trond, Pascal Baltazar, and Théo de la Hogue. "DBAP–Distance-Based Amplitude Panning." In ICMC, 2009.

homophonic texture with maximum temporal synchronicity and a superimposed texture of non-convergent soloists.

In order to make sense of the continuous complex stream of audio signals generated by the coexistence of independent or musically-related sonic voices, specialized listening skills are required. Albert Bregman has theorized on the concepts of *Auditory Scene Analysis* to describe the process carried out by the auditory system to isolate, group, identify and segregate elements and threads in a complex environment of cohabiting sound sources. Bregman underlines the fact that a listener receives as stimuli a "pattern formed by pressure changes over time, and if we look at a graph of the waveform of a mixture of sounds, there is nothing obvious in it that labels the sound as a mixture or tells you how to take it apart".[51] Since sound sources may overlap in their frequency content, the spectral decomposition of the signal does not help either to isolate the sound sources. Therefore, Bregman argues that a particular set of cognitive processes is set in motion when a listener intends to decompose auditory mixtures: "one is the activation of learned schemas in a purely automatic way", another "is the use of schemas in a voluntary way" and a third will involve "using general acoustic regularities".[52]

The automatic activation of a well-learned mental schema (a mental representation of a particular set of characteristics, such as one's name) occurs, according to Bregman, "whenever the incoming sound matches the schema's acoustic definition in even an approximate way". This is the process that occurs when people hear their names spoken in noisy environments. Bregman explains: "this hypersensitivity and automatic activation presumably occurs because people so frequently hear their names spoken that its schema is in a highly potentiated state".

The intention of trying to hear a sound – for example, our name – (once again a well rooted schema) called out in a sonic complex environment is for Bregman an indicator of a different process of the auditory system to decipher a complex acoustic signal, he calls it, "the use of schemas in a voluntary way".[53]

These two process require a pre-built knowledge of the structure of particular sounds or sound classes formed by "prior listening". Bregman observes that the auditory system may use other mechanisms to comprehend spontaneous sonic scenes since the requirement of a stage of previously-formed schemas takes time to form through repeated listening and isolated contact with the sounds. Therefore, not all sounds are available as mental schemas at the moment of perception, and other methods have to be in use to complete the perception process. Bregman proposes that *general acoustic properties* can be used as "primitive auditory scene analysis" for "decomposing all types of mixtures" and following Shepard's ideas of *psychophysical complementarity* and perception of regularities on the physical

[51] Bregnian, Albert S. "Auditory Scene Analysis: Hearing in Complex Environments," 1993.
[52] Ibid.
[53] Ibid.

world,[54] Bregman suggests that "a good strategy for finding the laws of auditory organization would be to try to discover relations among the components of the incoming sound that are frequently present when parts of the sound have been created by different environmental events."[55] Bregman pinpoints the following regularities:

- Regularity 1. Unrelated sounds seldom start or stop at exactly the same time.
- Regularity 2. Gradualness of change.
- Regularity 3. When a body vibrates with a repetitive period, its vibrations give rise to an acoustic pattern in which the frequency components are multiples of a common fundamental.
- Regularity 4. Many changes that take place in an acoustic event will affect all the components of the resulting sound in the same way and at the same time.[56]

Though Bregman's analysis gives us an insight into how the auditory system behaves in a complex sonic environment raising challenges on how implement and study the concepts of schemas and regularities in an electroacoustic music performance context, the performance and listening exercise discussed in this chapter implies a few differences.

For example, most of the scenarios described by Bregman describe an *every day* situation in which simultaneous sounds are spontaneously created not for the unique purpose to be heard but as an acoustic consequence of another main activity: the steps of someone walking on the street, engine sounds of a car passing by, children playing, a dog barking, etc. In contrast, the performance environment is not natural; it is an artificial and splendidly-controlled acoustic situation where every sound is there to be perceived as sound for its own sake. Even more, the task of keeping the polyphony under strict control creates an artificial situation of sonic complexity. The sounds of an electroacoustic band are integrated in a musical discourse and purposefully challenge the process of perception using techniques such as advanced manipulation of the spectrum, bending, morphing and contrasting timbres, acute synchronicity/asynchronicity of sonic events, artificial dynamic evolutions, etc. Hence, I propose that the experimental electroacoustic performer task is to empirically unveil the powers and mechanism of the auditory system by systematically investigating the perception, listening and performing of complex sonic scenes.

[54] Shepard, Roger N. "Psychophysical Complementarity." In Perceptual Organization, 279–341. Routledge, 2017.
[55] Bregman, 1993
[56] Ibid.

From another perspective, the sonic plane concept, which is based on the coexistence of diverse sound lines or instrumental voices, implies aspects of sociopolitical behavior. In fact, the polyphonic sonic texture can be seen as a process of permanent negotiation for sharing the common acoustic space and entertaining an equilibrium of performance energy. Why should one of the voices not acoustically override and sonically obliterate the other voices, making them inaudible? Why should a performer in a hyperactive mode not just refuse to stop improvising indefinitely? Why should the rule of playing in a trio not for example become a tutti or a solo? The answer to these questions reveals the underlying sociological aspects of creative sonic group work as well some form of implicit democratic values of a common code of behavior among performers. These values are learned and cultivated through being part of and living in a society. Knowledge of how to share an acoustic space in a sonic performance context is an intersubjective skill based on trust, support and equality.

The topics of civics and the implicit code of behavior in a band can be raised and observed from the very beginning of the first meetings and improvisation sessions. I have observed two different situations while inviting bands to freely perform at the start of sessions: The first involves some kind of unspoken politeness where the use of the acoustic space starts from a very prudent, discrete, delicate and *space given* attitudes. I believe a big part of this is the hierarchical situation of being in a context where the participants arrive as *guests* to the moderator or the institutional territory, so the rules of etiquette, politeness and good manners are paramount. The other situation is when experienced performers join the sessions. Experience in improvising allows the performers to take more risks, push the situations to the limits and trigger ideas as well as musical arguments and counter arguments, freely using the dynamic range and clear role taken. These attitudes may also appear in the band after a few sessions where trust, support and friendship start to build up within a *beginner* group.

Spontaneously asking two or three (or more) performers to publicly improvise together is a social laboratory where self-organization and a balance between anarchy and democracy is found intuitively and guided by listening but also by attentiveness to performance details such as body language, visual cues and glances. The topic has been largely studied in social psychology,[57] and music therapy, in which musical improvisation has been used as a tool for social mediations among groups of individuals with particular conditions.[58]

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[57] a report of different studies, approaches and methodologies can be found at Davidson, Jane W. "Music as Social Behavior." Empirical Musicology: Aims, Methods, Prospects, 2004, 57–75.

[58] The Journal of Music Therapy has a substantial body of work on the matter. See for example Gooding, Lori F. "The Effect of a Music Therapy Social Skills Training Program on Improving Social Competence in Children and Adolescents with Social Skills Deficits." Journal of Music Therapy 48, no. 4 (December 1, 2011): 440–62.

An important argument developed in social cognition that can be at the foundation of interpersonal dynamics in electroacoustic improvisation and performance is what Hove and Risen call *self-other equivalence*. While analyzing the effects of interpersonal synchrony, mimicry, and affiliation in a musical context, Hove and Rise underline the importance of *including the other in the self*:

> Perceiving an agent's action automatically and directly maps onto the observer's action system, creating a neural coupling between the agent and observer [. . .] Thus, shared representations for perception and action naturally extend to shared representations for self and other [. . .] This "self-other equivalence" may promote meaningful social bonds and interpersonal closeness by helping people understand others' actions [. . .] or by increasing people's tendency to project positive views of the self onto others. [59]

Creating and preserving spaces for the experimentation of interpersonal dynamics through music and interdisciplinary art forms with improvisation is an opportunity for a society to develop, expand and promote democratic values of equality and participatory voicing of its citizens and should be considered a governmental responsibility, for example by allocating funds and resources for its development. As a local illustration, events such as the *Helsinki Meeting Point*[60] curated by the choreographer and dancer Giorgio Convertito and the *Blind Dates for Improvisers*[61] curated by researcher and performer Sergio Castrillon have over several years promoted and fostered the reflection and debate within performers and practitioners the ideas of spontaneously sharing a performative space. This in my opinion can be projected to a larger social dimension to reveal modern forms of sharing a public physical and mental space.

The sonic plane is then the unfolding of an intersubjective dimension or *συμφωνία symphōnia* in the Greek sense of sounding together,[62] that goes beyond the simple superimposition of sonic threads. It is a metaphor for a social laboratory that can help us to safely understand, re-create and recover the values, concepts and foundations that can allow us to preserve an organized human life, as Noam

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59 Hove, Michael J., and Jane L. Risen. "It's All in the Timing: Interpersonal Synchrony Increases Affiliation." Social Cognition 27, no. 6 (2009): 949–960.

60 "Helsinki Meeting Point." Helsinki Meeting Point. Accessed September 22, 2018. `https://helsinkimeetingpoint.wordpress.com/`.

61 "Improvisation Summer Series." museum of impossible forms. Accessed September 22, 2018. `https://museumofimpossibleforms.org/events/2018/6/1/mif-improvisation-summer-series`.

62 "Symphony | Music." Encyclopedia Britannica. Accessed September 22, 2018. `https://www.britannica.com/art/symphony-music`.

Chomsky is urging us to do.[63] We as electroacoustic performers may not have enough political power to address global issues as nuclear weapons proliferation or environmental policies, but we have a strong knowledge and a dissemination vehicle for ideas such as peaceful coexistence of diverse and divergent personalities, values of democracy and equality in a self-organized use of the voice, empowering and participatory decision-making as well as raising of awareness and critical thinking. An improvisation session is a reservoir of potential energy for acting and reacting and can be the means to influence and increase the consciousness and perception of our surroundings, our ecosystem and ultimately ourselves as an intelligent and conscious species.

5.4.6 Implementations

† This chapter is an invitation to group performance, inside and outside the educational institutions, for creating regular meetings for musical encounters and for debating and discussing the challenges and the potentials of collective spontaneous sonic creation.

† Implementing the idea of a sonic plane means creating situations where one can be aware of the other, to take care and pay attention to others' voices and open a mental and physical space to perform polyphony, to experiment in forms of intersubjectivity, to discuss, analyze and foster critical views in our interpersonal dynamics, inside the electroacoustic band and beyond.

† I suggest collectively and through a process of negotiation and discussion creating and inventing performance situations that deal with the way that a band shares the simultaneity of space-time and acoustic fields. I propose allocating enough time to develop everybody's voice, ideas and strategies in every improvisation session using the musical and performative resources of the band.

[63] Chomsky, Noam. "Prospects for Survival." Massachusetts Review 58, no. 4 (Winter 2017): 621–34.

5.5 The Mass – Noise

An improvisation framework built around a multichannel system and the concept of noise.

5.5.1 Tags

Noise sphere, noise wall, noise music, japanoise, mass of sound.

5.5.2 Goal

The goal of this section is to experiment, analyze and investigate the performance options of noise as a sound mass.

5.5.3 Description

The task consists of performing a wall of noise through which a duo struggles to communicate. Previous to starting the improvisation, a duo should be chosen among the group whose goal is to carry out a common improvisation. All other members of the band will perform a noise wall or a noise sphere using high levels of volume and rich continuous spectra. A multichannel loudspeaker array must be arranged in a circle surrounding the performers or in an ideal situation as a geodesic dome. Each signal from the performers is connected to a central audio card and a computer that can distribute, map and spatialize the sounds. The audio signals of the duo should be set in motion as a *random walk* around the system from one speaker to another, while the signals from the band are distributed to all the speakers simultaneously.

Because the experiment involves high sound level pressures and complex spectra, the duration of the task should be short. The options of abandoning the improvisation at any moment, using hearing protection or skipping the entire task should always be open to all the performers. It should also be the responsibility of the moderator to monitor the overall volume to avoid unpleasant situations, keep the duration short, offer ear protection, inform participants about regulations of exposure to loud sounds and to guide the group to a calm and trusting atmosphere.

It is possible that in some situations involving acoustic instruments, even without any amplification, the sound levels may reach the limits of comfort. In the case of a having within the band a motivated section of brass players, woodwinds and/or percussionists, for example, the emphasis should be on creating an electroacoustic sound, by playing physically softer but compensating by using more electric amplification.

The sounds used to build the noise wall must be of a continuous nature, thus avoiding attacks and surprising events. The resulting spectrum should be complex and should incorporate the whole frequency range. The noise wall can be introduced with a slow fade-in or crescendo to make it more tolerable. Since the duration is short, the duo should be very fast and reactive, identifying each other's material and playing in a complementary way either by imitation or by contrast. Critical judgments of the experiment from the performers and the moderator about the qualities of the noise wall and the efficiency of the duo are relevant tools to analyze the nature of noise, its performance possibilities and its relevance as a sonic element.

5.5.4 Variations

Performing and focusing only on the noise wall can help to build the concept and sonic identity of the sound mass and noise.

5.5.5 Discussion

The fifth sonic element is the mass. Following the metaphor of geometric sonic axioms, the mass adds one dimension from the sonic plane. In geometry, stepping up from the two-dimensional plane leads us to consider a three-dimensional object or volume. To avoid misunderstandings with the use of the word *volume*, which in an acoustic context refers to the degree of loudness, I prefer the term *mass* to refer to the next dimensional expansion in the sonic elements. It is also important to note that the term *mass* has been extensively used and theorized in the context of electroacoustic music by Pierre Schaeffer and his research team.[64] The notion of *mass* in a Schaefferian sense is an extension of the sound quality of pitch that can be definite, complex, slightly variable or unpredictable and is coupled with the idea of *facture* (the way sounds evolve over time).[65] Nevertheless, in my proposal for conceptualizing sonic elements as a progressive addition of dimensions from the silence to the point, the line and the polyphonic plane, the concept of mass includes aspects of sound spatiality, acoustic loudness and spectral complexity.

[64] Schaeffer, Pierre. Traité Des Objets Musicaux: Essai Interdisciplines. Paris: Éditions du Seuil, 1969.

[65] Normandeau, Robert. "A Revision of the TARTYP Published by Pierre Schaeffer." In Proceedings of the Seventh Electroacoustic Music Studies Network Conference, 21–24, 2010.

The projection of sounds in the surrounding space is an essential aspect of sonic mass. Although every sound exists in space-time and therefore has an embedded spatial dimension (even as a mental representation an imagined sound exists in the physical space of the brain), the dislocation of a sound source from a unique emitting point and its consequent projection, multiplication and spatialization over a multi-point sound source system can be understood as an added dimension. In the sonic mass, points, lines and planes exist and move in a space-volume surrounding the listener. With the sonic mass, in addition to its localization properties, sounds acquire the possibility of becoming omnidirectional and of multiplying their presence in several simultaneous locations. A geodesic dome, a multichannel system or an omnidirectional loudspeaker will support the expansion of the spatial qualities of the sound source. For example, a monophonic signal from a synthesizer voice that is usually played through a single loudspeaker will develop a totally new set of musical powers when performed and specialized in a multichannel loudspeaker array.

The other aspects of the mass involve loudness and spectra. Creating and performing a sonic mass involves handling high levels of sound pressure combined with complex spectra. It is known that the perceived loudness of a sound is deeply related with the spectral content of the sound, therefore, these two qualities should be considered together.[66] I propose to relate the concept of sonic mass with noise (though, noise as I will explain later does not have to be loud). The sonic mass is the binary complement of the silence canvas. The sonic mass is a complex loud surrounding spectra or *a noise sphere*, let us then, discuss the notion of noise.

Noise has been a topic of great interest for musicians and philosophers throughout the twentieth century until today. A line of aesthetics and research could be traced up from the Japanese noise (japanoise), industrial music, through *musique concrète*, until Edgar Varèse, John Cage and ultimately Luigi Russolo and the futurists. However, as observed by Paul Hegarty even if this lineage cannot be wished away,“it is one that is retrospectively imposed”.[67] Hegarty analyzes the qualities and interpretations of noise that link the path from Russolo to Akita Masami.[68] These are rupture, disturbance and refusal, so the pathway of noise

[66] Steinberg, J. C. “The Relation between the Loudness of a Sound and Its Physical Stimulus.” Physical Review 26, no. 4 (October 1, 1925): 507–23.

[67] Hegarty, Paul. “Just what is it that makes today’s noise music so different, so appealing? 1.” Organised Sound 13, no. 1 (2008): 13–20.

[68] Akita Masami, born December 19, 1956, better known by his stage name “Merzbow”, is a Japanese noise musician. He is best known for his style of harsh, confrontational noise exemplified on his 1996 release, *Pulse Demon*. “Since the 1980s while working in his ZDF studio, Akita Masami quickly gained notoriety as a purveyor of a musical genre composed solely of pure, unadulterated noise. In 1982 Masami founded the first Noise label, Lowest Music and Arts. He would eventually coin the phrase “Noise Composition” as a description for his sound, and display his pre-recorded Noise via live performances. These presentations have included Akita’s electronics battling with

music cannot be a smooth developing curve. For similar reasons, the definition of noise resists to be fixed and any attempt to define it will always fail.

> Like chaos theory, noise theory is not 'just noise' but rather an attempt to structure noise's relation to form, structure, logic and linearity. This attempt should, in my view fail, or else it will no longer be noise. But all thinking dooms the unthinking to be thought, brought in, and lose its noisiness – this too is part of an inevitable circuiting of failure, which is in itself noise.[69]

Despite the impossibility of defining noise, broadly speaking the notion of noise is taken to refer to something negative and problematic: errors, disruption of signals, pain, disturbance. noise is traditionally considered to be outside the music and meaning, associated with excessive loudness, chaos, disorder, unsolicited and annoying sounds. Salomé Voegelin elucidates the noise-sound relation in an inspiring phenomenological description "Sound is noisy when it deafens my ears to anything but itself." Noise-sounds in art and every-day life are "extreme sounds that take possession of one's ears by one's own free will and against it, isolating the listener in the heard."[70] By unveiling the subversive forces implicit in the concept of noise and confronting the nihilistic paradox of lacking definition, several thinkers and philosophers have taken on the task of conceptualizing and analyzing what noise is and what it means. In his article "Noise music", Paul Hegarty proposes a summary of various theorizations of noise [71]

- *Ecstatic* emphasizing the "physical taking over from the rational" and referring to the rave/club culture.
- *Extreme/Excess* Noise as potential: "noise is the avant-garde, the furthest music has got". In Russolo's view noise is both an essential part of nature and a new reality of the industrialized metropolis and can bring new social harmony.
- *Adorno* "Noise music is just another commodification of attempted avant-gardism"

traditional instruments like drums and guitar, as well as solitary shows with nothing more than the man standing before a table strewn with homemade equipment;" The Beauty of Noise: An Interview with Masami Akita of Merzbow by Chad Hensley." Accessed October 6, 2018. `http://www.esoterra.org/merzbow.htm`.

69 Hegarty, Paul. "Noise Music." The Semiotic Review of Books 16 (2006).1-4

70 Voegelin, Salomé. Listening to noise and Silence: Towards a Philosophy of Sound Art. New York, United States: Bloomsbury Academic & Professional, 2014. 44-45

71 Hegarty, Paul. "Noise Music." 1-4;
"Noise | Grove Music." Accessed October 7, 2018.

- *Attali* "Noise is what society does not accept". Noise "is an inheritance of sacrifice, with the notion of sound being physically threatening." For Attali, the history of music could be seen as the progressive domestication of noise, through familiarity, secularization of music, or legal controls.

- *Deleuze and Guattari* Noise is "a proliferation of sound, deterritorialization of both music and listener. Noise is rhizomatic, a plateau of intensities, etc. Such an approach is used as a means of identifying transgressive, 'subversive' culture"

- *Failure/impossibility* "Noise is only ever defined against something else, operating in the absence of meaning, but caught in the paradox of nihilism – that the absence of meaning seems to be some sort of meaning. Not thinking about it at all: here, to try to think critically or to understand noise is to betray it, to lose its radicality."

- *Authenticity/purity* "Noise as pure expression (like Jackson Pollock, or Clement Greenberg's Pollock). This would be one response to Adorno, in saying that noise is only possible in reaction to an all-pervasive hyperculture industry"

The analysis of Hegarty highlights the challenges and potentials of handling the concept of noise and its consequences in the music field. Noise – in sound art and in music – is a physical experience, or a psychological experience, as Voegelin points out: "Noise does not have to be loud, but it has to be exclusive: excluding other sounds, creating in sound a bubble against sounds, destroying sonic signifiers and divorcing listening from sense material external to its noise."[72] There is an excess in noise. The listener surrenders to the sound mass. Noise is the incarnation of anarchy or social disorder; it is an experience of power and oppression transgressing the senses and meanings. The noise and silence reveal each other. These two concepts encapsulate the impossible ultimate qualities of a sound experience. Thesis and anti-thesis simultaneously implode and explode from each other, and our perception cannot attend to that sublime communion of abstract entities. Only death is silence as Attali remarked: "silence is the noise of noise."[73] Quoting the work *La somme* of French philosopher Georges Bataille, Hegarty writes:

> In the early stages of *La somme* noise is the interruption of the interruption, that is, the restoration of order. This in turn means that silence is the noise of noise, the break- down of the feedback loops of information

[72] Voegelin, 43-44.
[73] Attali, Jacques. Noise: The Political Economy of Music. Vol. 16. Manchester University Press, 1985.

> and structure. As well as that, silence is the opening into noise that is yet another level (or embedding) of the true and empty universe.[74]

Noise and silence have a very intimate relationship: they are two faces of sonic impossibility. There is no such thing as pure silence, and there is no such thing as pure noise. An *infinite-bandwidth white noise signal is a purely theoretical construction.*[75] If we cannot materialize the concept in physics, we can through performance struggle to approach it.

Performing noise

In sound performance, noise and silence are more than sonic tools; noise-walls and silence-canvas are states of mind or even states of spiritual contemplation. Performing noise and silence has in common the abandonment of all musical expectations, all the discursiveness and all of the well-organized poetry of sounds. Performing noise and silence has more to do with digging into the soul and facing one's inner deeper fears. The fear of silence is very similar to the fear of noise: we fear losing our voice as we fear losing our ears. The fear of noise, the surrender to disorder has to do with the fear of losing control of giving up to irrationality. The act of performing the dismantling of the soul and pushing the consciousness/unconsciousness to the limits can be seen and appreciated in the noise scene with performers such as Merzbow, Maso Yamazaki (Masonna), Hijokaidan, Keiji Haino, the Harsh Noise Wall movement led by the French artist Romain Perrot (Vomir) and in other musicians and sound artists such as Tissa Mawartyassari, Lasse Marhaug, Finey Janes (PussyVision), Margaret Chardiet (Pharmakon), Punk/industrial bands like Katie Monks (Dilly Dally), Frau, among many others.

Hegarty analyses and describes Merzbow's performance extensively in his texts. In the following quote, for example, the musicianship of Merzbow is underlined to the point of virtuosity:

> Merzbow's sound is not one where noise is added to music as additional instrumentation or alteration. This is noise all the way down, with the sound built entirely from feedback, white noise, overdriven instruments, relentless change, and it is almost entirely inexplicable from the standpoint of music. Nonetheless, where it happens is on recordings, or in

[74] Biles, Jeremy, and Kent L. Brintnall. Negative Ecstasies: Georges Bataille and the Study of Religion. Oxford University Press, 2015. 100-101

[75] Lubis, Muhammad Zainuddin, and M. Si. "Signal Processing for Power Spectral Density (PSD)." Signal Processing for Marine Acoustic and Dolphin Using Matlab, Edition, 2016.

> concert, just like music. So it does not fall into the trap of being a simple refusal. This is a refusal from within, a destructuring and not an avoidance. Order is not rejected but dismantled over and over.[76]

And in perspective with Romain Perrot:

> White noise can be relaxing, maybe even a meditative aid. One extreme form of recent noise music is the genre of 'harsh noise wall,' which, in the hands of its leading practitioner Vomir (Romain Perrot) is an unbending mass of noises layered together to become almost static. This has the purpose of stilling the world, an excessive take on the idea of 'noise cancellation' available in certain types of headphones, but it does not do as much stilling as Merzbow. It performs one moment of silencing and stays there. Merzbow fractures his own noise, even resorting to bursts of more tangible musical elements, particularly rhythms, to keep noise in play. This is a location of the silence through excess that Bataille goes looking for, its breaking down of form even as it takes form (for example, as a track on a CD), an exact rendering of the project that undoes the idea of project.[77]

The performance of noise that I am suggesting here is closer to the interpretation of Japanese noise music than the crystalline use of noise of Lachenmann and Marc André. Although both directions release the music from organized pitch and harmony, extending the capabilities and techniques of the instrument, the Japanese noise music involves a high level of loudness. Extreme loudness can be attained with excessive amplification, microphones are welcome to introduce feedback loops and larsen effects. If performing noise is a physical experience, the body must engage in one way or another with the accumulation of energy required to reach a jubilant state. This ecstatic experience can be accentuated by an extreme deprivation of movement or the opposite by a euphoric intimate dance in symbiosis with noise. The sounds electronically or acoustically generated are at a boiling point with a high inner activity rate, extremely fast changes in constant ebullition, or at the other extreme, totally static, frozen, repetitive and inert to the point of boredom and irksomeness but pushing the comfort zone of enjoyment. A good technique for performing noise is to aim to play to the extreme of forces and speed, once this point is reached, consciously understand it as only halfway to the zenith. A successful noise performance should end in a form of exhaustion, collapse or breakdown, which usually means instantaneous silence.

Performing noise offers the opportunity to transgress the limits, whatever they may apply to: personal, social, musical, sonic. Performing noise is crossing the bridge of known paradigms. With the suggested configuration of establishing

[76] Biles, Brintnall. Negative Ecstasies. 102
[77] Ibid.

a duo that tries to communicate through a massive and colossal noise-sonic-structure built by the others, the point is to introduce an error in the system: the noise is distracted and unfocused by a conversation that occurs while the noise is avoiding anything intersubjective. The *signal to noise ratio* is disproportionate and unbalanced, and the hopelessness of reaching a harmonic coexistence can only entail frustration, but it is exactly from that frustration point that something to learn may appear.

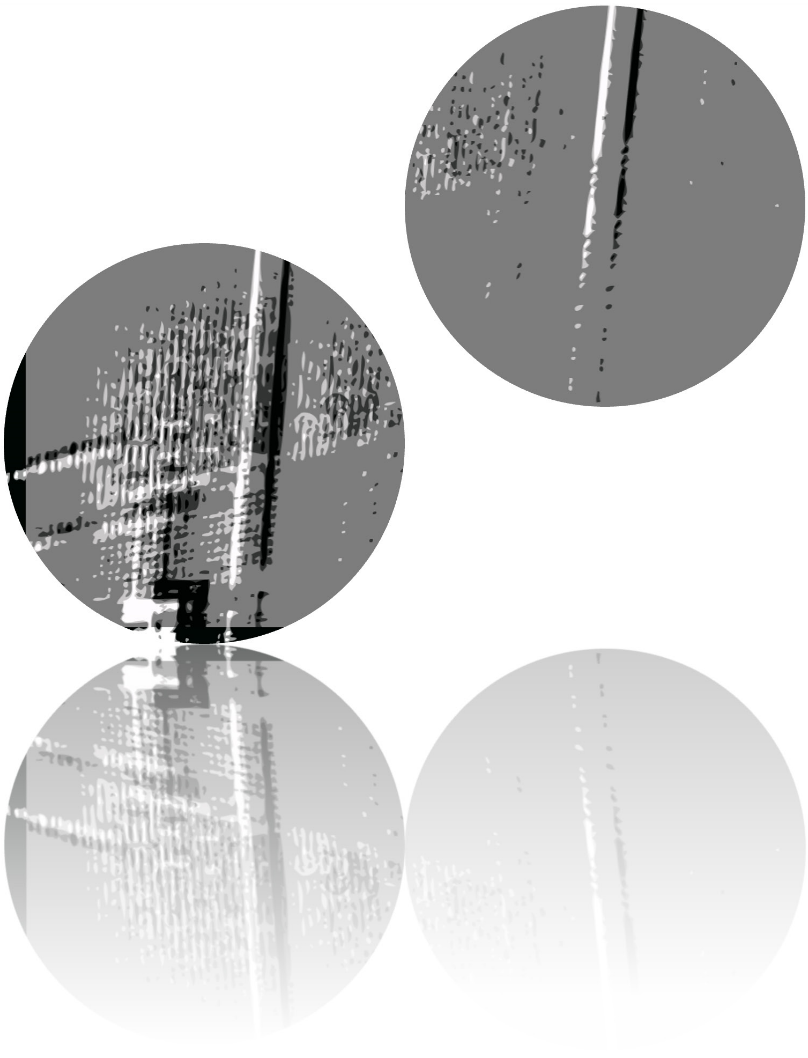
I see the performance of noise as an opportunity to embed in a musical experience the anarchy and subversive feelings against the malfunctioning of society. Performing noise as a vindication of power through sound with a performance of excess, upholding the unheard voices of the underground layers of society against the titanic forces of unbearable sound, obliterating the meaning of sounds with sounds and ultimately reaching the mystical silence and transcending beyond acoustic waves. Finally, it is not so much about the high levels of sound pressure as it is about the inner willingness to cross a performative boundary that is only known by each performer.

5.5.6 Implementations

† Set up a multichannel master compressor for the band that can work as a limiter to control the sound pressure level from exceeding unhealthy limits.

† Put together a set-up applying as many imaginable forms of feedback as possible using piezo microphones, resonating objects, delays, distortions and noise machines.

† Study the spatialization of different colors of noise using an amplitude based panning or an ambisonics algorithm to compare and judge the qualities of the sound system.



6

Electroacoustic Elements

6.1 Amplification – Hopscotch

Sonic Hopscotch is a childhood-inspired game in which players follow and explore a path of sound volume changes.[1]

6.1.1 Tags

Volume, Amplitude, Loudness, Dynamic Range, Trajectories

6.1.2 Goal

The object of this non-competitive game is to master the perception and performance of a well-studied collection of dynamic intervals. How many dynamic interval can the band/soloist handle, a performer discriminate, and an audience savour?

Another reason to play the Sonic Hopscotch is to raise awareness of the potential dynamic range of an amplified band/instruments.

By focusing the listener's attention only on the perception of loudness, the performer should have access to investigate and evaluate the idea of a *Just Noticeable*

[1] Hopscotch is basically "a popular playground game in which players toss a small object into numbered triangles or a pattern of rectangles outlined on the ground and then hop or jump through the spaces to retrieve the object."
"Hopscotch." Wikipedia, December 27, 2018. `https://en.wikipedia.org/w/index.php?title=Hopscotch&oldid=875573816`.

Difference in the Sound Level Pressure as well as intuitively quantifying and improving the discrimination of small perceptible level changes in the acoustic realm and expressing it as a series of discrete steps or scales.[2]

6.1.3 Description

Sonic Hopscotch can by played by any number of players (a solo version is also possible) with a sound source generator, acoustic or electronic (preferably with personal amplification). The instrument used in this activity must have a volume control of some kind.

Hopscotch is an ordered sequence of steps to be traversed by gradually increasing the distance and the difficulty to reach a targeted step. To make a sonic version dynamic scales and a progression rule must be established.

To build the dynamic scale, the player(s) should choose a reference sound. It is essential to come to agreement on the loudness with the whole group by carrying out dynamic tuning. At a moderate, comfortable agreed-on volume, the performers play a sound whose volume is kept frozen or unchanged. This process is then repeated. That will be the reference sound. Care has to be taken to avoid strong changes in other aspects of the sound in order to facilitate maximum attention on the dynamic qualities.

The simpler dynamic scale comprises two different levels or one interval; it should be easy enough to play with anyone: two sounds where the second one is either louder or softer. Double check that all of the players agree on the direction of the interval. Many experiments with the size of the interval are possible, but the struggle is to build a unified concept and to expand the vocabulary by agreements on verbal communication about the loudness and the volume relations between the reference sound and the other one.

A scale of two consecutive values will need to introduce a new interval. The scale can be built in an increasing or decreasing manner: The rising crescendo and the gradual decrescendo. Another possible path takes the sound reference, first one step up then one step down. Each step should be submitted for aural comparison and commonly judged by the players. Everybody must agree on the accomplishment and precision of the performed scale. The size of the step should be perceptible to all. If no agreement is reached, keep that number of steps as a

[2] The Difference Threshold (or "Just Noticeable Difference" is the minimum amount by which stimulus intensity can change in order to produce a noticeable variation in sensory experience.
Weber's Law of Just Noticeable Difference, University of South Dakota: `http://apps.usd.edu/coglab/WebersLaw.html(June2018)`

starting point and repeat the process of agreeing on the task, performing it and discussing it.

When the perception and performance of two intervals played one after the other is mastered, then the number of dynamic levels can be gradually increased. Four intervals are an obvious progression if the path of up and down is chosen. Just cut each of the previous intervals in two: finding the "in-betweens". For three intervals in the same direction, one needs four sounds: the reference and three more, either getting louder or softer.

Particular attention has to be given to the repetition and rehearsal of the sound levels, without overemphasizing an absolute value, the participants should focus on getting a clear perceptual impression of direction while being able to reproduce the experience of a progression in the volume of the sound. This training must enable the participants to build a precise sonic vocabulary for the dynamic levels.

With six different dynamic levels, we get closer to the typical musical notation of *fortissimo, forte, mezzo forte, mezzo piano, piano, pianissimo.* More can be added of course progressively; perception is the limit! For inspiration, one can think of György Ligeti, who, in his *Piano Etudes*, uses extreme dynamic notation from "pppppppp" (8p) to "ffffffff" (8f) for a total of 18 different dynamic levels (including mf and mp).

To illustrate one of the possible paths of building and performing a dynamic scale, let us take a six-level scale and build a crescendo. The resulting dynamic progression in a Sonic Hopscotch manner is:

pp
pp p pp
pp p mp p pp
pp p mp mf mp p pp
pp p mp mf f mf mp p pp
pp p mp mf f ff f mf mp p pp
pp p mp mf f mf mp p pp
pp p mp mf mp p pp
pp p mp p pp
pp p pp
pp

The player(s) start(s) by playing a soft sound of a moderate duration followed by a short silence. After that, each step should be added one at a time. Following each introduction of a new value, the path should be played in both directions, up and down. Thus, the dynamic scale always starts from step one, reaches step x and comes back to step one. When all of the steps of the scale have been played, the inverse operation should be performed: taking or eliminating one step at a time until reaching the starting position and finishing in silence.

The Sonic Hopscotch dynamic game: once a dynamic scale is mastered, define an arbitrary order by associating each step to one dynamic value. For example, for four sounds, the association table will look like this:

1 f
2 mp
3 p
4 mf

The game consists of performing a predefined path by skipping one step at a time. Thus, if the numbers represent the steps, it will be equivalent to perform in this order:

2, 3, 4, 3, 2
1, 3, 4, 3, 1
1, 2, 4, 2, 1
1, 2, 3, 2, 1

or

mp, ff, mf, ff, mp
pp, ff, mf, ff, pp
pp, mp, mf, mp, pp
pp, mp, ff, mp, pp

This last proposal will translate into 25 sonic events that should be possible to classify in four dynamic levels. A recording may help to judge the level of success.

6.1.4 Variations

Split the group between listeners and players. Each player decides on a path without revealing it to the other group members. Then the listeners have to transcribe it. At the end, players compare the transcription to the original. Encourage players to work with small interval changes.

One version engaging in free playing consists of unlocking the other sound parameters (duration, pitch, tone, articulations, spatialization) while maintaining a predefined pattern of dynamic changes. The group must then decide by ear and through unspoken agreements when the new dynamic section starts.

Set up a system for amplifying the ensemble making sure that each musician gets a channel in a mixing desk. Ask them to improvise at a constant dynamic (maybe forte), while a volunteer live-mixer player follows a predefined mixing score built from a Sonic Hopscotch.

Revisit the Hopscotch proposed above but modify it to incorporate time, even exaggerated time, for example, four minutes of pianissimo, 60 seconds of piano, 40, mezzo forte, 20 seconds of forte and just a few seconds of fortissimo. Reflecting on the tolerable limits of loudness and durations will help to establish a common vocabulary of musical qualities and therefore contribute to the development of trust among the players.

6.1.5 Discussion

Musicians have set the bar very high for several centuries if not millennia handling and mastering the sound levels of acoustic instruments. (This is probably why it is so powerful and inspiring to collaborate with trained acoustic musicians in an electroacoustic music context.) Furthermore, contemporary digital representations of sound are so nuanced that it raises questions about listeners' ability to distinguish among different sounds. In the other hand as a paradox we must heal from the war of loudness carried out by broadcasting and studio companies which compress audio signals to the maximum to make them stand on the media, i.e. "the louder, the better". The constant raising of amplification is often unnecessary and even annoying. At one point listening to extended periods of loud music will affect people's ear performance. Consequently, this chapter is an opportunity to review the concept and the potential of greater dynamic ranges in a live performance context using electronic instruments. As well as how much sound can be performed and enjoyed at more comfortable levels.

Let us consider for example one second in a software that can perform audio blocks at 24bits and 48Khz. Such an application represents at each sample or every 20 microseconds an amplitude among 16,777,216 different values, and in one second, a total of 805,306,368,000 sample points are available. That is a vast dynamic range of 144dB (theoretically speaking). However, playing back this accurate representation of amplitudes as sound pressure levels with the same accuracy is a challenge. For today's electronics, the noise floor of audio devices, many times related to noisy power lines, or thermal noises from electronic components and quantization errors introduced in the digital to analog convertion reduce the dynamic range. It is difficult if not unrealistic to deliver such an extensive dynamic range. What's more, if the machines could play it, a full dynamic range of 144dB SPL will be excessive, reaching dangerous regions of loudness. However, the high resolution of mathematical representation of audio signals has allowed us to experiment and perform complex operations in signal processing: oversampling, noise reduction and fractional sampling, among others.

By using a sound level meter, it is possible to get an idea of the proportions in sound pressure level between the noise floor of a rehearsal room and a reasonable listening intensity level. In my case, I measured about 40dB SPL in a quiet room and around 105dBA when listening to an animated band rehearsal. That is about a 65dBA difference. Therefore, the 16bits theoretical dynamic range of 96dB will be a very optimistic one to match in performance control. Sharpening our sensitivity thresholds and their quantification is a long task involving theory and experimental practice. There are, however, unambiguous and detailed documents available addressing the theoretical details to guide the experimentation, for example, on the psychophysical relationships of different unities and quantities used in measurements of audio signals levels,[3] or in the integration of time through new unit levels (LUFS, LU) and the recommendations of broadcasting unions.[4]

As Murray Campbell and Clive Greated remind us in *The Musician's Guide to Acoustics*, the perception and discrimination of loudness is a complex operation that involves subjective judgments that cannot be objectively measured. Loudness perception is influenced by the duration, frequency spectrum of the sound, and the context in which the sound is heard.[5] Therefore, the challenge of the activity proposed here is to balance subjective judgments without involving scientific measurements (though one can be tempted to do just that). However, a monitoring device of the sound pressure level with a calibrated scale may be an excellent tool to have. The idea is to raise awareness and discuss the possible dynamic range that the band can handle with electrically-generated sound, as well as to address questions of balance with amplified and electronic instruments.

Dynamically distributing the sonic energy of an ensemble of musicians over a set of loudspeakers requires experience, listening and judgment. The task could be given to one person or shared by a whole group. In a small ensemble, the task of live-mixing can be distributed among the players by calibrating the maximum levels of a shared mixer; the levels would thus not be touched at any point after, and the mix is done by ear by the same players. For larger groups (maybe over four or five musicians) and large venues, other than a good quality monitoring system, the responsibility of looking after the levels for the audience is fundamental, and so it is often given to trustworthy, dedicated hands. The importance and musical responsibility of these extra hands at the main mixing desk cannot be underscored enough. A deep understanding of the band sound and a skillful delivery of the

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[3] Bader, Rolf. Springer Handbook of Systematic Musicology. Springer, 2018;
Parker, Scott, and Bruce Schneider. "Loudness and Loudness Discrimination." Perception & Psychophysics 28, no. 5 (1980): 398–406;
Smith, Julius O. "Mathematics of the Discrete Fourier Transform (DFT)." W3K: Charleston, SC, USA, 2007.

[4] EBU–Recommendation, R. "Loudness Normalisation and Permitted Maximum Level of Audio Signals," 2011.

[5] Campbell, Murray, and Clive Greated. The Musician's Guide to Acoustics. OUP Oxford, 1994.

music in the room will open possibilities of expansion and support for the other players. Music performance is teamwork, and it would be a great chance to find the right person for the live-mixing role inside the band or close to it. More about the simultaneity of sound sources and its balance will be discussed in chapter 7.2 Vertical Time – "Red Herring" in the musical elements.

Another important consideration is the control mechanism to manipulate the sound level of the instruments or the volume control. An alternative is to ensure an analog control of the volume via a potentiometer or a fader in the last stage of the signal path of the instrument. In this way, fast-spontaneous access is possible. However, it is not always realistic to expect to permanently block a hand on the slider fader controlling the overall level moment-to-moment. Therefore, more appropriate interfaces can be used and accurately mapped to facilitate expressive control of loudness, for example, pedals or pressure-sensitive keyboards or pads with velocity control, among others. One particular case is the computer performer (a player who uses the qwerty keyboard of a laptop as the primary interface), delivering particularly numerically precise values by writing them down or by setting a graphical interface. In this case, I suggest using the computer as a training tool to guide and study the dynamic changes, to perform *blind tests* to identify different interval changes and to program dynamically consistent sets of sounds for performance. There will eventually be instruments that by nature and on purpose do not include volume control. If the use of an external controller as suggested above is not a possibility, for example, a handheld synth with a built-in loudspeaker but no audio line output, one option is to work physically with the loudspeaker or resonator, damping the sound manually with the help of clothes, tissues or bare hands. In the worst case, don't use instruments. Instead, use body percussion or voice effects to experience the dynamic scales and intervals.

6.1.6 Implementations

† Fine tune the amplification system at the place where you rehearse by calibrating a comfortable-loud sound and an audible pianissimo. As an example, see Engineer Dave Moulton's report on adjusting the levels in a small room for critical listening.

> if we've 'calibrated' our system so that one speaker, driven by a –14 dBFS signal, yields 85 dB SPL, then our 'nominal level' in stereo will be about 90 dB SPL and the maximum level is probably a little less than 105 dB SPL (this will be slightly less than zero dBFS going to each of two speakers). Assuming that our speakers each require 1 Watt of power to generate 88 dB SPL at our listening position

(typical), each speaker is going to require 16 Watts of power to play back 0 dBFS.[6]

† Patch your instrument controller to use discrete values of dynamics, for example, the octave of a keyboard map to different key velocities. Experiment with different transfer functions to alter the mapping. Use your favorite synthesis and samples as the sound source or even a microphone input.

† Write an algorithm that can generate and remember dynamic paths over temporal structures. Again, use your known sound sources and experiment as well with a real-time live audio stream.

† Build a vactrol and use it as a voltage to resistance converter and find or hack a volume pot or a VCA (Voltage Controlled Amplifier). Try and experiment driving the vactrol with different voltage sources, including microphones, consumer electronics, other instruments, and synthesizers.

† Build an R2R DAC and program an 8-bit microcontroller to perform square waves and sequencing different controlled volumes.

[6] Moulton, Dave. "Audio Levels In a Small Listening Room." TvTechnology. Accessed December 29, 2018. `https://www.tvtechnology.com/opinions/audio-levels-in-a-small-listening-room`.

6.2 Signal Processing – The Hall of Mirrors

The Hall of Mirrors is an improvisation situation in which players lose themselves in sonic transformations of live audio streams. It is a play framework to perform time, frequency and space-based operations by sharing signals and performance roles within a simple repetitive temporal structure.

6.2.1 Tags

Sound treatments, effect chain, theme and variations, matrix mixer, live sampling.

6.2.2 Goal

The main objective in this section is to motivate the players to collect and study a consistent set of processing audio tools. The number of available implementations of audio signal processors in real-time is so broad that picking up a few of them for performance purposes requires a very critical attitude and the capacity to make *tasteful* choices. A sensible goal is then to reach an understanding of sonic transformation possibilities (i.e. by re-building a categorization) and to use them in a music performance context.

Another goal is to revisit the concept of live-sampling by working on the ability to record, store, re-arrange, manipulate and recall chunks of musical moments in a metamorphosis of textures, qualities, tones, rhythms and timbre variations.

6.2.3 Description

The *Hall* is a space-time framework; the *mirrors* are sound transformations. The *Hall of Mirrors* is a situation where the original sound sources are lost among their transformations. It should be impossible to distinguish the sonic object from its mirror-transformed reflections.

There are two roles in the performance: a sound source *generator* and a sound *processor* performer. The sound source can be produced with a microphone, an electronic instrument, synthetically generated using pre-recorded material, from the system itself in a feedback configuration, or even from an electromechanical structure designed for sound-making purposes. The processors should handle a set of audio processing tools such as distortion and effects pedals, delay units, ring modulators, analogue filters, frequency shifters, reverb units, or a sound card and a computer running a series of audio plugins, such as granular-processors, spectral delays and convolution reverbs, or even electromechanical devices, such as voltage-controlled fans spinning different objects in front of the loudspeaker to modify and filter the resulting tone of the sound. Every performer should have the possibility to act as a generator or as a processor at any moment, so each performer set must include at least one extra audio input to process signals from the ensemble and one extra output to forward the signal to the others. Ideally, everybody will have available in their systems as many inputs and outputs as the number of participants, but one extra input and output allows one to participate in the performance.

The situation unfolds by collectively playing in a synchronized manner and endlessly repeating sound events articulated with a temporal structure of five moments: preparation, attack, sustain, release, silence. The duration of a sound event should be about the duration of a collective breath (including some apnea seconds). At every moment, the sound of each player is available to everybody for processing (the hall). The performer generating sounds must try to match his or her sonic qualities with the processed resulting sound; similarly, the processors have to progressively or imperceptibly transition towards a metamorphosed version of the sound source (the mirrors). Using live-sampling techniques of recording and recalling signals in situ and reinforced by the endless reiteration of the temporal structure, it should be possible to create a feeling of collapsing the sequence of events to a form of memory-based transformations of the timeline (What happened before: the sound or its variations? Who is playing what?). The ensemble should find a common end within the suggested duration of five to ten minutes.

The amplification of the ensemble should ideally be local: one loudspeaker at the proximity of each player (at least one channel on the power amplifier) or more if handled by the performers themselves. In other settings, for example, mixing the ensemble signals to a stereo field or diffusing them through an array of loudspeakers involves an extra role in the performance which needs permanent access to the mixing control. The complexity of the performance will depend on the size of the available mixer and the possible paths and selection of signal processors. A matrix mixer can be connected as a central unit. A matrix mixer is an audio device that can route the signals of each input channel to all of the output channels, for example, in number of inputs and outputs 4X4 or 8X8, but also irregular variants such as 4X6 or 2X8. The form is fixed by the number of possible physical connections in the device. A software application that can shift and interpolate among the delta times over configurations of the matrix gains saved on momentary state variables will be a luxury for this performance! If a mixer is not available, the connection between inputs and outputs should be hardwired in advance with an alternative distribution system, such as several multichannel sound cards or audio line splitters.

Much effort can be granted and attention spent on exploring, judging and evaluating the signal processing pool. It is about choosing and selecting with a critical listening spirit. The connectivity of the unit processors should be prepared prior to the start of the improvisation, but of course, they can be swapped and rebuilt during the performance – even becoming the performance itself. Because some of the signal paths offer the possibility of fine-tuning a set of presets in advance, the possibility of preparing some pre-recorded material is an option as well. Quoting sounds that will be played later on by a physical gesture of one player allows one to mislead the visual cues and to confuse the perception of acoustic causality and reinforce the *Hall of Mirrors* effect.

6.2.4 Variations

- Using the distances between microphones and speakers, generate a dynamic mix and to pick up the signals for processing avoiding wired connections, implementing a kind of *acoustic matrix mixer*.
- Program an automatized sound processing chain to perform the hall of mirrors as soloist,

6.2.5 Discussion

Jonathan Sterne and Tara Rodgers discuss in their article "The Poetics of Signal Processing" the intrinsic materiality of a signal.

> In conventional professional usage, signal processing presupposes a distinction between an electrical, electronic, or digital signal that is manipulated, and the meaning and content of the signal (see Nebeker).[7] Thus, the signal has a certain materiality to it — it takes up space in a channel or in a storage medium, and it is an object that can be manipulated in various ways.[8]

Manipulating the content and meaning of audio signals or processing the materiality of sounds is a fascinating and inspiring experience since it can be done in very creative ways by using and integrating different technologies. Mechanical, electromechanical, acoustic, analogue and digital principles can be used to alter the timbre qualities of a sound. In the mechanical, electromechanical and acoustic domain, transformations related with rotations, motions and transduction give a great gamut of possibilities to explore. The following list gives few examples of classic electromechanical sound transformations as a starting point for further investigations:

[7] Nebeker, Frederik. Signal Processing: The Emergence of a Discipline. New York: IEEE p, 1998

[8] Sterne, Jonathan, and Tara Rodgers. "The poetics of signal processing." differences 22, no. 2-3 (2011): 31-53.

- using rotating devices to alter the radiation pattern of a loudspeaker as in the *Leslie rotating speaker*;
- setting in a swinging motion a microphone or a loudspeaker to produce phasing and tremolo effects;
- using amplifiers to excite plates, springs, cans and all sorts of materials and then picking up the resulting vibrations;(see chapter 4, "transducers and alternative loudspeakers")
- passing the sounds through pipes, tubes and hoses to create delays and filter effects as in the *talkbox*.

The *Candela Vibrophase* is an impressive implementation of a tremolo pedal by Zachary Vex presented in the NAMM 2016 which "uses the photo, thermal and electric properties of light to modify the sound of its input signal" via spinning modulation discs powered by a "tealight candle".[9].

In the analog processing domain, there are as well all sorts of fantastic possibilities; looking back to history is a real source of inspiration, for example, the *oilcan delays* developed by Ray Lubow (at the Tel-Ray company) in the 1960s exploited in a clever way the electrostatic storage of signals to create delay effects.[10] Distortions, overdrives, filtering, waveshaping, wave rectifiers, amplitude modulators, frequency dividers with vacuum tubes, transistors and operational amplifiers produce a colorful and organic sound that many digital implementations search to emulate.[11] Particular to the digital domain, the time accuracy of digital delay networks and the precision of frequency analysis and representations of audio signals have opened the way for fabulous and original transformations of sounds, such as spectral delays,[12] filtering, freezing, granular synthesis, convolutions, cross synthesis and alternative practices, such as *databending* and *datamoshing* among many others.[13] Building a typology of sound processors may be a way to make sense of all the richness of audio signal processing. Other than grouping by the

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[9] McLean, Alex, and Roger T. Dean. The Oxford Handbook of Algorithmic Music. Oxford University Press, 2018. 392–393

[10] Tarquin, Brian. Stomp on This! Boston: Cengage Learning PTR, 2014;
"Oil Can Delays." Accessed December 3, 2018.
`http://www.geofex.com/Article_Folders/oil_can_delays.htm`.

[11] Pakarinen, Jyri, Vesa Välimäki, Federico Fontana, Victor Lazzarini, and Jonathan S. Abel. "Recent Advances in Real-Time Musical Effects, Synthesis, and Virtual Analog Models." EURASIP Journal on Advances in Signal Processing 2011, no. 1 (December 2011);
Zölzer, Udo. DAFX: Digital Audio Effects. John Wiley & Sons, 2011.

[12] Charles, Jean-François. "A Tutorial on Spectral Sound Processing Using Max/MSP and Jitter." Computer Music Journal 32, no. 3 (2008): 87–102.

[13] Bach, Glenn. "The Extra-Digital Axis Mundi: Myth, Magic and Metaphor in Laptop Music." Contemporary Music Review 22, no. 4 (2003): 3–9.

underlying technology (electronic, electric, mechanical, electromechanical), transformations of audio signals can be classified according to the main operations performed on the signal

amplitude-Based or Dynamic Transformations
Time-Based Transformations
Spectral -Based Transformations
Spatial Based Transformations

However, these categories don't have an unequivocal or simple relation or map one-to-one onto perceptual parameters of sound. The dependence among several perceptive sound parameters when performing unidimensional modification can be demonstrated with the digital delay line-feedback. This basic time-based manipulation will produce a vast range of dynamic, timbre and rhythmic transformations depending on the variations of the delay time durations. The resulting effects are perceptible as spectral modifications, such as low pass filters, comb filters and modulation effects when working with short delay times (from 1 sample delay to about 20ms), and as textural and rhythmical effects perceived as rhythmical structures or progressions with longer delay times beyond 50ms. The examples could go on by including the modulation of localization of signals in a multichannel array. Panning a signal over several loudspeakers at a low rate will be perceived as a motion effect; at audio rate speeds it will produce radical changes on timbre similar to those of the amplitude modulation. In the analog electronics domain, an interesting implementation for dealing with the simultaneous change of timbre and volume that accompanies a decrescendo in an acoustic instrument as opposed to simple fade-outs of some electronic instruments is the Low Pass Gate (LPG). LPG mixs a VCA (Voltage Control Amplifier) and a VCF (Voltage Control Filter), so it is basically a VCFA (Voltage Controlled Filter Amplifier) for simultaneously affecting the dynamic and spectral content of a signal when performing a simple amplitude-based transformation such as a decrescendo.[14]

For the complexities of interaction among the affected parameters of signal processors and their perceptual musical and sonic effect, building a perceptual based taxonomy of audio effects is a complex task. The *Hall of Mirrors* is an opportunity for the performers to study the mechanisms of audio processing tools and their performance while judiciously listening to the resulting sounds. Thus, based on critical listening and theoretical investigations, the performer should build their own categorizations or personal typologies of sound processing tools. A starting point can be to sort out and separate the vocabulary used to describe the signal processors into the technical aspects and underlying technology, musically perceived qualities and the subjective effects on the listener. Another suggestion

[14] Parker, Julian, and Stephano D'Angelo. "A Digital Model of the Buchla Lowpass-Gate." In Proc. Int. Conf. Digital Audio Effects (DAFx-13), Maynooth, Ireland, 278–285, 2013.

to develop critical listening is to maintain the simplicity of the effect chain, listening and understanding one unit at the time before jumping into the complex and interconnected network of sound processors. This process should be preliminary to group improvisation, so when the improvisation situation is running, the imagination can freely flow, inventing and speculating on sound transformations.

The choice for this improvisation of simple attack-resonance (AR) sound gestures (surrounded by silences), other than facilitating the evaluation of the sound processors units, makes the temporal structural element dictate the musical form. The overall form of the improvisation is the result of the repetitive process, i.e., performing twelve such AR sounds in a row, allowing for enough silence between them and with a duration of around 20 seconds each will translate to about 4-5 minutes, enough time to keep a clear image of the musical evolution and to have critical views on it. As stated earlier, for this performance, the AR sound implies a five-step sequence: starting always from silence, then a preparation time of anacrusis style, the attack itself, a resonating time and the time for the processes to end, then silence again (which can be counted as the next beginning). Tailoring those different times is a collective effort to carry out the plan. Among the sonic events, silence in particular should be as clean as possible.

Commonly, breathing allows one to understand the ensemble's inner rhythms. Inhaling and exhaling together the different moments of the sound gesture increases the expressive power, and in an improvisation context, it can help the performer to extend their techniques beyond their current limits. The resonance moment can be seen as a cathartic moment where madness is a gift, the pushing force of the Dionysian spirit of the music. Reaching the end of the breathing impulse should be accompanied by a totally air-free body, an apnea instant exhausting to the end the exhaling process.

Live-sampling can be described as a virtuoso performance of isolating fragments through real-time recording of an audio signal for further processing or even direct playback. Varying the playback speed, the starting point and the size of samples of the playback fragment, adding effects, mixing live with other materials and accurate triggering of sonic events produces a form of instrumental performance that can compete in complexity with the playback of a traditional instrument. In this performance situation, integrating all those possibilities under the umbrella of a dynamic structure puts all the instruments and audio machines on the same level.[15]

Attaining fluency on a variety of sound transformations is a long process, mostly determined by the access to processing units and devices, to allocate enough time to experiment in different situations, to read their manuals, study the technical aspects, and to share observations with fellow musicians. Familiarizing oneslef

[15] Aveyard, Jon, and Dan Wilkinson. "Third City 2017: Improvisational Roles in Performances Using Live sampling." Open Cultural Studies 2, no. 1 (2018): 562–573.

with hardware and software for audio transformations is a long process of exploring the market of available machines, plugins and devices. A personal monetary effort is necessary at some point. Therefore, choosing the right machine to fulfill one's musical needs is a path of following the industry developments, gear review reading, peer chatting, testing of demo units, but also of buying, selling and exchanging audio equipment. Therefore, as a host for an electroacoustic performance workshop, it is a helpful practice to accumulate a particular set of tools that can easily be reprogrammed or reconfigured to understand and evaluate a particular process. As long as the players have access to a small sound card and an open source audio development platform, the possibilities are very large. Battery-powered units can be built as well rather cheaply for testing purposes and eventually performance. At the other end of the spectrum, an army of signal processing units can be installed in a rack or packed in forms that allow transportation and setting. The important point is to keep a critical judgment on the gear to resist the pressure by commercial firms that need permanent sales and income. For a musician, it is ultimately more critical to achieve musical results than to collect mountains of gear, though it could also be a professional opening for some towards building, repairing, reviewing, selling or joining the market of audio processing products.

6.2.6 Implementations

Below, there are a few suggestions of how to implement some of the concepts exposed in this section:

† Program a software using virtual busses to create a complex matrix of senders, receivers, and modifiers. Create or map a user interface to access the relevant parameters.

† Make a solo version with one or more signal chains where the levels and variables are manipulated in real time. Another version can be made solo as well but with a non-input mixer, where the triggering sound is the product of self-resonating electronic components of the board. The feedback paths can be spiced up with outboard gear and with the built-in options of sound sculpting in each machine. Consider limiters and compressors, keeping an eye on the audio input and output levels.

† Build a sampler application that can take the incoming signal in different buffers simultaneously and give access to their manipulation through a user interface, knobs, tablets and touchable interfaces, for example.

6.3 Signal Generation – The Trigger

A performance task to create awareness in the possibility of change and role taking. An opportunity to research and study the principles of sound synthesis.

6.3.1 Tags

Sound synthesis, event generation, attack-resonance, function generator, oscillators, comparator, integrator, feedback.

6.3.2 Goal

The main goal of this chapter is to encourage experimentation through the performance of different models and algorithms of sound synthesis in a musical context.

A parallel goal is to identify a role taken in the ensemble by defining the musical behavior of a *trigger*. The trigger will be someone who plays an event and listens carefully to the answers, proposing a change in direction or a supportive promotion of musical ideas to the ensemble. The trigger will be a performance attitude that can be identified and observed.

A final subsidiary goal is to promote the development of a common vocabulary within the ensemble by working around the concept of a sound cue. What makes a sound a trigger proposal and not a sporadic comment? How is it different from proposing a change to play a supportive trigger? How to identify the qualities in the ongoing music that can be addressed by the trigger? How can analytical listening unfold questions, statements, and affirmations in the trigger proposals?

6.3.3 Description

The Trigger is an improvisation situation in which the role of deciding on changes or evolutions in the direction of the music is left to (an) identifiable player(s). From one to all, including the maximum steps in between, players can assume the role of event generators. The trigger is then a performer playing a sound cue that should reflect and influence the music of the ensemble, either as a radical change, as a diametric antithesis of the current sound world or as a progressive movement in one direction.

The resulting improvisations are relatively short with clear beginnings and endings. Its purpose is to challenge the ensemble to understand and reply in a diversity of ways to the proposed short trigger-events. An initial number of players volunteer to work as triggers. The trigger-performers must carefully choose the moment of intervention and must select a brief sonic event that indicates a clear change in the on-going sonicscape. The role of performing triggers should be understood by the ensemble so that if another player would like to take the role, she should play by the same rules – short trigger sounds and extended silences.

There must be a physical limit on the amount and density of distinguishable triggers for the human ear before saturation. Let us imagine an extreme situation where the ensemble of eight musicians exchanges their triggering role at a rate of eighteen notes at a moderate tempo of 60 bpm (beats per minute). This means that each performer should be making decisions and operations at a rate of 250 ms per event, where each event should tend towards a change. This situation is probably a performance limit since, beyond this rate it will be a challenge to track, answer and decide. The situation could also be based on the contrary: on medium-term attack sounds and extended answers from the ensemble, and even conquering silence territories.

The improvisations are played several times within discussions of how well the trigger role was understood and followed. Because of the proposed integration with sound synthesis concepts, these experiments can ultimately be described as a shared experience where the attack and resonance of sonic gestures are shared and distributed among the players. So, one player performs the attack followed by other who perform the resonance. Triggering a sound process, or setting in motion a sonic development, is as important as the process itself, in the same way that creating a synthetic sound demands extreme attention at the way the sound is triggered. The attack will determine a lot of the sonic qualities and potentialities of the unfolding sound. In the following sections, I will illustrate how certain elements from the electronic sound generation can be aligned with the trigger situation.

6.3.4 Variations

Create a solo version. The trigger event and the resulting induced change or resonance effect should have a clear difference. Triggers can be introduced along with the play or from silences.

Although one of the main points in this task is to listen to the ensemble and to trigger events by carefully choosing the moment, a version with a rhythmical sequence of triggers of determined length can be tried out, for example, every 20 seconds or so. In this way, the cycling of changes will help the ensemble and the trigger person to prepare.

6.3.5 Discussion

Triggering sonic processes is an action very closely related to sound synthesis, which is the generation of audio signals from scratch through the interconnection of basic building blocks, such as integrators, comparators, vectors, shifts, slews, voltage sequences, noise sources, counters, multiplication and offset, among others. Connecting those primitive units is often called *patching* as a reference to the analog synthesizers. Performing a synthesizer requires a patch to be set in the same way that performing live-sampling and live-processing requires connectivity to be ready at the start. However, the act of modifying and re-inventing the signal paths during performance is a powerful gesture in electroacoustic music and demands of the performer a form of technical focus virtuosity to allow the musical flow and group interaction to happen without disturbance.

As introduced in the chapter on sound processing, the border between sound processing and sound synthesis is blurred by the use of pre-recorded samples. On the one hand, digitalizing an acoustic wave can be understood as a processing technique of Amplitude Modulation; on the other hand, converting digital samples into acoustic sound fits some aspects of the definition of sound synthesis: recreating a sound by specifying sound pressure functions. The conversion process of re-generating the previously recorded sound is often referred to as re-synthesis in order to differentiate it from the operation of generating the numerical values of sound samples. A borderline then is often drawn by asserting that sound synthesis does not require a physical acoustic source.[16] This assertion will, however, leave the synthesis on the pre-recorded material of live-sampling acoustic sources – as in Live Granular Synthesis – out of the equation. Therefore, the definition has to be stretched to consider the use of sound recorded and stored in buffers from acoustic sources as another source for the synthesis process. Of course, synthesis processes can in turn be treated and manipulated through signal processors paths.[17]

If there is any point or need to divide between signal processing and sound synthesis, I argue that there exists a duality of different intentions. If the purpose is to modify a sound generator or source of any nature, we are walking on signal processing paths; on the other hand, if the purpose is to generate signal sounds, we are entering the territory of synthesis. During a musical performance, such a distinction may be useless because the resulting sound is a digression of those possibilities. One moment the sound is being processed, and in the next, it is being generated. Many available synthesizers include processing units and simultaneously, most samplers include live recording inputs allowing one to store and

[16] "Synthesis and Resynthesis Techniques Rob Weale" accessed June 2018, `https://web.archive.org/web/20181108030034/http://www.ears.dmu.ac.uk/`

[17] Keller, Damián, and Barry Truax. "Ecologically-Based Granular Synthesis." In ICMC, 1998;
Roads, Curtis, Stephen Travis Pope, Aldo Piccialli, and Giovanni De Poli. Musical Signal Processing. Routledge, 2013. 125-187

process the samples in pitch, tempo, and tone. The analytical process of studying and understanding the mechanism of audio signal generation can only be beneficial for the performer of electroacoustic music by contributing to the development of listening judgments and criteria.

In electroacoustic music, audio signals can be generated with analog techniques of voltage manipulations in an analogy of sound pressure levels, or in the digital domain, by fast computation of amplitude sample levels numerically expressed and converted into audio rates. A third possibility will be to design and build an electromechanical noise machine using solenoids, step motors, engines or resonating surfaces of a variety of materials. These three possibilities can implement many ideas for sound generation in their way and therefore create idiosyncrasies, opening sonic and musical qualities for investigation and performance.

Reviewing the considerable number of implementations in the analog, digital and electromechanical domain is a very extensive work that should be addressed with many exercises, experiments, readings and research. It goes the same route as in the signal processor chapter: experimenting with all the available tools and instruments and gathering a preferred set of tools while sharpening a vocabulary and building mental categorizations. More than reviewing the details of each existing technique, here I am concerned with establishing a parallel between the functioning of those generative tools and the sound of an electroacoustic ensemble as a whole. Let us, for example, consider the idea of repetition as a sound generator. The same intention of generating a cyclical process to produce a harmonic spectrum and a waveform can be associated with triggering a repetitive musical moment. For that, the repetition element should be incorporated into the proposal.

Cycling and repeating is probably the simplest form of sound generation. One way of achieving it in the analog domain is with a circuit called a *Function Generator*. A Function Generator is a circuit that generates voltage trajectories and trigger states based on a feedback configuration of a comparator and an integrator. A comparator has a voltage threshold reference and a second voltage input. Once the threshold is crossed in any direction at the input, the comparator will flip its output state to the power supply voltages. In other words, if the voltage input is greater than the reference, the output will tend towards the positive power line; if the input is less than the reference, the output will tend towards the negative power line, and if the voltage input is zero, the output will converge towards zero. This generalization will depend on the components' quality of power lines and many other factors that make it possible to perform the comparison operation in a real implementation.[18] Re-injecting the output back into the comparison stage can then create an oscillation, and the time of flipping states of the circuit

[18] "555 oscillator Tutorial – The Astable Multivibrator." Basic Electronics Tutorials (blog), September 6, 2013.
`https://www.electronics-tutorials.ws/waveforms/555_oscillator.html`.

will become the period of a square waveform. To control the time of bringing the output voltage back to the comparison state, an integrator can be used. An integrator produces an *output voltage which is proportional to the integral of the input voltage.*[19] That is to say: the magnitude of the output signal is determined by the interval of time a voltage is present at its input. Charging and discharging a capacitor produces an ascending or descending voltage ramp or the integral of the voltage input. Joined to the comparator for re-triggering the process, the integrator can produce a triangle waveform where the pitch will be dependent on the wave period. The operation of comparison and integration can be performed with vacuum tubes, transistors, operational amplifiers or numerically in a digital system. An electromechanical version will require a sensing mechanism for the comparison and a driver to carry state changes on a resonating element.

From the performance perspective, these three tools (comparison, integration, feedback) can also be implemented. For example, in the context of the activity proposed here, if a threshold is crossed, a sound cue is triggered to instigate the ensemble to change the musical state. Integration can be performed by playing a sound trigger cue that clearly raises or drops a sound parameter such as rhythm, dynamics, spectral density, among others. For the concept of feedback, some particular feature from the music played by the ensemble can be spotted and re-triggered, inciting one to push forward the music in one direction.

In a dissection of commercially available synthesizers, oscillators and waveform generators are very likely to be found. I invite the performers to explore the qualities and get familiar with the particularities of different oscillators. For example, analog oscillators do not suffer from a common issue in the digital world: aliasing distortion. Aliasing happens when the frequency of a digital wave or its harmonics reach the Nyquist Frequency, producing non-harmonically related new frequencies and intermodulation effects after conversion. Several techniques have been developed to address the issue, including elegant algorithms like the one exposed by Jussi Pekonen in his thesis about virtual analog synthesis.[20] Pekonen discusses *new polynomial bandlimited function generators* and introduces optimized a look-up table and polynomial-based functions for these algorithms. While these techniques have made their way into software implementations, there are still many instruments that produce such distortion effects at the oscillator core. Such effects are more noticeable when modulating the oscillators but will eventually be the signature of early digital instruments. I would like to make clear that I am not signaling the aliasing distortion as something ugly or intolerable.

[19] "Op-Amp Integrator – The Operational Amplifier Integrator." Basic Electronics Tutorials (blog), August 24, 2013. `https://www.electronics-tutorials.ws/opamp/opamp_6.html`.

[20] Pekonen, Jussi. "Filter-Based Oscillator Algorithms for Virtual Analog Synthesis." (2014)

Aliasing and other digital glitches are welcomed by some artists who see them as a potential expressive tool.[21]

Many other particular sound qualities can be researched in different implementations of analog oscillators, including for example: through zero oscillators, complex oscillators, linear and exponential frequency modulation, hard sync, soft sync.[22] The digital generation of sound has been strongly influenced by the analog heritage but has opened new paths for experimentation. As discussed by Julius O. Smith III in his Keynote Paper, Viewpoints on the history of digital synthesis, a typology of digital synthesis will cover categories of Processed Recordings, Spectral Models, Physical Model and Abstract Algorithms.[23] Particular attention has to be paid to the implementations and familiarity with that typology. In my opinion there is still ground for development and for the discovery of new synthesis paradigms. Performers will play a key role in that process.

If oscillators are powerful tools for sound generation, there are still other elements to consider. This being said, it is of course tempting to find musical references to artists using or building their performance around noise machines that are basically a set of interconnected oscillators. Also known as drone makers, those simple square wave generators can produce an incredible amount of timbre variations and oscillations. Other key components in the synthesis process are the modulators altering the available parameters of the oscillators. If we take our function generator and trigger it at a slow rate, we can use it as Low-Frequency oscillators slowly affecting the resulting sound, or if the function generator is triggered only once, it can also be used as a one-shot type of modulator known as an envelope. Along with modulators, filters, amplifiers and waveshapers, wave folders and wave processors contribute enormously to the sound synthesis and should be further investigated by designing more exercises and experiments. Because the main purposes of these units are to alter or process the sound, they should be considered as signal processor units and can be addressed in the same way as described in the previous chapter.

A special case of a sound generating unit is the noise Generator. Noise is a complex signal very rich in frequency content. It can be found in nature, for example, in proximity to a powerful waterfall. This complexity has attracted musicians and artists in evolving an aesthetic trend called Noise Music or Noise Art.[24] The topic

[21] Cascone, Kim. “The Aesthetics of Failure: ‘Post-Digital’ Tendencies in Contemporary Computer Music.” Collected Work: Computer Music Journal. XXIV/4 (Winter 2000): Encounters with Electronica. Published by: Cambridge, MA: MIT Press, 2000. 24, no. 4 (2000): 12–18.

[22] Strange, Allen. Electronic music: systems, techniques, and controls. William C Brown Pub, 1983.

[23] Smith, Julius O. "Viewpoints on the history of digital synthesis." In Proceedings of the International Computer Music Conference, pp. 1-1. International Computer Music Association, 1991.

[24] Hegarty, Paul. "Noise music." The Semiotic Review Of Books 16 (2006).

of noise is addressed in chapter 5.6 Noise Wall. However, from a synthesis point of view the noise generator should have its own dedicated experimentation and designed improvisations as the raw material and basis of subtractive synthesis. Starting from a complex signal and sculpting it by filtering and reducing its spectra.

Coming back to our triggering exercise, I would like to invite the performers to build their own repertoire of triggering gestures by investigating the concepts mentioned so far. Sound synthesis is a big chapter in electroacoustic music and demands discipline and devotion. There is a place to start, and it is the instruments itself. Isolating the components, re-imaging the connections, re-patching, manipulating the exposed parameters, creating presets or memorizing signal paths. Hand in hand with making music, the goal here is to trigger the curiosity for learning and mastering the ideas behind sound synthesis.

6.3.6 Implementations

† Build a battery-powered pulse generator with the pitch and level controls. Research a circuit based either in an a stable multivibrator using transistors, or in the avalanche transistor configuration, or in a Schmitt trigger design with CMOS or op-amps packed in a small box with audio connectors.

† Using a microcontroller (Teensy, STM32, Arduino or equivalent), write the code implementing a digital oscillator with the basic waveforms: Saw, Square, Triangle, Sine.

† In your favorite software, write a preset of cross-modulation: two oscillators modulating each other frequencies. Choose the relevant parameter to be exposed to a user. If your software does not allow such a patch, look for one that can do it.

6.4 Broadcasting – Non Listening Orchestra

The non-listening orchestra is an experiment to investigate the assumptions of presence and being, right now, right here, in a collective musical experience. The main tool to carry on the experiment will be the possibility to broadcast the sound of the performers to different places, avoiding the option of listening or monitoring the sound of the other members of the band and even avoiding visual contact.

6.4.1 Tags

Telecommunications, signal distribution, radio, telematics.

6.4.2 Goal

This experiment should encourage the performers to research, discuss and develop ideas related to the non-verbal, non-musical communication among the members of a band. How important is eye contact? How is physical energy and presence communicated? Is the listener the ultimate goal of the music, making sense and putting all the sounds together? Is it possible to read musical intentions avoiding visual and aural cues? Where is the place for intuition in musical performance?

This experiment should be an opportunity to explore and study the techniques of disseminating a musical performance that takes place at the same time but not at the same place. It is also an occasion to review how electroacoustic music has benefited from the development of telecommunications and how these developments can be set up for pushing forward musical experiences in the future.

6.4.3 Description

To perform the experiment, several separate spaces are needed. The musician's signal should be picked up and centralized in a recording platform. If only one room is available, the musicians should be spread in a way to avoid visual contact, and each musician's setting should not be amplified. The monitoring of their signals is done with headphones, and there would not be any signal exchange among them. Only the central recording platform can monitor the whole. After every musician has installed their setting and a basic sound check is done, to avoid signal clipping and distortion on the recording, the band must agree on a schedule. An improvisation length is decided on – let us say ten minutes, and a starting time defined, for example, 10:25 am. Therefore, every performer should have a watch or a way to control the time. Starting from silence, each performer plays an improvisation without knowing or listening to what the others are doing while the whole gets recorded.

When the improvisation is over, all the members of the band gather in a listening space and listen to the playback of the recording. A very subtle mixing may be needed, but it is not the point of the experiment. The leading questions for the discussion are: aesthetic and qualitative judgments of the result. Is there enough acoustic space in each one's improvisation to let things happen? has the band developed a *sound* making possible to predict to some extent the result? Can the musicians identify each other's voices? If the resulting recording is submitted to a blind text for a third audience, will they notice that none of the musicians are listening to each other? Is it possible to question the archetypes of improvisation practice for dynamic and spectral balance? Are there any coincidences either in rhythm, texture, dynamics? Does it sound like a possible improvisation in normal listening conditions?

Most of these questions do not have a definitive answer. The purpose of the discussion is to develop argumentation skills and identify personal tastes, preferences, and expectations. Being able to challenge their own positions demands an open spirit and aesthetic flexibility that is required in the discipline of improvisation. Openness means to be ready to perform and play in any situation accepting with humbleness the musical outcomes from *rencontres fortuites* on stage.

The experiment should be carried out several times, introducing slight changes if desired or just repeating it, for example, breaking down the time in smaller agreed frameworks, or introducing conditionals. Conditionals can be events, such as silence or a peak in volume or a pitch, chord, sequence or a surprise decision. The recording should be taken for private listening after the session and commented on further in other sessions.

6.4.4 Variations

One possible variation of the experiment includes different degrees of monitoring. For example, listening only to one performer, or having access to a small mixer where different channels can be switched on or off.

An *off-line* version can be done by inviting the musicians to record an improvisation at their home and put in them together at the studio for collective listening without prior mixing.

6.4.5 Discussion

The technical development of electroacoustic music and telecommunications technologies share common paths since many interests and challenges are common to both disciplines, basically, the transmission, encoding, and decoding of audio signals. There are of course many points of divergence as well, for example, a broader set of signals and the purpose of carrying a meaningful message in the telecommunications industry, against electroacoustic music that deals with the aesthetic use of sounds and abstract meanings, among many others. The idea of transmitting audio signals away from the source has radically changed our musical experience. This can be called the dislocation of space in audio technology, developed in parallel with the dislocation of time originated by the recording of audio. Listening to an audio stream that is being produced in a distant acoustic space is an extension of our sense of hearing. Through the history of developments of audio signal transmissions, from the late nineteenth century when the telephone was developed until modern quantum transmission experiments, musical applications have been and are on the agenda of developers, musicians, and engineers.[25] For example, from Thaddeus Cahill and his project of broadcasting music using the Telharmonium in the first decade of the twentieth century,[26] all the way until the increasing interest on telematic concerts over the internet,[27] and the popularity of streaming services like Spotify and SoundCloud, Youtube and online jam sessions such as eJamming, jammr, JamKazam, Ninjam, Jamulus and many others.[28]

Making musical use of the broadcasting properties of electronic sound can be taken into experimentations to inquire into assumptions of communication within an ensemble. Eye contact, for example, is very often referred to as a means to achieve a mutual understanding of sonic intentions and interactions among a band. In his article "The process of improvisation" (focusing on jazz improvisation), Ken Peplowski comment about eye contact.

> Also, we're constantly giving one another signals. You have to make eye contact, and that's why we spend so much time facing each other instead of the audience. When my solo is finished, someone else picks it up. We don't decide the order beforehand or even know who's going to take the

[25] Martini, R., C. Gmachl, J. Falciglia, F. G. Curti, C. G. Bethea, F. Capasso, E. A. Whittaker, et al. "High-Speed Modulation and Free-Space Optical Audio/Video Transmission Using Quantum Cascade Lasers." Electronics Letters 37, no. 3 (February 2001): 191–93.

[26] "Telharmonium | Grove Music." Accessed June 21, 2018. `http://www.oxfordmusiconline.com`

[27] Mizuno, Mikako. "On the Music through Network." Proceedings of Asia Computer Music Project (2011).

[28] Anderson, Mark. "Resources: Virtual Jamming." IEEE Spectrum 44, no. 7 (2007): 53–56.

> next solo. You just listen and you develop a sense for when it's time for the next person to play, and you watch for subtle signals that somebody is ready.[29]

The visual cues inform the performers about decisions and intentions in musical gestures. Furthermore, as discussed by Fredrickson in his study of 120 undergraduate band members, performing an ensemble piece with video and aural monitoring shows how musicians support their musical performance based on aural and visual cues.[30] What happens when each performer is deprived of accessing either visual or aural contact during the improvisation? Different musicians may rely upon different senses for making decisions, but once left alone in a solo performance while knowing that it will be part of a collective unmonitored improvisation, another set of cognitive skills comes into play.

I argue that those cognitive skills relate to developed intuition based on knowledge of the ensemble's sound and the familiarity with musical personalities of the performers. There is also a possibility that a performer uses this opportunity to explore annoying behaviors or extreme musical positions to defy a certain assumption that the musical result should be acceptable. Those are very enriching and valuable attitudes, and it is interesting to struggle for a non-sense or non-musical result. At the bottom line, it seems that an open mind to accept all the sounds in a *Cagean* spirit allows us to always find the music among those mixed improvised solos. However, what can we learn from aurally and visually isolating the musicians and still targeting a collective improvisation?

Over the years of performing this experiment, I have observed and heard some interesting but obscure argumentation about presence, connectivity, subliminal intuition, enhanced perception, and some other extra sensorial ideas that are not easy to define, test or investigate. However, I have found it beneficial to unveil those beliefs and to address the possibilities to question and assume critical views on these ideas. Listening to and analyzing the recording of such peculiar improvisation will also reveal the values placed on the sound and music of each person. Some may find that intolerable and some others may be fascinated, but why? The discussion has to be opened and the concept of music reviewed. What happens if the task given was to create a track, recorded at their own pace at their spaces at their timings and put together in a common session? Would the same discussion apply?

I would like to point out that similar experiments have been carried out to explore the idea of overlaying musical materials from different sources without the

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29 Peplowski, Ken. "The Process of Improvisation." Organization Science 9, no. 5 (1998): 560–61.

30 Fredrickson, William E. "Band musicians' performance and eye contact as influenced by loss of a visual and/or aural stimulus." Journal of Research in Music Education 42.4 (1994): 306-317.

musicians Listening and monitoring them simultaneous in different degrees. Most notably in the album *The Appointed Hour (2001)* by Peter Hammill and Roger Eno. In the review of the record Steven McDonald wrote

> Hammill and Roger Eno chose a key in which to begin and a specific time at which their performances would start. Then, sitting in their respective studios, miles apart, and with no communication whatsoever, they began to improvise, using various instruments. After one hour exactly, both ceased performing. Eno packed his tape off to Hammill, who then mixed the results, producing an hour-long master. An experiment that might well have resulted in cacophonous terror actually yielded engaging and extremely palatable results, with a variety of keyboard sounds, Eno's cello, piano, and guitars weaving through the mixture. There is a haunting quality to The Appointed Hour, as well as an underlying harmonic strength that supports repeated close listening.

Other experiments in the same vein include *xenochrony*, a term developed in the early sixties by Frank Zappa and applied to his desire for synthesizing recorded events from disparate times and locations.[31] The experiment of the non-Listening orchestra can also relate to some extent to the technique called *mashup music* used by many artists and consisting of blending to unrelated tracks into a new creation,[32] a practice probably derived from the *Quodlibet*,[33] and ending with contemporary practices of DJing.

Setting up the experiment of the non-Listening orchestra can be done in several ways, allowing for technical explorations. The simplest one will be to connect audio cables between each musician and the central recording unit, always keeping in mind the non-aural, non-visual cues rule. The wired connection must be implemented with balanced cables to optimize the signals over the length of the space. Eventually, external rooms may be used. Another alternative is to experiment with radio transmitters and receivers for broadcasting the signals over through space. FM car transmitters are very popular at the time of writing this paper and can be obtained in electronic stores. A simple AM transmitter can be built from a crystal oscillator and an audio transformer.[34] This is then a great opportunity to research the electromagnetic spectrum and radio signals. I like to mention one

[31] Pena, Carlos E. "Frank Zappa and the And." ARSC Journal. 45.1 (2014): 64.

[32] Casal, David Plans. "Crowdsourcing the Corpus: Using Collective Intelligence as a Method for Composition." Leonardo Music Journal 21 (2011): 25–28.

[33] "A quodlibet is a piece of music combining several different melodies, usually popular tunes, in counterpoint and often a light-hearted, humorous manner. The term is Latin, meaning 'whatever' or literally, 'what pleases.' `http://enacademic.com/dic.nsf/enwiki/71950`"

[34] `http://www.instructables.com/id/Build-a-very-simple-AM-Transmitter/` `http://scitoys.com/radio.html` June 2018

reference that I found very helpful in the pedagogical context: John Mills, *Letters of a Radio-Engineer to His Son,1922.*[35]

Using network protocols such as WLAN (wireless local area network) to set up a system for transmitting audio signals requires carefully preparing and ensuring reliability, bandwidth and configuration flexibility. Among the tools available during the present research project, the system *jacktrip* developed at the CCRMA in Stanford University has proven to be consistent and reliable for musical purposes.[36] A router and computer connections have to be prepared in advance. Once familiar with the system, it is very easy to use and can be even taken out for experimenting over longer distances. Many other systems for High-Quality Audio Network Performance over the Internet are in continual development for minimizing latencies and ensuring a comfortable musical performance. Integrating video signals and building avatars for virtual reality engines are also a promising development that should open doors for new forms of musical concerts, but the hardware necessary to experiment with those technologies are not widely available yet.

As the last point, I would like to bring the attention of the reader into the electromagnetic spectrum and what broadcasting radio signals over it means. Though this experiment is not intended to broadcast the signals beyond the studio rehearsal space, it is important to raise the awareness of the local regulations about the use of certain frequencies and wireless audio devices to avoid situations outside the law and to join the debate about coordination and management of the spectrum resources. It can only be beneficial for setting up performances and shows that include radio transmissions and audio over networks to be aware of the issues and matters to take into consideration.

6.4.6 Implementations

† Build an AM radio transmitter and test it with an AM receiver. Imagine a performance based on these devices.

† Set up a telematic performance for a small ensemble. What is needed? How to ensure low latency audio? Is video necessary?

† Organize a listening test mixing *real* improvisation performances with non-listening orchestra recordings. Do people recognize or identify the non-listening orchestra? If so, based on which cues?

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[35] Mills, John. Letters of a Radio-Engineer to His Son, 2009. `http://www.gutenberg.org/ebooks/30688`.

[36] `https://ccrma.stanford.edu/groups/soundwire/software/jacktrip/`
Cáceres, Juan-Pablo, and Chris Chafe. “JackTrip: Under the Hood of an Engine for Network Audio.” Journal of New Music Research 39, no. 3 (2010): 183–87.
see more references in chapter 4 “Performance Networks”

† Write a philosophical essay about the nature of music, for example, based on the experimentation proposed here: if nobody is listening, where is the music? Is the music a cognitive association in the listener, who makes meaningful connections and gives it sense? If so, what is the role of the musician? How can musicians communicate and express themselves if they do not share the same acoustic and visual space?

6.5 Spatialization – Hidden Lines

An improvisation experience for electroacoustic instruments playing over automatically-preprogrammed trajectories in a multichannel speaker setup.[37]

6.5.1 Tags

Spatialization, ambisonics, VBAP, amplitude panning, multichannel, envelopes.

6.5.2 Goal

6.5.3 Description

Improvisation requires a multichannel loudspeaker set up and electroacoustic sound sources, preferably with mono outputs. Though doable, handling stereo or more outputs per instrument increases complexity, blurring the clarity and purpose of the exercise. The speakers can be arranged in different configurations, for example:

- Ring of similar loudspeakers (4-8) surrounding the performers with a possible audience in the center.
- Hemispherical dome-like (half of a sphere) arrangement, with performers inside the geodesic structure using similar characteristics of loudspeakers.
- loudspeaker orchestra with a variety of loudspeakers arranged in an orchestra-like disposition. Mostly frontal but sides, highs, and back can be addressed according to the available units.
- Tree-like structure with loudspeakers arranged with a common center but pointing to different directions in the room. Performers are placed surrounding the structure, and a hypothetical audience sits on the periphery.
- One or two speakers per performer placed behind them arranged in a line or slightly curved arc. An audience will ideally be placed in front of the band.
- Symetrical or asymetrical distribution of loudspeakers among the audience.

[37] This chapter is strongly inspired by Dr. Andrew Bentley's courses on advanced techniques of spatialization, and some of my colleagues' work in the doctorate program in music technology (Dom Schlienger, Alejandro Montes de Oca, Juan de Dios Magdaleno and Paola Livorsi)

One computer running a spatialization software, e.g. VBAP,[38] Ambisonics Toolkit,[39] Spat,[40] ReaSurround,[41] or similar. The computer must handle all the loudspeakers through a sound card with enough analog channels as required. All the performers connect to the same sound card for spatialization.

A series of patterns controlling the parameters of the spatialization software to create trajectories must be programmed in advance. Fixed-point positions must also be included. Each spatial movement can have a fixed, determined duration, or it can be calculated and renewed on each iteration. This duration will reflect the speed of the trajectory in proportion with the number of loudspeakers. It should be important to keep track of the duration length of each trajectory to allow control over the time extent of the whole exercise.

The exercise starts with silence and evolves into a free improvisation. The computer running the spatialization software will algorithmically assign to each of the inputs a trajectory with a number of repetitions. When this initial trajectory has played in its totality its repetitions, a new pattern will be chosen until it reaches either a natural end or a pre-programmed total duration. The performers may react or integrate the spatial trajectory into sonic gestures and improvisation. For example, by reflecting the spatial trajectory: if a circular movement is proposed, the music can suggest periodicity or circularity. Contrasting and divergent sonic gestures are another alternative for the performers to react to the spatial lines. For example, slow random movements can induce a continuous musical gesture. Many other creative answers can be found on the spot of the improvisation for reacting to the sound put in motion on the space.

The choice of the trajectories and the number of repetitions and durations of each pattern assigned to each performer can be set to random, giving the possibility to each of the paths to appear at any moment. Another option is to program an overall form with convergent tendencies based on probabilities, for example, starting with slow and simple recognizable movements like a circle, then progressively increasing the speed and complexity of the patterns and eventually coming back to a similar state as in the beginning, or any other overall form. This type of form can be achieved by giving weighted possibilities, so some durations and patterns may have a higher possibility to appear than others following a set of rules. The main point of the exercise is to put the performers in a situation where they

[38] Pulkki, Ville. Spatial Sound Generation and Perception by Amplitude Panning Techniques. Helsinki University of Technology, 2001.

[39] Heller, Aaron J., Eric Benjamin, and Richard Lee. “A Toolkit for the Design of Ambisonic Decoders.” In Linux Audio Conference, 1–12, 2012.

[40] Carpentier, Thibaut, Markus Noisternig, and Olivier Warusfel. “Twenty Years of Ircam Spat: Looking Back, Looking Forward.” In 41st International Computer Music Conference (ICMC), 270–277, 2015.

[41] Néron Baribeau, Raphaël. “Méthodes de Spatialisation Sonore et Intégration Dans Le Processus de Composition,” Université de Montréal, 2015.

have to attentively listen to the movements of their sounds in space and musically react to that.

6.5.4 Variations

An important aspect of the performance experiment proposed here is the listening conditions of the performers. Therefore, the position in the room of both performers and loudspeakers have to be carefully chosen. While listening in the same space as the audience may facilitate the technical setting, it makes it difficult to assure an optimal listening point for everybody. One possible variation to handle this is to use a monitoring system with headphones running a binaural rendering of the mix. Setting up such a system requires a good binaural encoder/decoder of the room or a dummy head placed on the sweet spot and redirecting that signal to each performer.

An exciting approach to sound spatialization is to physically move the loudspeakers, either by a performer or by an electro-mechanical system. I suggest experimenting with wired or wireless speakers moving in the room, coupling a performer producing sounds and another one playing the spatialization. Small electromechanical machines can also be built around step or dc motors and mounting or attaching the speakers to them, alternatively, modifying turntables or any other device that can put in motion or turn a loudspeaker.

6.5.5 Discussion

There are two important components in this unit: the spatialization of sounds and the pre-programmed trajectories.

Sound spatialization refers to the use of loudspeakers to create a spatial, musical experience.[42] Since most of electroacoustic instruments can integrate a loudspeaker or a similar transducer to transform electric signals into acoustic energy, delivering sounds in a physical space, sound spatialization can be placed at the heart of the learning process in electroacoustic music. With the exception of some instruments that may have a built-in speaker, the property of electroacoustic instruments of decoupling the sound generator from its diffusion system has opened up research and created an incredible amount of implementations, questions, and even musical trends to learn from, to explore and to investigate.[43]

[42] "Spatialisation, Rob Weale" accessed June 2018, https://web.archive.org/web/20181108030034/http://www.ears.dmu.ac.uk/

[43] Baalman, Marije A. J. “Spatial Composition Techniques and Sound Spatialisation Technologies.” Organised Sound 15, no. 3 (December 2010): 209–18.

From the simple form spatialization using a single loudspeaker, a lot of experimentation and learning can be carried out. The position, direction, elevation, and angle of the loudspeaker will have strong consequences in the perceived sound and can easily be tested, for example, by fixing or freezing all the other sound parameters, e.g. a test signal (ultimately, other than noise and sine tones) like a sonic gesture or a musical sentence, played again and again while affecting the positioning of the loudspeaker. It should become obvious how interdependent the interaction between the physical properties of the space and the loudspeaker are. Playing the loudspeaker becomes playing the space or even more playing the room. After experimenting with position and therefore movement of the loudspeaker, a new dimension can be introduced by acoustically manipulating the sound emitted, for example, by using diffusing materials in front of the speaker elements and mechanically interacting with them and even beyond that of course, experimenting with transducers and different surfaces/objects for sound diffusion.[44]

It is probably not easy to imagine the number of questions that are introduced by increasing the number of loudspeakers to two. The whole field of stereophonic sound enters the game. How are the sound signals distributed over the two speakers, i.e., mixing and panning techniques, how the position, elevation, angle, distance between the loudspeakers and the listening point interact, how to produce a perception of movement in the sound source and ultimately how to perform the stereophonic space? From the performance perspective, playing within a stereophonic system has musical and sonic consequences that must be addressed and carefully studied. The interface to control and manipulate the perception of the stereo field is something to research by each electroacoustic musicians; from the panning pot paradigm to the multitouch controllers, an array of interfaces and available solutions implementing different technics are available.[45]

Multichannel systems: quadraphonic, octaphonic, 5.1, 7.1, 9.1, and other surround systems require for the performer a focus on the organization of the sounds in space that may feel overwhelming when handled simultaneously with the sound production task. Therefore, it is common to see this task delegated to a dedicated performer controlling the diffusion system, either with a traditional mixing desk or a dedicated controller and dedicated software.[46]

[44] Lähdeoja, Otso. Composing for an Orchestra of Sonic Objects: The Shake-Ousmonium Project. Ann Arbor, MI: Michigan Publishing, University of Michigan Library, 2016.

[45] Madden, Andrew, Pia Blumental, Areti Andreopoulou, Braxton Boren, Shengfeng Hu, Zhengshan Shi, and Agnieszka Roginska. "Multi-Touch Room Expansion Controller for Real-Time Acoustic Gestures." Audio Engineering Society, 2011. http://www.aes.org/e-lib/browse.cfm?elib=16102.

[46] Pysiewicz, Andreas, and Stefan Weinzierl. "Instruments for Spatial Sound Control in Real Time Music Performances. A Review." In Musical Instruments in the 21st Century, 273–296. Springer, 2017

As an alternative to having a space performer, an automatic system can be considered. Morton Subotnick developed during the seventies a technique that he calls *Ghost Scores and Ghost Electronics*.[47] In this technique, Subotnick pre-recorded control data on quarter-inch magnetic tape to derive voltage control from it and drive audio processors on live instruments. In this way Subotnick could achieve a precise control of the electronics over entire compositions. The idea of separating the control data into a pre-recorded form making it an automatic process obviates the need for a dedicated performer. In the experiment proposed here, that data will be the modulation of spatialization parameters over time, creating sound localization and motion effects. One option to carry out the modulation consists of using envelopes. An envelope is built around segments with target values, duration time and curve types. When triggered, the envelope will modulate the parameter over the duration determined by each of the segments, for example, going from value 0 to 1 in one second in a linear progression and staying at value 1 for two seconds and returning to 0 in 4 seconds in an exponential sequence. Each of these values can be pre-programmed by hard-coding them and creating a library or using stochastic methods of probability.

Each spatialization software implementation has been exposed to the user control parameters. For example, as discussed by Marshall et al. in the paper "Gesture Control of Sound Spatialization for Live Musical Performance", some of these control parameters include: position (x,y,z), azimuth, elevation, size, directivity, presence, distance, brilliance, reflections, reverberations, doppler effect, equalization, air absorption, decay.[48] To control these parameters with the above described envelopes, it will be important to *normalize* or to map the range of the parameters in a known scale, for example, 0 to 1 (or 0 to 127 if using MIDI as the control protocol). Then a connection between the control data (the envelopes) and the parameters have to respond to a perceptible effect of motion, direction or localization on space. For these purposes, each algorithm has to be tested and studied. In some cases it will be necessary to affect only one parameter, while in others, one controlling envelope should affect several parameters simultaneously, and in other cases, each parameter may require its own modulating envelope to achieve the desired effect.

The triggering of the modulation parameters can be chained as suggested above, i.e. once the envelope is over, a new one will be triggered or it can be programmed with conditionals. Conditionals act as control units, performing logical operations between two or more inputs. For example, if one input is bigger than the other one, then output a trigger; otherwise, output nothing. Using conditionals can give

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[47] Hanson, Jeffrey. "Morton Subotnick's Ghost Scores: Interaction and Performance with Music Technology". MA thesis. 2010.

[48] Marshall, Mark T., Joseph Malloch, and Marcelo M. Wanderley. "Gesture Control of Sound Spatialization for Live Musical Performance." In Gesture-Based Human-Computer Interaction and Simulation, 227–38. Lecture Notes in Computer Science. Springer, Berlin, Heidelberg, 2007.

to the performer the possibility to interact with the automatization system. A classical implementation–discussed in chapter 6.3–will be to follow the amplitude of the incoming audio signal and using a threshold value as comparison to trigger the next envelope. In this implementation, each new event of spatialization will be dependent on peaks or silences in the audio stream of the performer. The system will stop listening the incoming audio until the envelope has played in totality. Other mapping strategies can be explored, for example, dynamically changing the duration of the segments in the envelope according to the density of the spectrum, or following the number of events per second in an audio stream and coupling this value to the target values in the envelopes.

With these examples it should become clear how important the mapping strategies are between the control data and the spatialization parameters. A reasonable amount of time has then to be allocated to investigate the control of parameters of the algorithm used for the spatialization, a fine tuning of the physical position of loudspeakers, and the choice of the monitoring system for the performers. Consequently, the actual preparation for this activity can go well beyond the actual improvisation session.

6.5.6 Implementations

- † Program an algorithm to generate envelopes of different characteristics: number of segments, type of curves, durations that can be mapped onto a spatialization software via MIDI or OSC.
- † Create a pool or database of unipolar waveforms that can be used as control data.
- † Study, build or experiment with a voltage control quadraphonic/stereo mixing module.
- † With a variety of loudspeakers and amplifiers, set up a lo-fi loudspeaker orchestra that can be easily transported. As an inspiration, look at the work of Michael J. Schumacher and his multichannel portable system.[49]
- † Map a controller MIDI, OSC or custom made for manual control of the spatialization software.
- † Research the concepts, ideas and implementations of Ambisonics, Vector Base Amplitude Panning, Wave Field Synthesis.

[49] "Michael J. Schumacher — Portable Multi-Channel Sound System," August 18, 2018.
https://web.archive.org/web/20180818122208/http://michaeljschumacher.com/PM-CSS.

6.6 Music Automata – Conditional Rules

A rule-based improvisation to explore the rudimentary basics of artificial intelligence applied to electroacoustic music performance.

6.6.1 Tags

Decision making, control structures, symbolism, algorithmic composition, pattern recognition, machine learning, artificial creativity, Music Information Retrieval.

6.6.2 Goals

This chapter is conceived with the aim of facilitating a conversation about the use of computer systems as interactive improvisation partners in electroacoustic music.

The ultimate goal in this section is to arouse the curiosity of the performers to explore and unveil the mechanisms, concepts, possibilities, limits, and techniques behind the idea of artificial intelligence and electroacoustic improvisation.

The activity proposed in this chapter should work as an introduction to very basic topics, such as rule-based programming, control flow, machine learning, GOFAI (Good Old Fashioned Artificial Intelligence) and automatic/algorithmic decision-making.

By focusing on programmed instructions, the performers should get fluency expressing conditions and alternative paths in an electroacoustic group performance context, making it possible to identify such structures in an improvisation-interactive computer-based system.

Engage in the special activity of simultaneously analyzing and performing.

The performers should get an overview of references and topics to deepen their knowledge of the topic.

6.6.3 Description

Determine a duration for the improvisation (something between four to ten minutes). Each performer will set up and choose one rule (more rules can be added once the concept is understood). The rule should integrate a control structure of

the type of statement: *if-then-else*. For example,
"if the overall volume is soft, then play one sound crescendo, otherwise keep improvising".
Since the conditions may depend on the state of the music being performed at any point by the whole band or by one musician, to keep the improvisation going and avoiding a situation where nothing can happen because every performer is waiting for an event, the *else* statement must induce the performer to continue improvising. The improvisation is over when the fixed duration has been reached. All the performers must find an end.

Once the first stage of conditional rules is clear, the iterative process can be introduced. An iterative process can be as simple as "do an action a certain number of times", possibly connected with a conditional, e.g., "if something happens, then play a percussive sound ten times; otherwise, keep playing". If the condition is permanently checked a *for* or *while* loop can be performed. For example, "while performer x is playing, play in the low register; otherwise, improvise freely". The iteration may have an exit or stop condition so that the loop gets broken when something in the band or with one musician happens. When integrating several possibilities for different conditions, a *case* or a *switch* will be implemented. e.g., "if performer x is not playing, then play; if performer x is playing fast, then play slow; if performer x is playing noisy, then stop playing". At this point, the rules can get very complex, but it is important to be able to verbalize it at any moment. If the motivation allows it, the conditionals and the sound results can get as complex or intricate as desired, for example, involving checking for several performers' actions while producing iterative loops with several possible cases and exits.

As shown above, the rules can integrate observations and analysis of the band's sound, the behavior of one performer, or even in the interaction of a group of performers. I suggest focusing on the sound and musical aspects and leaving aside other possible considerations, such as body language, motion, light clues, etc. For example, if possible, avoid rules that will start with: "if performer x turns right, then something". By concentrating on the sound aspects, the discussion can evolve into audio analysis, audio descriptors and auditory scene analysis. However, some performative gestures may be interesting to research within the band but are more difficult to evaluate and to discuss objectively and can be treated separately, for example, "if the mood gets introverted, then ...".

Though the main aspects in this chapter are listening, analyzing, making decisions and performing planned actions, the quality of the improvisation should always be a concern. In that respect, it may be useful to record from an audience's perspective a stereo image of the performance and to dedicate a critical collective listening moment.

6.6.4 Variations

Split the group between free improvisers and conditional–rule followers/improvisers.

Use an audience to attempt to unveil the rules governing each performer.

Write down the rules and assign them randomly among the members of the band.

6.6.5 Discussion

With the advent of digital technologies and audio capable computers, many aspects of electroacoustic music have seen the opening and development of research paths. Sound synthesis has reached forms and implementations that are possible only in the digital domain. See for example the Lindenmayer system and formal grammars for sound synthesis.[50] Software and hardware for sound spatialization such as High Order Ambisonics is also only possible through the computational power offered by modern CPUs.[51] Telematic concerts are possible thanks to the use of encoding and transmitting techniques of digital signals.[52] Sound recording has benefited to a great extent from the manipulation, editing, storage and distribution of audio in a digital format.[53] Finally, the automatizing process for working with audio can range from analysis of acoustic data and high-level composition tasks as described by Kramer and Al. in their article: "AI and Music: Toward a Taxonomy of Problem Classes".[54]

The automatization process facilitated by computers have led to fascinating developments in Artificial Intelligence (AI). The area is under constant development, and musical implementations are projecting towards interactive improviser agents that can listen, decide, propose, combine, transform, recall and re-create musical and sonic material in an improvisation context. Eduardo Miranda and Duncan

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[50] Manousakis, Stelios. "Non-Standard Sound Synthesis with L-Systems." Leonardo Music Journal, 2009, 85–94.

[51] Gao, Shan, Xihong Wu, and Tianshu Qu. "High Order Ambisonics Encoding Method Using Differential microphone Array." In Audio Engineering Society Convention 144. Audio Engineering Society, 2018.

[52] Whalley, Ian. "Developing Telematic Electroacoustic Music: Complex Networks, Machine Intelligence and Affective Data Stream Sonification." Organised Sound 20, no. 1 (April 2015): 90–98.

[53] Godsill, Simon J, and Peter J W Rayner. "Digital Audio Restoration – a Statistical Model-Based Approach," n.d., 346.

[54] Kramer, Oliver, Benno Stein, and Jürgen Wall. "Ai and Music: Toward a Taxonomy of Problem Classes." Frontiers in Artificial Intelligence and Applications 141 (2006): 695.

Williams have analyzed publications related with Artificial Intelligence and Electroacoustic Music in the Organised Sound Journal between 1996 and 2015.[55] The authors identify "contributions in the fields of sound analysis, real-time sonic interaction and interactive performance-driven composition, to cite but three", and arrange them into two distinct categories "on the one hand, philosophically and/or psychologically inspired, symbolic approaches and, on the other hand, biologically inspired approaches, also referred to as Artificial Life approaches".[56]

The approaches related with simulating biological processes imitating "living beings with cognitive learning and evolving behavior" include methods such as "distributed autonomous agents, genetic algorithms, flocking or swarming simulations, and neural networks". Applications on sound synthesis and electroacoustic improvisation on these "biological" lines are promising, and we should see some *virtual musicians* gaining a reputation as the systems evolve. The artificial intelligent musical agent should acquire qualities such as self-programming to respond to different situations in musical learning, acoustic analysis, problem understanding, situation solving, and spontaneous creation.[57]

In his doctoral thesis, an active researcher in machine learning and machine listening, Nicholas Collins describes in detail three famous implementations: George Lewis' Voyager, Robert Rowe's Cypher, Jonathan Impett's Meta-trumpet and proposes five more applications, notably a *Free Improvisation Simulation* written in SuperCollider.[58] Another relevant project carried out at the IRCAM/RepMus Music Representation Team, is "DYCI2 : Dynamics of Creative Improvised Interaction" DYCI2 is described as a project that "focuses on conceiving, adapting, and bringing into play efficient models of artificial listening, learning, interaction, and generation of musical contents. It aims at developing creative and autonomous digital musical agents able to take part in various human projects in an interactive and artistically credible way; and, to the end, at contributing to the perceptive and communicational skills of embedded artificial intelligence." The project is based on previous research on stylistic modeling carried out by Gerard Assayag and Shlomo Dubnov and on improvisation with the computer by G. Assayag, M. Chemillier and G. Bloch. The software outcomes of that previous research include OMax, ImproteK and SoMax.[59] Although running and testing some of the programs cited above can be a task for a computer music expert, the ideas and

[55] Miranda, Eduardo R., and Duncan Williams. "Artificial Intelligence in Organised Sound." Organised Sound; Cambridge 20, no. 1 (April 2015): 76–81

[56] Ibid.

[57] By the time of writing this thesis, we may still have to wait to see this kind of application, but it is foreseeable in the future.

[58] Collins, Nicholas M. "Towards Autonomous Agents for Live Computer Music: Real-time Machine Listening and Interactive Music Systems." Ph.D. Thesis, University of Cambridge, 2007.

[59] Assayag, Gérard. "Creative Symbolic Interaction." Collected Work: Music Technology Meets Philosophy: From Digital Echos to Virtual Ethos, Vol. 1. Series: Proceedings of the International Computer Music Association. 2014. 1–6.

goals they embed can be scrutinized, studied and can potentially inspire more performance tasks and situations.

There are of course many other studies, experiments, and publications dealing with different topics of AI in music, see among many others the works by David Cope, Curtis Roads, Antonio Camurri, Eduardo Miranda, Petri Toiviainen, Niall Griffith, Peter M. Todd, Jose Fernández and Francisco Vico.[60]

There is a great opportunity to learn, discover and participate in the development of AI and electroacoustic improvisation. Technically, there is a great amount of computer science, but engineers need feedback, comments, and support from performer partners who can actively contribute and discuss important aesthetic questions, but also philosophical, psychological and even social or political questions.[61]

In this chapter, I am modestly inviting the performers to appropriate the concepts of symbolic approaches of AI by *simulating the simulation*. The symbolic approach of AI as described by John Haugeland in terms of "Good Old Fashioned Artificial Intelligence, GOFAI" is an attempt to describe intelligence in symbolic terms and use programmed instructions, human-like readable rules, in formal symbolic representations.[62], in other words, a logical manipulation of symbols. As explained by Petri Toiviainen in his comparison between symbolic and connectionist approaches in music research, Symbolic AI has shown limited results

[60] Cope, David. "Experiments in Musical Intelligence (EMI): Non-Linear Linguistic-Based Composition." Journal of New Music Research 18, no. 1–2 (1989): 117–139;
Griffith, Niall, and Peter M. Todd. Musical Networks: Parallel Distributed Perception and Performance. Cambridge: MIT Press, 1999.
Miller, Geoffrey F., Peter M. Todd, and Shailesh U. Hegde. "Designing Neural Networks Using Genetic Algorithms." In ICGA, 89:379–384, 1989;
Miranda, Eduardo Reck. Readings in Music and Artificial Intelligence. Vol. 20. Routledge, 2013;
Miranda, Eduardo Reck, and John Al Biles. Evolutionary Computer Music. Springer, 2007;
Roads, Curtis. "Artificial Intelligence and Music." Computer Music Journal 4, no. 2 (1980): 13–25;
Todd, Peter M., and Gregory M. Werner. "Frankensteinian Methods for Evolutionary Music." Musical Networks: Parallel Distributed Perception and Performace, 1999, 313–340;
Toiviainen, Petri. "Symbolic AI versus Connectionism in Music Research." 57–78.
Fernández, Jose D., and Francisco Vico. "AI Methods in Algorithmic Composition: A Comprehensive Survey." Journal of Artificial Intelligence Research 48 (2013): 513–582.

[61] see George Lewis' argumentation on the cultural and sociological implications from his own computer-driven, interactive and "virtual improvising orchestra". Lewis, George E. "Too Many Notes: Computers, Complexity, and Culture in Voyager." Leonardo Music Journal 10 (December 1, 2000): 33–39.

[62] Haugeland, John. Artificial Intelligence: The Very Idea. MIT Press, 1989.

in contrast to other modern advances. Studies in symbolic approaches to AI have failed to

> shed light on certain important areas of music cognition, such as those related to perception, motor action, and performance interpretation. Depending critically upon verbalization and introspection, they have proven ineffective for the investigation of the inarticulate aspects of musical activity. Since the 1980s, connectionism, or modeling with artificial neural networks, has gained popularity among music researchers as a tool for exploring such tacit musical knowledge.[63]

Toiviainen underlines the strengths and weaknesses in both approaches. Artificial Neural Networks (ANN) have proven more effective than Symbolic AI in their "learning capability, generalization capability, tolerance towards noise and contradiction, and tolerance towards overload of information". On the other hand, connectionist approaches show some problems: "limitation to *toy-size* problems, difficulties with long inference chains, limited explanation capabilities and difficulties with structured representation".[64] Aware of these limitations and difficulties, the exercise proposed in this chapter reflects an approach of AI from the Symbolic perspective in order to get an understanding of the primary conceptual tools and its historical significance. A logic continuation will be to invent an ANN implementation for a performance situation.

In order to illustrate the basic use of *Conditional Statements* and *Loop Control Statements* in an electronic music context let us build and discuss a simple *Automatic Pentatonic Melody Generator* after introducing the definition and basic concepts of control flow statements.

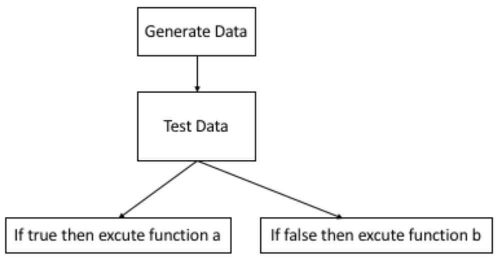
Control flow statements are at the heart of logic manipulation of symbols. In computer science control flow is the order in which individual instructions are executed when a program is running. Control flow statements are used to determine what path or section of code should run in a program at a given time. According to, the Matlab, Language Synthax Conditional Statements are a type of *if* or *switch*. The simplest conditional statement is an *if* statement.[65] For example using the SuperCollider syntax an *if* statement will look like this:

[63] Toiviainen, Petri. "Symbolic AI versus Connectionism in Music Research." 57–78.
[64] Ibid.
[65] "Control Flow – MATLAB & Simulink – MathWorks Nordic." Accessed July 18, 2018. `https://se.mathworks.com/help/matlab/control-flow.html`.

Listing 6.1. Basic Control Structure *If*

```
(
{var x=10.rand;
if(x>5,
    {"Funny,"++x+ "is more than 5".postln},
    {"Jop!!  "++x+ "is less than 6".postln})
}.value;
);
```

Fig. 6.1. Block diagram of a simple control structure



This small program will choose a random number between 0 and 10, store it in a variable x, *if* the number x is bigger than 5,*then* it will print "Funny,x is more than 5",*else* (or otherwise) it will print "Jop!! x is less than 6".

Loop Control Statements repeatedly execute a block of code. There are two types of loops, *for* and *while* loops; *for* statements loop a specific number of times, and keep track of each iteration with an incrementing index variable. *while* statements loop as long as a condition remains true.

Listing 6.2. Iterating over a List with the method *do* in SuperCollider

```
(
{
var a = Array.rand(10,0,10);
var x=0, y=0, z=0;
var test = 5;
        a.do{|i,k|
```

```
                case
                {i==test}{x=x+1}
                {i>test}{y=y+1}
                {i<test}{z=z+1};
        };
        postf("In the list: %.\n
        There are % numbers above % and % numbers below %.\n
        The number % appeared % times",a,y,test,z,test,test,x);
        "".postln;
}.value
);
```

The code above illustrates how to iterate over the content of a random array for analysis purposes, in this case, how many numbers are above and below a test number (5 in the example), and how many times that number is present in the list.

To proceed with our idea of writing a more musical program, we must define what the *Automatic Pentatonic Melody Generator* must do. For simplicity, we can describe the program with the following arbitrary constraints:

- The program should play notes in a pentatonic scale within an octave.
- The resulting melodic sequence should include a pedal note.
- The duration and timbre of each note should be automatically generated.
- The user must control global parameters such as tempo, volume, number of notes to play, note pedal, and eventually change the scale.

Below there is a first implementation of this program written in SuperCollider, we can identify and analyze the relevant parts of the code and build upon it. First of all we will need a synthesizer to play the notes of our melody generator.

The following Simple Subtractive synthesizer is not the focus of this section, but briefly explained is composed of two *Saw* oscillators passing through a *Resonant Low Pass Filter*; there are two envelopes affecting the volume and filter cutoff (*Linen and XLine* respectively). The arguments of the synthesizer can be understood as controllable inputs for frequency, volume, release time for the envelopes, detuning factor between the two oscillators and cutoff frequency and q factor for the filter.

Execute the following code in SuperCollider to start the server and to add to it the definition of the Synthesizer.[66]

Listing 6.3. Simple Subtractive Synthesizer

```
(
Server.default.waitForBoot{
SynthDef(\saw,{
    arg freq=440,amp=0.4,release=1,detune=1.01,cutoff=5000,q=0.5;
    var env = Linen.kr(Impulse.kr(0),0,1,release,doneAction:2);
    var osc = Saw.ar([freq,freq*detune],env);
    var sig = RLPF.ar(osc,XLine.ar(cutoff,100,release),q.reciprocal,
        amp);
    Out.ar(0,sig)}
            ).add;
};
);
```

Then run the first version of the program.

Listing 6.4. Automatic Pentatonic Melody Generator version I

```
(
{
        var scale = [0,2,3,7,8]; // minor pentatonic
        //var scale = [0,2,4,7,9]; // major pentatonic
        var amountOfNotes = 100;
        var tempo = (60/120)*(1/4);
        var volume = 0.5;
        var root = 48;
        var pedal = 36;

        amountOfNotes.do{|i|
                        var x = 10.rand;
                        var note = 60;

                if(scale.includes(x)){note=x+root}{note=pedal};
                s.sendMsg(\s_new,'saw',s.nextNodeID,1,1,\freq,note.
                    midicps,\release,tempo,\amp,volume);
                tempo.wait;
        }
}.fork
);
```

66 The code for this section can be downloaded at `https://github.com/Hyppasus/supercollider-examples/blob/master/Pentatonic-Melody-Generator.scd` SuperCollider software is available at: `https://supercollider.github.io/`

The words preceded by *var* represent variables and can be modified by the user. The pentatonic scale is written as a list of semitones, to change between the major and minor pentatonic scale comment the line with the minor scale with two forward slash // and uncomment the other line by erasing the two forward slash characters preceding the list. The *amountOfNotes* determine how many notes will contain the melodic sequence; *tempo* is written as fractions since durations in SuperCollider are expected in seconds; volume should be a floating number between 0 and 1; root and pedal are written as midinotes 48=C3 and 36=C2, 261.62Hz and 130.81Hz respectively. The core of the program is an *if* function encapsulated in an iterative *do* function. In each iteration, it will calculate a number between 0 and 9 then store it in the variable *x*. Afterwards, the program will verify if the number is included in the scale if is true, it will add it to the root number and store it in the variable *note*, if is not include in the scale it will establish the *note* to be equal to the pedal midinote defined earlier in the program. The following line after the *if* statement will create an instance of the *saw* synth with the argument *freq* as the stored *note* converted from midi to cycles per second (Hz), the argument *amp* set by the variable volume and the *release* set by the *tempo* variable. Then, the program will wait for the number of seconds expressed in the variable *tempo* and then iterate the process for the number of times defined in the variable *amountOfNotes*.

Listing 6.5. Automatic Pentatonic Melody Generator version II

```
({
        //var scale = [0,2,4,7,9]; // major pentatonic
        var scale = [0,2,3,7,8]; // minor pentatonic
        var amountOfNotes = 100;
        var tempo = (60/120)*(1/4);
        var volume = 0.5;
        var root = 48;
        var pedal = 36;

        amountOfNotes.do{|i|
                        var x = 10.rand;
                        var note = 60;
                        var cutoff = 5000;

        if(scale.includes(x)){note=x+root}{note=pedal};
        if(scale.includes(x)){cutoff=((1..10)*1000).choose}{cutoff
            =[500,15000].choose};
        s.sendMsg(\s_new,'saw',s.nextNodeID,1,1,\freq,note.midicps,\
            release,tempo,\cutoff,cutoff,\q,0.95,\amp,volume);
        tempo.wait;
        }
}.fork);
```

This second version add to the previous code control over the filter cutoff frequency with another if statement. If the number x is included in the scale the frequency will be a random choice between a list of 1000, 2000, 3000, 4000, 5000, 6000, 7000, 8000, 9000 or 10000Hz; if not it will be chosen between 500, 15000Hz.

Listing 6.6. Automatic Pentatonic Melody Generator version III

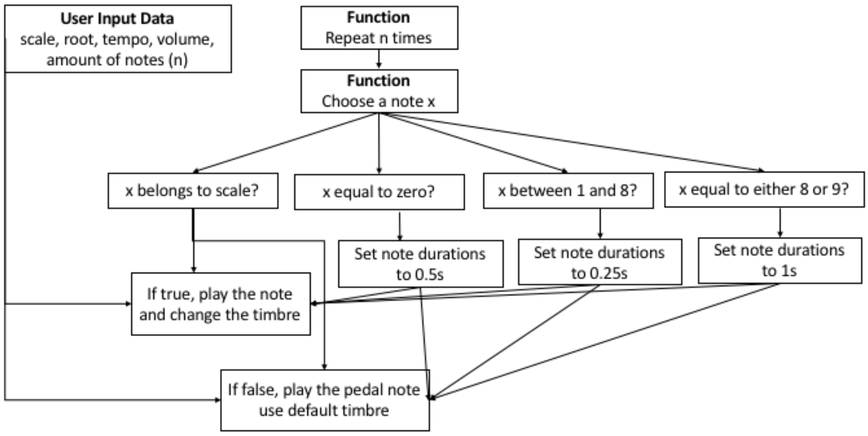
```
(
{
        //var scale = [0,2,4,7,9]; // major pentatonic
        var scale = [0,2,3,7,8]; // minor pentatonic
        var amountOfNotes = 100;
        var tempo = (60/120);
        var volume = 0.5;
        var noteduration = (1/4);
        var root = 48;
        var pedal = 36;

        amountOfNotes.do{|i|
                        var x = 10.rand;
                        var note = 60;
                        var cutoff = 5000;
        if(scale.includes(x)){note=x+root}{note=pedal};
        if(scale.includes(x)){cutoff=((1..10)*1000).choose}{cutoff
            =[500,15000].choose};
        case
        {x==0}{noteduration=1/2}
        {x>0 and:x<8}{noteduration=1/4}
        {x==8 or:x==9}{noteduration=1};
        s.sendMsg(\s_new,'saw',s.nextNodeID,1,1,\freq,note.midicps,\
            release,tempo,\cutoff,cutoff,\q,0.97,\amp,volume);
        (tempo*noteduration).wait;
        }
}.fork
);
```

In this third version, the duration of each note is controlled with a *case*. The *case* will test if the number x is equal to zero, if so, it will set the note duration to (1/2) times the *tempo*, as a half note; if the number x is between 1 and 7, it will set the note duration to (1/4) times the *tempo*, as a quarter note and if is either 8 or 9, it will set the note duration to 1 time the *tempo*, as a whole note. Note the use of logic operators *and* and *or*. All the rest of the code is the same as the two previous versions.

Though it is extremely simple and probably useless in a real improvisation context, the code of the Automatic Pentatonic Melody Generator contains several

Fig. 6.2. Block diagram of the Automatic Pentatonic Melody Generator version III



ingredients for a basic understanding of control flow sequences in a symbolic approach to AI. It can be further developed to integrate, for example, memory and recall over certain sequences chosen by different factors, such as amount of variation or repetition or even more by implementing several *heuristic rules* or *probability matrices* to match different musical styles.[67]

At this point, it is essential to mention the use of stochastic methods to generate and control sound parameters in a synthesizer or other formal compositional structures. Earlier machines such as the Olson-Belar "Composing Machine" built around 1951 reportedly "allowed the assignment of weighted probabilities to electronically produced random numbers".[68] In *Gendy3* by Iannis Xenakis not only "the musical structure but as well the sound synthesis is based on a stochastic algorithm that Xenakis invented and called 'Dynamic Stochastic Synthesis.'"[69] More recent implementations of Markov Chains driving granular synthesizers can be found in the work of Eduardo Miranda and Adolfo Maia.[70] Electronic musicians over the history have shown great interest and fascination with the

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[67] Fernández, Jose D., and Francisco Vico. "AI Methods in Algorithmic Composition: A Comprehensive Survey." Journal of Artificial Intelligence Research 48 (2013): 513–582.

[68] Burraston, Dave, and Ernest Edmonds. "Cellular Automata in Generative Electronic Music and Sonic Art: A Historical and Technical Review." Digital Creativity 16, no. 3 (2005): 165–185.

[69] Serra, Marie-Hélène. "Stochastic Composition and Stochastic Timbre: Gendy3 by Iannis Xenakis." Perspectives of New Music 31, no. 1 (1993): 236–257.

[70] Miranda, Eduardo Reck, and Adolfo Maia. "Granular Synthesis of Sounds through Markov Chains with Fuzzy Control." In ICMC, 2005.

possibilities of control and generation of sounds through statistics, probabilities, and distributions.

Kevin Jones reports in his doctorate thesis a series of cases and applications ranging from the "application of simple probability distributions through to intricate structures of interrelated stochastic constraints under the control of a general grammatical schema".[71] The output on Jones's work could be music notation for an instrumental performance of instructions for direct control of digital synthesis programs. More historical referents are referenced by Jones in the works of composers such as Xenakis, Brün, Koenig, Truax, Holtzmann, and Berg.

To translate the programming methods previously presented to an improvised musical performance situation, we need to consider the nature of the input for the conditional tests, the output or return of the process, as well as the possibilities of analyzing and performing at the same time. Simultaneously carrying out an analysis by ear on the audio stream in a moment-to-moment basis while performing a musical outcome may seem difficult and demanding. In fact, based on a popular list for students and teachers, attributed to Sister Corita Kent and involving John Cage's name, some authors will argue about the impossibility of such a task: stating a proposition that analyzing will block creativity.[72] Furthermore, researchers from the University of Haifa conducted a study comprising creative tasks such as the alternate uses task, the evaluation task and a Subset of Torrance Tests on a target group divided by different musical expertise to evaluate the "hypothesis that a strict evaluation phase [of an idea] may have an inhibiting effect over the generation phase [of the idea]", according to a two-fold model in which creativity involves a process of idea generation and idea evaluation.[73] The study brings draws attention of teachers and professionals to reflecting on how to evaluate without compromising creativity.

From a slightly different point of view, Roger Beaty from the University of North Carolina reviews the neural basis of musical improvisation in his article "The neuroscience of musical improvisation". Beaty analyzes under the framework pro-

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[71] Jones, K. "Computer Assisted Application of Stochastic Structuring Techniques in Musical Composition and Control of Digital Sound Synthesis Systems." Doctoral, City University London, 1980.

[72] Boone, Alice. "The Secret History of Awkward Silences." Teaching and Learning Together in Higher Education 1, no. 12 (2014): 4. Creativity, in, Music | April 16th, and 2014 11 Comments. "10 Rules for Students and Teachers Popularized by John Cage." Open Culture (blog). Accessed July 19, 2018.
`http://www.openculture.com/2014/04/10-rules-for-students-and-teachers-popularized-by-john-cage.html`;
Ervasti, Siiri. "Avoimen Etsijän Vaellus: Ohjaajan Roolit Devising-Prosessissa," 2016.

[73] Kleinmintz, Oded M., Pavel Goldstein, Naama Mayseless, Donna Abecasis, and Simone G. Shamay-Tsoory. "Expertise in Musical Improvisation and Creativity: The Mediation of Idea Evaluation." PloS One 9, no. 7 (2014): e101568.

posed by Jeff Pressing a series of neuroimaging studies on improvisation and concludes that "Like other forms of complex cognition, improvisation involves dynamic communication between regions across the entire cortex."[74] In other words, the review of the eight studies of functional magnetic resonance imaging reveals "Activation of premotor and lateral prefrontal regions suggests that a seemingly unconstrained behavior may actually benefit from motor planning and cognitive control." The intricate creative activity of improvisation demands a lot of brain faculties and capacities simultaneously, though some of the processes may be automated through exercising and memorization of gestures.

From my own experience as an improviser, I understand both positions. Sometimes it is important to let go of the *inspiration* without overthinking the structure and the form. Other times, a sharp analysis of the situation almost intuitively leads to decisions that can re-energize an improvisation set. In the context of this chapter, I am bringing the attention to the importance of the analysis of the input for making decisions and applying the rules. One aspect to highlight is the temporal window span of such analysis. A system of conditional rules can be built with a very small temporal window – at maximum a couple of seconds – then based on that data, apply the conditional and the control statements. It is also possible to observe larger spans of time. For example, "if in the past five minutes there has not been any silence then play *ferociously*". In a computer-based system, the audio input must be analyzed in all their main components and features, allowing the system to know as much as possible about the audio input. Frequency content, time density, amplitude range, spectral centroid, noisiness, brightness, harmonicity, spatial localization, are some of the possible features that can be extracted in a fixed or dynamic temporal window.[75]

The domain of research where a system can automatically extract, segment, interpret recognize, predict and improve performance handling the relevant information on audio signals is called *Machine Learning* and *Music Information Retrieval.* The machine learns to listen from us and to teach the machine to listen we should know how do we listen.[76] It is not as obvious as it sounds because listening is a very complex human faculty, and expert listening as promoted throughout this text is cultivated and trained over the years with intense practice. Improvisers and sound performers possess a lot of implicit knowledge that is not easy to verbalize or express with words.[77] Introducing the performers to reflect on this

[74] Nettl, Bruno, and Melinda Russell. In the Course of Performance: Studies in the World of Musical Improvisation. University of Chicago Press, 1998.

[75] Peeters, Geoffroy, Bruno L. Giordano, Patrick Susini, Nicolas Misdariis, and Stephen McAdams. "The Timbre Toolbox: Extracting Audio Descriptors from Musical Signals." The Journal of the Acoustical Society of America 130, no. 5 (November 2011): 2902–16.

[76] Wenwu, Wang. Machine Audition: Principles, Algorithms and Systems: Principles, Algorithms and Systems. Idea Group Inc (IGI), 2010.

[77] Zuijen, Titia L. van, Veerle L. Simoens, Petri Paavilainen, Risto Näätänen, and Mari Tervaniemi. "Implicit, Intuitive, and Explicit Knowledge of Abstract Regularities in

problem is one of the points of the exercise proposed here. Verbalize a conditional performance rule, increase the complexity by transforming the rule over the performance and intensify the levels of attention and analysis in a gradual fashion to approach the challenges of symbolic programming. Ultimately, I believe that verbally expressing the rules will facilitate the process of programming the same rules in a computer language. However, I am fully aware of the difficulty of the task and of the limits of this technique.

So far in this discussion, we have discussed many of the ingredients necessary to build musical automata based on symbolic AI. A critical concept to reflect on is the nature of the symbols in this context. Those symbols relate to the audio signals used as inputs and outputs or outcomes and returns to apply the rules and conditions. The symbols have a double quality considering their time nature: they can be discrete in time as isolated sonic events and gestures, or they can be continuous streams of audio like textures evolving or extending their durations over long periods of time. Defining a short and a long duration becomes an elastic concept depending on many variables, mostly in our memory capacities, which are influenced by other aspects, such as personal motivation, attention focus, type of sensorial input, context, intention and many others. However, as presented by Sutton and Al. in their article "Memory and Cognition", perception of events as experienced by the senses, or sensory memory, is a short duration of about three or four seconds.[78] The storage capacity of short-term memory, sometimes equated to consciousness, is small, "around seven items, and without active rehearsal, short-term memory lasts for about fifteen to twenty seconds. During its brief existence in short-term memory, some of the information may be immediately recalled or converted into behavior (for instance, dialing a phone number you've just been given by directory assistance)."[79]

A handy reference to support the exploration of salient sound features and to propose the audio outcomes for this exercise in an electroacoustic context is synthesized in the analysis of the TARTYP (*Tableau Récapitulatif de la Typologie*) introduced by Pierre Schaeffer as part of his typology of sound objects.[80] "The table is a classification of sound objects based on their properties in time and frequency domains, and it introduces an alphanumeric notation for sound ob-

a Sound Sequence: An Event-Related Brain Potential Study." Journal of Cognitive Neuroscience 18, no. 8 (July 21, 2006): 1292–1303.

[78] Sutton, John, Celia B. Harris, and Amanda J. Barnier. "Memory and Cognition." In Memory, 209–26. Histories, Theories, Debates. Fordham University, 2010

[79] Ibid., 212

[80] Schaeffer, Pierre. Traité Des Objets Musicaux: Essai Interdisciplines. Paris: Éditions du Seuil, 1969;
Normandeau, Robert. "A Revision of the TARTYP Published by Pierre Schaeffer." In Proceedings of the Seventh Electroacoustic Music Studies Network Conference, 21–24, 2010..

jects. Its structure alludes to inter-relationships between sub-collections of sound objects."[81]

While establishing the conditional rules for the exercise proposed here, considerable attention has to be given to all the qualities and aspects of the sound resulting from applying the control flow statements as well as the parameters to observe and pass through the conditionals. Encouraging dialogue among the band will reveal what is important and relevant for each performer and how each one listens to the details and achieves the analytical aspects.

To close this section, I would like to stress the humble approach taken in this chapter, of which the main objective is to introduce the state of mind of programming and to create automated electroacoustic improviser agents. The field is open for development, and practitioners involved in the research will trace the future and advent of the next level of developments.

6.6.6 Implementations

† Using the symbolic approach of programmed instructions, build a system that can listen to an audio stream input and shift the audio output according to a set of rules.

† Research and implement an algorithm for sound synthesis and sound transformation using Markov chains.

† Inspired by the *Conway's Game of Life*, invent an improvisation set.

† Find, download, test, try and experiment with one or more of the applications available implementing any form of Artificial Intelligence in an electroacoustic music performance context.

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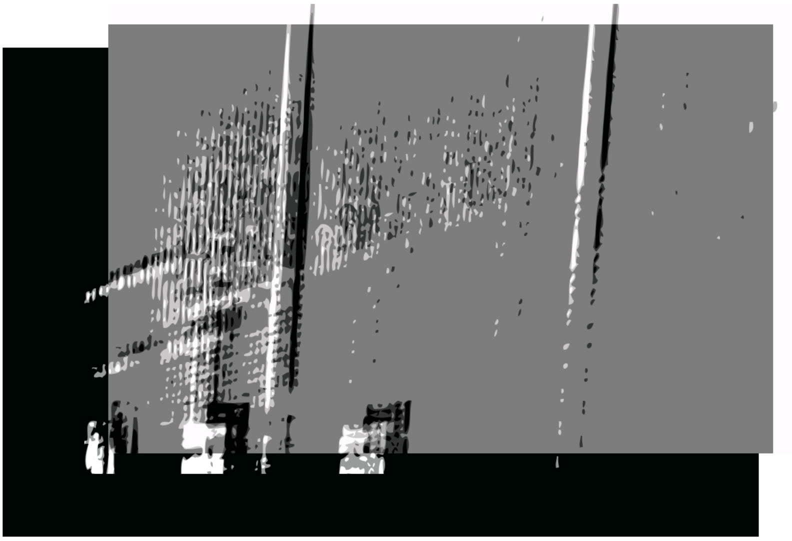
[81] Neuman, Israel. "Generative Grammars for Interactive Composition Based on Schaeffer's TARTYP." In ICMC, 2013.



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7

Musical Elements

7.1 Horizontal Time – Performing Cards

7.1.1 Tags

Time passing, sequence of events, sequencer, time, rational/irrational, linearity, succession.

7.1.2 Goal

In this section the objective is to analyze and integrate the qualities and aspects involved in the perception and performance of sequential time.

7.1.3 Description

The proposal in this chapter consists of requests from the players to prepare a set of iconographic, alphanumeric or text-based cards that will work as instructions, directions or suggestions to the players. The cards may refer directly to sound, or relations between sounds, between performers, attitudes or music styles. The cards can address one player, the whole group, or any combination thereof, it can also be a self-reflecting card communicating one's personal future intentions to the others. The level of abstraction and concrete meaning will be defined by each suggestion. For example, there can be cards with a very precise interpretation: *notated score of a soft cluster of pitches between C4 and C5 for 10 seconds*, or the cards can be very open and suggestive: *a black circle and no further explanation.*

If required, a *conductor*, *moderator* or in John Zorn's terms, a *prompter*[1] should volunteer from the group. The cards can eventually also be projected for all the musicians or a system can be set and prepared for any musician to have the possibility to choose the next card. See for example the *Bucket* project by Per Anders Nilsson, Palle Dahlstedt and Gino Robair. In their words, the bucket "is a signaling system implemented with a set of McMillen QuNeo controllers as input and output interfaces, powered by custom software."[2]

The cards could then be virtual and presented in a mobile phone or a screen computer to each musician. It is easy to develop the experiment into a form of *chat room* addressing either the members of the ensemble only or exposing the communication tricks to the audience as well.

The point that I would like to stress for this chapter on using performing cards is the control over the sequence of events. While several cards can potentially be proposed simultaneously to the ensemble or to one performer to create alternative paths, it is important to avoid the situation of getting far from the spontaneous performing cards and closer to building a score. Graphical scores will be addressed in another chapter. The relevant feature then in the present context of the cards is the sequence. When to play the next card and how? Radical or progressive changes? What are the critical durations to change, or does one keep playing one card? Is there a pulse to quantify the duration between the cards? Can the unfolding of time be dissected into musical units according to the card changes? The title of the chapter *Horizontal Time* is meant to underline these questions.

7.1.4 Variations

Variations, as suggested above, can include using physical cards or projection or individual screens. The cards can address one or many performers; the meaning can be explicitly set or open to interpretation. The cards can include either colors, text, images, pictures, ideograms, letters and numbers or mathematical, musical symbols.

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[1] "Cobra Notes," January 28, 2013. `https://web.archive.org/web/20130128204544/http://www.4-33.com/scores/cobra/cobra-notes.html`.

[2] Dahlstedt, Palle, Per Anders Nilsson, and Gino Robair. "The Bucket System-a Computer Mediated Signalling System for Group Improvisation." In NIME, 317–318, 2015.

7.1.5 Discussion

Cards have been used and are used in musical context for several purposes, for example, as a memory tool for analysis and theory learning,[3] or as tool for improvisation in Jazz,[4] or in music education as a play game for improving sight reading.[5] In a performance context, other than the project mentioned above (John Zorn) cards are utilized to drive a computer that can recognize patterns printed on them.[6]

Beyond the cards, the use of signs and body gestures to guide an improvisation group has developed on its own, notably in the *Soundpainting* system. Marc Duby exposes and analyzes in his doctoral thesis some methods such as Nicholas Bannan's *Harmony Singing*, Butch Morris and *Conduction* and John Zorn's *Game's Pieces* from the point of view of inter-communication among a large ensemble creating on-the-spot and a sound-painter guiding the articulation of the musical discourse.[7] Soundpainting is a sign language introduced by Walter Thompson at the beginning of the 1970s in New York, and includes at the time of writing (2018) a repertory of about 1500 signs. According to Walter Thompson's website, "The Soundpainting gestures are grouped into two basic categories: Sculpting gestures and Function signals. Sculpting gestures indicate What type of material and How it is to be performed, and Function signals indicate Who performs and When to begin performing. Who, What, How, and When comprise the Soundpainting syntax."[8]

Despite the attractiveness of the Soundpainting system, it is not fully suitable for the purpose of the activities proposed here. Basically, because I am suggesting re-inventing both the set of signs, meanings and relations; the soundpainting already has a tradition of linking signs and meanings. Another aspect that distances the objective of this chapter from soundpainting is that in these new sui-generis systems, the moderator is not a mandatory condition. Bypassing the soundpainter will be against the ontology of the system. However, there is one

[3] "Musicards – Online Music Theory Flash Cards." Accessed October 11, 2018. `https://musicards.net/`.

[4] "JazzDeck." JazzDeck. Accessed October 11, 2018.`http://www.jazzdeck.com/`.

[5] Krueger, Carol. "Flash Cards." Accessed October 11, 2018. `http://global.oup.com/us/companion.websites/9780195386042/flashcards/`.

[6] Jordà, Sergi, Günter Geiger, Marcos Alonso, and Martin Kaltenbrunner. "The ReacTable: Exploring the Synergy between Live Music Performance and Tabletop Tangible Interfaces." In the Proceedings of the 1st International Conference on Tangible and Embedded Interaction, 139–146. ACM, 2007;
Berry, Rodney. "Augmented Reality for Music." In Proc. of the International Computer Music Conference, 100–104, 2002.

[7] Duby, Marc. "Soundpainting as a System for the Collaborative Creation of Music in Performance." PhD Thesis, University of Pretoria, 2006.

[8] "Soundpainting | Soundpainting," September 24, 2018. `https://web.archive.org/web/20180924190658/http://www.soundpainting.com/soundpainting/`.

aspect that can nurture some thoughts for the card experiments, which is the use of hands and body as the means to communicate the intentions and eventually make unnecessary the need for cards.

Creating from scratch a grammar of symbols and meaning is, to say the least, a quixotic task. Instead, here the efforts should focus on the *Horizontal Time* or the unveiling of time and the sequence of events. So, the cards, signs and meanings are more of a pretext than a goal and can be basic and simple. The cards function as the tool to influence the flow of time during the performance. Let us examine now some aspects of that *flowing time*.

Horizontal time is passing time revealed by the succession of events. It has a fatality of non-return and simultaneously the ultimate hope that *there will be a tomorrow*. This teleological time has a direction and a motion towards the future. If we stay in our own human subjectivity, we have to accept the irrevocable end, death, that time passes and will finally lead to the end of life. We are pushed in that duration between the now and the end, and somehow left alone, in what Husserl called "La vie solitaire de l'âme" (the lone life of the soul). The sounds, produced by an intention, have a duration. If the sounds transcend perceived time, they will be of the order of the metaphysical and they will address the spirit and a system of beliefs. These sounds resonating beyond death fall into the fallacy of perception: if nobody is there to listen to them, do they exist? Following the metaphor of life, a sound starts, vibrates and vanishes; it has a duration. It could be surrounded by silences that have their own duration, and if another sound starts, a time-lapse is created; a *time-line* is revealed.

When the process of perception has gone through sound and consciousness of it reveals a duration, a relationship between two durations can be established. From a mathematical point of view, these two durations can exist in a rational or irrational relation. If they are rational, it means that a fraction of their duration will fill the other duration a whole number of times. The fractional duration is then a pulse useful for quantifying the length of time between the sounds. The pulse or beat is a temporal unit that marks the unquantified flowing time. If two sounds are in an irrational proportion, their durations do not have a common temporal unit. Let us consider as an illustration two metronomes. If both metronomes turn at different speeds, they will coincide a number of times according to their LCM (Least Common Multiple). So at 60 bpm and 120 bpm, both metronomes will meet every two beats of the 120 metronome. At 120 bpm (beats per minute) and 90 bpm, it will take 4 beats of the 90 bpm metronome to coincide again with the 120 bpm, which will have to go over 3 beats. Now, if their speeds were in an irrational proportion, for example, 60 bpm and 60 times π bpm, they will coincide the first time and never again because there exists no number that can evenly divide both numbers.

Curious about the idea of two clocks whose ticks will never match, I conducted an experiment of programming two computer-generated clocks monitored with headphones; thus, one clock per ear, and setting their speeds in an irrational proportion, I ended up with three observations. First, the tick sound of the clocks should be as sharp as possible; otherwise there will be an overlapping moment when their clicks approach and the differentiation of both will be blurred by the decay, making it impossible to determine if they played at the same time or not. Second, the computer that I have now cannot produce such clocks, because the CPU used to calculate the audio streams is governed by a single clock, so the frequency of this clock (2.5 Ghz on my machine) will determine the LCM between the two clocks. Third, if the computer could play such an irrational relationship of clocks, I would not be able to hear the difference because the distance between the ticks will at one point be under the threshold of temporal discrimination (some few milliseconds). So the ticks will not coincide, but my perception will melt them. These observations induce me to think about the tolerance of deviations and thresholds in our perception and the somehow *natural* tendency to organize and quantify temporal acoustic phenomena.

One key concept in dealing with durations and frequencies (since a frequency is only the reciprocal of time) is *Entrainment*. As defined by Clayton et al. "In Time with the Music: The Concept of Entrainment and its Significance for Ethnomusicology",[9] Entrainment is a process whereby two or more autonomous rhythmic processes are seen to interact, "each adjusting to characteristics of the other and ultimately 'locking in' to a common phase and/or periodicity". Their observations match for example the ones from Christiaan Huygens, who discovered in 1665 that two pendulum clocks, hung from the same wooden structure, will always oscillate in synchronicity. Other examples of entrainment given by the authors include the circadian rhythms of cyanobacteria,[10] and beyond the biological and mechanical domains the authors refer to "inter- and intra-personal relationships in human societies (social entrainment)". Their view of musical stimuli is relevant to this chapter:

> musicking humans can be seen as embodying multiple oscillators (or endogenous rhythmic processes), oscillators which may be mutually entrained in a process of self-synchrony as well as entraining to external stimuli in the processes of making and engaging with musical sound. Entrainment in musicking implies a profound association between different humans at a physiological level and a shared propensity at a biological level. The implications of this view for studies of socialization and identification are obvious, and so too is the link to questions of enculturation:

[9] Clayton, Martin, Rebecca Sager, and Udo Will. "In Time with the Music: The Concept of Entrainment and Its Significance for Ethnomusicology." In European Meetings in Ethnomusicology., 11:1–82. Romanian Society for Ethnomusicology, 2005.

[10] A circadian rhythm is any biological process that displays an endogenous, entrainable oscillation of about 24 hours. These 24-hour rhythms are driven by a circadian clock, and they have been widely observed in plants, animals, fungi, and cyanobacteria. `https://en.wikipedia.org/wiki/Circadian_rhythm`

> someone's ability to respond appropriately to a given musical stimulus can, since it is a learned application of a basic biological tendency, be a marker of the degree to which an individual 'belongs' in a particular social group.[11]

In fact, deciding *when* to show the next performing card is a choice that requires subjective judgment as well as intuition, reading each other's intentions; consequently, transcending the issue of entraining the music to an external time keeper. In our contemporary western music language, arrhythmic and pulseless textures reached by very complex and intricate rhythmical writing or by explicitly avoiding time signatures and bars can coexist with rhythm-based structures.[12] While using electrically-produced sounds, synthesis and samples, the durations of the sounds can be left to organic *natural* developments: *it lasts as long as it should last* or it can be arranged in *time grids*. While playing with the cards, time consciousness has to be carefully put in place, and it is the opportunity to reflect on the inner rhythmical structures of the sound and the group.

Another aspect facilitated by the use of the cards is a balancing of asymmetrical entrainment. "The degree of entrainment, and the negotiation of symmetrical entrainment between individuals, can be studied in terms of a negotiation of relative power between those individuals (i.e. if there is a significant imbalance of power or authority, the less powerful individual(s) may adjust their endogenous rhythms further and more readily than do the more powerful)."[13] The cards become a tool for empowering the performers to drive the improvisation, and if equally given the option to all the performers inside a ensemble, this may assist in the process of flattening out hierarchies.

Through the activity proposed in this chapter, I have hoped to open up a discussion about organizing events in a time-line: i.e. sequencing. A step sequencer is a musical device, hardware or software that can play back, record and edit a set of notes or values. The sequencer can advance via an internal or external clock. Playing with the cards will approach a model of sequencing where each step of the storage sequence is understood not only as a note value but as a whole sound described with all its available parameters and advanced, clocked or triggered by hand. In such a situation, it becomes apparent how important the decision of when to advance the sequence for the musical outcome is. A sequencer has many other features that can be taken into consideration. For example, it can advance over the steps of the sequence in a progressive order, or invert *retrograde* motion or in a random access. Steps can be skipped, engaged or looped. While playing the performance cards, the order in which they appear can be similar to the se-

[11] Clayton, Sager, and Udo Will. 2005.

[12] Coulembier, Klaas. "Multi-Temporality: An Analytical Approach to Contemporary Music, Embracing Concepts of Gilles Deleuze and Félix Guattari." Music Analysis 35, no. 3 (October 2016): 341–72.

[13] Clayton, Sager, and Udo Will. 2005.

quencer, pre-defined, looped, random or inverted. The sequencer metaphor can be taken beyond the limits of the framework proposed here and developed into a large electromechanical ensemble governed by a series of parallel sequencing agents.

7.1.6 Implementations

† Inspired by the notes available on the web from John Zorn's game: *Cobra* produce a set of cards that includes colors, relations among the players and the *guerrilla* option of not following the cards but continuing to improvise.

† Realize a software version where the computer picks up the cards either for the whole ensemble or for a subset of musicians.

† Set up a *chat room* to quickly exchange messages among the players, maybe using emoticons or short texts. Experiment with some of the group as audience and project the chat-room content or not.

† Program a step sequencer to trigger sonic events that change over each iteration.

7.2 Vertical Time – Red Herring

An improvisation exercise to develop polyphonic listening.

7.2.1 Tags

Simultaneity, counterpoint, polyphony, harmony, texture, polyphony, multithread.

7.2.2 Goal

The purpose of this chapter is to exercise simultaneously following two or more musical voices while creating another.

Another objective in this section is to practice inventing distractive musical arguments.

7.2.3 Description

This exercise can be carried out with or without instruments; at least two performers are needed, and their electroacoustic setting should allow them to play in a monophonic way.

For the version without instruments, ask a duo to tell each other a short story at the same time. In a multilingual international context, a common language must be chosen. The story can be about anything, from how the morning or last evening went, to a short improvised fiction. The pace, tone, and volume of the narrator's voice must be constant, fluent and with no interruptions. Both performers should end at about the same time. After finishing, they should be able to tell the story of the other partner so that during the exercise they were able to tell and listen simultaneously. Sometimes, the exercise may yield no results, impossible to tell the other story, or partial results, being able to tell parts of the story but missing connecting parts or details. These kind of results seem to be rather normal and common, probably because we are culturally trained not to speak on top of each other. However, special training must reveal that we can follow two or three (four?) stories simultaneously while creating one.

Instruments should be introduced following the spoken version. The same technique of reporting the details of the other's performance can be exploited. I propose taking a step further by purposely using creative resources to divert the attention of the other player with a *Red Herring* . The task is then a double one.

On the one hand the performer should carry on a creative sonic improvisation targeting the aural distraction of the other performer, on the other hand carefully listen to the other's improvisation to be able to report back – with a description as detailed as possible – and to take elements from it to be used for building the distraction.

7.2.4 Variations

- Record the sessions for self-analysis and evaluation.
- Gradually increase the number of performers, from two to three, up to four. Assess the focus and concentration of the group.

7.2.5 Discussion

In the book *The Time of Music New Meanings, New Temporalities, New Listening Strategies*, Jonathan Kramer proposes a taxonomy of musical time that includes:

- Gestural or Multiply-Directed Time, where logical events happen in an illogical order;
- Moment Time, where things happen in an arbitrary order; and
- Vertical Time, where nothing much happens at all.[14]

Kramer uses the concept of vertical time to describe minimalistic music "a single present stretched out into an enormous duration, a potentially infinite 'now' that nonetheless feels like an instant."[15] Vertical time in this context is a non-teleological time, an eternal present, a mind state produced but a non-narrative or non-changing music like *Vexations* of Erik Satie. Vertical time avoids the play of memory and expectations.[16] Although I agree with the idea of a possible extended present, I am not using the term to refer to Kramer's definition and its aesthetic implications.

In the context of this work, I understand the concept of vertical time as an antagonism to horizontal time. Therefore, instead of dealing with sequence of events,

[14] Kramer, Jonathan D. "The Time of Music New Meanings, New Temporalities, New Listening Strategies," 1988.
[15] Ibid.
[16] Lee, Richard Andrew. "The Interaction of Linear and Vertical Time in Minimalist and Postminimalist Piano Music." PhD Thesis, University of Missouri–Kansas City, 2011.

vertical time deals with simultaneity. In musical terms, the simultaneous performance of two or more voices is called polyphony.[17] In this tradition verticality implies quantification of pitch and rhythm to create intervals and harmonies and to ensure temporal synchronization. Electroacoustic music expands on the concept of pitch and harmony to integrate unpitched sounds, noises and continuous pitch-timbre as described by Denis Smalley:

> In electroacoustic music we are concerned not only with the received notion of the timbre of pitch but also the pitch within timbre, and moreover, timbre without pitch. Pitch is present even when not perceived. Perhaps it is resting, hidden deep in a spectromorphology, awaiting possible attention, a moment when, for example, the context might change so that perceptual focus becomes directed towards what was a sleeping attribute. The salience of pitch therefore becomes contextual in electroacoustic music. Timbre rather than being that part of the sound which is not pitch, encompasses the inherent qualities of the whole sound.[18]

The polyphonic reference in the context of this work ends at the definition of "music in multiple parts" that can be performed by one or more musicians. If we sidestep the quantization of time, we are left with the performance of simultaneous musical threads asking for attention.

From the assumption that by putting at least two of these musical threads to be improvised by two different musicians, at least two types of interaction may appear. In one, they *talk* about the same subject, they complement, imitate, paraphrase, copy and follow each other building one dramatic line. In the other the have a schizophrenic interaction, where they ignore each other, avoiding any possible exchange, and if any sonic commonality appears, it will be the result of chance or probably subliminal synergy. Are there any in-between possible interactions? As an improviser, I can argue that there are many subtle variations of these extremes. In fact, the Red Herring activity proposed here is an encouragement to experiment with a more contrapuntal attitude. In literature, a red herring is an argument or subject that is introduced to divert attention from the real issue or problem. The real issues are the discursive, sonic and musical elements proposed by the performer partner, and the distraction is intended to create a cognitive dissonance that will deviate the narrative of the improviser. "In the field of psychology, cognitive dissonance is the mental discomfort (psychological stress) experienced by a person who simultaneously holds two or more contradictory beliefs, ideas, or values. The occurrence of cognitive dissonance is a consequence of a person performing an action that contradicts personal beliefs,

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[17] "Polyphony | Grove Music." Accessed July 25, 2018.

[18] Smalley, Denis. "Defining Timbre — Refining Timbre." Contemporary Music Review 10, no. 2 (January 1, 1994): 35–48

ideals, and values; it also occurs when confronted with new information that contradicts said beliefs, ideals, and values”[19]

A sharp and fast sense of analytical listening and intuitive performance is required to create the dialectical tension between the two players while struggling to make sense of their own improvisation. I argue here that specific training in this respect gives tools and strategies to the performers to carry on both tasks. In the chapter “listening to Music” John Sloboda dedicates a full section to “Attention in music listening”, where he discusses several observations and experiments from a cognitive psychology point of view mostly related with polyphonic listening.[20] Although Sloboda’s observations do not necessarily refer to trained musicians as listeners and not in an electroacoustic music environment, his observations are relevant and will serve as a starting point to design more experiments and improvisation situations.

Quoting an experiment by Dowling in 1973 with two interleaved melodies presented simultaneously for identification,[21] Sloboda underlines Dowling’s findings necessary for the melody’s recognition: no overlapping in pitch and non-simultaneous identification.[22] Though this study and others seems to show the impossibility of the *simultaneous telling story* exercise, it is not an argument to not try.[23] Quite the opposite, after reading these cognitive experiments, I set up listening tests for myself using voice recordings with one and different languages with mixed voices, including background music or not, panoramic changes, played through headphones or speakers resulting in a high rate of success following multiple audio streams. From an experimental research perspective, it almost means that when a cognitive scientist says it is not possible, it is probably a very fruitful area for investigation.[24]

[19] “Cognitive Dissonance.” Wikipedia, January 2, 2019. https://en.wikipedia.org/wiki/Cognitive_dissonance.

[20] Sloboda, John A. "Listening to music." In The Musical Mind: The Cognitive Psychology of Music. Oxford: Oxford University Press, 1986. 151-193

[21] Dowling, W. Jay. “The Perception of Interleaved Melodies.” Cognitive Psychology 5, no. 3 (1973): 322–337.

[22] Dowling repport from his experiment that the subjects were not able to monitor both audio streams at the same time while attempting to identify them. See also Diana Deutsch’s argumentation on the similarity grouping principle in the pitch domain. Deutsch, Diana. “Music Perception.” The Musical Quarterly 66, no. 2 (1980): 165–79.

[23] Neisser, Ulric. “Toward a Skillful Psychology.” In The Acquisition of Symbolic Skills, 1–17. Springer, Boston, MA, 1983.

[24] Paulhan in 1887 reported that he could write one poem while reciting another. Paulhan, F. “La Simultanéité Des Actes Psychiques.” Revue Scientifique 39 (1887): 684–689.

Another source for Sloboda to highlight the simultaneity issue in aural attention are the experiments in speech recognition by Cherry.[25] These experiments "have shown that when two speech messages are presented simultaneously it is possible to shadow (verbally report) one of them, but that almost nothing is known about the characteristics of the other message. Thus, for instance, the non-shadowed message may change language, or repeat the same phrase over and over again without the subject being aware of it."[26], this will support the notion of *one single attentional channel* or *filter theory.* This theory seems to be related with the nature of the signal addressing different cognitive mechanisms. Therefore, if the inputs are of a different nature, it is possible to pay full attention to them simultaneously. For example, "We can hold a conversation whilst driving a car; listen to the radio whilst doing housework, and so on; but we cannot listen to a radio talk whilst reading a book". What to do then with the observations of musicians and listeners reports of been able to accurately follow independent voices in a polyphonic context? And what about teaching in a kindergarten? In that situation not only polyphonic listening abilities are required but multichannel attention.

Sloboda proposes that in polyphonic music, the different voices allow for figure ground reversal, such as in Rubin's "face-vase" paint, in which the visual perception oscillates between"a white vase on a black background, and as two black faces looking at each other across a white background". To facilitate the shifting of *focal attention*, Sloboda enumerates the following composing strategies that may give cues on how to perform the task proposed in this section: pitch separation to avoid masking tones, time segregation to give time to the perception to shift of focus, using different timbres, different dynamics, different motions and introducing changes in the focal line to maintain attention.[27]

Jeff Pressing also addresses the topic of multiple attention by challenging the idea of attention as a *single channel* processing capacity.[28] The single channel theory attempts to explain the cognitive mechanisms working when an individual tries to attend to two things at once. Pressing suggests that though an improviser may be able to shift "fairly quickly between different levels of meaning and structure – from referent to timbre to rhythm to remembered motives to melodic development to the sounds of other musicians to body movements to completely extraneous topics like sex or politics"[29], the density of tasks will result in an overload of

[25] Cherry, E. Colin. "Some Experiments on the Recognition of Speech, with One and with Two Ears." Journal of the Acoustical Society of America 25, no. 5 (1953): 975–979.

[26] Sloboda, "Listening to music." 166-167

[27] Sloboda, "Listening to music." 169-170

[28] Pressing, Jeff. "Cognitive Processes in Improvisation." In Collected Work: Cognitive Processes in the Perception of Art. Series: Advances in Psychology, No. 19 Published by: Amsterdam, Netherlands: North-Holland, 1984.; Published by: New York, NY: North-Holland, 1984. 345-363.

[29] Ibid.

demanding resources of conscious attention and driving the focus only to one aspect while forgetting the others. The other strategy, says Pressing, as an alternative to the rapid shifting of attention and which may resemble a meditative state is “a global and diffuse attention strategy that attempts to leave all detail under the control of unconscious processing (presumably located at the lower levels of the central nervous system).”[30] In my opinion different musical situations demand different strategies and attention mechanisms, and those can be trained and learned by systematically addressing them.

The task now is to experiment in an electroacoustic music context with these ideas and to challenge the perceptual systems and develop our own cognitive tools for improvisation and performance. I will close this chapter by reporting on my fascination for a reading on vertical time: In San Agustín, Confessions III, he recommends to the singers to contemplate the whole piece at once before starting singing. I have found excellent inspiration from San Agustin’s advice, applying it as a meditation exercise before performing: “contemplate the whole duration of the forthcoming improvisation as if the axis of time has been shifted ninety degrees”[31]

7.2.6 Implementations

† Design an improvisation situation based on the technique of *Hocket*.

> The medieval term for a contrapuntal technique of manipulating silence as a precise mensural value in the 13th and 14th centuries. It occurs in a single voice or, most commonly, in two or more voices, which display the dovetailing of sounds and silences by means of the staggered arrangement of rests; a “mutual stop-and-go device”.[32]

† Write an algorithm that will generate synthetic material based on the analysis of the input in a contrasting counterpoint.

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[30] Ibid.
[31] Agustín, San. Confessions (3 Vols.). Oxford: Clarendon Press, 1992.
[32] “Hocket | Grove Music.” Accessed July 26, 2018.

7.3 Timbre – Deus Ex Machina

A performance situation to attentively distribute the spectrum among all the members of the band and use the narrative tool *Deus Ex Machina* as a sudden resolution device for an improvisation.

7.3.1 Tags

Spectrograph, endings, surprise, dramatic turns.

7.3.2 Goal

Among the goals of this section are: Develop the ability to analyze and judge by ear the spectral balance of the band's sound and affect it, either by reinforcing specific zones of the spectrum or by performing in inhabited registers during group performance.

Expand the personal and collective repertoire of structural cues with the narrative device of *Deus Ex Machina*.

Increase the self-confidence to propose materials and ideas that turn the music in new directions.

Foster critical views on the notion of timbre.

7.3.3 Description

The ensemble is arranged in a half-circle with each performer using local amplification. The arrangement should allow each member of the ensemble to judiciously listen to and follow the performer(s) sitting on either side. The idea is to define frequency boundaries by ear by always playing in a lower register than the person sitting to the left and in a higher register than the one on the right. The extreme right and left have the limits of the audible, so the full sound spectrum is shared among the group and divided in frequency bands equivalent to the number of performers. The limits of each band are not rigid and should be fine-tuned and monitored constantly by ear, not fixed before-hand. The improvisation starts with all the performers and everybody rapidly identifies their own boundaries and performs in that frequency band. These parts of the exercise can be played a couple of times to understand the concept, but once it is clear for everybody, the *Deus Ex Machina* concept is introduced.

Deus ex Machina "is a plot device whereby a seemingly unsolvable problem in a story is suddenly and abruptly resolved by an unexpected and seemingly unlikely occurrence, typically so much as to seem contrived."[33] According to this idea, at an undefined moment during the spectral performance, any of the players can bring a musical quote or a sonic element diametrically opposing or surprising the actual performance and from there the same performer should bring the improvisation either to an end or to a new spectral development section. The improvisation ending should be driven by a *Deus Ex Machina* intervention.

7.3.4 Variations

One alternative to the experiment above is to integrate a progression into the spectral domain. For example, from note to noise: starting from simple waves organized and distributed according to the physical position of the player (as described above), evolve into complex timbres to a noisy spectra, at which moment the *Deus Ex Machina* can happen.

As a solo performance, the exercise can be carried out with a mixer, where the channels are set to different equalizations or holding contrasting materials, so one channel is reserved for the *Deus Ex Machina* voice appearance.

7.3.5 Discussion

The concept of timbre has been extensively discussed among musicians, theorists and practitioners of *contemporary* music (from the second half of twentieth century specially, but of course the discussion dates from well before contemporary times).[34] Robert Crowder brings the attention to two particularities of Timbre.

> Timbre is an auditory quality of great interest for two reasons. First, we cannot verbally describe the quality itself, adequately. Try, for example, to write a paragraph distinguishing the sounds of a tenor saxophone from those of a bassoon, without using non-musical descriptors (foggy, nasal, and so on). We can try to communicate these timbres with such adjectives, but we cannot describe them. Second, we cannot produce these timbres vocally, either.[35]

[33] "Deus Ex Machina | Ancient Greek and Roman Drama." Encyclopedia Britannica. Accessed July 31, 2018. `https://www.britannica.com/art/deus-ex-machina`.

[34] Barrière, Jean-Baptiste. Le Timbre: Métaphore Pour La Composition. Christian Bourgois, 1991.

[35] Crowder, Robert G. Auditory Memory. Oxford University Press, 1993.

In the context of electroacoustic music as noted by Denis Smalley, the concept precedes the music, and therefore, we "have to spend much time and intellectual energy extending or combating notions which were not necessarily designed for the music we make."[36] Despite this observation and struggling to decipher the concept and the implications of it, Smalley analyzes different aspects of the notion of timbre through the lens of electroacoustic music practice. He identifies the following components and qualities related to timbre: the duality of spectral physical qualities of the sounds and their perceptual counterparts; the spectromorphological,[37] and *physiognomic*[38] attributes of sounds to which we attribute meaning; the organic correlation between timbre and discourse, the symbolic links "between our identity and sonic identity, and in electroacoustic music, between our identity and that of the wide-open sounding and non-sounding world outside the music"; the delicate links of timbre with concepts like source, texture, pitch, coherence, duration; and the transformational discourse as an alternative parallel concept to the typological discourse.

After this comprehensive analysis, we are cautioned about the shortcuts linking spectral analysis to timbre and we are invited to consider the multidimensionality of the perceptual process of timbre. The sonogram is a tool that helps to inspect, study or compose sounds.[39]"But a sonogram is not a representation of the music as perceived by a human ear – in a sense it is too objective. Its shapes therefore have to be interpreted and reduced to perceptual essentials".[40] As a tool, a spectrogram or spectrum analyzer can plot the frequency content of a signal over time. The resolution in frequency, the scale and the window shape will show radically different results on the analysis, stressing temporal or frequency elements on the sound. In other words, in a spectral analysis, *we will see what we want to see*. However, the working mechanism of a spectral analyzer reveals physiological and physical connections with the human ear. See for example the article "The Cochlea as a Frequency Analyzer".[41]

Using the principle of the spectral analyzer in a creative performance context as proposed in this chapter should introduce a dimension of awareness of a wholistic

[36] Smalley, Denis. "Defining Timbre — Refining Timbre." Contemporary Music Review 10, no. 2 (January 1, 1994): 35–48.

[37] Smalley, Denis. "Spectromorphology: Explaining Sound-Shapes." Organised Sound 2, no. 2 (1997): 107–126.

[38] Chion, Michel. Guide Des Objets Sonores: Pierre Schaffer et La Recherche Musicale, 1983.

[39] A graphical representation of the component frequencies of a sound (or sequence of sounds) as a function of time, as produced by a sonograph, typically with the volume at each frequency indicated by the graph's intensity or colour.
"Sonogram, N." OED Online. Oxford University Press. Accessed August 1, 2018.

[40] Smalley, "Spectromorphology", 107–126.

[41] Gold, T., and R. J. Pumphrey. "Hearing. I. The Cochlea as a Frequency Analyzer." Proceedings of the Royal Society of London. Series B, Biological Sciences 135, no. 881 (1948): 462–91.

listening of the ensemble sound and simultaneously introduce performance strategies with each instrument to drive the individual sounds in different regions of the aural spectrum. For this reason I often recommend having dedicated analog controls at the end of the signal path in each instrument, whenever possible, for instant access to volume and sound equalization.

Smalley's erudite analyses on timbre expose the importance of a particular mode of listening to electroacoustic music and first described by Schaeffer as *reduced listening* or *écoute reduite*.[42] A *microscopic* listening that focus the attention on the spectromorphological detail and sound quality, such a deep focal mode of listening is facilitated by repeated listening and by abandoning the source-cause origin and meaning and by letting the ear listen to "the sound for its own sake". "'Reduced listening' refers to the notion of *phenomenological reduction* (*Époché*) because it consists to some extent of stripping the perception of sound of everything that is not 'it itself' in order to hear only the sound, in its materiality, its substance, its perceivable dimensions."[43]. Listening to the details of the sound matter should facilitate and guide the realtime-collective-by-ear-spectrum-analyzer exercise. But the experiment has another dimension: the unexpected turn of events.

From the same Schaefferian heritage but with a personal development, Alain Savouret in his book *Introduction à un solfège de l'audible: l'improvisation libre comme outil pratique* presents a hypothesis of the three listening modes: the *microphonic* listening, the *mesophonic* listening and the *macrophonic* listening.[44] Microphonic listening relates to the short percpetual memory and focuses on the components of sound, or it zooms into the *inner* qualities of sound but does not have a *topos* space; it is monophonic and *coherent*; time feels frozen. Mesophonic listening is a deployed energy; it is the listening of the space-time forms articulated in discrete shapes and phrases; it is dynamic and movable and relates to the middle-term memory; it is binaural. Macrophonic listening is an informed, framed energy; it is referential and allows us to name, quote, situate a fragment of music; it is influenced by our culture and education and relates to our long term individual memory, our history; it allows polysemic, polychronic and polytopic connections. To turn the direction of music needed in the *Deus Ex Machina* exercise, I suggest switching between the microphonic, mesophonic and microphonic listening. The shift of musical direction can be induced by alternating

[42] Schaeffer, Pierre. Traité Des Objets Musicaux: Essai Interdisciplines. Paris: Éditions du Seuil, 1969.

[43] Chion, Michel. Guide Des Objets Sonores: Pierre Schaffer et La Recherche Musicale. Paris: Buchet/Chastel: Institut National de la communication Audiovisuelle. 1983. English translation by John Dack and Christine North, 2009 available at `http://ears.pierrecouprie.fr/spip.php?article3597` 31–32;
Kim, Suk-Jun. "A Critique on Pierre Schaeffer's Phenomenological Approaches: Based on the Acousmatic and Reduced Listening." In Pierre Schaeffer Conference: MediART in Rijeka, Croatia, on Oct, 7:2010, 2010.

[44] Savouret, Alain. Introduction à Un Solfège de l'audible: L'improvisation Libre Comme Outil Pratique, 2010.

between performing with the sound-matter with a microphonic listening attitude and performing a musical or sonic reminiscence of a past moment. The shift of listening and perception has to maintained and affirmative, not cautious, it has to be the metaphor of God's machinery affecting the irrevocable spinning of destiny, a clear message to the ensemble to change direction. When this happens, the end or a new beginning can start. Being able to turn the direction of the collective creation in such a dramatic way is empowering, and everybody should experience this power. It is important to sense that anybody can play that role at any moment, but it is also important to understand that beyond the context of an exercise, so in a free improvisation setting, such a theatrical device may be ignored, and the performer calling it may be left alone to solve their own musical destiny. Ignoring the proposal can be the start of another experiment. See for example the *MacGuffin* narrative device. "In a film (now also in a novel or other form of narrative fiction): a particular event, object, factor, etc., initially presented as being of great significance to the story, but often having little actual importance for the plot as it develops."[45]

I will close this section by expressing a personal point of view on the overstated value given to the timbre in some circles of electroacoustic music. I have noticed over the years working with electronic musicians a veneration for certain technologies based on claims over a quest for *high fidelity* sound. Although in most cases this attraction for a *kind* of sound is founded on an authentic search for an ideal sound,at other times it becomes a blind/deaf search and in the worst cases, an obstacle for creativity. The phrase: "judge with the ears" is common among the circle of electroacoustic practitioners, I agree, but I will add "judge with a critical spirit"; the ears alone are not enough.

To better illustrate my point, let me refer to the contrasting views of Phythagoras and Aristoxenus in ancient Greece. Aristoxenus argued in his *Elementa Harmonica* that the ear should be the ultimate judge of the melodic intervals of the scale and not the arithmetical relations, as the Pythagoreans considered.[46] In this dichotomy of sense vs abstraction, I believe we have made a great praise of Aristoxenus, giving enough attention to the sensuality of the sounds. Probably too much. From around the Romantic Era until the *timbre as metaphor of composition*, it seems that we have been enticed and obsessed with the *sweetness* of the sound, wasted the enjoyment of the physical stimulus of the sound, lost in the acoustic caresses of the cochlea. I am calling for the recovery of the music from the tentacles of the senses. *Music is more than sound.* I am calling to recover the mental abstraction powers of *knowing* the sounds and making music with them. Of course, musicianly knowledge should be grounded on psychoacoustics, neuro-cognitive and perceptual experiences but most important it should stand on a critical spirit, avoiding overemphasizing the sound qualities over any other

[45] "McGuffin, N." OED Online. Oxford University Press. Accessed August 2, 2018.
[46] Hawkins, J. A General History of the Science and Practice of Music.(Vol. 1, Pp. 66-67). London, England: Dover Publications, 1868.

musical aspect. Music is also a social and cultural construction, a mental representation of past lived experiences, a complex semantic net of auditory images, meanings, dreams and non-verbalizable ideas from our private gardens. Music is a way to interact with our inner and outer worlds; the sound is just the vehicle. I do not care if my post gets delivery on an old bicycle or in a Ferrari. Albeit sometimes, I do understand how marvelous and fascinating it could be to watch a Lamborghini delivering the post.

7.3.6 Implementations

† Program a MIDI controller or any interface to work as a *spectrum slicer* based on the Bark Frequency Scale, where any of the bands of an incoming signal can be isolated for performance and further treatment and development.

† Write an algorithm that can turn on a radio station, on a webserver or a physical radio, within a predetermined time frame. Use it as the *Deus Ex Machina* call.

† After studying Jean-François Charles's research and tutorials on spectral processing,[47] design an improvisation situation combining a plot device and spectral trnasformations.

[47] https://www.jeanfrancoischarles.com/ – Charles, Jean-Francois Emmanuel. "Music Composition: An Interactive Approach." Ph.D., Harvard University, 2011.

7.4 Space – Graphic Scores

A performance experiment to deal with the role of the body when playing electroacoustic musical instruments.

7.4.1 Tags

Motion, body, displacements, graphics, spatialization,

7.4.2 Goal

With this experiment, the performers should reflect on the function and importance of the body, both as a performing element carrying meaning and as sound transformation possibility.

7.4.3 Description

For this experiment a graphical score must be chosen or prepared beforehand. Each performer should wear a small or medium-size loudspeaker either attached to the body or hanging in order to be able to move with the loudspeaker following the motion. The rest of the instrument could be stationary on a table or stand, but fully movable devices can allow for larger movements to be performed or for displacements around the room.[48]

The score should be *open* enough or non-prescriptive i.e., without performing notes and few or no performance suggestions. The interpretation of the score will then be focused on the performance of body position and motion. The performers should interpret the score as a series of positions, times, speeds, moments, directions and displacements of their bodies while improvising. These motions will affect the projection of the sound and will result in a choreography of sounds and bodies taking over the physical space. The interpretation and writing (since the task can be requested in advance) of the score should invite the exploration of non-traditional performance body positions even beyond comfort without fear of reaching the theatrical or comical.

The improvisation will be over either by agreeing on a maximum length or by a call of the *time-keeper* to allocate enough reflection and discussion time.

[48] This activity has been greatly influenced by my collaborations with the sound artist Marianne Decoster-Taivalkoski and the choreographer Jasmiina Sipilä;
Sipilä, Jasmiina. “Moving in a Landscape of an Inter-Disciplinary Improvisation Performance: Ways of Working and Facilitating,” 2015.

7.4.4 Variations

The interpretation of the graphic score can be done from solo to small groups, creating a peer audience to interact with.

If possible, using video recording with one or more cameras will give the opportunity for self-criticism and to confront the inner perception of motion with an external point of view.

Another possible variation will include the real-time performance of drawing the score and/or using live camera feeds. Though these extra ingredients may risk distracting the focus of the exercise, they can in certain cases, when people encounter difficulties to experiment with the body, ease the focus of attention and create a more relaxed environment.

7.4.5 Discussion

In the accompanying handbook to the monumental work *Treatise*, Cornelius Cardew (1936 – 1981) assert "notation is a way of making people move."[49] The term movement could be understood in this context at different levels, from a literal meaning of setting bodies in motion to a more abstract connotation related to emotions. However, what Cardew probably refers to is the use of notation as a tool to invite creativity or even as a means to trigger a social process and support the people's need and enthusiasm for gathering, *musicking* and expressing.[50] The proliferation of meanings of the word motion seems to go hand in hand with the polysemic qualities of the word *space* in the electroacoustic music context. Federico Macedo in his article "Phenomenology, Spatial Music and the Composer: Prelude to a Phenomenology of Space in Acousmatic Music" strives for clarification of the use of the term *space* and proposes a typology of four different senses: "The first sense is metaphorical – musical space as metaphor. The three remaining senses – musical space as performance place, musical space as sound spatialization and musical space as soundscape – are related to space in a literal sense, here understood as the space as perceived by human beings".[51] In an electroacoustic framework, the terms *Motion and space* together produce an intricate network of meanings worth exploring, apprehending and questioning with the tools of performance and improvisation.

[49] Cardew, Cornelius. Treatise Handbook Including Bun No. 2 [and] Volo Solo. London; New York: Edition Peters, 1971. 17-20.

[50] Small, Christopher. "Musicking — the Meanings of Performing and Listening. A Lecture." Music Education Research 1, no. 1 (March 1999): 9–22.

[51] Macedo, Frederico. Phenomenology, Spatial Music and the Composer: Prelude to a Phenomenology of Space in Acousmatic Music. Ann Arbor, MI: Michigan Publishing, University of Michigan Library, 2011.

To dismantle the polysemic web created by bringing such loaded words into play (space, motion, body, score), I propose breaking up the discussion into three aspects: graphic scores as creative triggers, body and electroacoustic music and space and performance. Thus, optimistically the performer(s) will reverse the process and consolidate during the improvisations these aspects and elucidate the essence and goal of the experience proposed here.

Earle Brown's work *December 1952* is probably the door that opened a new point of view in the musical notation and the process of composing. The work using vertical lines of different lengths and thicknesses purposely exists in a common territory between graphic art and music notation. Subsequent experiments by composers and musicians have taken the idea to different extents, challenging the un-equivocal and well-established meaning of musical symbols. One of the key works in that semantic research is the aforementioned *Treatise* of Cornelius Cardew. The treatise was composed around 1963 and 1967, it is a graphical score of 193 pages, including abstract shapes such as geometrical shapes of different sizes, conventional music signs, numbers, a horizontal middle line and empty musical staves.[52] The score does not include any further instruction, leaving the performer(s) a great deal of freedom of interpretation.

Cardew comments himself:

> Ideally such music should be played by a collection of musical innocents [people who had no formal musical training]... My most rewarding experiences with Treatise have come through people who by some fluke have (a) acquired a visual education, (b) escaped a musical education and (c) have nevertheless become musicians, i.e. play music to the full capacity of their beings.[53]

The notation as used by Cardew is in the words of Thomas Philip "a catalyst for action".[54] The score is an invitation to respond and musically interact around the *self-contained* world of symbols. I will call it a *creative trigger*. Something more than a pretext to improvise, a step further, a *push* to jump into the unknown,[55] a push for a metaphysical leap in the sense given by Cioran.[56] This experiment could then be done with another category of creative triggers, such as text-based scores or interacting with a dancer or a light designer. I chose, however, the graphic score because of a certain affinity between the suggested trajectory of a drawing and the visualization of a sonic movement. Nevertheless, any resource

[52] "SA12: John Tilbury on Treatise." Accessed July 30, 2018. `http://soundamerican.org/sa_archive/sa12/sa12-john-tilbury-on-treatise.html`.
[53] Cardew, 19.
[54] Thomas, Philip. A Prescription for Action. Routledge Handbooks Online, 2009.
[55] Weiss, Jason. Steve Lacy: Conversations. Duke University Press, 2006.
[56] Cioran, Emile M. The Trouble with Being Born. Skyhorse Publishing Inc., 2013.

available to facilitate the consciousness and *bringing into play* the performer's body will be appropriate.

The role of the body in electroacoustic music performance has definitely driven us beyond the paradigm of acoustic music performance with physical efforts and virtuosity. Observing how a laptop performance show looks, as Nick Collins suggests, we have probably gotten used to staring at the back of a laptop and to musicians staring at the screen.[57] The relationship between the body and technology gets even more complicated when considering the enhancement of bodies with technology thorough implants and by being "human-technology symbionts: thinking and reasoning systems whose minds and selves are spread across biological brain and non-biological circuitry"[58] Wearable musical instruments and an *open hands* mapping between gestures and sound only complicates the story. Julio D'Escriván in his article "To Sing the Body Electric: Instruments and Effort in the Performance of Electronic Music" synthesizes the paradox of the *effortless* digital instrument performance in a brilliant score: (reproduced here with the kind consent of the author)

> *Sentic Music for Seated Performer* (to be performed without a break):
>
> 1. Eyelid Music:
>
> Sit on a chair and face the audience. Close your eyes very gradually once. As your eyelids meet, intend something very passionately. Remain as expressionless as possible.
>
> 2. Index Finger Music:
>
> Remain on the chair. Place your left hand on your knee. Lift your index finger gradually to the point of its maximum extension. At this point intend something very passionately. Bring it slowly down.
>
> 3. Foot-tapping music:
>
> Remain on the chair. Tap the floor very softly with your right foot. When the tap occurs, intend something very passionately. When you finish, stay still until the audience reacts.[59]

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[57] Collins, Nick. "Generative Music and Laptop Performance." Contemporary Music Review 22, no. 4 (2003): 67–79.

[58] Clark, Andy. "Natural-Born Cyborgs?" In Cognitive Technology: Instruments of Mind, 17–24. Springer, 2001.

[59] Escriván, Julio d'. "To Sing the Body Electric: Instruments and Effort in the Performance of Electronic Music." Contemporary Music Review 25, no. 1–2 (February 1, 2006): 183–91.

The call with this chapter and discussion is to assume a position (pun intended) and take full-responsibility for how our performer's body is integrated into the electroacoustic performance. Should we as performers become invisible or abstracted, as suggested by the definition of acousmatic music: "music intended for loudspeakers"? Or should we in a gesture of full commitment to the genre become embedded/dis-embedded in the electroacoustic brain? Escaping from the extremes, the exercise of this chapter should remind us of the theatrical use of our bodies and of the incredible power of the *mise en scène* of the whole. The regard of a scenographer would only be beneficial while setting up a show.

The last point of reflection in this chapter is about one possible relationship between the sound space parameter and performance. Maja Trochimczyk proposes an analysis of spatial designs in an electroacoustic music context.[60] She suggests a general classification based on the categories of: Acoustic environments, Sound-space types and Categories of mobility. For acoustic environments, the author understands enclosed spaces such as concert halls, open air, private, virtual, headphones. In the mobility category, she includes the possibility of a moving audience or moving performers within these combinations: "static performers and static audience, mobile performers with static audience, static performers with mobile audience, mobile performers and mobile audience" Considering the mobility of performers and/or audience expands the discussion of moving sounds on a multichannel loudspeaker system opening the door to other forms of performance and sound art. The idea of moving sources can be traced back to different forms, for example, the rotating loudspeaker used in the Leslie Tone Cabinet (designed around 1911, and manufactured from 1940),[61] or the often quoted photograph of Stockhausen manipulating a loudspeaker in a turntable and four microphones, recording for the piece Kontakte (1960).[62] Finally, the one that has the strongest relation with the exercise offered here is the *homo-parleur* described by Georges Boeuf and Michel Redolfi in 1977 "The authors present their new spatialization system, two loudspeakers attached to the human body. Through a technical description and musical remarks, they analyze the possibilities of this instrument for their future musical theatre works."[63] Recently the idea of wearable loudspeakers for electroacoustic performance has raised some interest maybe due to the proliferation of mobile devices and wireless loudpseakers, See for example, "The Stanford Mobile Phone Orchestra" (MoPhO), "The Michigan Mobile Phone

60 Trochimczyk, Maja. "From Circles to Nets: On the Signification of Spatial Sound Imagery in New Music." Computer Music Journal 25, no. 4 (2001): 39–56.

61 "Leslie | Grove Music." Accessed July 31, 2018.

62 Dack, John. "Diffusion as Performance." IIASSRC Conference Proceedings, 2001.

63 Cahiers Recherche/Musique, no. 5. Paris. INA-GRM. 1977. 111-123;
Cuprie Pierre. "L'homo-Parleur – EARS ElectroAcoustic Resources Site." Accessed July 31, 2018.
`https://web.archive.org/web/20181108030034/http://ears.dmu.ac.uk`.

Ensemble" as described by Ana Xambó,[64] and the increasing number of patents for wearable loudspeakers.[65]

As stated above, the proposal for interpreting the graphic score is to integrate the movement of the loudspeaker in unison with the movement of the performer by attaching the loudspeaker to the performer's body. Consequently, this manipulation and direct spatialization of the sound source will produce perceptible changes in timbre, sound volume, perceived directionality, change in the reflection pattern and doppler effects. The performance of the space becomes a theatrical and sonic experience, and the performers are invited to seize this potential. As quoted by Curtis Roads,[66] James Dashow puts it in a more suggestive way.

> One could say that up to now, musical composition has been largely a question of What happens When. With spatialization, composition now becomes What happens When and Where. As more work is done to refine spatialization concepts and discover new modes of musical thinking in terms of space, it becomes clear that spatialization is our genuinely new contribution to musical art.[67]

7.4.6 Implementations

† Build a customized jacket or vest with battery power wireless loudspeakers for improvising around the audience.

† Replace the graphic score with other art forms, for example, a text-based set of instructions or a silent abstract film.

† Invite a choreographer and a scenographer to discuss sound in space from the point of view of their practice.

† Set-up a web browser to play back pre-recorded improvisations and randomly use mobile phones as moving sound sources.

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[64] Xambó, Anna. "Tabletop Tangible Interfaces for Music Performance: Design and Evaluation." PhD Thesis, The Open University, 2015.

[65] Boyden, James H. Portable speakers with phased arrays. United States US5815579A, filed December 1, 1995, and issued September 29, 1998. `https://patents.google.com/patent/US5815579/en`.

[66] Roads, Curtis. Composing Electronic Music: A New Aesthetic. Oxford University Press, 2015.

[67] Dashow, James. "On Spatialization." Computer Music Journal 37, no. 3 (2013): 4–6.

7.5 Form – Chekhov's gun

An improvisation device to facilitate and support the construction of a narrative form.

7.5.1 Tags

Memory, surprise, structure, form.

7.5.2 Goal

With the experiments proposed in this section the performer should investigate the mechanism available for consolidating a narrative in a group improvisation.

Cultivate structural thinking, inviting the exploration of tools and techniques from other art areas.

7.5.3 Description

The observations made by playwright and short-story writer Anton Chekhov about removing the unnecessary elements in a plot have become known as a dramatic principle *Chekhov's gun*. Quoted in different versions, the idea holds:

> If in Act I you have a pistol hanging on the wall, then it must fire in the last act.[68]

Based on this idea, I am proposing to perform an improvisation where a clear sonic distinctive element, *a sound-gun*, is introduced at the beginning by one performer then registered by the band and greatly developed later on. For example, if the improvisation starts with an evolving drone texture, one performer may decide to introduce a bar of 3/4 alluding to a waltz. The hint will be distinctive enough from the drone-texture so the rest of the band can catch it, then the improvisation goes on in an organic natural way until the hint comes back, and this time *everybody* should shift the performance into a Dionysian electroacoustic Waltz. The last part of the exercise consists in collectively finding a resolution and either turning back to the initial texture, modulating to a new one or finding and ending.

[68] Rayfield, Donald. Anton Chekhov: A Life. 1st American ed edition. New York: Henry Holt & Co, 1998.

The proposal consists then of three points: first someone plays a distinctive sound hint over a free improvisation, while the rest of the group identifies when the hint comes back and joins without hesitation, and last, a group decision is made about the resolution of the situation. If more than one performer proposes a cue simultaneously, it will be their task to lead the group towards a continuation and bring the element into play, preventing it from being forgotten. For example, if in the previous situation described above, simultaneous to the waltz insinuation somebody was playing back a sound file of tossing coins, and the *Electro-Waltz* gets fired first, the task of this second player will be to lead the improvisation after the Waltz back to the drone and then to trigger the sonic world of the coins. The idea situation of sound cueing should happen with discretion, therefore limiting the body language of verifying that all the members of the band get the cue or reduce the eye contact at that specific moment. It should be a detail of the *scenography* that gets utilized later on.

7.5.4 Variations

One possible variation of the exercise consists of changing the number of performers to two or three or even implementing a solo version.

The sound-gun and its firing is pre-arranged in a tape and unknown to the band until the improvisation starts, so the band must be attentive to what it is and when it will get fired, also the performers should play with the intuition to estimate if the sound-gun will come again.

7.5.5 Discussion

Form in musical improvisation has been a subject of criticism and debate among musicians, composers, performers and theorists. Probably one of the most famous comments comes from Pierre Boulez, who, in an interview with the musicologist Célestin Deliège in 1976,[69] and discussed by Paolo dal Molin in the chapter "Composing an Improvisation at the Beginning of the 1970s", commented on the *poor* qualities of formal thinking in improvisation compared to the composer ability to use morphological tools in contemporary music.[70] Boulez's criticism is about a certain *naïveté* in the structural thinking of a group of improvisers, who, according to him, reduce the musical form to waving or oscillating states between tension and relaxation. From Boulez's own words:

[69] Boulez, Pierre, and Célestin Deliège. Conversations with Célestin Deliège. London: Eulenburg Books, 1976.

[70] Dal Molin, Paolo, and Edward Campbell. "Composing an Improvisation at the Beginning of the 1970s." In Collected Work: Pierre Boulez Studies. Published by: Cambridge, England: Cambridge University Press, 2016. 270-300.

> Improvisation, and especially improvisation in groups where there is a degree of sympathy between the individual members, always follows the same curve of invention: excitement – relaxation – excitement – relaxation. In so-called primitive societies a similar situation exists in religious ceremonies whose relatively simple form involves a building up of psychological tension followed by relaxation. There is a whipping-up of collective excitement and when the uproar reaches its peak there comes the need to release the tension, and a period of relaxation follows.[71]

Having been part of improvisation groups, I can see where Boulez' criticism come from. I have heard those tension-relaxation improvisations many times, but I have also been part in a considerable number of occasions where the musical form has been treated in many different and creative ways. Once again, I consider that critical thinking and experimental pedagogy can reveal and foster performance tools to ingeniously handle structural problems in the musical narrative. From another perspectives, contemporary musicologists,[72] researchers in musical cognition,[73] sociologists and antropologist,[74] and musicians[75] have re-worked the concept of musical form integrating many aspects, transcend the will of a composer, and resulting in a fruitful ground for the performers of electroacoustic music to experiment, expand and create.

Musical form and structure has been a concern for musicians and theorists of all times. It will be possible to design experiments and improvisation situations, without being an aesthetic purist, around some of the compositional techniques that have made landmarks in our Western musical histories. Of course a straight implementation of renaissance counterpoint rules does not make sense since electroacoustic music is beyond the core concept of note and degree, (though instruments can be tuned and pitch structures programmed). Below are some ideas to experiment with form and structure in the context of electroacoustic improvisation. The list comes from techniques developed and treated by different musicians in different genres of music.

- Applying the concept of *motif* to establish a sonic formal unit over which temporal, frequency and timbre transformation can be applied, resulting in forms such as theme of variations and rondo. Treating electroacoustic materials with counterpoint techniques (retrograde motion, inversion, time stretching, expansion, transposition) and adapting forms of canon and imitations can eventually result in a form of *baroque* electronic music.

71 Boulez, Pierre. Par Volonté et Par Hasard : Entretiens Avec Célestin Deliège. Tel Quel. Éditions du Seuil, 1975. p.114-115
72 Landy, Clarke, Roy, Licata, Hirst, Barrière
73 McAdams, Bregman, Lerdahl
74 Attali, Lévi-Strauss
75 Wishart, Varèse, Smalley, Lucier, Chion

- Expanding in the development of consolidated and contrasting *thèmes* can be the basis for binary and ternary forms like ABA or ABCBA

- Employing free form by sections requires clear delimitation and character for each section to organise the improvisation.

- Applying minimalistic techniques, where non-development or static materials based on non-interventionist attitudes to respect the evolution of a process set in motion can create monolithic musical forms.

- Implementing the *content as form*. Inspired by Varèse ideas, letting the content *become* the form itself,[76] for example by playing with pre-recorded material of a waterfall or any other natural process and improvise with it.

- Using text-based forms: the music structure and form are governed by a pre-existing text to articulate an improvisation.

- At the time I was working with Alain Savouret, we used to apply a mental image of a musical form that was not advancing but digging. This was a very useful tool to let the sound materials and textures speak by themselves and reach their exhaustion not by a formal demand of a predetermined plan but for a confrontation with our own personal resources and mental and physical capabilities.

Following the idea of letting the sounds *speak for themselves* Krokonas Panayiotis proposes the concept of Morphopoiesis as a generalized process for working with sounds as musical form generators.[77] Based on schaefferian morphological criteria, Landy categorizations of sound transformations, and Smalley spectromorphological changes, Krokora exposes a four hierarchical level as a framework to analyze and generate musical forms out of sounds: "Cognition and Perception, Motion, Typo-morphology and Transformation."[78] Krokora's proposal seems to be appropriate to musical forms generated by the idea of setting in motion a musical process, i.e. a sound transformation or the development of a sonic material. Several experiments can be designed to test these ideas.

Any discussion about musical form would not be complete without considering human memory. It is because we can remember and recall past motifs, themes, chord progressions, rhythmical, melodic and timbrical patterns or musical and text sentences that a temporal structure can be built in a sonic composition or improvisation. As reported by Robert Crowder in the chapter "Auditory Memory", cognitive researchers seem to be attracted to research on the pitch domain,

[76] Varèse, Edgard, and Chou Wen-Chung. "The Liberation of Sound." Perspectives of New Music, 1966, 11–19.

[77] Kokoras, Panayiotis A. "Morphopoiesis: A General Procedure for Structuring Form." Electronic Musicological Review 9 (2005).

[78] Ibid.

melodies and harmonies, carrying tests identifying similarity, naming melodies or recalling notes sequences with masking tones and sounds and only recently on timbre and sound qualities.[79] Since electroacoustic music offers other alternatives than pitch to govern the formal organization of music – timbre, space and time for example – the research on musical memory in an electroacoustic improvisation context has to be carried out empirically by the practitioners themselves. Cognitive science research will ultimately enter the experimental feedback loop with musicians and develop systematic tests to inform performers and listeners about electroacoustic music memory.

There is however an aspect of research that can be valuable in the pedagogical process. It is the inner ear as a form of sensory-based auditory imagery. Crowder discusses and introduces in the same chapter the concept of a mental representation as "mental hearing or singing to oneself", an *Auditory Imagery* of an original acoustic experience.[80] Supported by Hebb's idea that "the same neural organizations (cell assemblies or phase sequences) were active both in imagery and the original experience."[81] Crowder argues for "the neural consequences of hearing an instrumental timbre and imagining that it (was)were, to some extent, equivalent". I am reading Crowder's postulate as the equivalent of training the inner ear by mental *visualization* or representation of sound. What Azzara and Gordon called *audiation* "hearing and comprehending in one's mind the sound of music that is no longer be there or may never have been physically present: Audiation is to music what thinking is to language. The abilities to retain, recall, compare, and predict are recognized as primary mental functions in Gordon's definition of audiation".[82] Imagining the sound recreates the neuronal connections of actually hearing it.

Training the ability to build mental-sonic-images of complex acoustic events can be done by concentrated focus listening, somehow allowing the body and brain to transparently register the sonic event and the mental state associated with it, so it can be silently recalled later on without the physical presence of the sounds. Keeping the focus and concentration throughout improvisation sessions demands regulated pauses and sensing of the *mood* by the facilitator but also by an open continuous conversation and collective time group management.

I will close this discussion by coming back to the Chekhov's gun exercise. What this exercise can teach us here is the necessary auditive attentiveness and group concentration to identify the *hanging gun* on the musical stream and to keep memory of it to identify it and let it happen as a musical liberation. Therefore, focus, memory and transparency are the lessons from this reflection and are at

[79] Crowder, Robert G. Auditory Memory. Oxford University Press, 1993.

[80] Ibid.

[81] Hebb, D. O. "Concerning Imagery." Psychological Review 75, no. 6 (1968): 466–477.

[82] Azzara, Christopher D. "Improvisation." In The New Handbook of Research on Music Teaching and Learning: A Project of the Music Educators National Conference, 171–187. Oxford University Press, 2002.

the same time tools to build unspoken musical structures. A group that has performed these challenges would have been increasing the common knowledge of the possible forms and can identify them in a performance context when such ideas raise through the skin and surface of the performance.

7.5.6 Implementations

† Use a soundscape recording to determine the form and structure of an improvisation task.

† Set up improvisation tasks using sonic motifs and themes.

† Write an algorithm that will generate and trigger a sonic cue such as *Chekhov's gun*

8

Performance Elements

8.1 Repeating – Hypermnesia, Amnesia

A performance experiment based on the extremes of short- and long-term memory.

8.1.1 Tags

Memory, loops, repetitions

8.1.2 Goal

Challenge the performer ability to remember a long performance and to stand an endless loop.

8.1.3 Description

The experiment has two versions: *Hypermnesia* and *Amnesia*, each of which deals with different spans of memory. They are not meant to be carried out during the same session. The experiment can be done with any number of performers with an electroacoustic performance setting.

Hypermnesia: Ask the group to perform a spontaneous free improvisation of a moderate length. Carefully take notes of the main sequence of events, the turning points, the salient materials. After the improvisation is over, hopefully not longer than twenty minutes, and allowing a good silence afterwards, ask the improvisers to repeat the improvisation, to perform an accurately as possible a replica of the first improvisation. Take notes. After the end of the second improvisation, debate and open a discussion about everybody's strategies to perform the tasks; compare the performers' sonic landmarks. According to my experience, the experiment will be more successful if the performers are taken by surprise with the task, so it is important to avoid giving clues about the task beforehand.

Amnesia: Ask the performer(s) to choose an action, gesture or sound of a brief duration. Then propose that they perform it in a loop, repeating all aspects over and over during an extended duration. Anything beyond five minutes will start to be challenging enough. The gesture chosen for looping should include a physical aspect, like turning a knob or a sequence of actions: slider one up, down, knob one full counter clockwise, slider two to fifty percent, then eighty, then forty percent, button one two times, done. The sequence should be clear in the performer's mind, and it should be possible to remember it without any notation.

8.1.4 Variations

The hypermnesia task could be split over sessions on different days, asking the group to recall and rebuild the previous session's last improvisation, for example.

The sequence of events composing the sonic gesture could be distributed in the band so that the group performs in a specific order, creating a collective loop machine.

8.1.5 Discussion

Performing and creating on the spot puts in action a full range of conscious, subconscious and perhaps superconscious perceptual and cognitive operations. Memory, as previously discussed in the chapter about musical form (7.5), in an electroacoustic music performance and improvisation setting, is still an open field for studies, research and investigation. While the theorists gain interest and attain a level of understanding of what we practitioners may know from empirical and experimental research, the experiences proposed here deal with two extreme conditions. The first one consists of remembering an extremely long sequence of sonic and musical events and the second one consists of holding and recalling a short sequence or chain of gestures until exasperation and vexation. Below are my observations after carrying out the experiments with several groups over the past five years.

A series of strategies to hold in memory sonic structures are revealed when asking a performer to spontaneously recall an improvisation without preparation (without knowing that they will be requested to do so). One possible answer to examine is the claim of not remembering anything. This answer probably means two things. First, that it is probably not the appropriate question to start, better questions will be to ask or comment about particular structural moments or progressions, such as, was there a climax in the improvisation? do you remember the soft section? how did you reach it? who was playing those inharmonic sounds? And second, that without performers consciously *storing* information in form of actions and events; every moment will resonate on their minds with a certain intensity and then it will vanish, evaporate and dissipate. This is a logical consequence of the necessary *readiness* in improvisation, which implies an attitude of permanently *letting the things go*. Holding the argument of not remembering anything could be seen with suspiciousness since there must be some images still resonating right after the improvisation. These images could be described as moods, energies, moments, relations or even metaphorically connected with very personal semantic connections and associated with sonic events.[1] Therefore, the task of the moderator is to open up and guide the conversation towards a collective reconstruction of events.

What, how, and why do we remember from a long improvisation? By "long" here, I mean at least 20 min. (In my experience the duration of 20 minutes is a comfortable collective breathing or generous collective span of attention). Considering that the sonic vocabulary in question extensively exceeds the organization of material by pitch and rhythm parameters – those most studied from the cognitive science perspective – other aspects must be brought into play to activate the memory processes. I have observed how the events related to an emotional aspect are easily stored and remembered. Some actions, gestures and a sequences can be recalled because of the emotional load they carried during the improvisation. For example, an error: a guitar player accidentally moves the connection to the amplifier and creates a scratching sound typical of a faulty connection. It sounds like a mistake, and it feels embarrassing since everybody notices it and it is heard as an involuntary (out of control) sound; however, the accident can be turned into an element full of expressivity by continuing to plug in and unplug the cable on purpose and by meticulously searching all those scratching sounds. The event and a lot of precise details surrounding it will be remembered after the session and even possibly years later because of the emotional content of overcoming the fear of a mistake.

Musicians and sound performers have a strong chronological memory. Sonic events and musical progressions happen in a certain order and direction. For example, a chronological description of events can look like this: "first, there was a duo then a tutti was reached and the whole group evolved into a pulsating

[1] I remember a performer who told me after been asked to recall the improvisation: "in my journey [the last improvisation] I met the other performers in central Africa. It was very intense and sunny we ended up digging in the sea in a thick and warm ocean."

dance with *frenzy* until a radio was turned-on". When it is possible to segregate the sequence of events in isolated or distinguishable temporal units, the chronological recall of events may be achievable and accurate. However, when the sonic events are not discrete temporal units or in a non-common-pulse based situation, a musical moment is obviously remembered as timeless or durationless. For example, a long, slowly evolving drone without clear structural cuts, it must be remembered as a *colour*, *texture* or as a *mood*, not involving some kind of *linear* succession of events, eventually as a spectromorphological evolution, but often as a timeless experience in which reporting a quantification of time is very difficult. Same kind of perceptions will be triggered by very sparse sonic events articulated by long silences.

The experiment proposed in this section could end in a confrontation of different experiences reaching some remarks and observations about the memory process, or it could also be further pushed for study and analysis. It could end up as a fixed art work! As an example, in a private conversation (2007) with the dancer Cathy Pollini, she described to me how during her work with the choreographer Johan Anselem for a solo piece in the cycle "À quoi je tiens", the whole process of writing the choreography consisted of re-creating to the smallest detail an original solo improvisation made during the first working session. There are many other examples across the disciplines where such practice has been carried out. Capturing and rebuilding a unique creative moment reached by a spontaneous improvisation. For such purposes, audio, video recording, photographs and any other means available to document the improvisation (the notes, written or not, of an audience member, for example) will be useful to revisit the improvisation and to compare it against personal and subjective memories. I am not saying that documentation is objective; I am well aware of the subjective point of view of documenting,[2] and even of the practice of *documentation as performance*.[3] I am suggesting that for a temporal art form, recordings and audiovisual material must be a powerful tool to reexamine the material outside the performance time.

The title of this experiment *Hypermnesia* "The Unusual Power of Memory" is not referring to a clinical condition but to the un-discovered or un-revealed power of the mind.[4] Though I cannot affirm that I have ever seen a group able to perform the same improvisation twice, I can argue, based on my own observations, that in a special context such as the electroacoustic performance and improvisation dealing with a high level of abstract symbolism and group interaction, long-term memory can be surprisingly precise and accurate.

[2] Auslander, Philip. "The Performativity of Performance Documentation." PAJ: A Journal of Performance and Art 28, no. 3 (2006): 1–10.

[3] as practiced by the research group in improvisation active between 2011 and 2014 at the University of Arts Helsinki – Andean, James. "Research Group in Interdisciplinary Improvisation: Goals, Perspectives, and Practice." University of the Arts Helsinki, Theater Academy, 2014.

[4] Payne, David G. "Hypermnesia and Reminiscence in Recall: A Historical and Empirical Review." Psychological Bulletin 101, no. 1 (1987): 5.

At the other end of the spectrum, I suggest working with the concept of *Amnesia*, “a pathological condition of loss of memory”.[5] Again, only as an evocative metaphor for performing a sonic improvisation based on a very brief or short chunk of memory, so nothing involving, development, or structural form or transformation, or narrative, nothing relaying on *flashforward* or *flashback* techniques. Therefore, restricting the material to a short sequence of movements generating a sound or a sonic gesture and to which the only possible performance operation is to repeat.

This reductionist approach of shrinking the material to the minimum possible and limiting the sound transformations and process to a very restricted amount will resonate with techniques used in minimalism;[6] however, my interest here focuses more on the performance challenge than the aesthetic result. The goal is to inspect the performance qualities required to interpret an endless repetitive musical moment such as in Erik Satie’s work *Vexations* with its 840 repetitions. The point of the proposed experiment is to focus on the iterative, mechanical repetition rather than a slow change of the kind described by Steve Reich in his writing “Music as Gradual Process”.[7]

An unavoidable reference for the experiment of repetitions is Pierre Schaeffer telling the story of how he experienced a closed groove in a phonograph as the birth of the *Musique Concrète* in 1948 *Le sillon fermé* or “locked groove”.[8] It was the listening of the closed groove that took Schaeffer to think and write about the *reduced listening* from a phenomenological perspective. What I am suggesting here is a matter of performing the loop, along with listening to it, of course.

The performing of repetitions is remarkably illustrated by Albert Camus in his recall and reading of the *Myth of Sisyphus*.[9] “The gods had condemned Sisyphus to ceaselessly roll a rock to the top of a mountain, whence the stone would fall back of its own weight. They had thought with some reason that there is no more dreadful punishment than futile and hopeless labor.” Camus engaged a philosophical discussion on the absurdity of the world and the meaningless of life and uses Sisyphus as a reasoning image. Camus explored the fatality and absurdity of the Sisyphean condition, his consciousness, reasoning and how the contemplation of his torments ultimately make him the master of his days and the rock *his world*. Camus concludes, Sisyphus may be imagined ultimately as a happy man despite his absurd fate. “The struggle itself toward the heights is enough to fill

5 “Amnesia, N.” OED Online. Oxford University Press. Accessed August 3, 2018.

6 Johnson, Timothy A. “Minimalism: Aesthetic, Style, or Technique?” The Musical Quarterly 78, no. 4 (1994): 742–773.

7 Reich, Steve. “Music as a Gradual Process.” Writings on Music, 1965-2000, 1968, 34–36.

8 Palombini, Carlos. “Musique Concrète Revisited.” Electronic Musicological Review 4 (1999).

9 Camus, Albert. The Myth of Sisyphus: Translated from the French by Justin O’Brien. H. Hamilton, 1965.

a man's heart. One must imagine Sisyphus happy". Camus's thinking has inspired and influenced some of the writers of the "Theater of the Absurd".[10] Repetition is a feature found in many plays representatives of the movement where actors get *trapped* into circular mechanical repetition of meaningless phrases.[11]

The excercise of *Amnesia* can be seen as an attempt to apply Camus's observations of the Sisyphus myth. The performance of a sonic chain of events repeating to infinity requires from the performer a mental and physical disposition for contemplation and reasoning. It is not a punishment; it is the opportunity to *revolt* and in our context, to transgress the sense of memory, the spans of attention, forgetting and remembering, getting the same sound again and again, reaching for the absurdity. Once during an artistic residence at *Institut Chorégraphique International* in Montpellier in 2009, I had the opportunity to see a private working session of choreographer Mathilde Monnier where she performed a scene of falling off a chair hundreds of times, I was astonished at such a remarkable performance since she did not seem to experience any pain though the falls looked extremely natural. After seeing that, I ran back to my electronic music studio and started to experiment with extended repetitions of gestures and sounds; it was a strong, liberating and inspiring experience stimulating creativity.

To close this chapter, I want to stress the invitation to investigate the limits of remembering complex sequences of sonic events over an extended period of time; use the closed short loop as a device to challenge and rediscover the listening; invent performance situations that require pushing the limits of the senses, talents and qualities. Sonic improvisation can be the vehicle of marvelous discoveries about ourselves.

8.1.6 Implementations

† Experiment with vinyl discs, create artificial physical loops with a cutter, and if you dare, cut the discs in pieces and paste them creating new arrangements.

† Write an algorithm that can compare two versions of an improvisation and quantify the differences.

[10] Bennett, Michael Y. "The Cambridge Introduction to Theatre and Literature of the Absurd by Michael Y. Bennett." Cambridge Core, October 2015.

[11] Esslin, Martin. "The Theatre of the Absurd." The Tulane Drama Review, 1960, 3–15.

8.2 Imitating – Shadowing

An exercise to increase control over the instruments by copying all the sonic qualities and characteristics of a dynamically changing model.

8.2.1 Tags

Imitation, ear copying, shadowing.

8.2.2 Goal

With this exercise the performers should improve the reactivity and control over their own particular instrumental setting by imitating the sound of another performer.

Another objective for the performers is to develop a critical, quick judgment by analyzing a stream of sounds and extracting the outstanding features while simultaneously reproducing them with their own means and instruments.

8.2.3 Description

The idea of shadowing exploits the fundamental pedagogical principle of sonic imitation with the purpose of improving reactiveness and adaptability to musical and sonic changes. The task should work as a form of high level ear training, playing by ear while instantaneously analyzing and copying all the musical dimensions of a *model* material. Copying includes mimicking timbre, amplitude, transients, rhythmic and all possible sonic information extracted from a dynamic changing acoustic source.

By encouraging self-criticism after each improvisation, it is possible to evaluate how sonically close each musician was to the soloist and then trigger discussions about the criteria to determine and evaluate the timbral proximity of two sounds. The task also provides a way to discover each other's sonic vocabulary and familiarize the group with each other's sonic gestures and therefore facilitate the communication of musical and sonic intentions.

Starting from silence, one musician decides to start and play freely in the spirit of a solo. As soon as possible, all the rest of the musicians join in in an attempt to be as sonically as close as possible to the soloist, imitating the music and sound content as if they were sonic shadows. The goal is then to copy and reproduce instantly all the aspects of the solo: volume, intensity, timbre, rhythm, musical intentions, performance qualities. The task can be played as a long improvisation by spontaneously starting each solo one after the other or as a free form by sections, separating each solo with silences. For the purpose of detailed analysis, it is recommended to record or isolate each solo performance.

8.2.4 Variations

Variations on the shadowing exercise can consist of defining who is following whom. For example, one possible variation could be to individually and silently define whom to follow at the starting moment and never change until the end. During the discussion, the roles of shadows and guides can be revealed by questioning if people identify who was following them.

Another alternative is to propose to follow a pre-chosen sound file. It can be as complex as an electroacoustic composition or a previous recording from the same band or a solo recording. The whole can be recorded again and eventually used as a new starting point. The advantage of using sound files preceding the shadowing is that several versions can be performed and the similarity can then be evaluated and discussed further.

8.2.5 Discussion

Imitation is a learning strategy in many musical oral/aural traditions, including popular music and in many societies around the globe.[12] The principle is to absorb a musical culture composed of instrumental dexterities, melodic sequences, rhythmical structures, emotional content and sound qualities through the process of copying the more experienced musicians, transmitting knowledge in non-verbal forms.

The proposal here is not to create a social hierarchy by identifying the master or the model to follow but to use aural skills to sonically and musically copy each other. Electroacoustic instrument settings can be extremely personalized, so it is not a necessary alternative to believe in copying somebody's instrumental

[12] Green, Lucy. How Popular Musicians Learn: A Way Ahead for Music Education. Ashgate Popular and Folk Music Series. Aldershot: Ashgate, 2002;
Wiggins, Trevor. "Whose Songs in Their Heads?" In Collected Work: The Oxford Handbook of Children's Musical Cultures. Series: Oxford Handbooks. Oxford University Press, 2013. 590-608.
Smith, Robert (Bob). "Sharing Music with Indigenous Australian Boys." In Collected Work: Male Voices: Stories of Boys Learning through Making Music. Published by: Camberwell, Victoria: ACER Press, 2009. 79-94.

technique. We are left therefore with the sound qualities and musical intentions. Copying means in the context of this chapter to follow or to shadow the sonic material of a predefined target. Because the nature of electroacoustic instruments, this can turn into a very difficult task. Rapid changes in the sound source, for example, moving from sample sound files to physical modelling synthesis then to a granular process of a contact mic attached to a spring, requires from the performer shadowing all the creative and inventive powers using their instruments as well as a fast analysis of the sound to determine the salient aspects and what can be imitated. The task can be seen then as a high level ear training and as an expansion of instrumental dexterities. Shaping and morphing the sounds, adjusting levels, programming transformations and basically re-inventing the instrument in a moment-to-moment basis are the resources requested to accomplish the task. This process of mimicking each other creates bonds and helps performers become familiar with each other's musical personalities.

Electroacoustic music entails recording sounds and soundscapes in a very detailed (though subjective) way, which lead the discussion in a more philosophical and aesthetic direction, probably involving the concept of mimesis, representation and imitation as discussed by Halliwell.[13] Halliwell discusses the development of the concept of mimesis and its implications for musico-poetic forms while dealing with ideas of imitating, nature, the good and beauty. From Plato, Aristotle, the Greco-Roman tradition through the Renaissance, the birth of *aesthetics* and the twentieth century, discussions of anti-representionalism, the mimetic theory(ies) are deeply connected with the evolution of ideas in art theories. It is then an open task for the philosophers and aestheticians to closely look at how sound recording as performance, live-sampling and the electroacoustic-digital musician are bending and creating new relations with the acoustic world, natural environment and musical practice. Attali is probably the most famous thinker who has addressed the issues of technology as means of production, recording and dissemination of music and their socio-political effects. I will leave the discussion here with a quote from Attali that I read as an exaltation of electroacoustic improvisation:

> Although these new practices may faintly resemble those of the medieval jongleurs, they in fact constitute a break with sacrificial, representative, and repetitive music: before the advent of recording and modern sound tools, the jongleurs were the collective memory, the essential site of cultural creation, and the circulation of information from the courts to the people. Recording stabilized the musical work and organized its commercial stockpiling. But now the field of the commodity has been shattered and a direct relation between man and his milieu is being reestablished. Music is no longer made to be represented or stockpiled, but for participation in collective play, in an ongoing quest for new, immediate communi-

[13] Halliwell, Stephen. The Aesthetics of Mimesis: Ancient Texts and Modern Problems. Princeton, United States: Princeton University Press, 2002.37–72

cation, without ritual and always unstable. It becomes nonreproducible, irreversible.[14]

8.2.6 Implementations

- † Outside the pressure of the real time task of shadowing an implementation of the copying technique can consists of re-creating or sonically transcribing one electroacoustic composition. This idea has been experimented and explored with Sergio Castrillon during his workshop "Instrumental Interpretation On John Chowning 2018"
- † As a purely imitating-timbre implementation, try to sonically re-build a series of presets from a software synthesizer.
- † With a multitrack recording, set up a system for automatically recording and playing back while improvising and shadowing the recording.
- † Write an essay about the ethics of sampling and using or re-utilizing somebody's else music.

[14] Attali, Jacques. Noise: The Political Economy of Music. Vol. 16. Manchester University Press, 1985.

8.3 Contrasting – Antimusic

A performance task to develop the attitude of sonically and musically contrasting materials.

8.3.1 Tags

Contrasting, arguing, juxtaposing

8.3.2 Goal

The goal of this chapter is to foster the faculty to create sonic contrasts, producing materials that create difference and opposition from a sound model.

The other objective is to experiment with behaviors such as arguing, opposing, questioning.

8.3.3 Description

Starting from silence, a member of the group spontaneously starts improvising; immediately after, the group joins the improvisation and aims to sonically produce material that deviates as much as possible from the one proposed by the soloist. As an elaboration on the shadowing chapter, this task involves as well following and reacting to a musical and sonic material proposed by a soloist or a target but instead of replicating and mimicking the musical proposition, the goal is to perform a contrasting version of it.

8.3.4 Variations

Integrate a radio (software or hardware) into the performance. The task is to randomly shift the radio stations while playing contrasting music on top of whatever material turns on.

A different version can be implemented by programming a looping system with very long delay times, i.e., simultaneously with the beginning of the improvisation the looper starts recording one or more performers for 40-60 seconds, then it plays back and the ensemble should play in contrast to their own music while the looper record a new section from the band; after other 40 to 60 seconds the second section starts playing and a new contrasting material should be generated, the process can go on as long as wished. Varying the delay time for longer transitions will break the predictability of changes.

8.3.5 Discussion

The exercise may be in a certain way liberating since contrasting a sonic material can suggest many different interpretations when compared with the rigorousness of reproducing a sound, which may seem to have only one possible solution. However, the task of producing contrast can be deliberately strict as well. Is it possible to imagine the equivalent of a negative picture in the sonic domain? Can the sonic contrast be extrapolated until a form of *anti-music* or *anti-sound* is achieved? Is there, as in the copying exercise, one perfect solution? Can one sound oppose another in each sonic parameter?

One might claim that the negative or the diametrically opposed sound of any sound is actually silence. Though this will take us back to the idea of performing silence, it will not help us to advance in the training of responsiveness and playing by ear. The objective of the task is to search for a sound that creates contrast with a sound in a musical performance situation.

Contrast can be understood at different levels, from contrasting a single parameter up to a multiparametric antagonism. A contrast can be created from a single sound dimension such as volume, for example, by playing quietly if the leading sound or soloist is playing loudly, or making a crescendo if the soloist proposes a decrescendo. If the material contains aspects of granulation, contrast can be done with a smooth texture, or fast attacks can contrast long drones; if the spectrum is harmonic and high-pitch centered, it may be answered with an inharmonic low spectrum; if the sounds are played with a very frontal presence a contrast will be to use a type of reverberation to create distance.

More complex versions of multiparametric antithesis and contrast require extreme attention and focus on all the sonic details. The performer has to integrate all the perceptual elements to produce a sound contrasting the dynamic information, temporal data, texture material, frequency content, spectromorphological details and spatial content information. Contrasting ideas can be very inspiring and challenging, and it is an excellent exercise of musical rhetoric.

Creating sonic contrast can be related to a dialectical thinking. Let us then review the idea of opposites and categories under the lens of dialectics. Michael Cherlin in his article "Dialectical Opposition in Schoenberg's Music and Thought" explores the conceptual framework of dialectical thought within Schoenberg's critical and pedagogical writings.[15] While in our context a framework like this is not directly applicable because of the dissimilarity of the aesthetic perspectives, the definition of Dialectical Opposition is nevertheless useful for elucidating the possibilities of creating sonic opposition as proposed in this chapter.

> The process wherein progress, change or some desired resultant is obtained through antagonisms or other types of opposition applied to matter, ideas, values, emotions, etc. The opposition is normally dyadic, pitting two forces, ideas, values, etc. against one another to result in a third force, idea, value, etc. The opposition can be conceived of as necessary in that the resultant (i.e., the 'third' force, idea, value, etc.) cannot be obtained without it. Although normally dyadic, the concept of dialectical opposition can be enlarged to include the resultants from complex force fields of opposition.[16]

A third force resulting from the dialectical opposition is quite interesting, what would that mean in the sonic domain? If the anti-sound matches its counter part, which is the third new force generated? Cherlin walks us through some relevant examples of different approaches to the problematic of opposition. This list can give us a hint on how far the reasoning can go and what an application in the sonic world of electroacoustic improvised performance might look like.

- Heraclitus and the opposition of contraries as a fundamental aspect of the universe.
- The poet Willian Blake and his poem "Heaven and Hell 1790-93", in which eternal forces seem to be always opposed.
- Hegelian dialectics, which assume that "opposition leads to higher synthesis" and becomes the mechanism for universal progress.
- Hermeneutics and the modes of opposition of the whole versus part, objectivity versus subjectivity.
- Fichte and the three stages of argumentation in thesis, antithesis and synthesis.
- Fétis, Marx, Hauptman, Rieman, Schenker, Adorno and their influence of dialectical opposition in musicology during the nineteenth and twentieth centuries.

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[15] Cherlin, Michael. "Dialectical Opposition in Schoenberg's Music and Thought." Music Theory Spectrum 22, no. 2 (2000): 157–176.
[16] Ibid.

Researching the nature and qualities of opposites can illuminate our knowledge about nature. At least it looks like research in physics will be very busy working out the properties of antimatter and antiparticles in the decades to come.[17] Let us move on with the help of Cherlin into a broad understanding of oppositions to start interpreting the qualities of the *anti-music* and *anti-sound*

Cherlin suggests the categories of four basic types of opposition by Aristotle as an analytical and reasoning tool. Aristotle's four types of opposition are: *relatives, contraries, privation/possession, affirmation/negation.*

Aristotle explains relative opposition: "Pairs of opposites which fall under the category of relation are explained by a reference of the one to the other, the reference being indicated by the preposition 'of' or by some other preposition. Thus, double is a relative term, for that which is double is explained as the double of something".[18] In a sonic context, the relative opposition could be a sound panned full left as opposed to the one panned full right, "to be left is contrary to being right".

Opposite contraries, i.e., "Pairs of opposites which are contraries are not in any way interdependent, but are contrary to each other. The good is not spoken of as the good of the bad, but as the contrary of the bad, nor is white spoken of as the white of the black, but as the contrary of the black. These two types of opposition are therefore distinct."[19] Cherlin observes the difficulty of defining it in a musical context: "The category of contraries, with some remarkable exceptions, is typically understated within the discourse of contemporary music theory. To be sure, concepts such as bitonality or polymeter imply one key or one meter pitted against another. Yet these terms or terms like them are the exception rather than the rule."[20] Cherlin goes on by questioning the ideas of consonance and dissonance as musical opposed contraries "while we recognize consonance and dissonance, and the closely related ideas of passage (with its sense of ongoing) and cadence (with its sense of closure) as basic musical contraries, the role of opposition is usually softened by a characterization wherein dissonance is subordinate to and dependant on consonance."[21] The duality of consonance and dissonance are not necessarily meaningful in an electroacoustic context and spectral dualities of harmonicity and inharmonicity or simplicity vs complexity do not have a

[17] Evans, C., S. Aghion, C. Amsler, G. Bonomi, R. S. Brusa, M. Caccia, R. Caravita, F. Castelli, G. Cerchiari, and D. Comparat. "Towards the First Measurement of Matter-Antimatter Gravitational Interaction." In EPJ Web of Conferences, 182:02040. EDP Sciences, 2018;
Mavromatos, Nick E. "Matter-Antimatter Asymmetry in the Universe via String-Inspired CPT Violation at Early Eras." In Journal of Physics: Conference Series, 952:012006. IOP Publishing, 2018.

[18] Gaskin, Richard. Simplicius: On Aristotle Categories 9-15. A&C Black, 2014.

[19] Ibid.

[20] Cherlin, "Dialectical Opposition in Schoenberg's Music and Thought." 157–176.

[21] Ibid.

relation of tension as in tonal music. However, in perceptual terms, noisiness and identifiable pitch with single harmonics can be a feature used to create a contrast by contraries. Aristotle also brings attention to the intermediate qualities that are not at the extremes: "Some intermediate qualities have names, such as grey and sallow and all the other colours that come between white and black; in other cases, however, it is not easy to name the intermediate, but we must define it as that which is not either extreme, as in the case of that which is neither good nor bad, neither just nor unjust."[22] We must then pay attention to and look for those extreme dual qualities.

About *Privatives and Positives*: they "have reference to the same subject. Thus, sight and blindness have reference to the eye. It is a universal rule that each of a pair of opposites of this type has reference to that to which the particular 'positive' is natural."[23] In music, Cherlin proposes as an example the diatonic and chromatic scales so that a diatonic scale does not contain *chromaticisms*, and a chromatic scale does. From a sonic perspective, the spectrum, dynamic, spatial and temporal evolutions should be examined to extract certain properties such as symmetry, regularity and repetition for building the opposition by privation/possession.

To explain the idea of opposition by *Affirmation and Negation*, Cherlin uses the concept of musical expectation: "a full cadence affirms the tonic, and a deceptive cadence is a kind of negation (to delay, is to deny 'for now'). More generally, any fulfilled expectation is an affirmation and any denied expectation is a negation. For example, the expectation of x is tantamount to asserting a 'truth value' to the statement 'x will happen'; if x indeed is realized then the truth value of the statement is affirmed; if x is not realized then the truth value of the statement is negated."[24] Musical expectations are studied in detail by David Huron, who built a thesis around human responses (instinctive and reflexive) to musical streams based on paradigms such as tension, surprise, prediction and expectation.[25] In an acousmatic musical context, James Andean proposes a reading of Huron's concepts by integrating the system of two layers (the musical and the narrative) of acousmatic music as one stimulus treated through two mental processes *delayed* in time or happening at slightly different times: "where our response to the narrative layer is immediate and reflexive, our response to the musical layer is, in fact, mediated by an additional stage of mental processing, or at least activated less

[22] Gaskin, 2014.
[23] Gaskin, 2014.
[24] Cherlin, Michael. "Dialectical Opposition in Schoenberg's Music and Thought." 157–176.
[25] Huron, David. "Sweet Anticipation: Music and the Psychology of Expectation." Edited by Oliver (Reviewer) Schwab-Felisch. Empirical Musicology Review 2, no. 2 (2007): 67–70.

quickly, perhaps, than our more reflexive reactions".[26] This point of view can inform the performer of the possibilities of creating an opposition of affirmation and negation by playing with the narrative and musical aspects of the sound. Within the context of the exercise proposed here of creating an *antimusic*, the performer must consider on top of the musical intentions and narrative hints in the material, any performative gesture, i.e. a raising hand *preparing* to *attack* or trigger a sound, any signs of rhythmical entrainment or even facial expressions as cues for creating frustration or fulfillment and therefore contrast.

Creating Antimusic on the spot is not an easy task; rather it requires from the performer not only a sharp listening attitude and a fast reaction but as well an informed knowledge of how to create an antithesis, how to form a counter argument on the spot and how sonic material asserts the impression of opposition. Creating contrast is a performance quality that has to be trained and taken as a separate topic to address. In fact, I have remarked over the years how only through repeated experiences, dedicated reflections and time, an electroacoustic band can produce alternative performative behaviors other than the common gentle mix of politely and collectively creating a sonic fusion in which performers hide from each other, and never dare to step forward or to enliven the moment with argumentation and contrast. In the early sessions of work with a new ensemble it is typical to address the topics of risk taken, contrast and argumentation several times .

8.3.6 Implementations

† Using Aristotelian categories, invent four different situations that will produce contrasting sonic voices.

† Could you set up a trio where the Thesis, Antithesis and Synthesis of an improvisation are played simultaneously?

† Using a *fixed media* composition, create several versions that struggle to be the antimusic of the piece. Submit it to your peers for discussion and group evaluation

[26] Andean, James. "The Musical-Narrative Dichotomy: Sweet Anticipation and Some Implications for Acousmatic Music." Organised Sound; Cambridge 15, no. 2 (August 2010): 107–15.

8.4 Transgressing – Masks

An experiment on using and adapting tools from theater performance.

8.4.1 Tags

Physical Theater, Jean Lecoq, histrionics.

8.4.2 Goal

The objective with this experimentation is to facilitate the introduction of histrionic elements into the performance.

Using masks allows the performers to discover or unveil certain aspects of their own personality while giving them the chance to try unforeseen musical and performance behaviors.

8.4.3 Description

Ask the performers to wear a mask previously chosen (a task to be prepared, requiring enough time to think and to find the appropriate mask). With the participants wearing the masks at all times, the exercise consists of performing firstly as somebody else, ideally somebody from the group. Then, during a second time they perform as something else, an inanimate object, for example. This is of course metaphorical, and it means performing as if the chosen object would have performance capabilities. Further the participants play as animals, underlying the motion qualities and the symbolism. Finally, the players perform as the chosen mask. If possible, there will be mirrors in the room or use mobile phone cameras, then propose to spend some time observing the mask before playing, talking to the mask in the mind and listening to its voice, thinking about its character, its fears, its nature, its powers. Then perform an improvisation.

8.4.4 Variations

One possible variation on this task is to ask the performers to create and build their own masks, then build one for someone else.

Extend the facial mask to include the instrument using ornaments, embellishments and decorations. Consider wearing a costume as well.

8.4.5 Discussion

Masks have a dual function: a performative object and a tool for performance skill development. In an overview of the use of masks in theater, David Roy underlines the quality and power of the mask to allow and invite the performers for a psychological and physical exploration of themselves by concealing their identity: "Mask usage with actors and training disassociates the performer from his or her own personal id, thus both releasing the performer into being the "other" similar to the shaman role. Through the disassociation, allowing objectivity the performer was also able to gain a deeper understanding of a sense of self."[27] Roy remarks as well a difference between the effects of the mask into the performer and the audience and the functionality of the masks (representational, emotive and indexical and disguise). "Anthropologically, the mask works as a metaphor or signifier for the spectator to separate the individual performer, and distance that perception to allow an alienating effect. In simplistic terms, through forcing the spectator to accept the necessity for the suspension of disbelief, the spectator can willingly immerse themselves in the message and meaning of the spectacle and performance, creating their own meaning." I am interested here in the use of the masks as a tool to explore the performance, physically and psychologically. The semiotic aspects of the mask in relation to performance belong to the narrative domain or what the performers want to say or stress in a public show. These considerations should be opened for collective examination and prepared or brought during the play as a dramatic device.

Among the possible enactments of the concept of the mask, I found it appealing for the purposes intended in this book the *neutral mask*. A notion worked out by Jacques Lecoq: the neutral mask is "tending toward a 'fulcrum point which doesn't exist.' As the actor approaches this fixed point, he becomes 'a blank sheet of paper', a 'tabula rasa'."[28] Lecoq refers to a body-mind state of transparency and readiness struggling to leave aside the *personality.*

> To approach neutral action, one must lose oneself, denying one's own attitudes or intentions. At the moment of neutral action, one does not know what one will do next, because anticipation is a mark of personality; one cannot describe how one feels because introspection intrudes on simplicity; one reacts in a sensory way, because when the mind stops defining experience, the senses still function. Economy demands that both motion and rest be unpremeditated. Neutral activity witholds nothing; it is an energized condition, like the moment of inspiration before speech.

[27] Roy, David. "Masks as a Method: Meyerhold to Mnouchkine." Edited by Zoe Strecker. Cogent Arts & Humanities 3, no. 1 (December 31, 2016): 1236436.
[28] Eldredge, Sears A., and Hollis W. Huston. "Actor Training in the Neutral Mask." The Drama Review: TDR 22, no. 4 (1978): 19–28.

> The neutrality that the mask seeks is an economy of mind and body, evidenced at rest, in motion, and in the relationship between them.[29]

In electroacoustic music performance circles, it is not common to see performers wearing masks; there are still many reminiscences of the classical music performance setting. One famous exception to this statement is Stockhausen performing the live electronics part in his Mikrophonie 1 (1964) as seen in the DVD "*TRANS und so weiter (TRANS and so on)* (1974)".[30] On the other hand in electronic dance music, DJs and performers very often use a variety of audiovisual elements, lights, video projections, sculptures, costumes, and many times masks to enhance the show. See for example in this respect the interview of Bevin Kelley by Tara Rodgers.[31]

The point that I am trying to communicate here about using masks for electroacoustic performance is to give tools to the performer to discover other facets of themselves and to experiment with different performance attitudes. For example, it is very common to see members of a band taking roles and getting *stuck* into them, so that experimentation and research are left behind, diverging the sessions towards more social encounters. This is not bad *per se* since the ultimate goal is to *keep the flame burning* among the performers and awaken their appetite to perform, improvise and create; therefore, content plans and time investment can be negotiated and discussed of course. The mask is an excellent device to offer to musicians, because it helps to expand their understanding of performance possibilities.

One important aspect while considering the use of masks is to be conscious of the time necessary in the process to make a meaningful experience for the performers. For example, as a reference about Lecoq's mask methodology:

> At the Ecole Lecoq, that study lasts for eight days. The moment of putting on the mask is crucial, since the body will immediately begin to accept or reject the mask. The actor may feel the urge to impose a movement or a body image, but he must inhibit that urge, allowing his own thoughts, his breathing, and his stance, to be replaced by those of the mask. Lecoq does not allow his students to view themselves in a mirror at this point, but some teachers find that the mirror can help a student see the change in his condition. The mask is treated with the respect due to a human face. It is handled by the sides or by top and bottom; one never grabs it by the nose or places the hand over its eyes. There is no speaking in the

[29] Ibid.

[30] `http://www.stockhausen-verlag.com/Verlag_DVD_6.htm`

[31] Rodgers, Tara. Pink Noises: Women on Electronic Music and Sound. Duke University Press, 2010.

neutral mask; if the student needs to say something, he must first raise the mask onto the forehead.[32]

The sessions must be carefully planned and adapted to each performing group. For some, one session with a *Masquerade Mask* will be enough, but for other bands, it would be possible to experiment with a variety of techniques like body painting, mythological masks, *commedia dell'arte* masks or satire masks and inviting professional actors and dancers. Masks can be understood also by extension of the concept as ornaments, props and costumes that fulfill the same function. For example, hats, scarves, a fancy dress or even electronic devices extending the body with sensors and actuators (led, small speakers, cables, working or not). These will have similar effects as the masks and can be considered in the same performance exercises category. However, in using different kinds of tools like this, the mask can be thought of as a reference.

A final remark, while engaging in the process of exploring the hidden potentialities of the performers and proposing avenues for transgressions beyond the personality, respectful intuition and open dialog are probably the only methods to mediate the intersubjectivities. Special care has to be taken not to accidentally foster psychodrama sessions for which an electroacoustic musician is rarely professionally competent (that being the work of a psychotherapist or a psychologist). Transgression in this context means to raise the consciousness to imagine the unspoken questions. Beyond solving these questions, there is a dream; once the question gets verbalized, it gets half solved and starts losing its transgressive power.

8.4.6 Implementations

† Set up a set of well-defined characters in the form of sonic tracks or sound files to be proposed as *imposed tape* solo improvisation in the group. A solo performer must improvise with the tape without previously listening to the tape.

† Create an improvisation situation around the topic of exaggerated facial expressions.

† Arrange a performance situation using *décor* and scenography for different topics: surrealistic kitchen, grotesque hospital, foolish train station, non-sense concert, anything in a similar vein.

† Ask the performers to carry on an improvisation in an uncomfortable body position.

[32] Eldredge, Sears A., and Hollis W. Huston. "Actor Training in the Neutral Mask." The Drama Review: TDR 22, no. 4 (1978): 19–28.

8.5 Transcending – Drop the Idea

A performance experiment to reflect on the construction of a performer's identity, habits, impulses, and unconscious reflexes.

8.5.1 Tags

Consciousness, anoetic, noetic, autonoetic, memory, Stream of Consciousness, active imagination, zen, renouncing.

8.5.2 Goal

With this experiment the goal is to confront the performers with the mechanisms of spontaneous creation of thoughts as well as challenging their habits and memory reflexes.

8.5.3 Description

This is an improvisation situation in which the performers are asked to continuously re-start an improvisation but to very quickly let it go, or renouncing to it, dropping the ideas. Therefore, the improvisation will never properly start. The instruction is to avoid any developments, verbosity, and even to struggle not to conclude the proposal. Do you have an idea of how to start? In that case, start and forget it! The best results in my experience will happen by holding the experiment as long as possible. The point is not to rest in silence; if silence is an idea coming to the performers mind, it should be abandoned as any other idea and a new one should come. Aesthetic judgments are often obstacles in this context, so it is important to keep an open mind to the overall resulting sonic world. The task can be surprisingly exciting or extremely boring. The performer's duty is to abandon and let go of the ideas exhausting their creativity.

8.5.4 Variations

One variation of this experiment consists of playing the improvisation and adding the rule of speed changes: performing as many possible shifts of intentions and materials as quickly as possible.

8.5.5 Discussion

This task has been developed after conversations and exchanges with my colleague choreographers and dancers: Jasmiina Sipilä and Giorgio Convertito. The idea with the performance assignment of renouncing all ideas is to drain all the reflexes and habits while looking for authentic personal creative regeneration. This proposition of emptying the mind to surpass the conscious inventiveness may resonate with some aspects of ideas such as *Stream of Consciousness* and *active imagination* but mostly with the practice called in Zen Buddhism 只管打坐 *Shikantaza* (*Serene Reflection* or *Silent Illumination*). Looking at some details of these ideas will eventually inspire more experimental research and foster the initiative of creating performance situations.

With the current focus on Artificial Intelligence, Biotechnologies and Nanotechnologies, the interest in the working mechanisms of human consciousness and the relation with the different identified types of memory is opening an avenue in tangible expansion for conquering territories of the inner human life. As discussed and illustrated by Endel Tulving in his article "Memory and consciousness 1985", the relation between memory and consciousness still calls for deeper research.[33]

> Nowhere is the benign neglect of consciousness more conspicuous than in the study of human memory. One can read article after article on memory, or consult book after book, without encountering the term 'consciousness.' Such a state of affairs must be regarded as rather curious. One might think that memory should have something to do with remembering, and remembering is a conscious experience. To remember an event means to be consciously aware now of something that happened on an earlier occasion. Nevertheless, through most of its history, including the current heyday of cognitive psychology, the psychological study of memory has largely proceeded without reference to the existence of conscious awareness in remembering.[34]

Tulving also observes that most of the research in human consciousness consists of "epistemological, metaphysical, and existential theorizing, without corresponding empirical facts". He engages then with clinical observations and laboratory experiments into building a hypothesis of relation between memory and consciousness based on three different types of each. Three memory systems: procedural, semantic and episodic are correlated with three different kinds of consciousness: anoetic (non-knowing), noetic (knowing), and autonoetic (self-knowing).

Procedural memory "is concerned with how things are done — with the acquisition, retention, and utilization of perceptual, cognitive, and motor skills" and

[33] Tulving, Endel. "Memory and Consciousness." Canadian Psychology/Psychologie Canadienne 26, no. 1 (1985): 1.

[34] Ibid.

is characterized by anoetic consciousness. Semantic memory "has to do with the symbolically representable knowledge that organisms possess about the world" and is associated with noetic consciousness. Episodic memory "mediates the remembering of personally experienced events" is correlated with autonoetic consciousness.[35] The categorization of consciousness proposed by Tulving is built around the concept of knowledge. If an organism is "capable of perceptually registering, internally representing, and behaviourally responding to aspects of the present environment, both external and internal" is said to possess anoetic consciousness. Noetic consciousness "allows an organism to be aware of, and to cognitively operate on, objects and events, and relations among objects and events, in the absence of these objects and events. The organism can flexibly act upon such symbolic knowledge of the world. Entering information into, and retrieval of information from". Autonoetic consciousness"confers the special phenomenal flavour to the remembering of past events, the flavour that distinguishes remembering from other kinds of awareness, such as those characterizing perceiving, thinking, imagining, or dreaming".[36] A person aware of a past event as a "veridical part of his own past existence" is said to possess autonoetic consciousness.

As discussed in chapter two, the performer-improviser works with a *knowledge base* and a specialized procedural and declarative memory: *knowing 'that' and knowing 'how'*.[37] Therefore, we can advance, based on empirical experimentation and according to Pressing and Tulving's theories, that the integration between the knowledge, memory and consciousness mechanisms set in motion by an electroacoustic musician's improvisations are a substantial and intricate matter far from being fully understood. We can however, put these assumptions under empirical and experimental study and design performance situations where either of those categories are isolated, underlined or emphasized. For example, how to exhibit the anoetic consciousness and its relation with the procedural memory? Is it even thinkable or realistic to ask for a performer to forget or abandon what has been learned? Eddie Prevost commenting on meta-musicians, meaning and music re-iterates this idea of fresh listening approach. "The intention is to transcend all previous experience of music production and music consumption. The intention is making music, and listening to it as if for the first time". [38] I argue that even if it sounds improbable, the mind can be turned in these directions of emptiness of thoughts.

A narrative device used in literature and anchored in psychology is *Stream of Consciousness.* In this technique, as used in the *modernist* movement,[39] for example,

[35] Ibid.
[36] Ibid.
[37] Pressing, Jeff. "Improvisation: Methods and Models." In John A. Sloboda. Generative Processes in Music, Oxford, 1988, 129–178.
[38] Chase, Stephen Timothy. "Improvised Experimental Music and the Construction of a Collaborative Aesthetic." PhD Thesis, University of Sheffield, 2007. pp.92
[39] Bowling, Lawrence Edward. "What Is the Stream of Consciousness Technique?" Publications of the Modern Language Association of America, 1950, 333–345.

in James Joyce's Ulysses the goal is to portray a character's thought processes "either in a loose interior monologue, or in connection to his or her sensory reactions to external occurrences"[40] In our context, Stream of Consciousness could be performed as letting all the thoughts and ideas flow and shift without a defined narrative purpose, letting the mind and the thoughts wander without forcing a direction, the goal being to attempt to reach an anoetic state of consciousness.

Cognitive psychology, neuropsychology and anthropology would eventually give us the keys to decode the links of consciousness and memory or what artists like Joyce have been experimenting with. There is however a source of ancient knowledge related with these matters, for example, Zen philosophy. According to Zen philosophy, one can encounter the endeavor for emptying the mind through meditation, for example, through the concept of *Mushin* "meaning the mind without mind, also referred to as the state of 'no-mindness'. That is, a mind not fixed or occupied by thought or emotion and thus open to everything. 'Being free from mind-attachment'."[41] Or the practice of *Shikantaza* that according to Taigen Dan Leighton, "involves withdrawal from exclusive focus on a particular sensory or mental object to allow intent apprehension of all phenomena as a unified totality".[42] The outcome of the experiment of renouncing to the sonic, musical and instrumental ideas as they come can be then compared with a meditation exercise of driving the mind to reach a contemplative purposeless state.

If the purpose is to unveil the unconscious knowledge and memories influencing our identity as performers, one methodology that can be exploited is *Active Imagination.* Developed by Carl Jung in the first decade of the twentieth century, Active Imagination allows one to communicate or bridge conscious and unconscious aspects of the personal psyche. Key to the process is the aim of exerting as little influence as possible on the mental images as they unfold.[43]

There is under the surface of a simple task like "Drop the idea" a marvelous fertile land for the experimental and electroacoustic performer. There are remarkable resources in our inner world of consciousness and memory to research, to learn and to use, for example, the power of inner listening and sonic imagination in form of *silent improvisations* (improvising in the mind without emitting sounds); recognizing our identity through dramatic, narrative and performative devices; unfolding our instrumental, sonic and musical habits and revealing them for fur-

[40] Joyce, James. Ulysses. 1st edition. New York: Vintage, 1986;
"Stream of Consciousness (Narrative Mode)." Wikipedia, June 4, 2018.`https://en.wikipedia.org/wiki/Stream_of_consciousness`

[41] Suzuki, Daisetz Teitaro. Manual of Zen Buddhism. Youcanprint, 2017;
Odin, Steve. Artistic Detachment in Japan and the West: Psychic Distance in Comparative Aesthetics. University of Hawaii Press, 2001.

[42] Leighton, Taigen Dan, and Yi Wu. Cultivating the Empty Field: The Silent Illumination of Zen Master Hongzhi. Tuttle Publishing, 2000.

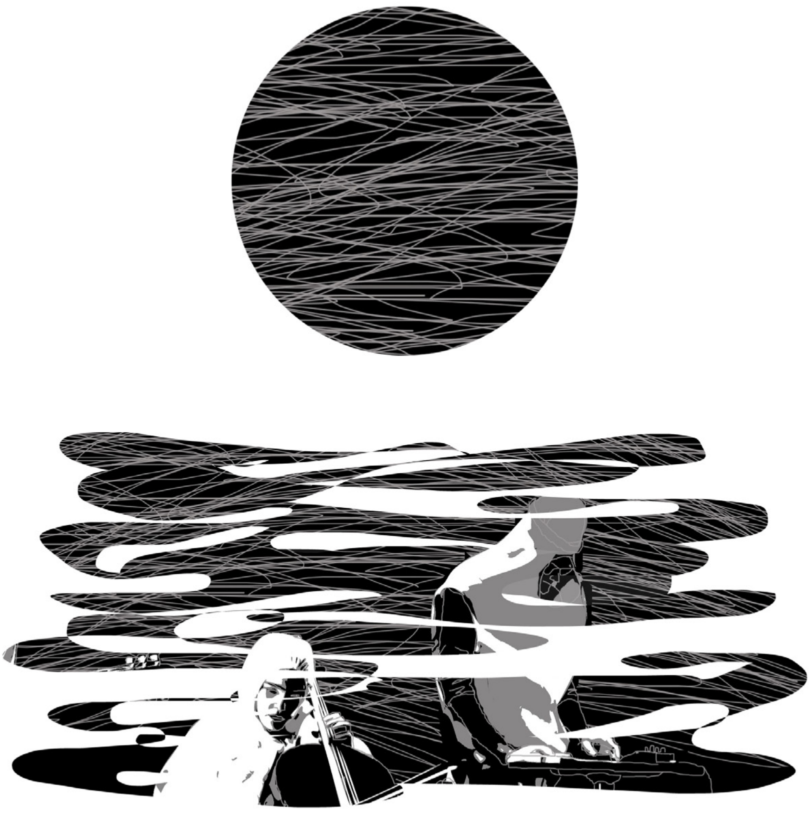
[43] Jung, Carl Gustav. Jung on Active Imagination (Edited and with an Introduction by Joan Chodorow). Princeton: Princeton University Press, 1997.

ther scrutiny. I would like to emphasize that the topic and ideas presented in this chapter do not question the development and construction of a personal *style* based on the well-crafted and studied repertory of sonic and instrumental gestures. The artist's *own voice* is a question to be addressed by each individual and left for their own discretion and judgments. The exercise is intended to reveal aspects of the performance that can possibly escape to the consciousness of the performer as well as cultivate the research of unexplored materials.

8.5.6 Implementations

† Write an algorithm that randomly accesses internet radio or an extensive sound library to be used as a *sonic score* for improvisation.

† Based on an analog switch or an analog multiplexer or a digital matrix design, build a system that can shift its state by swapping a number of inputs under a trigger signal in the same way that intended in this chapter.



9

Values

This chapter is a collection of thoughts compiled in an effort to extract the fundamental ideas of the discipline investigated in this thesis. The principal questions are: What are the values of improvised performance with electronic instruments? What form the essential components of an ethics of electroacoustic improvised musical performance?

9.1 Awakeness & Presence

Performance happens in the present. In contrast to composition, where music can be laid down in a time canvas where imagination and creativity can organize the sounds, events and thoughts into a *frozen* past, present and future, performance occurs within the avalanche of flowing time. The performance or the acoustic materialization of sounds happen as time runs on, a time that flies like a fateful dart that transports each moment to the next with the inevitability of *non-return*. What was performed is left behind, and if one attempts to turn the eyes to catch and revive those past moments, the only thing will be found is the immeasurable and threatening wave of time wanting to swallow us. The performed sounds, events and actions are gone forever, and no, there is no need to cry, nothing will change, it is gone! Only the rhetoric of politics, the juggling of historians, the melancholy of poetry, or the magic tricks of critics can change our perception of what has happened and persuade us to change it. But the performer has to be honest and humble before the past. Once the sounds of music have left the brain, hands or mouth, they only belong to the dark night of memories. One can bash one's head against the concrete wall of played sounds, but they will no longer be accessible: the recording is only a caricature, the resonance is only nostalgia, the microphone can only record what happens in a very limited surface of the storm of air molecules that a performer sets in motion. Of course, one can choose to live in nostalgia, in the fantasy of documentation. I know that very well. I have collected so many recordings that I will need two lives to sit down and listen non-stop to all those hours of recorded sound. I know how difficult it is to let the sounds go. I know how it feels to caress the illusion of being able to climb back through time, but only performance has helped me to exploit that bubble. A performer cannot undo the sound (unsound the sound?), a composer may find their way, but the act of performing sounds means accepting the life of sounds, and their death too.

The future is another fictional tale for a performer. When embracing the sounds to come, the conscious mind can only relegate the performance of the present to subconscious processes. That is not good for vicious hands who want to always return to primitive reptilian habits. It is a fallacy that cannot be reached. The mind can live alone in that fallacy, caressing the crystal of the forthcoming sounds and dreaming how they will really be, but suddenly all the sounds are gone. No chance to play them, so the mind turns back to the unattainable future, hoping, waiting. Sisyphus laughing at the newcomers. The sounds that are not played yet are as unattainable as those already played; they are a product of the mind, an ethereal creation of hope and nostalgia. If the performer cannot surmount the past and cannot access the future, what is their destiny? Obviously the only option is to live in the present, to be awake, alert, ready to act, ready to bite every instant, colonize the momentum, conscious of the present, present in the present. A performer should rouse from sleep, break the dream bubble of subconsciousness and be here, now.

The mind likes to escape from the momentum by dreaming and remembering; it can create its own world out of memories and predictions to the point of blurring the present so much that any real moment loses all comprehensibility. Consequently, the present gives a feeling of impossibility. One cannot access the present because it is a thick overlapping of layers that resonates from the past and portends a future; the present is just a diffuse, ambiguous mass of time. One can try to reduce that thickness to understand and experience what the present is. But is it possible to renounce any past and drop any expectation of what is to come? Can the perception system slice the moments to the shortest possible imaginable grain? Can our consciousness abandon the horizontality of time in favor of a vertical time? Time flows beyond any mental exercise, so that the time slices can be, at best, only a sharp exponential slope of infinitesimal moments, there must be an eternity between them.

This state of *zero time* perception demands a lot of physical energy, it requires serenity to avoid paranoia and psychosis; it requires the acceptance of the limited, slow, approximate and clumsy temporal perception of the human condition; it requires strength to overcome the warm and cozy laziness of lying on the mattress of a thick enough present; it requires discipline and permanent efforts to learn to let go and avoid all dreams and memories. Only extended periods of meditation, silence and sudden sharp sound attacks can help us to create time fissures.

However, one cannot live in a permanent wakefulness. It is unbearably painful for the consciousness. It will submerge our existence in the deepest possible sadness. Opening the eyes and ears and listening to the human condition for so long can only lead to a strong desire for suicide, facing the impossibility of any meaningful action or any meaningful life. Forgetting, remembering, dreaming and expecting are survival tools that have to be applied in the right doses so that we can be socially functional. Among the functions of sleep is the processing (repeating and cycling) of emotions, perceptions, ideas, fears, anxieties, in the private corners of our solitude. We need the past and the memories to learn from our actions; we need predictions of the future, even if their accuracy is always relative, but we need them in order to have a vision. We need to balance the opportunity to dream with the ability to forget. In a musical perspective, a performer needs to compose, learn to zoom out the temporal dimensionality, while a composer can benefit from the practice of performing to maintain a connection with the instantaneous present.

Tempering the perception of *now* can only be beneficial from a spiritual point of view. Eventually it can help us elucidate the paradoxes of complex thoughts such as quantum mechanics; it can help us to fasten our surroundings and to properly listen to each other. It can help us to understand what telecommunications are for and what the ethical issues are; it can help us to improve the awareness in a musical context. Being *here and now* is a value and a skill not to be forgotten or underestimated.

9.2 Forbearance & Tolerance

Performing and improvising electroacoustic music is an embodied experience characterized by carefully balancing producing and not-producing sounds, doing and perceiving, listening and audiationing (aural imagination), redoing and experimenting, musicking, socializing and retiring in privacy. It is an opportunity to explore the roles of initiator, catalyst, spoiler, maker, nihilist, rebel, agitator, mediator or follower among others. To improvise, the performer should investigate the creation of rules, follow them, break them and forget them. One of the more difficult challenges in sonic performance is finding a middle ground between hyperactivity and procrastination without creating a situation where inventiveness and risk are not allowed. How to explore the psychological boundaries of action and inaction without spoiling interpersonal relations? The extremes of doing too much and doing nothing deserve attention, but both cases can be annoying and irritating. The attitudes of not sharing the acoustic space (by constantly making sounds) as well as its opposite of permanent non-engagement in the action can be perceived as aggressive behaviors. How to avoid falling into lasting-censoring-lethargic silences or into never-ending solos? And how to do it while simultaneously circumventing the tepid waters of comfort where nothing happens? If improvised performance is based permanently on the well-behaving interactive musical dialogue between individuals, it is almost impossible to spark any interesting idea out of the sounds, and creativity may succumb to the repetitions of learned formulas without *mistakes*.

The solution may be to understand that each performance is different, each improvisation carries its own destiny and does not need to carry all the means of expression at the same time. A collective improvisation does not need one to play all the roles at once. Researching behavior, mental states and digging the soul of one role should be more than enough. The key to overcoming the feelings of passive and active aggression generated by a performer who takes the risk of deepening the personality and consequences of assuming an extreme behavior must be *tolerance* and *forbearance*.

Tolerance to give others the space to transgress pre-established roles and agreements on how to behave. Tolerance means letting the musical expression make unexpected turns, supporting the research of extreme attitudes and integrating in the musical narrative all the performance affordances. Tolerate differences of interests and diversity of opinions, tolerate moments of instability to see them as a potential force for change. Tolerate the deconstruction of musical aesthetics and overcome personal musical expectations. Tolerate ugly sounds as much as those that are full of subjective beauty. Tolerate and support the music of the other, the intention to fulfill an ontological need for musical expression. The tools and means to achieve expression are different to every single performer, and there should not be a limiting canon.

Forbearance, on the other hand, means enduring with patience the provocations of subjectivity to judge and act against the natural flow of musical events. Improvising can be a lot about the *self*, about the individuality of an artistic voice, about the strengths of personality and the desire to realize musical visions. These can even be seen as an objective, but in the process of collectively digging up the soul of a character, the subjectivity of opinions can be an obstacle. Forbearance means to step back when the *I* becomes too demanding. There are levels of intensity when the inner need for identification pushes forward even against the vital space of others. Then it is meaningful to shrink the ego, to apply self-discipline to the desire of always push in one direction. Improvisation narratives allow the performer to penetrate the soul and deepen not in a horizontal line but in an introspective way.

Tolerance and forbearance are some of the ingredients to open the ears and listen, not only to the music erupting from the fingers, but to the one that the others are giving; even nature and the non-human surroundings are constantly crying out for attentive ears, for a spirit of indulgence and lenience. This could even benefit some of our decadent societies of intolerance and egoism.

9.3 Risks & Fears

"Less is more", "listen to each other", "give space" will persistently repeat the canon of improvisational attitudes in a beginner session. Although it is an understandable suggestion and a plausible advise to give at one point to one or more musicians who intend to play together, it is a recommendation that can eventually annihilate any possibility of overcoming performance fears and risk-taking. The politically correct and well-behaving manners in an improvised performance can be a real obstacle to moving forward and making *interesting* things happen. When these silent agreements are taken too literally, very often the performance ends with mezzo-forte, moderato, dull and lifeless music. It is probably easy to listen and accept as a musical outcome for a few listeners, but definitely not exciting to play for many performers.

Some of the real challenges of improvised performances appear when walking towards the edge of the comfort zone of safe musical outcomes. The aim is to confront individual fears and, eventually, to risk the metaphysical leap and conquer them. Identifying fears is not an easy task because it is a solitary and private process. It may be obvious to outsiders, but facing it can be a slow process of acceptance, humility and sincerity. The fear of silence, for example, very common among guitar players and drummers – probably reflecting a sense of responsibility to carry the music on – is often associated with seeing the silence as an end; this is a fear that can take a long time to be defeated. Only the trust in others, serene acceptance of emptiness and acute listening to the time flowing can help to take the risk and stop. Subtle proposals of role changing and exercises of discontinuity may help, but only when the fear is faced in solitude, the key to embrace the extended silences as musical expression can be integrated.

The fear of noise related to the fear of ugliness is not different. Noise as a disturbance either in loudness or in timbre is something difficult to accept and to perform when a musician has spent years of practicing to achieve a well-crafted *round, beautiful* sound. Transgressing these mental constructions can only be justified in the name of the expansion of musical means. It requires accepting *ugliness* as another ingredient of reality and opening the doors to sonic experiments. In an experiment, not all the outcomes are *successful*; quite the opposite, it is more common to be in the unfinished and unexpected; errors and mistakes are the seed of ideas to investigate, not something to avoid or feel shame about.

Difference can create fear. If the stars did not shine again, we would be scared to death, so I believe it is a normal survival tool. Identifying patterns and being able to predict them and anticipate them often feels like a victory of the mind, sorting out the chaos of the reality. Then it is easy to establish a habit and perambulate the known paths over and over again. In a practical musical example, it is not uncommon to notice the uncomfortable atmosphere among some contemporary music performers when in an improvisation other musicians defy the aesthetic conventions and introduce modal elements or tonal structures on simple rhythmical patterns and even more, presenting aesthetic clashes such as *Hip Hop* or Electronic Dance Music against the "free improvisation" framework. The discomfort comes from the challenge to well-learned aesthetics and listening modes, and becomes the fear of ridicule. The fear of losing reputation and being taken for a fool can create a blockage and end with a shared *bad* experience. It is still worth trying, not because of any aesthetic improvement, but because, often, while facing an identified fear, there is another one just hiding in the shadow refusing to be faced.

That situation of facing and grabbing a fear in the intimacy of the private space while discovering that other fears run away to hide from the consciousness sets up the boundaries of risk-taking. The structure of subconsciousness seems to be built from or upon fundamental fears. The fear of death, abandonment or social rejection exist for a reason, perhaps to hold us together and allow us to live in society, and it is not necessary for everybody to question them. The structures of the subconscious mind are very powerful and can create monsters out of conscious bravery. Monsters are more difficult to handle than the innocent fears of aesthetic clashes. If a fear becomes a monster and the monster is released, the soul is subjugated to pain and torment, only deep beliefs, serenity and love can overturn the battle and exhaust the suffering, eventually accepting the human condition.

The fears related to performance that invite self-exploration and self-criticism can teach us something about our own nature, but also about our interaction with the society in which we live. The fear of silence can be encountered as the fear of never stopping the avalanche of media that assaults the eyes and the senses. The web never sleeps, and challenging its ubiquity is almost a blasphemy. The fear of noise keeps some of us paralyzed from raising the voice about fundamental issues like education, health, environment, immigration. The fear of difference keeps entire towns divided and fragmented. The fear of unusual states of mind maintains the intoxication and isolation of suffering souls. The role of the improviser-performer becomes fundamental for the organized human life, since it exposes the qualities of taking risks to boost the imagination (the collective and the individual) to uncover possible alternative realities for us, humans, to live.

9.4 Catharsis, Ecstasy, Trance

Catharsis is the purification of emotions that involves some form of transcendental state of the body-mind. That transcendental state characteristic of catharsis is known by many performers (if not experienced in person at least by reports from others), although they may have given different names in different circumstances and contexts: flow, inspiration, frenzy, delight, enchantment, ecstasy and trance. It always feels very esoteric if not slippery to try to comprehend and rationalize those states to the point that many musicians will simply avoid the topic. It is not only the concept that escapes an objective examination or definition, but the body-mind state itself. The more you look for it, the less it seems to happen. Others will recommend keeping the discipline of daily work and creation just in case the *divine* inspiration appears. It can be a flash of a second, or it can last for an extended period of time; it can be externalized as an extroverted, hilarious or convulsive behavior or as deep contemplative, frozen, state. Some will relate it to the releasing of subconscious powers, while others will relate it to manifestations of supraconscious thought and action. But either case, there is the constant of a sensation of freedom or some kind of emotional relief that crosses the point of transgression.

If there is no recipe or magic formula for attaining the ecstasy-trance and if that body-mind state resists any objectification, why bother to present it as a value? My answer is: by creating a metaphor of the cathartic trance, the performer must face performance attitudes and self-driven tasks that facilitate the exploration of the self and the discovery of the personality. If the cultural construct of what is associated with the cathartic state involves the repeated endless sequence of actions (as in some forms of dance music), this can become a performance task in itself: looping a small set of actions for a considerable amount of time. After completing the exhaustion of such a task, reaching the transcendental state is not as relevant as was the experience of pushing an idea to its limits and realizing it until the last drop of performance energy is rooted out. On the other hand, if the performer gives a connotation of the transcendental moment as a contemplative ecstatic state, the resulting task will involve the progressive reduction of performance elements to the bare minimum necessary (if at all). Participating in an improvised performance is an opportunity to use maximum attention and concentrate on listening and being in a vertical time, now in a full presence to the point of forgetting time and allowing the soul to jump over its own nature (the metaphysical leap of Cioran), the disintegration of the self in the eternal ocean of the universal soul.

The solo-band duality may have a strong influence to facilitate the catharsis. The band can create the tribal context for transgression and trance, while the solitary activity of deep concentration and meditation can be the perfect arena for the mind to put aside all fears and the purge of emotions in a contemplative ecstasy.

Improvised performance supports the possibility of enacting catharsis and living through the unconventional states of mind utilizing the most powerful performer's tools: imagination and will.

9.5 Love & Trust

Performing a sound is an act of will. The round trip of a performed sound begins somewhere in the aural imagination, then, pushed by a will, it reaches the hand and becomes acoustic vibrations; once out there these changes in air pressure touch the ear and become thoughts after a series of transductions of different forms of energy. Does music need to become sound to exist? No. There are forms of music that exist only as mental representations. Is there music in the dreams? Yes. Music can remain in the realm of aural imagination and interconnected thoughts, bypassing the mechanical world of acoustics. The conscious choice of setting an energy in motion leads to music being heard, perceived by others, shared. The acoustic energy, the musical voice, radiates into the environment, touches the inanimate objects, plants, things, tickles and caresses the human ears. Putting the sounds out there is an extended desire of touching in the same way that listening is a research of the reality by extending the sensation of touching beyond the reach of the hand and the eye.

Performing sounds is a struggle to apprehend reality, to make sense of existence. Sounds make reality resonate. Part of the acoustic energy is absorbed, part of it reflected, and part amplified by sympathetic vibration. When there is a listener in addition to the performer, the search for reality becomes an intersubjective process of identification of self-awareness through the senses of the other. The sonic world of the flowing music creates a bridge among the subjects. The sound "touches" the listener, the bodies are connected through that bridge. It is a shared sensual experience where sounds are materializations of ideas, thoughts, feelings that can raise other thoughts, feelings, fantasies and emotions. Hence, the way in which sounds are given is very important. If it is about sharing, ultimately, it should be an act of love. It could be an act of destruction and betrayal, like promising water but administering poison. There is no need to go around distributing poison; the world does not need more destruction, we have had enough for now. Only love can heal all the hate that has been spread in our societies.

Give the sounds with love.

This does not mean or advocate only shallow, mellow, soft, sweet, trivial, mild sounds. The performance act of sharing sounds with love implies honesty, transparency, simplicity, integrity, care. From the quiet and isolated clicks of the transient sounds in the silent canvas to the blasting synthesizer shaking the walls, all the sounds can be delivered through an authentic act of love. Love is the force that binds all bodies together, from the atom's particles to the stars. It is the magnetic attraction between opposite poles. Or, is there any other meaningful explanation?

In the pedagogical dimension, love is the main component of any learning experience. On the other hand, hate can only be traumatic. I have had the luck to work as a pedagogue of art and music in very diverse and contrasting environments. Even in some places where desolation and despair floated in the air all the time. What I learned from these experiences are the ingredients of a fundamental learning experience: the need to erase all social categories, and the need for trust, support and love. Only by identifying and stressing the commonalities is it possible to start a conversation, then a building process of trust can start, and it can take time, but when the creative mechanisms are activated with support, challenge and love, the learning experience becomes meaningful.

Most learning experiences consist of surmounting mistakes and frustrations, challenges and rewards; discipline and perseverance; so the fuel to keep the engine of motivation running is ultimately made from love and trust.

Afterword

10

Closing Remarks

The research presented here has been an opportunity for me to grow as a musician in improvising and performing alongside wonderful, inspiring musicians in the classroom (laboratory of performance) and in concerts; as a researcher by experimenting with audio technologies, electronics and digital systems; as a teacher by sharing countless hours of delightful moments of thinking, analyzing, learning and investigating all the corners of electroacoustic music performance and improvisation in a shoulder-to-shoulder fashion, and finally, and perhaps most importantly, as a scholar dedicating all my physical and mental efforts into learning and absorbing the magical powers of converting electricity into musical expression.

All these dimensions and ideas are reflected in the pages of this work. My highest dream is to offer a consolidated discipline, guideposts and a pool of resources to inspire and support the new generations of motivated musicians who desire to explore the paths of electroacoustic music performance. I wanted to communicate on every page of this writing the passion and love for the design and configuration of electronic instruments, the invention of musical situations for performance, the investigation of performing roles, the use of technology for sonic research, and the listening with sparkling curiosity. If I could start again this process, I would do it in the same way, again and again, patiently rediscovering the wheels of electromagnetism, piezoelectricity, voltage control, coding of unit generators, psychoacoustic effects, intersubjective interactions and mystical dimensions of the discipline investigated here. I would dedicate my time equally to work in the two most beautiful laboratories of electroacoustic performance: the classroom and the stage.

The future of music technology is open to curious spirits. Although, it should be clear that technology is not a requirement for music, I have argued elsewhere that not even sound is a *sine qua non* condition for music; we could find in our bodies the simplest and most complex tools for doing music. Technology helps us to discover other dimensions of sound and sonic experience. Nanotechnologies, biotechnologies, quantum internet, intelligent computers and new electronic components (memristors) will offer us other directions to explore, rethink our tools, recreate the traditional instruments or invent new ones, to enhance the concert experiences, to blend the concepts of reality, to harmonize more obviously with nature. There are great avenues for research, and the improvisers, experimental and creative spirits are the ones who can lead the musical experience beyond what we know today.

11

Annexes

In the following pages, I have included three scores made in collaboration with ensembles that work with improvisation techniques and, or, electroacoustic means in Helsinki. The pieces were created and performed during the research and they are included as samples of secondary outcomes of the investigation.

The first score is *Korkealla Hiljaisuuden* (At the highs of silence) for the **Rank Ensemble** in 2015. The score consists of two pages: one introduction with the poem "The Seven Selves" by Kahlil Gibran,[1] and a second page with a matrix of actions, parameters and times.
About Rank Ensemble: `https://rankensemble.wordpress.com/about/`

The second score is *Ricercare a cinque* "For Amplified Piano, Three Manipulators and One Page Turner", dedicated and performed by the **Defunensemble** in 2012.
About Defunensemble: `http://www.defunensemble.fi/`

The third score is *20 Tulitikkua* (20 matches) For anything between 10 to 20 synthesizers with pitch, timbre and volume control.

Media Links: The following links are a few examples of my personal work as a performer in projects carried out in collaboration with colleagues from the doctoral school that illustrate the topics of this book.

Three Dusks to Dark with Jasmiina Sipilä and Outi Korhonen.
`https://vimeo.com/185284217`.
Aquatrio plays Aquarmonio with Marianne Decoster-Taivalkoski and Alejandro Montes de Oca.
`https://vimeo.com/184912956`
More and Most with Sirkka Kosonen and Malin Skinnar.
`https://youtu.be/JozAIkBsbcg`
Manialog with Andrew Bentley and Alejandro Montes de Oca
`https://soundcloud.com/tenuria/2017-03-30-manialog`

Code Repository `https://github.com/Hyppasus`

[1] In the public domain and available at `http://www.gutenberg.org/ebooks/5616`

Korkealla hiljaisuuden (At the highs of silence)
15-17min.
Rank ensemble - Alejandro Olarte. 2015.

This work is a collective comprovisation with the RANK ensemble and inspired by the poem: "The seven selves" from the Lebanese-American writer Kahlil Gibran. This text was published in 1918 under the title of the "Mad man"– a compilation of short aphorisms and parables written in a style somewhere between poetry and prose. Korkealla hiljaisuuden (At the highs of silence) is then a framework of improvisation strategies to explore the formal construction and the imagery world of the poem. My aim is to use the musical potential of the ensemble–which I deeply admire–to explore different levels of representation, mimesis and abstraction when working within instrumental music and a text that won't be present in form of words during the performance.

THE SEVEN SELVES

Kahlil Gibran
The Madman
His Parables and Poems
(1918)

In the silent hour of the night, as I lay half asleep, my seven selves sat together and thus conversed in whispers:

First Self: Here, in this madman, I have dwelt all these years, with naught to do but renew his pain by day and recreate his sorrow by night. I can bear my fate no longer, and now I must rebel.

Second Self: Yours is a better lot than mine, brother, for it is given me to be this madman's joyous self. I laugh his laughter and sing his happy hours, and with thrice winged feet I dance his brighter thoughts. It is I that would rebel against my weary existence.

Third Self: And what of me, the love-ridden self, the flaming brand of wild passion and fantastic desires? It is I the love-sick self who would rebel against this madman.

Fourth Self: I, amongst you all, am the most miserable, for naught was given me but the odious hatred and destructive loathing. It is I, the tempest-like self, the one born in the black caves of Hell, who would protest against serving this madman.

Fifth Self: Nay, it is I, the thinking self, the fanciful self, the self of hunger and thirst, the one doomed to wander without rest in search of unknown things and things not yet created; it is I, not you, who would rebel.

Sixth Self: And I, the working self, the pitiful labourer, who, with patient hands, and longing eyes, fashion the days into images and give the formless elements new and eternal forms--it is I, the solitary one, who would rebel against this restless madman.

Seventh Self: How strange that you all would rebel against this man, because each and every one of you has a preordained fate to fulfil. Ah! could I but be like one of you, a self with a determined lot! But I have none, I am the do-nothing self, the one who sits in the dumb, empty nowhere and nowhen, when you are busy re-creating life. Is it you or I, neighbours, who should rebel?

When the seventh self thus spake the other six selves looked with pity upon him but said nothing more; and as the night grew deeper one after the other went to sleep enfolded with a new and happy submission.

But the seventh self remained watching and gazing at nothingness, which is behind all things.

Korkealla Hiljaisuuden

Electric Guitar, French Horn, Harp, Sonic Objects

RANK Ensemble - Alejandro Olarte

	Introduction	Pain	Joy	Love	Destruction	Silence	Worker	Craziness	Coda
Time	30-50 sec.	About 2 min.	About 2 min.	About 2 min.	About 2 min.	About 2 min.	About 2 min.	About 2 min.	30-50 sec.
Speed	Moderato	Slow	Allegretto con moto	Fast	Moderato	Slow	Allegro	Fast	Moderato
Dynamics	Mezzo-forte Diminuendo	Forte – uneven	Mezzo-piano Mezzo-forte	Constant Mezzo-forte	Forte	Crescendo-subito silence. Each player reach his loudest point.	Mezzo-Piano Mezzo-Forte	Forte Irregular	Mezzo-Forte Diminuendo
Materials	Duration of a horn long note. Middle register. The others free material. l.v.	Glissandi	Free Material.	Pulsed shared rhythm improvisation. Only with quarter, eighteen, or quarter dotted	Paper Metal cans, Cracking Crashing	Spaced attacks. The loudest peak should be mimed	Mechanical sounds	Variety, high levels of change, restless. Maximum of entropy. Avoid repetitions.	Duration of a horn long note. Low register.
Comments	Falling to sleep.	Change your playing position to different uncom-fortable s one	The group start simultaneously. Choose anyone on the group and follow him, change of target.	Add onomatopoeias to melt with the texture freely	Destroy something that you particularly like	Create the silence by preceding it with a Forte.	Only one voice made by playing one after another	Changes as fast as possible	Deep sleeping

RICERCARE A CINQUE

For Amplified Piano, Three Manipulators and One Page Turner

Dedicated to Sami Klemola, Emil Holmström and Defunensemble

Duration: slightly more than 10 minutes

Alejandro Olarte, Helsinki 2012

Amplified Piano—Grand Piano without cover

The amplification system consists of two dynamic microphones (one placed on the center front at the level of the music stand and the second at the middle right side) and two active loudspeakers located underneath the piano or under the pianist chair (the speakers position should minimize but not completely avoid feedback). The pianist will control the overall level of the amplification with a volume pedal. The system should be as invisible as possible.

Three Manipulators

Two will be placed at each side of the piano with a set of tools and materials arranged in a music stand, chair or an accessible surface. Those materials used to excite the strings include:

- A glass bottle,
- A plastic ruler,
- Four different mallets in different materials (wooden, cotton, brush),
- A wooden, a polyethylene and a metal block (30cm X 10cm X 5cm app).
- Tuning forks,
- A set of ping-pong balls.

The third manipulator has the task of freely preparing the strings of the piano by placing objects on it (clothespins, nails, metal chains, papers and tissues). This manipulator has a constant and independent rate of activity through on the whole performance. If sound production is not its main role, noises and resulting sounds from the preparation should not be avoided. On the contrary these odd sounds contribute to the overall content of the piece.

Page Turner

The page-turner will be sitting at one side of the pianist and has the role of turning the pages of a set of abstract paintings in a very noisy, loud and distracting way. The pages have to be turned in the following moments, looking for precision and controlling the time with a watch in a very discrete manner (the beginning is given by a clear sign from the pianist):

1'27" 2'22" 3'49" 6'11" 7'38" 8'32" 10'01"

This time framework should be ignored by the other performers.

Musical Sections

There are four states/sections in the piece. The performance consists (for the pianist and the two free manipulators) of playing within the four frameworks and moving the music very smoothly from one state to the next.

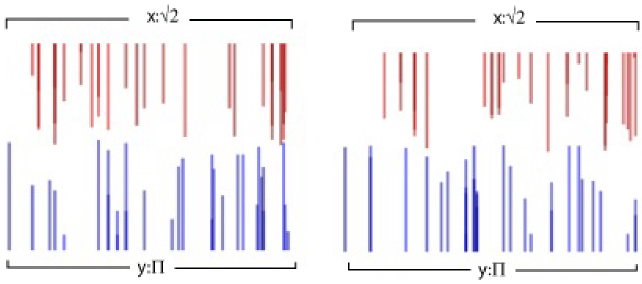
Anákrousis

Anacrusis plus accent and resonance played by the pianist. The harmonic and melodic content is restricted to the whole tone scale of Eb. (Eb, F, G, A, B, Db). Use the middle Eb3 as a starting-recurrent point for the accent.

The two manipulators imitate the length and the articulation played at the piano starting shortly after the end of the pianist gesture—in a call reply manner, mimesis. The imitation should be a single gesture alternating freely different modes and objects to strike the strings.

The development process consists of adding notes to the anacrusis and to the accent both melodically and harmonically as well as elaborating complex rhythmical patterns. As a consequence of extending the length of the gesture, the resonance will be reduced overlapping with the gestures of the manipulators until reaching a continuous fast playing.

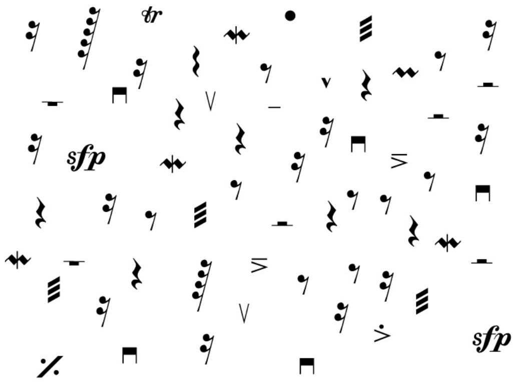
Hippasus Metapontum



Theorems: Between two points there is always one point. Two clocks running in an irrational proportion will never tick simultaneously.

A dynamic state based in rhythms that never synchronize —irrational proportions. Look for fast changes in the attacks producing an antinomy based music. The process consists of reducing the sound density without reducing the gestures.

Thespian

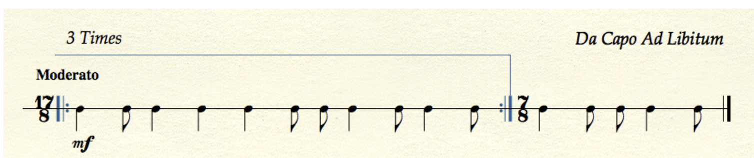


"Lassitude predisposes to a love of silence, for in it words lose their meaning and strike the ear with the hollow sonority of mechanical hammers; concepts weaken, expressions lose their force, the word grows barren as the wilderness. The ebb and flow of the outside is like a distant monotonous murmur unable to stir interest or curiosity. Then you will think it useless to express an opinion, take a stand, to make an impression; the noises you have renounced increase the anxiety of your soul. After having struggled madly to solve all problems, after having suffered on the heights of despair, in the supreme hour of revelation you will find that the only answer, the only reality, is silence." from Facing Silence in "On the Heights of Despair" by Emile M. Cioran 1934 (Pe culmile disperării—Epätoivon huipulla).

Very active, fast, nervous, excited, non-sounding (as possible) playing gestures. Togetherness.

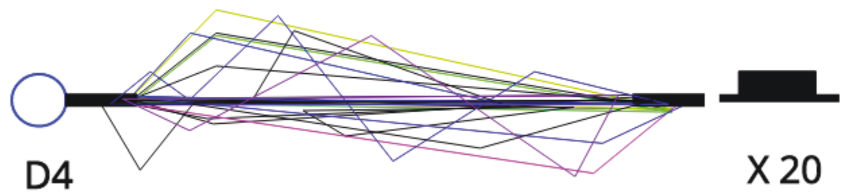
The process goes by adding isolated sounds until the next state is built.

Sappho



Improvise on this rhythmical structure, carefully underlying the begging of each cycle. The melodic material is the same as in anákrousis. The piece ends shortly after the last page turns and it should end on the last measure of 7/8.

20 TULITIKKUA BY ALEJANDRO OLARTE



For anything between 10 to 20 synthesizers with pitch, timbre and volume control.

The piece consists in the progressive modulation of pitch, amplitude, and timbre around the note D4 (midi note: 62, frequency: 293.66 Hz) and the natural instabilities of musical expression generated by group negotiations. The visual metaphor will be 20 matchsticks burning 20 times.

The piece starts with a clear signed agreed beforehand and given by any member of the band. All musicians should start at the same time and play the note with a moderate volume and any chosen timbre for a time equal or less than 16 seconds after all the musicians have reached the end of the note a common short silence of about 4 seconds should be held.
Once the silence period is gone, an iteration of 19 more cycles can start again this time triggered by the playing of any of the musicians (as soon as a new sound start, everybody should join).
In each new cycle, every musician should freely and slowly introduce continuous modulations of one, two or all of the parameters proposed (pitch, amplitude, timbre). The modulations can be controlled either manually (pitch bends, filter knobs, etc) or programmatically with LFOs, Envelopes, Oscillators, etc..). To respect the continuous aspect of the modulation the use of sequencers (if any) should be done in a way to avoid perceptible step changes.
Each cycle finishes in a brief silence after all the band converges again into the note D4 and the duration of each cycle should not be more than 20 seconds.
For example, if in a cycle a musician decides to play a fast glissando up and down around the note, and the gesture last only 2 seconds, the final note (D4) should be held until everybody plays it and then banish it to a common silence.
Modulations should get very wild and the sound should be colourful and dynamically powerful but always resting and starting from D4 with breathing silences in between

12

Resources and Thematic Bibliography

Works Cited

Aaron, Samuel, Alan F. Blackwell, and Pamela Burnard. 2016. "The development of Sonic Pi and its use in educational partnerships: Co-creating pedagogies for learning computer programming." *Journal of music, technology and education* 9 (1): 75–94.

Acosta, Rodolfo. 2007. "Musica Academica Contemporanea En Colombia Desde El Final De Los Ochenta". *Circulo Colombiano de Musica Contemporanea.*

Adorno, Theodor W., Wesley V. Blomster, and Anne G. Mitchell. 2003. *Philosophy of Modern Music.* New York: Continuum.

Agustín, San. 1992. *Confessions (3 Vols.)* Oxford: Clarendon Press.

Algra, Keimpe, and Katerina Ierodiakonou. 2015. *Sextus Empiricus and Ancient Physics.* Cambridge University Press.

Alperson, Philip. 1984. "On Musical Improvisation". *The Journal of Aesthetics and Art Criticism*, no. 1: 17–29.

– . 2010b. "Robust Praxialism and the Anti-aesthetic Turn". *Philosophy of Music Education Review*, no. 2: 171–193.

Andean, James. 2009. "Space within Space: Report on a Concert".

– . 2010. "The Musical-narrative Dichotomy: Sweet Anticipation and Some Implications for Acousmatic Music". *Organised Sound; Cambridge*, no. 2: 107–115.

Andean, James, et al. 2014. "Research Group in Interdisciplinary Improvisation–Goals, Perspectives, and Practice. In, Arlander, Annette. "This and that: essays on live art and performance studies."" University of the Arts Helsinki, Theater Academy.

Anderson, Mark. 2007. "Resources: Virtual Jamming". *IEEE Spectrum* 44 (7): 53–56.

Andresen, Uwe. 1979. "A New Way in Sound Synthesis". Audio Engineering Society.

Anicius Manlius Severinus Boethius (Rome, 480-524/525. 1867. *De Institutione Arithmetica Libri Duo, De Institutione Musica Libri Quinque.* B. G. Teubner, Leipzig.

Arfib, Daniel. 1978. "Digital Synthesis of Complex Spectra by Means of Multiplication of Non Linear Distorted Sine Waves". In *Audio Engineering Society Convention 59.* Audio Engineering Society.

Argo, Mark. 2004. "The Slidepipe: A Timeline-based Controller for Real-time Sample Manipulation". In *Proceedings of the International Conference on New Interfaces for Musical Expression*, 189–192. Hamamatsu, Japan.

Arthurs, Thomas. 2016a. "Secret Gardeners: An Ethnography of Improvised Music in Berlin (2012-13)".

Ashley, Richard. 2009. "Musical Improvisation". *The Oxford handbook of music psychology*: 413–420.

Assayag, Gérard. 2014. "Creative Symbolic Interaction." *Music technology meets philosophy: From digital echos to virtual ethos, vol. 1. Series: Proceedings of the International Computer Music Association* (San Francisco, USA): 1–6.

Attali, Jacques. 1985. *Noise: The Political Economy of Music.* Vol. 16. Manchester University Press.

Aufermann, Knut F. 2002. "Feedback Processes: An Investigation into Non-linear Electronic Music". *Unpublished master's thesis. Middlesex University, London.*

Auslander, Philip. 2006. "The Performativity of Performance Documentation". *PAJ: A Journal of Performance and Art* 28 (3): 1–10.

Austin, Larry. 2001. "Sound Diffusion in Composition and Performance Practice II: An Interview with Ambrose Field". *Computer Music Journal*, no. 4: 21–30.

Aveyard, Jon, and Dan Wilkinson. 2018. "Third City 2017: Improvisational Roles in Performances Using Live Sampling". *Open Cultural Studies*, no. 1: 562–573.

Azzara, Christopher D. 2002a. "Improvisation". In *The new handbook of research on music teaching and learning: A project of the Music Educators National Conference*, 171–187. Oxford University Press.

Baalman, Marije A. J. 2010. "Spatial Composition Techniques and Sound Spatialisation Technologies". *Organised Sound*, no. 3: 209–218.

Baclawski, K. 2018. "The Observer Effect". In *2018 IEEE Conference on Cognitive and Computational Aspects of Situation Management (CogSIMA)*, 83–89.

Bader, Rolf. 2018. *Springer Handbook of Systematic Musicology.* Springer.

Bakan, Michael B., Wanda Bryant, and Guangming Li. 1990. "Demystifying and Classifying Electronic Music Instruments". *Collected Work: Selected reports in ethnomusicology. VIII (1990): Issues in organology.* 37–64.

Barrett, Steven F. 2010. *Arduino Microcontroller Processing for Everyone!* Morgan / Claypool Publishers.

Barrière, Jean-Baptiste. 1991. *Le Timbre: Métaphore Pour La Composition.* Christian Bourgois.

Barton, Scott Donald. 2012. *Understanding Musical Discontinuity.* University of Virginia.

Battier, Marc. 2007. "What the GRM Brought to Music: From Musique Concrète to Acousmatic Music". *Organised Sound* 12 (3): 189–202.

Bayle, François. 1993. *Musique Acousmatique: Propositions– –positions.* Paris: Institut National de l'Audiovisuel : Editions Buchet-Chastel.

Bayle, François, et al. 1998. "L'espace Et L'électroacoustique". *Collected Work: L'espace: Musique/philosophie. Series: Musique et musicologie: Les dialogues.* (Paris, France): 372–390.

Beaty, Roger E. 2015. "The Neuroscience of Musical Improvisation". *Neuroscience and Biobehavioral Reviews* 51:108–117.

Bell, Renick. 2013. "Towards Useful Aesthetic Evaluations of Live Coding". In *International Computer Music Conference.*

Bencina, Ross. 2011. "Inside scsynth." In *Collected Work: The SuperCollider Book*, 721–740. United Kingdom: MIT Press, 2011.

Bengler, Ben. 2011. *The Audio Mixer As Creative Tool in Musical Composition and Performance.* Institut fur Elektronische Musik und Akustik (IEM), Universitat für Musik und darstellende Kunst Graz (KUG).

Bennett, Michael Y. 2015. *The Cambridge Introduction to Theatre and Literature of the Absurd.* Cambridge University Press.

Ben-Shahar, Ohad, and Steven Zucker. 2010. "General Geometric Good Continuation: From Taylor to Laplace Via Level Sets". *International Journal of Computer Vision*, no. 1: 48–71.

Bentley, Andrew. 1981. "Simple Equipment for Electronic Music Making". In *Electronic Music for Schools*, 107–131. Cambridge University Press.

Berdahl, Edgar, and Wendy Ju. 2017. "2011: Satellite CCRMA: A Musical Interaction and Sound Synthesis Platform". In *A NIME Reader: Fifteen Years of New Interfaces for Musical Expression*, ed. by Alexander Refsum Jensenius and Michael J. Lyons, 373–389. Current Research in Systematic Musicology. Cham: Springer International Publishing.

Berkowitz, Aaron. 2010. *The Improvising Mind: Cognition and Creativity in the Musical Moment.* Oxford University Press.

Berry, Rodney. 2002. "Augmented Reality for Music". In *Proc. of the International Computer Music Conference*, 100–104.

Bianchi, André Jucovsky, and Marcelo Queiroz. 2012. "Real Time Digital Audio Processing Using Arduino". In *Proceedings of the Sound and Music Computing Conference, Stockholm, Sweden*, 30:538–545.

Biles, Jeremy, and Kent L. Brintnall. 2015. *Negative Ecstasies: Georges Bataille and the Study of Religion.* Oxford University Press.

Birnbaum, David, et al. 2005. "Towards a Dimension Space for Musical Devices". In *Proceedings of the 2005 conference on New interfaces for musical expression*, 192–195. National University of Singapore.

Black, H. 1953. *Modulation Theory. Bell Telephone Laboratories Series.* Van Nostrand.

Blackwell, Alan F., and Nick Collins. 2005. "The Programming Language As a Musical Instrument." In *PPIG*, 11.

Blackwell, Tim, Oliver Bown, and Michael Young. 2012. "Live Algorithms: Towards Autonomous Computer Improvisers". In *Computers and creativity*, 147–174. Springer.

Blasser, Peter. 2015. "Stores at the Mall".

Blažanović, Marta. 2010. "Berlin Reductionism–an Extreme Approach to Improvisation Developed in the Berlin Echtzeitmusik-scene". In *Beyond the Centres: Musical Avant Gardes Since 1950. Conference Proceedings. Available on http://btc. web. auth. gr/_ assets/_ papers/BLAZANOVIC. pdf, accessed February*, 11:2012.

– . 2012. "Echtzeitmusik. the Social and Discursive Contexts of a Contemporary Music Scene". *Diss., Humboldt-Universität zu Berlin*: 204.

Boone, Alice. 2014. "The Secret History of Awkward Silences". *Teaching and Learning Together in Higher Education*, no. 12: 4.

Borgo, David. 2018. "The Complex Dynamics of Improvisation". In *Springer Handbook of Systematic Musicology*, 1017–1027. Springer.

Boulez, Pierre. 1975. *Par Volonté Et Par Hasard : Entretiens Avec Célestin Deliège*. Tel quel. Éditions du Seuil.

Boulez, Pierre, and Célestin Deliège. 1976. *Conversations with Célestin Deliège*. London: Eulenburg Books.

Boutin, Henri, Charles Besnainou, and LAM IJLRDA. 2008. "Physical Parameters of an Oscillator Changed by Active Control: Application to a Xylophone Bar". In *Proceedings of the 11th International Conference on Digital Audio Effects*, 1–4.

Bovermann, Till, et al. 2017. *Musical Instruments in the 21st Century*. Springer.

Bowers, John, and Phil Archer. 2005. "Not Hyper, Not Meta, Not Cyber but Infra-instruments". In *Proceedings of the 2005 conference on New interfaces for musical expression*, 5–10. National University of Singapore.

Bowling, Lawrence Edward. 1950. "What Is the Stream of Consciousness Technique?" *Publications of the Modern Language Association of America*: 333–345.

Bregnian, Albert S. 1993. "Auditory Scene Analysis: Hearing in Complex Environments".

Bresler, Liora. 1994. "Zooming in on the Qualitative Paradigm in Art Education: Educational Criticism, Ethnography, and Action Research". *Visual Arts Research*: 1–19.

Bretan, Mason, and Gil Weinberg. 2017. "Integrating the Cognitive with the Physical: Musical Path Planning for an Improvising Robot." In *AAAI*, 4371–4377.

Brown, Andrew R. 2012. *Sound Musicianship: Understanding the Crafts of Music*. Vol. 4. Cambridge Scholars Publishing.

Bueno, Otávio. 2005. "Dirac and the Dispensability of Mathematics". *Studies In History and Philosophy of Science Part B: Studies In History and Philosophy of Modern Physics*, no. 3: 465–490.

Burczyk, Steven C. 2016. *Groovebox*. Oxford University Press.

Burraston, Dave, and Ernest Edmonds. 2005. "Cellular Automata in Generative Electronic Music and Sonic Art: A Historical and Technical Review. Digital Creativity".

Butterworth, Stephen. 1930. “On the Theory of Filter Amplifiers”. *Wireless Engineer*, no. 6: 536–541.

Cáceres, Juan-Pablo, and Chris Chafe. 2010. “JackTrip: Under the Hood of an Engine for Network Audio”. *Journal of new music research*, no. 3: 183–187.

Cage, John. 1937. “The Future of Music: Credo”. *Audio Culture: Readings in Modern Music. New York: Continuum.*

Cage, John, et al. 1965. *Cartridge Music.* Wergo.

Campbell, Murray, and Clive Greated. 1994. *The Musician’s Guide to Acoustics.* OUP Oxford.

Camurri, Antonio. 1990. “On the Role of Artificial Intelligence in Music Research”. *Journal of New Music Research*, no. 2: 219–248.

Camus, Albert. 1965. *The Myth of Sisyphus: Translated from the French by Justin O’Brien.* Repr. H. Hamilton.

Cardew, Cornelius. 1971a. “Towards an Ethic of Improvisation”. *Treatise handbook*: 17–20.

– . 1971b. *Treatise Handbook Including Bun No. 2 [and] Volo Solo.* London; New York: Edition Peters.

Carôt, Alexander, Pedro Rebelo, and Alain Renaud. 2007. “Networked Music Performance: State of the Art”. In *Audio engineering society conference: 30th international conference: intelligent audio environments.* Audio Engineering Society.

Carpentier, Thibaut, Markus Noisternig, and Olivier Warusfel. 2015. “Twenty Years of Ircam Spat: Looking Back, Looking Forward”. In *41st International Computer Music Conference*, 270–277.

Carr, Ian, and Leonard Lyons. 1982. *Miles Davis: A Critical Biography.* London: Quartet Books.

Carr, Paul. 2014. “Frank Zappa and the And”. Ed. by Carlos E. (Reviewer) Peña. *ARSC journal*, no. 1: 64–65.

Casal, David Plans. 2011. “Crowdsourcing the Corpus: Using Collective Intelligence As a Method for Composition”. *Leonardo Music Journal*: 25–28.

Cascone, Kim. 2000. “The Aesthetics of Failure:“post-digital” Tendencies in Contemporary Computer Music”. *Computer Music Journal* 24 (4): 12–18.

Cassidy, Aaron, and Aaron Einbond, eds. 2013b. *Noise in and As Music.* Huddersfield: University of Huddersfield Press.

Cerqueira, Mark. 2010. “Synchronization Over Networks for Live Laptop Music Performance”. *Master’s Thesis, Department of Computer Science, Princeton University.*

Chapman, Dale E. 2012. *Turntablism.* Oxford University Press.

Charles, Jean-François. 2008. “A Tutorial on Spectral Sound Processing Using Max/MSP and Jitter”. *Computer Music Journal*, no. 3: 87–102.

Charles, Jean-Francois, et al. 2018. “Using the Axoloti Embedded Sound Processing Platform to Foster Experimentation and Creativity”. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, ed. by Thomas Martin Luke Dahl Douglas Bowman, 204–205. Blacksburg, Virginia, USA: Virginia Tech.

Chase, Stephen Timothy. 2007. "Improvised Experimental Music and the Construction of a Collaborative Aesthetic." PhD thesis, University of Sheffield.

Cherlin, Michael. 2000. "Dialectical Opposition in Schoenberg's Music and Thought". *Music Theory Spectrum*, no. 2: 157–176.

Cherry, E. Colin. 1953. "Some Experiments on the Recognition of Speech, with One and with Two Ears". *Journal of the Acoustical Society of America*, no. 5: 975–979.

Chion, Michel. 1983. *Guide Des Objets Sonores: Pierre Schaffer Et La Recherche Musicale.*

– . 1990. *L'audio-vision: Son Et Image Au Cinéma*. Nathan-Université. Paris: Nathan.

Choi, Hongchan, and Jonathan Berger. 2013. "WAAX: Web Audio API eXtension." In *Proceedings of the International Conference on New Interfaces for Musical Expression*, 499–502.

Choksy, Lois, et al. 2001. "Comprehensive Musicianship: An American Technique and Philosophy for Teaching Music". *Teaching music in the twenty first century*: 115–123.

Chomsky, Noam. 2017a. "Prospects for Survival". *The Massachusetts Review*, no. 4: 621–634.

Chowning, John M. 1973. "The Synthesis of Complex Audio Spectra by Means of Frequency Modulation". *Journal of the audio engineering society*, no. 7: 526–534.

Cioran, Emile M. 2013. *The Trouble with Being Born*. Skyhorse Publishing Inc.

Clark, Andy. 2001. "Natural-born Cyborgs?" In *Cognitive technology: Instruments of mind*, 17–24. Springer.

Clayton, Martin, Rebecca Sager, and Udo Will. 2005. "In Time with the Music: The Concept of Entrainment and Its Significance for Ethnomusicology." In *European meetings in ethnomusicology.* 11:1–82. Romanian Society for Ethnomusicology.

Collins, Nicholas M. 2007a. "Towards Autonomous Agents for Live Computer Music: Realtime Machine Listening and Interactive Music Systems". PhD thesis, University of Cambridge.

Collins, Nick. 2003. "Generative Music and Laptop Performance". *Contemporary Music Review* 22 (4): 67–79.

– . 2008a. "Errant Sound Synthesis." In *International Computer Music Conference.*

– . 2011. "Live Coding of Consequence". *Leonardo*, no. 3: 207–211.

Collins, Nick, and Julio d'Escriván. 2017. *The Cambridge Companion to Electronic Music*. Cambridge University Press.

Collins, Nicolas. 2007b. "Composing inside Electronics". PhD thesis, University of East Anglia. Accessed on March 14, 2014.

– . 2008b. "A Solder's Tale: Putting The "Lead" Back In "Lead Users"". *IEEE Pervasive Computing* 7 (3): 32–38.

– . 2009. *Handmade Electronic Music: The Art of Hardware Hacking*. 2 edition. New York: Routledge.

Collins, Nicolas, et al. 2003. “Live Coding in Laptop Performance”. *Organised sound: An international journal of music technology* 8 (3): 321–330.

Consortium, MIMO. 2011. *Revision of the Hornbostel-sachs Classification of Musical Instruments by the MIMO Consortium.*

Cooley, James W., and John W. Tukey. 1965. “An Algorithm for the Machine Calculation of Complex Fourier Series”. *Mathematics of Computation*, no. 90: 297–301.

Cope, David. 1989. “Experiments in Musical Intelligence (EMI): Non-linear Linguistic-based Composition”. *Journal of New Music Research*, no. 1: 117–139.

Costantini, Giovanni, Massimiliano Todisco, and Giovanni Saggio. 2010. “A Wireless Glove to Perform Music in Real Time”. In *8th WSEAS International Conference on Applied Electromagnetics, Wireless And Optical Communications, Penang, Malaysia.*

Coulembier, KLAAS. 2016. “Multi-temporality: An Analytical Approach to Contemporary Music, Embracing Concepts of Gilles Deleuze and Félix Guattari”. *Music Analysis; Oxford* 35 (3): 341–372.

Crowder, Robert G. 1993. *Auditory Memory.* Oxford University Press.

Csikszentmihalyi, Mihaly. 1997. “Happiness and Creativity: Going with the Flow”. *Futurist*, no. 5: 8.

Dack, John. 2001. “Diffusion As Performance.” IIASSRC Conference Proceedings.

Dahlhaus, Carl. 1987. *Schoenberg and the New Music: Essays by Carl Dahlhaus.* Cambridge University Press.

Dahlhaus, Carl, and Hans Hildenbrand. 2004. “Composition Et Improvisation”. In *Collected Work: Essais sur la nouvelle musique.* 191–199. Genève: Contrechamps.

Dahlstedt, Palle, Per Anders Nilsson, and Gino Robair. 2015. “The Bucket System-a Computer Mediated Signalling System for Group Improvisation.” In *Proceedings of the International Conference on New Interfaces for Musical Expression*, 317–318.

Dal Molin, Paolo, and Edward (b.1958) Campbell. 2016. “Composing an Improvisation at the Beginning of the 1970s”. In *Collected Work: Pierre Boulez studies.* 270–300. Cambridge, England: Cambridge University Press.

Dalgleish, Mat. “The Modular Synthesizer Divided”.

Dashow, James. 2013. “On Spatialization”. *Computer Music Journal*, no. 3: 4–6.

Davidson, Jane W. 2004. “Music As Social Behavior”. *Empirical musicology: Aims, methods, prospects*: 57–75.

Davies, Hugh. 1996. “A History of Sampling”. *Organised Sound* 1 (1): 3–11.

– . 2001b. “Electronic Instruments”. In *Oxford Music Online.* Oxford University Press.

– . 2001c. *Electronic Percussion.* Oxford University Press.

– . 2001f. *Mellotron.* Oxford University Press.

– . 2001g. *Synthesizer.* Oxford University Press.

Davies, Hugh, and Susan McClary. 2014. *Anderson, Laurie.* Oxford University Press.

Dean, Roger. 2003. *Hyperimprovisation: Computer-interactive Sound Improvisation.* A-R Editions, Inc.

D'Errico, Michael A. 2011. "Behind the Beat: Technical and Practical Aspects of Instrumental Hip-hop Composition". PhD thesis, Tufts University.

Desantos, Sandra, Curtis Roads, and François Bayle. 1997. "Acousmatic Morphology: An Interview with François Bayle". *Computer Music Journal*: 11–19.

d'Escriván, Julio. 2006. "To Sing the Body Electric: Instruments and Effort in the Performance of Electronic Music". *Contemporary Music Review* 25 (1): 183–191.

Deutsch, Diana. 1980. "Music Perception". *The Musical Quarterly*, no. 2: 165–179.

Dolan, Emily I. 2017. "Review: MIMO: Musical Instrument Museums Online". *Journal of the American Musicological Society*, no. 2: 555–565.

Dowling, W. Jay. 1973. "The Perception of Interleaved Melodies". *Cognitive psychology*, no. 3: 322–337.

Driscoll, John, and Matt Rogalsky. 2004. "David Tudor's Rainforest: An Evolving Exploration of Resonance". *Leonardo Music Journal*: 25–30.

Duby, Marc. 2006. "Soundpainting As a System for the Collaborative Creation of Music in Performance". PhD thesis, University of Pretoria.

Dunne, Jared. 2007. "Monome 40h Multi-Purpose Hardware Controller". *Computer Music Journal* 31 (3): 92–94.

EBU–Recommendation, R. 2011. "Loudness Normalisation and Permitted Maximum Level of Audio Signals".

Eckel, Gerhard, et al. 2012. "A Framework for the Choreography of Sound". In *International Computer Music Conference.*

Edwards, Peter. 2014. "Collaborating with Circuits. Music, Invention and Electricty". MA thesis, The Insitute of Sonology & STEIM.

Eldredge, Sears A., and Hollis W. Huston. 1978. "Actor Training in the Neutral Mask". *The Drama Review: TDR*, no. 4: 19–28.

Elliott, David J. 1995. *Music Matters: A New Philosophy of Music Education.* Oxford University Press.

– . 2009. *Praxial Music Education: Reflections and Dialogues.* Oxford University Press.

Elliott, John. 1991. *Action research for educational change.* Milton Keynes: Open University Press.

Emmerson, Simon, and Denis Smalley. 2001. *Electro-acoustic Music.* Oxford University Press.

Ericsson, K. Anders, and Neil Charness. 1994. "Expert Performance". *American Psychologist*, no. 8: 725.

Ervasti, Siiri. 2016. "Avoimen Etsijän Vaellus: Ohjaajan Roolit Devising-prosessissa". MA thesis.

Esslin, Martin. 1960. "The Theatre of the Absurd". *The Tulane Drama Review*: 3–15.

Evans, C., et al. 2018. "Towards the First Measurement of Matter-antimatter Gravitational Interaction". In *EPJ Web of Conferences*, 182:02040. EDP Sciences.

Fels, Sidney, and Michael Lyons. 2015. "How to Design and Build New Musical Interfaces". In *Human-Computer Interaction – INTERACT 2015*, ed. by Julio Abascal et al., 642–643. Lecture Notes in Computer Science. Springer International Publishing.

Fernández, Jose D., and Francisco Vico. 2013. "AI Methods in Algorithmic Composition: A Comprehensive Survey". *Journal of Artificial Intelligence Research* 48:513–582.

Flanagan, Patricia J. 2013. "Haptic Interface Aesthetics–'feedback Loops, Live Coding and How to Harness the Potential of Embodied Estrangement in Artistic Practices and Aesthetic Theories within Interface Culture'". In *International Conference of Design, User Experience, and Usability*, 58–67. Springer.

Flood, Lauren. 2016b. "Building and Becoming: DIY Music Technology in New York and Berlin". PhD thesis, Columbia University.

Fredrickson, William E. 1994. "Band Musicians' Performance and Eye Contact As Influenced by Loss of a Visual And/or Aural Stimulus". *Journal of Research in Music Education*, no. 4: 306–317.

Friz, Anna. 2009. "Radio As Instrument". *Wi: Journal of Mobile Media.*

Gao, Shan, Xihong Wu, and Tianshu Qu. 2018. "High Order Ambisonics Encoding Method Using Differential Microphone Array". In *Audio Engineering Society Convention 144*. Audio Engineering Society.

Gardner, James. 2017. "The Don Banks Music Box to the Putney: The Genesis and Development of the VCS3 Synthesiser". *Organised Sound*, no. 2: 217–227.

Gaser, Christian, and Gottfried Schlaug. 2003. "Brain Structures Differ between Musicians and Non-musicians". *Journal of Neuroscience*, no. 27: 9240–9245.

Gaskin, Richard. 2014. *Simplicius: On Aristotle Categories 9-15.* A&C Black.

Gelfand, Stanley A. 2017. *Hearing: An Introduction to Psychological and Physiological Acoustics.* CRC Press.

Genevois, Hugues, and Raphaël De Vivo. 1999. *Les Nouveaux Gestes De La Musique.* Parenthèses.

George, Damien. 2016. *MicroPython Python for Microcontrollers.*

Goble, J. Scott. 2003. "Perspectives on Practice: A Pragmatic Comparison of the Praxial Philosophies of David Elliott and Thomas Regelski". *Philosophy of Music Education Review*, no. 1: 23–44.

Godøy, Rolf Inge. 2010. "Gestural Affordances of Musical Sound". In *Musical Gestures*, 115–137. Routledge.

Godsill, Simon J, and Peter J W Rayner. "Digital Audio Restoration - a Statistical Model Based Approach": 346.

Gold, T., and R. J. Pumphrey. 1948. "Hearing. I. the Cochlea As a Frequency Analyzer". *Proceedings of the Royal Society of London. Series B, Biological Sciences*, no. 881: 462–491.

Gooding, Lori F. 2011. "The Effect of a Music Therapy Social Skills Training Program on Improving Social Competence in Children and Adolescents with Social Skills Deficits". *Journal of Music Therapy*, no. 4: 440–462.

Gorne, Annette Vande. 2002. "L'interprétation Spatiale. Essai De Formalisation Méthodologique"'. *Démeter.*

Grashel, John. 1993. "An Integrated Approach Comprehensive Musicianship: John Grashel Explains How Comprehensive Musicianship, Too Long Ignored by Instrumental Educators, Can Be Used to Advantage in the Rehearsal Room". *Music Educators Journal*, no. 8: 38–41.

Green, David M. 1971. "Temporal Auditory Acuity." *Psychological Review* 78 (6): 540–551.

Green, Lucy. 2002. *How Popular Musicians Learn: A Way Ahead for Music Education.* Ashgate popular and folk music series. Aldershot, Hants ; Burlington, VT: Ashgate.

Griffith, Niall, and Peter M. Todd. 1999. *Musical Networks: Parallel Distributed Perception and Performance.* MIT Press.

Grimshaw, Jeremy. 2011b. *The Ideology of the Drone: La Monte Young the Mystic.* Oxford University Press.

– . "The Tabula (not So) Rasa: La Monte Young's Serial Works and the Beginnings of Minimalism, 1956-58".

Guberman, Shelia. 2015. "On Gestalt Theory Principles". *Gestalt Theory*, no. 1: 25–44.

– . 2016. "Gestalt Psychology, Mirror Neurons, and Body-mind Problem". *Gestalt Theory*, no. 2.

– . 2017. "Gestalt Theory Rearranged: Back to Wertheimer". *Frontiers in psychology* 8:1782.

Hajdu, Georg. 2005. "Quintet.net: An Environment for Composing and Performing Music on the Internet". *Leonardo*, no. 1: 23–30.

Halliwell, Stephen. 2002. *The Aesthetics of Mimesis: Ancient Texts and Modern Problems.* Princeton, United States: Princeton University Press.

Hansen, Kjetil Falkenberg. 2010. "The Acoustics and Performance of DJ Scratching". *PhD diss., KTH Royal Institute of Technology*: 1–74.

Hanson, Jeffrey. 2010. "Morton Subotnick's Ghost Scores: Interaction and Performance with Music Technology". MA thesis.

Haugeland, John. 1989. *Artificial Intelligence: The Very Idea.* 26. Cambridge, MA: MIT Press.

Hawkins, John. 1868. *A General History of the Science and Practice of Music.* Vol. 1. JA Novello.

Heath, Thomas Little. 1956. *The Thirteen Books of Euclid's Elements.* Courier Corporation.

Hebb, D. O. 1968. "Concerning Imagery." *Psychological review*, no. 6: 466–477.

Hegarty, Paul. 2006. "Noise Music". *The Semiotic Review of Books.*

– . 2008. "Just What Is It That Makes Today's Noise Music so Different, so Appealing? 1". *Organised Sound*, no. 1: 13–20.

Heller, Aaron, Eric Benjamin, and Richard Lee. "A Toolkit for the Design of Ambisonic Decoders": 12.

Hewitt, Edwin, and Robert E. Hewitt. 1979. "The Gibbs-Wilbraham Phenomenon: An Episode in Fourier Analysis". *Archive for History of Exact Sciences*, no. 2: 129–160.

Hove, Michael J., and Jane L. Risen. 2009. "It's All in the Timing: Interpersonal Synchrony Increases Affiliation". *Social Cognition* 27 (6): 949–960.

Hugill, Andrew. 2012. *The Digital Musician.* Routledge.

Huleihil, Mahmoud, and Huriya Huleihil. 2011. "Digital Text Based Activity: Teaching Geometrical Entities at the Kindergarten". In *Intelligent Interactive Multimedia Systems and Services*, 99–112. Springer.

Hunt, Andy, and Marcelo M. Wanderley. 2002. "Mapping Performer Parameters to Synthesis Engines". *Organised sound* 7 (2): 97–108.

Hunt, Andy, Marcelo M. Wanderley, and Matthew Paradis. 2003. "The Importance of Parameter Mapping in Electronic Instrument Design". *Journal of New Music Research* 32 (4): 429–440.

Huron, David Brian. 2006. *Sweet Anticipation: Music and the Psychology of Expectation.* MIT Press.

Ippolito, Jon. 2002. "Ten Myths of Internet Art". *Leonardo*, no. 5: 485–498.

Jestrovic, Silvija. 2000. "The Performer and the Machine: Some Aspects of Laurie Anderson's Stage Work". *Body, Space, & Technology Journal*, no. 1.

John, Graham St. 2006. "Electronic Dance Music Culture and Religion: An Overview". *Culture and Religion*, no. 1: 1–25.

Johnson, Timothy A. 1994. "Minimalism: Aesthetic, Style, or Technique?" *The Musical Quarterly*, no. 4: 742–773.

Jones, K. 1980. "Computer Assisted Application of Stochastic Structuring Techniques in Musical Composition and Control of Digital Sound Synthesis Systems". Doctoral, City University London.

Jordà, Sergi. 2002. "Improvising with Computers: A Personal Survey (1989-2001)". *Journal of new music research*, no. 1: 1–10.

Jordà, Sergi, et al. 2007. "The reacTable: Exploring the Synergy between Live Music Performance and Tabletop Tangible Interfaces". In *Proceedings of the 1st international conference on Tangible and embedded interaction*, 139–146. ACM.

Joyce, James. 1986. *Ulysses.* 1st edition. New York: Vintage.

Jung, Carl Gustav. 1997. *Jung on Active Imagination (edited and with an Introduction by Joan Chodorow).* Princeton: Princeton University Press.

Jung, Rex E., and Oshin Vartanian. 2018. *The Cambridge Handbook of the Neuroscience of Creativity.* Cambridge University Press.

K. Koffka. 1935. *Principles of Gestalt Psychology.*

Kandinsky, Wassily. 1947. "Point and Line to Plane (1926)". *Kandinsky: Complete Writings on Art*: 527–699.

Kane, Brian. 2006. *Improvising Tape Music.* Spark.

Kapur, Ajay. 2005. "A History of Robotic Musical Instruments." In *International Computer Music Conference.* Citeseer.

Kapur, Ajay, et al. 2005. "Wearable Sensors for Real-time Musical Signal Processing". In *Communications, Computers and signal Processing, 2005. PACRIM. 2005 IEEE Pacific Rim Conference on*, 424–427. IEEE.

Keller, Damián, and Barry Truax. 1998. "Ecologically-based Granular Synthesis." In *International Computer Music Conference.*

Kim, Suk-Jun. 2010. "A Critique on Pierre Schaeffer's Phenomenological Approaches: Based on the Acousmatic and Reduced Listening". In *Pierre Schaeffer Conference: mediART in Rijeka, Croatia, on Oct*, 7:2010.

Kleinmintz, Oded M., et al. 2014. "Expertise in Musical Improvisation and Creativity: The Mediation of Idea Evaluation". *PloS One*, no. 7: e101568.

Kokoras, Panayiotis A. 2005. "Morphopoiesis: A General Procedure for Structuring Form". *Electronic Musicological Review.*

Kramer, Jonathan D. 1988. "The Time of Music New Meanings, New Temporalities, New Listening Strategies".

Kramer, Oliver, Benno Stein, and Jürgen Wall. 2006. "Ai and Music: Toward a Taxonomy of Problem Classes". *Frontiers in Artificial Inteligence and Applications*: 695.

Kubisch, Christina. 2004. *Electrical Walks: Electromagnetic Investigations in the City.*

Lähdeoja, Otso. 2016. "Composing for an Orchestra of Sonic Objects: The Shakeousmonium Project". In *Proceedings of the International Computer Music Conference. Utrecht.* Ann Arbor, MI: Michigan Publishing, University of Michigan Library.

– . 2018. "Composing the Context: Considerations on Materially Mediated Electronic Musicianship". *Organised Sound*, no. 1: 61–70.

Landy, Leigh. 2007c. *Understanding the Art of Sound Organization.* MIT Press.

Le Brun, Marc. 1979. "Digital Waveshaping Synthesis". *Journal of the Audio Engineering Society*, no. 4: 250–266.

Lee, Richard Andrew. 2011. "The Interaction of Linear and Vertical Time in Minimalist and Postminimalist Piano Music". PhD thesis, University of Missouri–Kansas City.

Lee, Sang Won, Georg Essl, and Mari Martinez. 2016. "Live Writing: Writing As a Real-time Audiovisual Performance". *Ann Arbor*: 48109–2121.

Leighton, Taigen Dan, and Yi Wu. 2000. *Cultivating the Empty Field: The Silent Illumination of Zen Master Hongzhi.* Tuttle Publishing.

Leonardson, Eric. 2007. "The Springboard: The Joy of Piezo Disk Pickups for Amplified Coil Springs". *Leonardo Music Journal* 17:17–20.

Lewis, George E. 2000a. "Too Many Notes: Computers, Complexity and Culture in Voyager". *Leonardo Music Journal*: 33–39.

– . 2008. *A Power Stronger Than Itself: The AACM and American Experimental Music.* University of Chicago Press.

Lewis, George, and Benjamin Piekut. 2016b. *The Oxford Handbook of Critical Improvisation Studies.* Vol. 1. Oxford University Press.

Li, C. K. 2016. "The Powers of the Dirac Delta Function by Caputo Fractional Derivatives". *Journal of Fractional Calculus and Applications*, no. 1: 12–23.

Lindemann, Eric, et al. 1991. "The Architecture of the IRCAM Musical Workstation". *Computer Music Journal*, no. 3: 41–49.

Long, Jason, et al. 2015. "A Comparative Evaluation of Percussion Mechanisms for Musical Robotics Applications". In *Automation, Robotics and Applications (ICARA), 2015 6th International Conference on*, 173–178. IEEE.

Lortat-Jacob, Bernard. 1987. *L'improvisation Dans Les Musiques De Tradition Orale: Ouvrage Collectif.* Peeters Publishers.

Lossius, Trond, Pascal Baltazar, and Théo de la Hogue. 2009. "DBAP–distance-based amplitude panning". In *International Computer Music Conference.*

Lubis, Muhammad Zainuddin, Henry Munandar Manik, and Pratiwi Dwi Wulandari. 2016. *Signal Processing for Marine Acoustic and Dolphin Using Matlab.* LAP Lambert Academic Publishing.

MacDonald, Raymond, David J. Hargreaves, and Dorothy Miell. 2017. *Handbook of Musical Identities.* Oxford University Press.

Macedo, Frederico. 2011. *Phenomenology, Spatial Music and the Composer: Prelude to a Phenomenology of Space in Acousmatic Music.* Ann Arbor, MI: Michigan Publishing, University of Michigan Library.

Madden, Andrew, et al. 2011. "Multi-touch Room Expansion Controller for Real-time Acoustic Gestures". Audio Engineering Society.

Magnusson, Thor. 2006. "Affordances and Constraints in Screen-based Musical Instruments". In *Proceedings of the 4th Nordic conference on Human-computer interaction: changing roles*, 441–444. ACM.

– . 2013. "The Threnoscope: A Musical Work for Live Coding Performance". In *ICSE.* Live 2013.

– . 2014. "Herding Cats: Observing Live Coding in the Wild". *Computer Music Journal*, no. 1: 8–16.

– . 2017. "Musical Organics: A Heterarchical Approach to Digital Organology". *Journal of New Music Research* 46 (3): 286–303.

Manning, Peter. 2003. "The Influence of Recording Technologies on the Early Development of Electroacoustic Music". *Leonardo Music Journal*: 5–10.

Manousakis, Stelios. 2009. "Non-standard Sound Synthesis with L-systems". *Leonardo Music Journal*: 85–94.

Marshall, Mark T., Joseph Malloch, and Marcelo M. Wanderley. 2007. "Gesture Control of Sound Spatialization for Live Musical Performance". In *International Gesture Workshop*, 227–238. Springer.

Martin, Jeffrey A. 2005. "Composing and Improvising". In *Collected Work: Praxial Music Education: Reflections and Dialogues.* 165–176. New York: Oxford University Press.

Martini, R., et al. 2001. "High-speed Modulation and Free-space Optical Audio/video Transmission Using Quantum Cascade Lasers". *Electronics Letters*, no. 3: 191–193.

Mavromatos, Nick E. 2018. "Matter-antimatter Asymmetry in the Universe Via String-inspired CPT Violation at Early Eras". In *Journal of Physics: Conference Series*, 952:012006. IOP Publishing.

McFadden, Jane. 2007. "Toward Site". *Grey Room*, no. 27: 36–57.

McLean, Alex. 2008. "Live Coding for Free". *Floss+Art. London: OpenMute*: 224–231.

McLean, Alex, and Roger T. Dean. 2018. *The Oxford Handbook of Algorithmic Music*. Oxford University Press.

McLean, Alex, et al. 2010. "Visualisation of Live Code." In *EVA*.

McNiff, Jean, and Whitehead Jack. 2009. *You and Your Action Research Project.* 3rd ed. Routledge.

McPherson, Andrew. 2017. "Bela: An Embedded Platform for Low-latency Feedback Control of Sound". *The Journal of the Acoustical Society of America*, no. 5: 3618–3618.

Merleau-Ponty, Maurice. 2013. *Phenomenology of Perception.* Routledge.

Michon, Romain, et al. 2017. "Faust2api: A Comprehensive API Generator for Android and iOS". In *Proceedings of the Linux Audio Conference (LAC-17), Saint-Etienne, France*, 18–21.

Miller, Geoffrey F., Peter M. Todd, and Shailesh U. Hegde. 1989. "Designing Neural Networks Using Genetic Algorithms." In *ICGA*, 89:379–384.

Mills, John. 2009. *Letters of a Radio-engineer to His Son.*

Mills, R. H. 2014. "Tele-improvisation: A Multimodal Analysis of Intercultural Improvisation in Networked Music Performance". PhD thesis, University of Technology Sydney.

Miranda, Eduardo Reck. 2000. *Readings in Music and Artificial Intelligence.* Vol. 20. Contemporary music studies. Amsterdam: Harwood Academic.

Miranda, Eduardo Reck, and Andrew Brouse. 2005. "Interfacing the Brain Directly with Musical Systems: On Developing Systems for Making Music with Brain Signals". *Leonardo*, no. 4: 331–336.

Miranda, Eduardo Reck, and Adolfo Maia. 2005. "Granular Synthesis of Sounds through Markov Chains with Fuzzy Control." In *ICMC.*

Miranda, Eduardo Reck, and Marcelo M. Wanderley. 2006. *New Digital Musical Instruments: Control and Interaction beyond the Keyboard.* Vol. 21. The computer music and digital audio series v. 21. Middleton, Wis: AR Editions, Inc.

Miranda, Eduardo Reck, and Duncan Williams. 2015. "Artificial Intelligence in Organised Sound". *Collected Work: Organised sound: An international journal of music technology. XX/1 (April 2015): Organised sound celebrates 20 years.* (Cambridge, England) 20 (1): 76–81.

Miranda, Eduardo R., et al. 2009. "Computer Music Meets Unconventional Computing: Towards Sound Synthesis with in Vitro Neuronal Networks". *Computer Music Journal*, no. 1: 9–18.

Mitsuhashi, Yasuhiro. 1982. "Audio Signal Synthesis by Functions of Two Variables". *Journal of the Audio Engineering Society*, no. 10: 701–706.

Miyakawa, Felicia M. 2017. "Turntablature: Notation, Legitimization, and the Art of the Hip-hop DJ". In *From Soul to Hip Hop*, 59–83. Routledge.

Mizuno, Mikako. 2011. "On the Music through Network". *Proceedings of Asia Computer Music Project*: 4.

Mooney, James. 2015b. "Hugh Davies's Self-built Instruments and Their Relation to Present- Day Electronic and Digital Instrument-building Practices: Towards Common Themes". In *International Festival for Innovations in Music Production and Composition.* The University of Leeds.

Moore, Darren, et al. 2016. "cellF: A Neuron-driven Music Synthesiser for Real-time Performance". *International Journal of Performance Arts and Digital Media*, no. 1: 31–43.

Moro, Giulio, et al. 2016. "Making High-performance Embedded Instruments with Bela and Pure Data".

Mulshine, Michael, and Jeff Snyder. 2017. "Oops: An Audio Synthesis Library in C for Embedded (and Other) Applications." In *Proceedings of the International Conference on New Interfaces for Musical Expression*, 460–463.

Nachmanovitch, Stephen. 1990b. *Free Play: Improvisation in Life and Art.* Penguin.

Nebeker, Frederik. 1998. *Signal Processing: The Emergence of a Discipline: 1948 to 1998.* IEEE Computer Society Press.

Neisser, Ulric. 1983. "Toward a Skillful Psychology". In *The Acquisition of Symbolic Skills*, 1–17. Springer, Boston, MA.

Néron Baribeau, Raphaël. 2015. "Méthodes De Spatialisation Sonore Et Intégration Dans Le Processus De Composition", Université de Montréal.

Nettl, Bruno, and Melinda Russell. 1998. *In the Course of Performance: Studies in the World of Musical Improvisation.* University of Chicago Press.

Nettl, Bruno, et al. 2001. "Improvisation. Grove Music Online".

Neuman, Israel. 2013. "Generative Grammars for Interactive Composition Based on Schaeffer's TARTYP". In *International Computer Music Conference.*

Nilsson, Per Anders. 2011. *A Field of Possibilities: Designing and Playing Digital Musical Instruments.* Academy of Music / Drama; Högskolan för scen och musik.

Norilo, Vesa. 2015. "Kronos: A Declarative Metaprogramming Language for Digital Signal Processing". *Computer Music Journal*, no. 4: 30–48.

Normandeau, Robert. 2010. "A Revision of the TARTYP Published by Pierre Schaeffer". In *Proceedings of the Seventh Electroacoustic Music Studies Network Conference*, 21–24.

Nottoli, Giorgio, et al. 2014. "Texture: A Granular Synthesizer for Real-time Sound Generation". *WSEAS Transactions on Signal Processing*: 601–610.

Novak, David. 2010. "Playing Off Site: The Untranslation of Onkyô". *Asian Music*, no. 1: 36–59.

Oliveros, Pauline. 2005. *Deep Listening: A Composer's Sound Practice.* New York: iUniverse.

Oliveros, Pauline, et al. 2009. "Telematic Music: Six Perspectives". *Leonardo Music Journal*, no. 1: 95–96.

Pachet, Francois. 2003. "The Continuator: Musical Interaction with Style". *Journal of New Music Research*, no. 3: 333–341.

Paine, Garth. 2010. "Towards a Taxonomy of Realtime Interfaces for Electronic Music Performance." In *Proceedings of the International Conference on New Interfaces for Musical Expression*, 436–439.

Pakarinen, Jyri, et al. 2011. "Recent Advances in Real-time Musical Effects, Synthesis, and Virtual Analog Models". *EURASIP Journal on Advances in Signal Processing*, no. 1.

Palombini, Carlos. 1999. "Musique Concrète Revisited". *Electronic Musicological Review.*

Parker, Julian, and Stephano D'Angelo. 2013. "A Digital Model of the Buchla Lowpass-gate". In *Proc. Int. Conf. Digital Audio Effects (DAFx-13), Maynooth, Ireland*, 278–285.

Parra Cancino, Juan Arturo. 2014. "Multiple Paths. Towards a Performance Practice in Computer Music".

Pätynen, Jukka, and Tapio Lokki. 2011. "Evaluation of Concert Hall Auralization with Virtual Symphony Orchestra". *Building Acoustics*, no. 3: 349–366.

Paulhan, F. 1887. "La Simultanéité Des Actes Psychiques". *Revue Scientifique*: 684–689.

Payne, David G. 1987. "Hypermnesia and Reminiscence in Recall: A Historical and Empirical Review." *Psychological Bulletin*, no. 1: 5.

Peeters, Geoffroy, et al. 2011. "The Timbre Toolbox: Extracting Audio Descriptors from Musical Signals". *The Journal of the Acoustical Society of America* 130 (5): 2902–2916.

Peignot, Jérôme. 1960. "De La Musique Concrète À L'acousmatique". *Esprit (1940-)*, no. 280 (1): 111–120.

Pekonen, Jussi, et al. 2014. "Filter-based Oscillator Algorithms for Virtual Analog Synthesis".

Peplowski, Ken. 1998. "The Process of Improvisation". *Organization Science*, no. 5: 560–561.

Pereira, Carlos Arthur Avezum. 2017. "O Silêncio Como Afeto Ou a Escuta Corporal Na Recente Música Experimental". PhD thesis, Universidade de São Paulo.

Perkis, Tim, et al. 2007. *The League of Automatic Music Composers, 1978-1983.* New World Records.

Peters, Gary. 2009. *The Philosophy of Improvisation.* University of Chicago Press.

Peters, Nils. 2010. "Sweet [re] Production". PhD thesis, McGill University.

Pierce, John R. 2012. *An Introduction to Information Theory: Symbols, Signals and Noise.* Courier Corporation.

Pinch, Trevor, and Frank Trocco. 1998. "The Social Construction of the Early Electronic Music Synthesizer". *Icon*: 9–31.

Piringer, Jörg. 2001. *Elektronische Musik Und Interaktivität: Prinzipien, Konzepte, Anwendungen.* na.

Plourde, Lorraine. 2008. "Disciplined Listening in Tokyo: Onkyō and Non-intentional Sounds". *Ethnomusicology*, no. 2: 270–295.

Poli, Roberto. 2011. "Steps toward an Explicit Ontology of the Future". *Journal of Futures Studies*, no. 1: 67–78.

Pressing, Jeff. 1984b. "Cognitive Processes in Improvisation". In *Collected Work: Cognitive processes in the perception of art. Series: Advances in psychology, No. 19*, 345–363. Amsterdam: North-Holland.

– . 1988a. "Improvisation: Methods and Models". In *Collected Work: Generative processes in music: The psychology of performance, improvisation and composition*, 129–178. Oxford, United Kingdom: Clarendon Press.

– . 1988b. "Improvisation: Methods and Models". *John A. Sloboda: Generative processes in music, Oxford*: 129–178.

– . 1992. *Synthesizer Performance and Real-time Techniques.* Oxford University Press.

– . 1998a. "Psychological Constraints on Improvisational Expertise and Communication". In *Collected Work: In The Course Of Performance: Studies In The World Of Musical Improvisation. Series: Chicago Studies In Ethnomusicology*, 47–67. Chicago: University of Chicago Press.

Prévost, Eddie. 1995. *No Sound Is Innocent: AMM and the Practice of Self-invention, Meta-musical Narratives, Essays.* Copula.

Puckette, Miller. 1991a. "Combining Event and Signal Processing in the MAX Graphical Programming Environment". *Computer Music Journal*, no. 3: 68–77.

– . 1991b. "FTS: A Real-time Monitor for Multiprocessor Music Synthesis". *Computer Music Journal*, no. 3: 58–67.

Pulkki, Ville. 2001b. "Spatial Sound Generation and Perception by Amplitude Panning Techniques". PhD thesis, Helsinki University of Technology.

– . "Generic Panning Tools for MAX MSP": 4.

Pysiewicz, Andreas, and Stefan Weinzierl. 2017. "Instruments for Spatial Sound Control in Real Time Music Performances. a Review". In *Musical Instruments in the 21st Century*, 273–296. Springer.

Rayfield, Donald. 2013. *Anton Chekhov: A Life.* 1st American ed edition. New York: Faber & Faber.

Reich, Steve. 1968. "Music As a Gradual Process". *Writings on Music, 1965-2000*: 34–36.

Richards, John. 2008. "Getting the Hands Dirty". *Leonardo Music Journal*: 25–31.

– . 2013. "Beyond DIY in Electronic Music". *Organised Sound*, no. 3: 274–281.

– . 2017. "The Music of Things". *Journal of the Japanese Society for Sonic Arts*, no. 2: 16–20.

Roads, Curtis. 1980. "Artificial Intelligence and Music". *Computer Music Journal* 4 (2): 13–25.

– . 2003. "The Perception of Microsound and Its Musical Implications". *Annals of the New York Academy of Sciences*, no. 1: 272–281.

– . 2004. *Microsound.* MIT press.

– . 2015. *Composing Electronic Music: A New Aesthetic.* OUP Us.

Roads, Curtis, and John Strawn. 1996. *The Computer Music Tutorial.* MIT press.

Roads, Curtis, et al. 2013b. *Musical Signal Processing.* Routledge.

Roberts, Charles, and Graham Wakefield. 2016. “Live Coding the Digital Audio Workstation”. In *Proceedings of the 2nd International Conference on Live Coding.*

Rodgers, Tara. 2010. *Pink Noises: Women on Electronic Music and Sound.* Duke University Press.

Rohrhuber, Julian, et al. 2007. “Purloined Letters and Distributed Persons”. In *Music in the Global Village Conference (Budapest).*

Rouget, Gilbert. 1980. *La Musique Et La Transe. Esquisse D’une Théorie Générale Des Relations De La Musique Et De La Possession.* Vol. 66. Gallimard Paris.

Rovan, Joseph Butch, et al. 1997. “Instrumental Gestural Mapping Strategies As Expressivity Determinants in Computer Music Performance”. In *Kansei, The Technology of Emotion. Proceedings of the AIMI International Workshop*, 68–73. Citeseer.

Roy, David. 2016. “Masks As a Method: Meyerhold to Mnouchkine”. Ed. by Zoe Strecker. *Cogent Arts & Humanities* 3 (1): 1236436.

Russ, Martin. 2013. *Sound Synthesis and Sampling.* New York: Focal Press.

Rymer, Jess. 2017. “An Argument for Investigation into Collaborative, Choreomusical Relationships within Contemporary Performance: A Practical and Theoretical Enquiry into the Distinct Contributions of a Collaborative, Cocreative Approach.” *Avant*: 181–191.

Rzewski, Frederic. 1999. “Little Bangs: A Nihilist Theory Improvisation”. *Current Musicology*, **numbers** 67-68: 377–386.

Sarath, Ed. 2009. *Music Theory through Improvisation: A New Approach to Musicianship Training.* Routledge.

Sarath, Edward W. 1993. “Improvisation for Global Musicianship: Improvisation Integrates Many Aspects of Music Learning. Edward W. Sarath Looks Specifically at How Improvisation and Multiculturalism Work Together”. *Music educators journal*, no. 2: 23–26.

Savouret, Alain. 2010a. *Introduction À Un Solfège De L’audible: L’improvisation Libre Comme Outil Pratique.*

Schaeffer, Pierre. 2016b. *Traité Des Objets Musicaux.* Nouv. éd. Paris: Le Seuil.

Schlienger, Dominik. 2016. “Acoustic Localisation for Spatial Reproduction of Moving Sound Source: Application Scenarios & Proof of Concept”. In *International Conference on New Interfaces for Musical Interaction.*

Schmidt, Albrecht. 2016. “Increasing Computer Literacy with the BBC Micro: Bit”. *IEEE Pervasive Computing*, no. 2: 5–7.

Schoeberl, Martin. 2008. “A Java Processor Architecture for Embedded Real-time Systems”. *Journal of Systems Architecture*, no. 1: 265–286.

Scholtz, Jean C. 2002. “Human-robot Interactions: Creating Synergistic Cyber Forces”. In *Multi-Robot Systems: From Swarms to Intelligent Automata*, 177–184. Springer.

Schön, Donald A. 1995. “Knowing-in-action: The New Scholarship Requires a New Epistemology”. *Change: The Magazine of Higher Learning*, no. 6: 27–34.

Serra, Marie-Hélène. 1993. “Stochastic Composition and Stochastic Timbre: Gendy3 by Iannis Xenakis”. *Perspectives of New Music* 31 (1): 236–257.

Shepard, Roger N. 2017. "Psychophysical Complementarity". In *Perceptual organization*, 279–341. Routledge.

Sherlock, LaGuinn P, and Craig Formby. 2005. "Estimates of Loudness, Loudness Discomfort, and the Auditory Dynamic Range: Normative Estimates, Comparison of Procedures, and Test-retest Reliability". *Journal of the American Academy of Audiology* 16 (2): 85–100.

Sloboda, John. 2005. *Exploring the Musical Mind: Cognition, Emotion, Ability, Function.* OUP Oxford.

Sloboda, John A. 1986a. "Listening to Music". In *The Musical Mind.* Oxford: Oxford University Press.

– . 1986b. *The Musical Mind: The Cognitive Psychology of Music.* Oxford University Press.

– . 1988. *Generative Processes in Music: The Psychology of Performance, Improvisation, and Composition.* Clarendon Press/Oxford University Press.

Small, Christopher. 2011. *Musicking: The Meanings of Performing and Listening.* Wesleyan University Press.

Smalley, Denis. 1986. "Spectro-morphology and Structuring Processes". In *The language of electroacoustic music*, 61–93. Springer.

– . 1994. "Defining Timbre — Refining Timbre". *Contemporary Music Review* 10 (2): 35–48.

– . 1997. "Spectromorphology: Explaining Sound-shapes". *Organised sound* 2 (2): 107–126.

Smith, Julius O. III. 1991. "Viewpoints on the History of Digital Synthesis". In *Proceedings of the International Computer Music Conference*, 1–10. Montréal, QC: McGill University.

Smith, Robert (Bob). "Sharing Music with Indigenous Australian Boys". In *Collected Work: Male voices: Stories of boys learning through making music.* 79–94. Camberwell: Camberwell, Victoria: ACER Press.

Sobh, Tarek M., Bei Wang, and Kurt W. Coble. 2003. "Experimental Robot Musicians". *Journal of Intelligent and Robotic Systems*, no. 2: 197–212.

Steinberg, J. C. 1925. "The Relation between the Loudness of a Sound and Its Physical Stimulus". *Physical Review*, no. 4: 507–523.

Sterne, Jonathan, and Tara Rodgers. 2011. "The Poetics of Signal Processing". *differences* 22 (2-3): 31–53.

Stevens, John, Julia Doyle, and Ollie Crooke. 2007. *Search and Reflect: A Music Workshop Handbook.* Rockschool.

Straebel, Volker. 2009. "From Reproduction to Performance: Media-specific Music for Compact Disc". *Leonardo Music Journal*: 23–30.

Strange, Allen. 1983. *Electronic Music: Systems, Techniques, and Controls.* William C Brown Pub.

Sutton, John, Celia B. Harris, and Amanda J. Barnier. 2010. "Memory and Cognition". In *Memory*, red. by Susannah Radstone and Bill Schwarz, 209–226. Histories, Theories, Debates. Fordham University.

Suzuki, Daisetz Teitaro. 2017. *Manual of Zen Buddhism.* Youcanprint.

Tarquin, Brian. 2014. *Stomp on This!* Boston: Nelson Education.

Teboul, Ezra. 2017. “The Transgressive Practices of Silicon Luthiers”. In *Guide to Unconventional Computing for Music*, 85–120. Springer.

Teboul, Ezra J. 2015. “Silicon Luthiers: Contemporary Practices in Electronic Music Hardware”. A.M., Dartmouth College.

Thoresen, Lasse. 2012. “Exosemantic Analysis Analysis of Music-as-heard”. Stockholm: The Electroacoustic Music Studies Conference.

Thoresen, Lasse, and Andreas Hedman. 2015. *Emergent Musical Forms: Aural Explorations*. Department of Music Research / Composition, Don Wright Faculty of Music, University of Western Ontario.

Tilbury, John. 2001. *Cardew, Cornelius*. Oxford University Press.

Todd, Peter M., and Gregory M. Werner. 1999. “Frankensteinian Methods for Evolutionary Music”. *Musical networks: parallel distributed perception and performace*: 313–340.

Todorovic, Dejan. 2008. “Gestalt Principles”. *Scholarpedia* 3 (12): 5345.

Toiviainen, Petri. 2013. “Symbolic AI Versus Connectionism in Music Research”. In *Readings in music and artificial intelligence*, 57–78. Routledge.

Tremblay, Pierre Alexandre. 2012. “Mixing the Immiscible: Improvisation within Fixed-media Composition”. In *Proceedings of the Electroacoustic Music Studies Conference Meaning and Meaningfulness in Electroacoustic Music, Stockholm, June 2012*.

Trochimczyk, Maja. 2001. “From Circles to Nets: On the Signification of Spatial Sound Imagery in New Music”. *Computer Music Journal*, no. 4: 39–56.

Truax, Barry. 1998. “Composition and Diffusion: Space in Sound in Space”. *Organised Sound*, no. 2: 141–146.

Tulving, Endel. 1985. “Memory and Consciousness.” *Canadian Psychology/Psychologie canadienne*, no. 1: 1.

Valle, Andrea. 2013. “Making Acoustic Computer Music: The Rumentarium Project”. *Collected Work: Music and the moving image. XVIII/3 (December 2013): Re-wiring electronic music* (Champaign), no. 3: 242–254.

Varèse, Edgard, and Chou Wen-Chung. 1966. “The Liberation of Sound”. *Perspectives of new music*: 11–19.

Viara, Eric. 1991. “CPOS: A Real-time Operating System for the IRCAM Musical Workstation”. *Computer Music Journal*, no. 3: 50–57.

Voegelin, Salomé. 2014. *Listening to Noise and Silence: Towards a Philosophy of Sound Art*. New York, United States: Bloomsbury Academic & Professional.

Vuolevi, Aleksi. 2018. “Replicant Orchestra: Creating Virtual Instruments with Software Samplers”, Tampere University of Applied Sciences.

Walling, Peter T., and Kenneth N. Hicks. 2009. *Consciousness: Anatomy of the Soul*. AuthorHouse.

Wang, Wenwu. 2010. *Machine Audition: Principles, Algorithms and Systems: Principles, Algorithms and Systems*. IGI Global.

Webster, Peter. 2002. “Historical Perspectives on Technology and Music”. *Music Educators Journal*, no. 1: 38–43.

Webster, Peter R. 1990. “Creativity As Creative Thinking”. *Music Educators Journal*, no. 9: 22–28.

Webster, Thomas, Guillaume LeNost, and Martin Klang. 2014. "The OWL Programmable Stage Effects Pedal: Revising the Concept of the On-stage Computer for Live Music Performance." In *Proceedings of the International Conference on New Interfaces for Musical Expression*, 621–624.

Weinberg, Gil. 2002. "The Aesthetics, History and Future Challenges of Interconnected Music Networks." In *International Computer Music Conference.*

Weinberg, Gil, and Scott Driscoll. 2006. "Toward Robotic Musicianship". *Computer Music Journal*, no. 4: 28–45.

Weiss, Jason. 2006. *Steve Lacy: Conversations.* Duke University Press.

Weissenbrunner, Karin. 2017. "Experimental Turntablism-live Performances with Second Hand Technology: Analysis and Methodological Considerations". PhD thesis, City, Universtiy of London.

Werner, K. 1996. "Effortless Mastery: Liberating the Master Musician within (new Albany, IN, Jamey Aebersold)".

Whalley, Ian. 2009. "Software Agents in Music and Sound Art Research/creative Work: Current State and a Possible Direction". *Organised Sound*, no. 2: 156–167.

– . 2015. "Developing Telematic Electroacoustic Music: Complex Networks, Machine Intelligence and Affective Data Stream Sonification". *Organised Sound*, no. 1: 90–98.

Wiggins, Trevor. 2013. "Whose Songs in Their Heads?" In *Collected Work: The Oxford handbook of children's musical cultures.* 590–608. Oxford University Press.

Wigram, Tony. 2004. *Improvisation: Methods and Techniques for Music Therapy Clinicians, Educators, and Students.* Jessica Kingsley Publishers.

Williams, Christopher. 2011a. "Echtzeitmusik Berlin: Selbstbestimmung Einer Szene | Self-defining a Scene". *Critical Studies in Improvisation / Études critiques en improvisation* 7 (2).

Williams, Justin. 2011b. "Historicizing the Breakbeat: Hip-hop's Origins and Authenticity". *Lied und populäre Kultur / Song and Popular Culture* 56:133–167.

Wilson, Ray. 2013. *Make: Analog Synthesizers: Make Electronic Sounds the Synth-DIY Way.* Maker Media, Inc.

Wishart, Trevor. 1985. "Beyond Notation". *British Journal of Music Education*, no. 3: 311–326.

– . 1994. *Audible Design: A Plain and Easy Introduction to Practical Sound Composition.* Orpheus the Pantomime.

– . 1996. *On Sonic Art. a New and Revised Edition.*

Wright, Matthew. 2005. "Open Sound Control: An Enabling Technology for Musical Networking". *Organised Sound*, no. 3: 193–200.

Wright, Matthew, and Adrian Freed. 1997. "Open SoundControl: A New Protocol for Communicating with Sound Synthesizers." In *International Computer Music Conference.*

Xambó, Anna. 2015. "Tabletop Tangible Interfaces for Music Performance: Design and Evaluation". PhD thesis, The Open University.

Xenakis, Iannis. 1992. *Formalized Music: Thought and Mathematics in Composition*. 6. Pendragon Press.
Yanco, Holly A., and Jill L. Drury. 2002. "A Taxonomy for Human-robot Interaction". In *Proceedings of the AAAI Fall Symposium on Human-Robot Interaction*, 111–119.
Young, Michael. 2007a. "Au (or) a: Exploring Attributes of a Live Algorithm". *EMS: Electroacoustic Music Studies Network De Montfort/Leicester*.
– . 2007b. "NN Music: Improvising with a 'living'computer". In *International Symposium on Computer Music Modeling and Retrieval*, 337–350. Springer.
Zölzer, Udo. 2011. *DAFX: Digital Audio Effects*. John Wiley & Sons.
Zuijen, Titia L. van, et al. 2006. "Implicit, Intuitive, and Explicit Knowledge of Abstract Regularities in a Sound Sequence: An Event-related Brain Potential Study". *Journal of Cognitive Neuroscience*, no. 8: 1292–1303.
Zvonar, R. *A History of Spatial Music (2006).*

Online Resources

"555 Oscillator Tutorial - the Astable Multivibrator". Basic Electronics Tutorials. 2013. `https://www.electronics-tutorials.ws/waveforms/555_oscillator.html`.
"A-100 Do It Yourself Page". 2018. `http://www.doepfer.de/DIY/a100_diy.htm`.
"Acts of Discovery - Hughsheehan.com". 2018. `https://hughsheehan.com/Acts-of-Discovery`.
"ADC and DAC Glossary - Tutorial - Maxim". 2018. `https://www.maximintegrated.com/en/app-notes/index.mvp/id/641`.
"AK4137eq | Product | AKM - Asahi Kasei Microdevices". 2018. `https://www.akm.com/akm/en/product/datasheet1/?partno=AK4137EQ`.
Amnesia, N. 2018. In *OED Online*. Oxford University Press.
"Anderson, Laurie | Grove Music". 2018. `http://www.oxfordmusiconline.com/view/10.1093/gmo/9781561592630.001.0001/omo-9781561592630-e-4002261316`.
"Aquatrio Plays Aquarmonio". Vimeo. 2018. `https://vimeo.com/184912956`.
"Axoloti Core | Axoloti". `http://www.axoloti.com/product/axoloti-core/`.
"Bela: An Embedded Platform for Low-latency Interactive Audio". Kickstarter. 2018. `https://www.kickstarter.com/projects/423153472/bela-an-embedded-platform-for-low-latency-interact`.
"Build a Laser Communication System". 2018. `https://www.allaboutcircuits.com/projects/build-a-laser-communication-system/`.
"C411 PP | High-performance Miniature Condenser Vibration Pickup". 2018. `https://fi.akg.com/C411PP.html?dwvar_C411PP_color=Black-GLOBAL-Current`.

Charles, Jean-Francois Emmanuel. “Spectral DJ”. https://www.spectraldj.com/.
“Cockos Incorporated | NINJAM”. 2018. https://www.cockos.com/ninjam/.
“eJAMMING AUDiiO – the Collaborative Network for Musicians Creating Together Online in Real Time”. 2018. http://www.ejamming.com/.
“Electroacoustic Music in the United States | Grove Music”. 2018. http://www.oxfordmusiconline.com/view/10.1093/gmo/9781561592630.001.0001/omo-9781561592630-e-1002249352.
Electroacoustics, N. 2018. In *OED Online*. Oxford University Press.
“Electro-music.com :: Links [DIY Synths and Electronics]”. 2018. http://electro-music.com/forum/links.php?id=28.
“Electronic and Computer Music Instruments - Music - Oxford Bibliographies - Obo”. 2018. http://www.oxfordbibliographies.com/view/document/obo-9780199757824/obo-9780199757824-0204.xml.
“Electronic Instruments | Grove Music”. 2018. http://www.oxfordmusiconline.com/view/10.1093/gmo/9781561592630.001.0001/omo-9781561592630-e-0000008694.
“ER-301 Orthogonal Devices”. http://www.orthogonaldevices.com/er-301.
“EricaSynths - Fusion Drone System”. 2018. https://www.ericasynths.lv/shop/eurorack-systems/fusion-drone-system/.
“Flower Electronics”. 2018. http://www.flowerelectronics.com/.
“George E. Lewis”. Columbia University Department of Music. 2016. Visited on 12/25/2018. https://music.columbia.edu/bios/george-e-lewis.
“Hacking Perl in Nightclubs”. 2018. https://www.perl.com/pub/2004/08/31/livecode.html/.
“Helsinki Meeting Point”. Helsinki Meeting Point. 2018. https://helsinkimeetingpoint.wordpress.com/.
Holzer, Derek. “Macumbista.net”. http://macumbista.net/.
Hopscotch. 2018. In *Wikipedia*. Page Version ID: 875573816. Visited on 12/06/2018.
“Improvisation Summer Series”. Museum of impossible forms. 2018. https://museumofimpossibleforms.org/events/2018/6/1/mif-improvisation-summer-series.
“...:::INSTITUT FUER FEINMOTORIK:::...” 2018. http://www.institut-fuer-feinmotorik.net/info.html.
“JoMoX SunSyn | Vintage Synth Explorer”. 2018. http://www.vintagesynth.com/misc/sunsyn.php.
Knif, Jonte. “Knifaudio”. http://knifaudio.com/knifonium/.
Korg. 2018. “Prologue SDK | Prologue - Polyphonic Analogue Synthesizer | Korg (USA)”. Korg Global. https://www.korg.com/us/products/synthesizers/prologue/sdk.php.
“Leslie | Grove Music”. 2018. http://www.oxfordmusiconline.com/view/10.1093/gmo/9781561592630.001.0001/omo-9781561592630-e-0000047644.
“L’homo-parleur - EARS ElectroAcoustic Resources Site”. 2018. http://ears.pierrecouprie.fr/spip.php?article1170.

"Marc Vilanova". 2019. https://web.archive.org/web/20180815212529/https://www.marcvilanova.com.

McGuffin, N. 2018. In *OED Online*. Oxford University Press.

Moulton, Dave. 2018. "Audio Levels in a Small Listening Room". TVTECHNOLOGY. https://www.tvtechnology.com/opinions/audio-levels-in-a-small-listening-room.

"MozziByte Mozzi Arduino Mini Sensor Sonification Sound Synth". Kickstarter. 2019. https://www.kickstarter.com/projects/mozzibyte/mozzibyte-mozzi-arduino-mini-sensor-sonification-s.

"Music from Outer Space Your Synth-DIY Headquarters". 2018. http://www.musicfromouterspace.com.

"Music Technology / MIR Conference and Journal Calls: MTG/conferences". 2018. Original-date: 2017-06-08T15:18:46Z. Visited on 10/26/2018. https://github.com/MTG/conferences.

"Musical Instrument | Grove Music". 2018. http://www.oxfordmusiconline.com/view/10.1093/omo/9781561592630.001.0001/omo-9781561592630-e-3000000097.

"Musikmesse - Europe's Biggest Trade Fair for the Music Industry". 2018. https://musik.messefrankfurt.com/frankfurt/en.html.

"MuX | Build Sound". 2018. http://www.playmux.com/.

"NAMM - National Association of Music Merchants". NAMM.org. 2018. https://www.namm.org/home.

"Network | Definition of Network in English by Oxford Dictionaries". Oxford Dictionaries | English. 2018. https://en.oxforddictionaries.com/definition/network.

"NIME | International Conference on New Interfaces for Musical Expression". 2018. http://www.nime.org/.

"Noise | Grove Music". 2018. http://www.oxfordmusiconline.com/view/10.1093/gmo/9781561592630.001.0001/omo-9781561592630-e-1002292545.

"Norns". 2018. https://monome.org/norns/.

"Oil Can Delays". 2019. http://www.geofex.com/Article_Folders/oil_can_delays.htm.

Olarte, Alejandro. 2018a. "Eurobela, SuperCollider Patches". https://github.com/Hyppasus/supercollider-eurobela.

– . 2018b. "Pentatonic Melody Generator, SuperCollider Patch". https://github.com/Hyppasus/supercollider-examples/blob/master/Pentatonic-Melody-Generator.scd.

"Online Resources - Synth DIY Wiki". 2018. https://sdiy.info/wiki/Online_resources.

"Op-amp Integrator - the Operational Amplifier Integrator". Basic Electronics Tutorials. 2013. https://www.electronics-tutorials.ws/opamp/opamp_6.html.

"Operational Amplifier Basics - Op-amp Tutorial". Basic Electronics Tutorials. 2013. https://www.electronics-tutorials.ws/opamp/opamp_1.html.

"Percussa Super Signal Processor Eurorack Module". Kickstarter. 2019. https://www.kickstarter.com/projects/percussa/percussa-super-signal-processor-eurorack-module.

"Pisound - Audio & MIDI Interface for Raspberry Pi". Indiegogo. 2018. https://www.indiegogo.com/projects/1983605.

"PJRC Store". 2018. https://www.pjrc.com/store/teensy3_audio.html.

"Plugin Boutique Radio Review - Find Your Frequency". MUSICTECH. 2018. Visited on 12/04/2018. https://www.musictech.net/2018/03/plugin-boutique-radio-review/.

"Popular Mechanics 1966". 2018. https://archive.org/stream/PopularMechanics1966/Popular%20mechanics-06-1966#page/n173/mode/2up.

"PZ-pre - Radial Engineering". 2018. Visited on 11/19/2018. https://web.archive.org/web/20181108223541/http://www.radialeng.com/product/pz-pre.

"S-2000 Synthesizer". 2018. http://www.metasonix.com/index.php/s-2000-synthesizer.

"Schertler Group - Pickups - DYN-UNI-p48". 2018. https://www.schertler.com/en_IT/shop/pickups/dyn-uni-p48.

Slub (band). 2017. In *Wikipedia*. Page Version ID: 800184496. Visited on 12/12/2018.

Sonogram, N. 2018. In *OED Online*. Oxford University Press.

"Symphony | Music". Encyclopedia Britannica. 2018. https://www.britannica.com/art/symphony-music.

"Synthesizer | Grove Music". 2018. http://www.oxfordmusiconline.com/view/10.1093/gmo/9781561592630.001.0001/omo-9781561592630-e-0000027270.

"Telharmonium | Grove Music". 2018. http://www.oxfordmusiconline.com/view/10.1093/gmo/9781561592630.001.0001/omo-9781561592630-e-0000046183.

"The Beauty of Noise: An Interview with Masami Akita of Merzbow by Chad Hensley". 2018. http://www.esoterra.org/merzbow.htm.

Thompson, Bill. 2018. "CEC — eContact! 12.3 — Scrapyard Aesthetics and the Swansong of the Inspiron by Bill Thompson". CEC | Canadian Electroacoustic Community. https://econtact.ca/12_3/thompson_dismantle.html.

"Toplap". 2018. https://toplap.org/wiki/Main_Page.

"Turntablism | Grove Music". 2018. http://www.oxfordmusiconline.com/view/10.1093/gmo/9781561592630.001.0001/omo-9781561592630-e-1002225770.

"Tutorials | JUCE". 2018. https://juce.com/learn/tutorials.

Watson, rew, and Nicolas Basque. 2018. "CEC — eContact! 7.4 — Diffusion Multi-canal 2 / Multi-channel Diffusion 2". CEC | Canadian Electroacoustic Community. https://econtact.ca/7_4/index.html.

"Weber's Law of Just Noticeable Difference". 2018. http://apps.usd.edu/coglab/WebersLaw.html.

Weisstein, Eric W. 2018. "Line Segment". http://mathworld.wolfram.com/LineSegment.html.

Zvonar, Richard. 2018. "CEC — eContact! 7.4 — a History of Spatial Music". CEC | Canadian Electroacoustic Community. https://econtact.ca/7_4/zvonar_spatialmusic.html.

Patents

Anderson, Claudia Amelia Parry, Jeffrey David Anderson, and Steven E. Bash (Audio Enhancement). 1998. Method and System for Providing Improved Wireless Audio Transmission. U.S. pat. 5818328A, **patentfiled**1998.

Besnainou, Charles, and Stephane Vaiedelich. 1992. Bow Musical Instrument Made of Composite Material. Pat., **patentfiled**1992.

Boyden, James H. (Interval Research Corp). 1998. Portable Speakers with Phased Arrays. U.S. pat. 5815579A, **patentfiled**1998.

Iwahara, Makoto, and Toshinori Mori. 1978. Stereophonic Sound Reproduction System. Pat., **patentfiled**1978.

Peters, Nils Günther, Dipanjan Sen, and Martin James Morrell. 2018. Transformed Higher Order Ambisonics Audio Data. Pat., **patentfiled**2018.

Ssergejewitsch, Theremin Leo (Firm Of M J Goldberg Und Sohne). 1928. Method of and Apparatus for the Generation of Sounds. U.S. pat. 1661058A, **patentfiled**1928.

List of Figures

All the illustrations are by Outi Korhonen specifically designed to accompany this book and are based on audiovisual material collected along the research process by the author.

Thematic Bibliography

Improvisation

Acosta, Rodolfo. 2018. "Experimentation and improvisation in Bogotá at the end of the twentieth century". In *Experimentalisms in practice: Music perspectives from Latin America*, 227–250. Oxford University Press.

Alperson, Philip. 2010a. "A topography of improvisation". *The Journal of Aesthetics and Art Criticism* 68 (3): 273–280.

– . 2016. “Musical improvisation and the philosophy of music”. In *The Oxford handbook of critical improvisation studies, vol. 1. Series: Oxford handbooks, (Number of volumes: 2)*, 419–438. New York: Oxford University Press.

Amiot, Emmanuel, et al. “Fourier Oracles for Computer-Aided Improvisation”: 4.

Andean, James, and Alejandro Olarte. 2018. “Sound Practices: The Sonic and the Musical in Interdisciplinary Improvisation”. In *Music and Sonic Art, Theories and Practices*, **by** John Dack Mine Doğantan-Dack. Cambridge Scholars Publishing.

Arthurs, Tom. 2015a. “Improvised music in Berlin 2012-13: a brief ethnographic portrait”. *Critical Studies in Improvisation/Études critiques en improvisation* 10 (2).

– . 2015b. “The Secret Gardeners: An Ethnography of Improvised Music in Berlin (2012-13)”. PhD thesis, The University of Edinburgh.

– . 2016b. “Improvised Music in Berlin 2012-13: A Brief Ethnographic Portrait”. *Critical Studies in Improvisation / Études critiques en improvisation* 10 (2).

Ashline, William L. 2003. “The Pariahs of Sound: On the Post-Duchampian Aesthetics of Electro-acoustic Improv”. *Contemporary Music Review* 22 (4): 23–33.

Azzara, Christopher D. 1991. “Audiation, improvisation, and music learning theory”. *The quarterly. II/1-2: The work of Edwin Gordon.* 2 (1): 106–109.

– . 1999. “An Aural Approach to Improvisation: Music educators can teach improvisation even if they have not had extensive exposure to it themselves. Here are some basic strategies”. *Music Educators Journal* 86 (3): 21–25.

Barrett, Richard, et al. “Notation in Contemporary Music: Composition, Performance, Improvisation”.

Beaty, Roger E., et al. 2016. “Creative Cognition and Brain Network Dynamics”. *Trends in Cognitive Sciences* 20 (2): 87–95.

Berkowitz, Aaron L., and Daniel Ansari. 2010. “Expertise-related deactivation of the right temporoparietal junction during musical improvisation”. *Neuroimage* 49 (1): 712–719.

Berliner, Paul F. 1995. “Thinking in jazz: The infinite art of improvisation”. Ed. by Jeff (Reviewer) Pressing. *Music perception: An interdisciplinary journal* 13 (2): 247–53.

Bethune, Christian. 2009. “L’improvisation comme processus d’individuation”. *Critical Studies in Improvisation / Études critiques en improvisation* 5 (1).

Béthune, Christian. 2010. “De l’improvisation”. *Nouvelle revue d’esthétique* 5 (5): 153–160.

Biasutti, Michele. 2015. “Pedagogical applications of cognitive research on musical improvisation”. *Frontiers in psychology* 6:614.

Bjerstedt, Sven, and Musikhögskolan i Malmö. 2014. “Storytelling in jazz improvisation: implications of a rich intermedial metaphor”. PhD thesis, Lund University, Malmö Academy of Music.

Borgo, David, and Joseph Goguen. 2004. "Sync or swarm: Group dynamics in musical free improvisation". In *Proceedings, Conference on Interdisciplinary Musicology*, 52–53.

Bowers, John. "Improvising Machines Ethnographically Informed Design For Improvised Electro-Acoustic Music". PhD thesis.

Bowers, John, et al. 2014. "HCI: human-computer improvisation". In *Proceedings of the 2014 companion publication on Designing interactive systems*, 203–206. ACM.

Bresnahan, Aili. 2015. "Improvisation in the Arts". *Philosophy Compass* 10 (9): 573–582.

Bryan-Kinns, N. 2004a. "Mobile group music improvisation". *Proc. of Engagability and Design 2004, Birmingham, UK.*

Bryan-Kinns, Nick. 2004b. "Daisyphone: the design and impact of a novel environment for remote group music improvisation." In *Proceedings of the 2004 conference on Designing interactive systems processes, practices, methods, and techniques - DIS '04*, 135–144. Cambridge, MA, USA: ACM Press.

Burnard, Pamela. 2000. "How children ascribe meaning to improvisation and composition: rethinking pedagogy in music education". *Music education research* 2 (1): 7–23.

Burrows, Jared. 2004. "Resonances: Exploring improvisation and its implications for music education". PhD thesis, Theses (Faculty of Education)/Simon Fraser University.

Casal, David Plans, and Davide Morelli. 2007. "Remembering the future: applications of genetic co-evolution in music improvisation". In *Proceedings of the European Conference on Artificial Life*, 21.

Charles, Jean-Francois Emmanuel. 2011. "Music Composition: An Interactive Approach". PhD thesis, Harvard University.

Childs, Barney, et al. 1982. "Improvisation". *Perspectives of New Music*: 26–111.

Cobussen, Marcel, Henrik Frisk, and Bart Weijland. 2010. "The Field of Musical Improvisation". *Konturen* 2 (1): 168–185.

COSTA, Rogério, and Stéphan Schaub. 2013. "Expanding the concepts of knowledge base and referent in the context of collective free improvisation". In *XXIII Congresso da Anppom. Natal.*

Covington, Kate. 1997. "Improvisation in the Aural Curriculum: An Imperative". *College Music Symposium* 37:49–64.

Dahlhaus, Carl. 1972. "Komposition und Improvisation". *Neue Zeitschrift für Musik* 133 (9): 496–99.

– . 2000b. "Was heisst Improvisation?" In *Allgemeine Theorie der Musik. I: Historik–Grundlagen der Musik–Ästhetik. Series: Carl Dahlhaus: Gesammelte Schriften in 10 Bänden, No. 1*, 405–417. Laaber: Laaber-Verlag.

– . 2004. "Composition et improvisation". *Essais sur la nouvelle musique*: 191–200.

Dahlhaus, Carl, Marion Siéfert, and Lucille Lisack. 2010. "Qu'est-ce que l'improvisation musicale?" *Tracés: Revue de sciences humaines. 18 (mai 2010): Improviser: De l'art à l'action*, no. 18: 181–196.

Davidson, Neil. “Composition in Improvisation: Forms and Otherwise”: 133.
Déguernel, Ken. 2018. “Apprentissage de structures musicales en contexte d’improvisation”. PhD thesis, Université de Lorraine.
DeMarco, Tobyn C. 2012. “The Metaphysics of Improvisation”.
Dessen, Michael. 2010. “New polyphonies: Score streams, improvisation and telepresence”. *Leonardo Music Journal*: 21–23.
Disappearance, Disparagement. 2016. “Musical Improvisation and the Philosophy of Music”. *The Oxford Handbook of Critical Improvisation Studies* 1:419.
Duch, Michael Francis. “Free Improvisation – Method and Genre”: 1.
Eckel, Gerhard. 2013. “Improvisation as epistemic practice”. *H. Frisk and S. Österjö (Eds.)* 42–47.
Eigenfeldt, Arne. 2007. “Real-time Composition or Computer Improvisation? A composer’s search for intelligent tools in interactive computer music”. *Proceedings of the Electronic Music Studies* 2007.
Elliott, Marissa Silverman, and Gary McPherson. “Improvisation, Enaction, and Self-Assessment”.
Etty, B. 2002. “Critical thinking”. In *The new handbook of research on music teaching and learning: A project of the music educators national conference*, 162. Oxford University Press.
Figueroa, Silvana K. 2003. “Musical Improvisation as a Type of Action”. In *R. Kopiez et al.(Hg.), Proceedings of the 5th Triennial ESCOM Conference, Hannover: University of Music and Drama*, 570–573.
Filsinger, Mark H. “Novice Music Teachers Learning to Improvise in an Improvisation Professional Development Workshop”: 466.
Ford, Charles C. 1995. “Free collective improvisation in higher education”. *British Journal of Music Education* 12 (2): 103–112.
François, Alexandre RJ, Isaac Schankler, and Elaine Chew. 2013. “Mimi4x: An interactive audio-visual installation for high-level structural improvisation”. *International Journal of Arts and Technology* 6 (2): 138–151.
Gagne, Christopher R. 2014. “Improvisation within the beginning band curriculum: Creating a comprehensive improvisational resource for the middle school music educator”.
Goldman, Andrew. 2013. “Towards a cognitive–scientific research program for improvisation: Theory and an experiment.” *Psychomusicology: Music, Mind, and Brain* 23 (4): 210.
Gould, Carol S., and Kenneth Keaton. 2000. “The essential role of improvisation in musical performance”. *The Journal of Aesthetics and Art Criticism* 58 (2): 143–148.
Green, Lucy. 2005. “The music curriculum as lived experience: Children’s natural music-learning processes”. *Music educators journal. XCI/4 (March 2005): Reconceptualizing curriculum* 91 (4): 27–32.
Hagelia, Ole Andreas Undhjem. 2018. “Obtaining a unique sound in improvised sampling music using the iPad: Improvisational techniques with the iPad in interplay with other conventional instruments”. Master’s Thesis, Universitetet i Agder; University of Agder.

Hamilton, A. 2000. “The art of improvisation and the aesthetics of imperfection”. *The British Journal of Aesthetics* 40 (1): 168–185.

Hamilton, Andy. 1990. “The Aesthetics of Imperfection”. *Philosophy* 65 (253): 323–340.

– . 2002. “15 The art of improvisation and the aesthetics of imperfection”. *Teaching music in secondary schools: a reader*: 209.

Hickey, Maud. 2009. “Can improvisation be ‘taught’?: A call for free improvisation in our schools”. *International Journal of Music Education* 27 (4): 285–299.

Hsu, William. 2008. “Two Approaches for Interaction Management in Timbre-Aware Improvisation Systems.” In *ICMC*.

Hunt, Joel V. 2018b. “Negotiated Moments: Improvisation, Sound, and Subjectivity ed. by Gillian Siddall and Ellen Waterman”. *Notes* 75 (2): 306–310.

“Introduction: Improvisation”: 4.

Kamoche, Ken, Miguel Pina e Cunha, and João Vieira da Cunha. 2003. “Towards a theory of organizational improvisation: Looking beyond the jazz metaphor”. *Journal of Management Studies* 40 (8): 2023–2051.

Kanellopoulos, Panagiotis. 2007. “Musical improvisation as action: An Arendtian perspective”. *Action, Criticism, and Theory for Music Education* 6 (3): 97–127.

Kanellopoulos, Panagiotis A. 1999. “Children’s conception and practice of musical improvisation”. *Psychology of Music* 27 (2): 175–191.

Keipi, Aaro. 2016. “The inspiration in improvisation: identifying and classifying the approaches to emotion-based musical improvisation”.

King, Adelaide Wilcox, and Annette L. Ranft. 2001. “Capturing knowledge and knowing through improvisation: What managers can learn from the thoracic surgery board certification process”. *Journal of management* 27 (3): 255–277.

Kloppenberg, Annie. 2010. “Improvisation in process: ‘Post-control’ choreography”. *Dance Chronicle* 33 (2): 180–207.

Lange, Barbara Rose. 2011a. “Teaching the Ethics of Free Improvisation”. *Critical Studies in Improvisation / Études critiques en improvisation* 7 (2).

– . 2011b. “Teaching the ethics of free improvisation”. *Critical Studies in Improvisation/Études critiques en improvisation* 7 (2).

Lewis, George E. 2000b. “Ways & Means: Too Many Notes - Computers, Complexity and Culture in "Voyager"”. *Leonardo Music Journal; Cambridge, Mass.* 10:33–39.

Lexer, Sebastian. 2012. “Live Electronics in Live Performance: A Performance Practice Emerging from the piano+ used in Free Improvisation.” PhD thesis, Goldsmiths, University of London.

Linson, Adam. 2014. “Investigating the cognitive foundations of collaborative musical free improvisation: Experimental case studies using a novel application of the subsumption architecture”. PhD thesis, The Open University.

– . “Fundamental considerations for empirical computational research on improvisation”.

Linson, Adam, et al. 2015. “A subsumption agent for collaborative free improvisation”. *Computer Music Journal* 39 (4): 96–115.

Magerko, Brian, et al. 2009. "An empirical study of cognition and theatrical improvisation". In *Proceeding of the seventh ACM conference on Creativity and cognition - C&C '09*, 117. Berkeley, California, USA: ACM Press.

Marshman, Anne T. 2003. "The power of music: A Jungian aesthetic". *Music Therapy Perspectives* 21 (1): 21–26.

Mcauliffe, Sam. 2017. "Studying Sonorous Objects to Develop Frameworks for Improvisation". *Organised Sound; Cambridge* 22 (3): 369–377.

Menezes, Jose Manuel. "Creative process in free improvisation". Master Thesis, University of Sheffield.

Mills, R. H. 2010. "Dislocated sound: A survey of improvisation in networked audio platforms". In *New Interfaces for Musical Expression.* University of Technology, Sydney.

Mills, Roger, and Kirsty Beilharz. 2012. "Listening Through the Firewall: Semiotics of sound in networked improvisation". *Organised Sound* 17 (1): 16–27.

Mooney, J. R., A. Parkinson, and P. Bell. 2008. "Sound spatialisation, free improvisation and ambiguity". In *Proceedings of the SMC Conference 2008.* Sound / Music Computing.

Moore, Robin. 1992. "The decline of improvisation in Western art music: An interpretation of change". *International review of the aesthetics and sociology of music*: 61–84.

Nachmanovitch, Stephen. 1990a. "Free play: Improvisation in art and life". *New York: Tarcher.*

– . 1990c. *Free play: Improvisation in life and art.* Penguin.

– . 2006. "Improvisation as a tool for investigating reality". *Keynote address – International Society for Improvised Music University of Michigan, Ann Arbor.*

Neeman, Edward. 2014. "Free Improvisation as a Performance Technique: Group Creativity and Interpreting Graphic Scores". PhD thesis, Juilliard School.

– . "Free Improvisation as a Performance Technique:" 206.

Nettl, Bruno. 1974. "Thoughts on improvisation: A comparative approach". *The Musical Quarterly* 60 (1): 1–19.

Nettl, Bruno, et al. 2013. "Improvisation. Grove music online". *Oxford Music Online. Oxford University Press. Retrieved from http://www. oxfordmusiconline. com/subscriber/article/grove/music/13738. Retrieved May* 6:2013.

Neuman, Israel. 2015. "SIG~: Performance Interface for Schaefferian Sound-Object Improvisation". In *ICMC.*

Nika, Jérôme. 2016. "Guiding human-computer music improvisation: introducing authoring and control with temporal scenarios". PhD thesis, UPMC - Université Paris 6 Pierre et Marie Curie.

Nunn, Tom. 1988. "Electroacoustic percussion boards: sculptured musical instruments for improvisation". *Leonardo* 21 (3): 261–265.

O'Neill, Brian, et al. 2011a. "A Knowledge-Based Framework for the Collaborative Improvisation of Scene Introductions". In *Interactive Storytelling*, ed. by Mei Si et al., 85–96. Lecture Notes in Computer Science. Springer Berlin Heidelberg.

Parmar, Robin. 2011. "No Input Software: Cybernetics, Improvisation, and The Machinic Phylum". *ISSTA 2011.*

Payne, Cynthia. 2007. "Procedures and Approaches in Telepresent Music Improvisation".

Pressing, Jeff. 1984c. "The history of classical improvisation: A thousand years of fluid performance traditions". *Keyboard* 10 (12): 59.

– . 1986. "Cognitive processes in improvisation". Ed. by Jamshed J. (Reviewer) Bharucha. *Music perception: An interdisciplinary journal* 3 (3): 315–22.

– . 1987. "The micro- and macrostructural design of improvised music". *Music perception: An interdisciplinary journal* 5 (2): 133–72.

– . 1998b. "Psychological Constraints on Improvisational Expertise and Communication". *The Course Of Performance: Studies In The World Of Musical Improvisation*: 47–67.

Racy, Ali Jihad. 1998. "Improvisation, ecstasy, and performance dynamics in Arabic music". *In the course of performance: Studies in the world of musical improvisation*: 95–112.

– . 2000. "The many faces of improvisation: The Arab Taqāsīm as a musical symbol". *Ethnomusicology*: 302–320.

Ratté, Michel. 1997. "Improvisation as form". *Resonance* 6 (1): 28–31.

Rzewski, Frederic. 2006. "On improvisation." *Contemporary Music Review* 25 (5/6): 491–495.

Sansom, Matthew. 2001. "Imaging Music: Abstract Expressionism and Free Improvisation". *Leonardo Music Journal* 11:29–34.

Sansom, Matthew James. 1997. "Musical meaning: A qualitative investigation of free improvisation". PhD thesis, University of Sheffield.

– . 2007. "Improvisation & Identity: a Qualitative Study". *Critical Studies in Improvisation/Études critiques en improvisation* 3 (1).

Saunders, James. 2017. *The Ashgate Research Companion to Experimental Music.* Routledge.

Savery, Richard James. 2015. "Algorithmic Improvisers". M.F.A., University of California, Irvine.

Savouret, Alain. 2010b. *Introduction à un solfège de l'audible: l'improvisation libre comme outil pratique.*

Sayer, Tim. 2016. "Cognitive load and live coding: a comparison with improvisation using traditional instruments". *International Journal of Performance Arts and Digital Media* 12 (2): 129–138.

Schyff, Dylan van der. 2013. "The Free Improvisation Game: Performing John Zorn's Cobra". *Journal of Research in Music Performance.*

– . "The Free Improvisation Game: Performing John Zorn's Cobra".

Scully, Patrick. 2014. "The pedagogy of improvisation".

Seabrook, Deborah. 2017. "Performing Wellness: Playing in the Spaces Between Music Therapy and Music Performance Improvisation Practices". In *Voices: A World Forum for Music Therapy*, vol. 17.

Sherman, Carl. 2011. "The neuroscience of improvisation". *The Dana Foundation.*

Sipilä, Jasmiina. 2015. "Moving in a Landscape of an Inter-disciplinary Improvisation Performance": 76.

Sloboda, John. 2001. *Generative Processes in MusicThe Psychology of Performance, Improvisation, and Composition.* Oxford University Press.

Solomon, Larry. 1986. "Improvisation ii". *Perspectives of new music*: 224–235.

Soules, Marshall. 2004. "Improvising character: Jazz, the actor, and protocols of improvisation". *The other side of nowhere: Jazz, improvisation, and communities in dialogue*: 268–297.

Stefanou, Danae. "Investigating Social Creativity and Concept Invention in Collaborative Musical Situations": 6.

Teitelbaum, Richard. 2006. "Improvisation, computers and the unconscious mind". *Contemporary Music Review* 25 (5): 497–508.

Thomson, Scott. 2006. "Minute Particulars: Meanings in Music-Making in the Wake of Hierarchical Realignments and Other Essays". *Critical Studies in Improvisation/Études critiques en improvisation* 1 (3).

– . 2007a. "The Pedagogical Imperative of Musical Improvisation". *Critical Studies in Improvisation / Études critiques en improvisation* 3 (2).

– . 2007b. "The pedagogical imperative of musical improvisation". *Critical Studies in Improvisation/Études critiques en improvisation* 3 (2).

Van Nort, Doug, Pauline Oliveros, and Jonas Braasch. 2013. "Electro/acoustic improvisation and deeply listening machines". *Journal of New Music Research* 42 (4): 303–324.

Verrico, Kristina, and Jill Reese. 2016. "University musicians' experiences in an iPad ensemble: A phenomenological case study". *Journal of Music, Technology & Education* 9 (3): 315–328.

Veselinović-Hofman, Mirjana. 1995. "Aspects of alterity of a music piece". *4th international symposium Folklore–Music–Work of Art*: 1–8.

Vithoulkas, G, and DF Muresanu. 2014. "Conscience and Consciousness: a definition". *Journal of Medicine and Life* 7 (1): 104–108.

Walduck, Jacqueline Sarah. 1997. "Role-taking in free improvisation and collaborative composition". PhD thesis, City University London.

Waters, Simon. 2018. "Contribution Towards an Ethics of Listening: An Improvising Musician's Perspective". *Critical Studies in Improvisation / Études critiques en improvisation* 12 (1).

Weinberg, Gil, et al. 2007. "A real-time genetic algorithm in human-robot musical improvisation". In *International Symposium on Computer Music Modeling and Retrieval*, 351–359. Springer.

Wierenga, Stephen Red. 2016. "Searching for Sounds: Instrumental Agency and Modularity in Electroacoustic Improvisation". PhD thesis, City University of New York.

work(s): Bruno Nettl Reviewed. 1974. "Thoughts on Improvisation: A Comparative Approach". *The Musical Quarterly* 60 (1): 1–19.

Xambó, Anna, et al. 2014. "SoundXY4: Supporting tabletop collaboration and awareness with ambisonics spatialisation". *Proceedings of the International Conference on New Interfaces for Musical Expression (NIME 2014)*: 40–45.

Electroacoustic & Computer Music

Andean, James. 2011. “Ecological psychology and the electroacoustic concert context”. *Organised Sound* 16 (2): 125–133.

Appleton, Jon. 1999. “Reflections of a former performer of electroacoustic music”. *Contemporary Music Review* 18 (3): 15–19.

Atkinson, Simon, and Leigh Landy. 2004. “The Electroacoustic Resource Site (ears): Philosophy, Foundation and Aspirations.” *Organised sound: An international journal of music technology* 9 (1): 79–85.

Bailes, Freya, and Roger T. Dean. 2012. “Comparative time series analysis of perceptual responses to electroacoustic music”. *Music Perception: An Interdisciplinary Journal* 29 (4): 359–375.

Barreiro, Daniel L. 2010. “Considerations on the handling of space in multichannel electroacoustic works”. *Organised Sound* 15 (3): 290–296.

Basanta, Adam. 2010. “Syntax as Sign: The use of ecological models within a semiotic approach to electroacoustic composition”. *Organised Sound; Cambridge* 15 (2): 125–132.

Battier, Marc, and Leigh Landy. 2004. “Electroacoustic musics: a century of innovation involving sound and technology - resources, discourse, analytical tools”. *Organised Sound; Cambridge* 9 (1): 1–2.

Bell, Adam. 2016. “The Process of Production| The Production of Process: The Studio as Instrument and Popular Music Pedagogy”. *21st Century Music Education: Informal Learning and Non-Formal Teaching* 7.

Berweck, Sebastian. 2012. “It worked yesterday: On (re-) performing electroacoustic music”. PhD thesis, University of Huddersfield.

Bossis, Bruno. 2006. “The Analysis of Electroacoustic Music: from sources to invariants”. *Organised Sound* 11 (2): 101–112.

Camargo, Lucio Edilberto Cuellar. 2000. “The Development of Electroacoustic Music in Colombia, 1965-1999: An Introduction”. *Leonardo Music Journal* 10:7–12.

Camilleri, Lelio, and Denis Smalley. 1998. “The analysis of electroacoustic music: Introduction”. *Journal of New Music Research* 27 (1): 3–12.

Canazza, Sergio, et al. “Active Preservation Of Electrophone Musical Instruments. The Case Of The “Liettizzatore” Of “Studio Di Fonologia Musicale” Rai, Milano”: 6.

Clarke, Michael. 2012. “Analysing Electroacoustic Music: an Interactive Aural Approach”. *Music Analysis* 31 (3): 347–380.

Coessens, Kathleen. 2017. “An Afterthought to Experimental Encounters”. *Experimental Encounters in Music and Beyond*: 197.

Collins, Nicholas. Nick Collins Reading List.

Cooley, J. W., P. Lewis, and Peter Welch. 1967. “Historical notes on the fast Fourier transform”. *IEEE Transactions on Audio and Electroacoustics* 15 (2): 76–79.

Cox, Cathy Lynn. 2006. “Listening to acousmatic music”. PhD thesis, Columbia University.

Davies, Hugh, ed. 2014. "The Grove Dictionary of Musical Instruments". In *Electronic Instruments*, 2:151–193. New York: Oxford University Press.

Dean, Roger T. 2014. "Low Frequency Spatialization In Electroacoustic Music And Performance: Composition Meets Perception". *Acoustics Australia* 42 (2).

Dean, Roger T., and Freya Bailes. 2010. "A rise–fall temporal asymmetry of intensity in composed and improvised electroacoustic music". *Organised Sound* 15 (2): 147–158.

Eigenfeldt, Arne. 2011. "Real-time Composition as Performance Ecosystem". *Organised Sound; Cambridge* 16 (2): 145–153.

Emmerson, Simon. 1998. "Acoustic/electroacoustic: the relationship with instruments". *Journal of new music research* 27 (1): 146–164.

– . 2008. "Pulse, metre, rhythm in electro-acoustic music". In *Electroacoustic Music Studies Network International Conference Proceedings*, 2–7.

EMS, Network. 2015. "EMS2015: The Art of Electroacoustic Music". In *EMS2015: The Art of Electroacoustic Music.* The University of Sheffield: The EMS Network.

Fujii, Koichi. 2004. "Chronology of early electroacoustic music in Japan: What types of source materials are available?" *Organised Sound* 9 (1): 63–77.

Garrison, Travis. 2013. "Reconsidering the model listener: An exploration in the critical analysis of electroacoustic music". PhD thesis, University of Florida.

Haworth, Christopher. 2016. "'All the Musics Which Computers Make Possible': Questions of genre at the Prix Ars Electronica". *Organised Sound; Cambridge* 21 (1): 15–29.

Hoffman, Elizabeth. 2013. "On Performing Electroacoustic Musics: a non-idiomatic case study for Adorno's theory of musical reproduction". *Organised Sound; Cambridge* 18 (1): 60–70.

Hunt, Joel V. 2018a. "Expanding the Horizon of Electroacoustic Music Analysis ed. by Simon Emmerson and Leigh Landy". *Notes* 74 (4): 635–639.

Ishii, Hiromi. 2018. "Japanese Electroacoustic and Japanese Instruments". *Contemporary Music Review* 37 (1): 49–66.

Jordà, Sergi, et al. 2005. "The reacTABLE". *Free sound. Series: Proceedings of the International Computer Music Association*: 579–582.

Kendall, Gary S. 2010a. "Meaning in Electroacoustic Music and the Everyday Mind". *Organised Sound; Cambridge* 15 (1): 63–74.

– . 2010b. "Spatial perception and cognition in multichannel audio for electroacoustic music". *Organised Sound* 15 (3): 228–238.

Kolkowski, Aleksander{\textbar}Rabinovici, Alison, ed. 2013. "Material Culture and Electronic Sound". In *Bellowphones and Blowed Strings: The Auxeto-Instruments of Horace Short and Charles Algernon Parsons*, 1–42. Washington, DC: Smithsonian Scholarly Press.

Landy, Leigh. 2007a. "The ElectroAcoustic Resource Site (EARS)". *Journal of Music, Technology & Education* 1 (1): 69–81.

– . 2007b. "The ElectroAcoustic Resource Site (EARS) approaches its next phase: going global and addressing the young." In *ICMC.* Citeseer.

Lynch, Hugh, and Robert Sazdov. 2011a. "An Ecologically Validexperiment For The Comparison Of Established Spatialtechniques": 5.

– . 2011b. "An Investigation into Compositional Techniques Utilized for the Three-dimensional Spatialization of Electroacoustic Music". In *Proceedings of the Electroacoustic Music Studies Conference, New York.*

– . 2013. "An Investigation into the Perception of Spatial Techniques Used in Multi-Channel Electroacoustic Music". In *International Computer Music Conference.* Michigan Publishing.

– . 2017. "A perceptual investigation into spatialization techniques used in multichannel electroacoustic music for envelopment and engulfment". *Computer Music Journal* 41 (1): 13–33.

Massa, Donald P. "An Overview of Electroacoustic Transducers": 19.

Massa, Frank. 1985. "Some personal recollections of early experiences on the new frontier of electroacoustics during the late 1920s and early 1930s". *The Journal of the Acoustical Society of America* 77 (4): 1296–1302.

Maubrey, Benoit. 1995. "Audio jackets and other electroacoustic clothes". *performances with clothing equipped with sound amplifiers and loud speakers* 28 (2): 93–97.

McNutt, Elizabeth. 2003. "Performing electroacoustic music: a wider view of interactivity". *Organised Sound* 8 (3): 297–304.

Menzies, Dylan. 1999. "New performance instruments for electroacoustic music". PhD thesis.

Miranda, Eduardo Reck. 2013. *Readings in music and artificial intelligence.* Vol. 20. Routledge.

Mooney, J. R. 2015a. "Hugh Davies's Electroacoustic Musical Instruments and their Relation to Present-Day Live Coding Practice: Some Historic Precedents and Similarities". In *Proceedings of the First International Conference on Live Coding*, 53–62. ICSRiM.

Mooney, JR. "Hugh Davies's Electroacoustic Musical Instruments and their Relation to Present-Day Live-Coding Practice : Four Suggestions": 10.

Moore, Adrian, and Adam Stansbie. 2013. "Compositional methods in electroacoustic music". *Journal of Music, Technology & Education* 6 (3): 251–254.

Moore, Adrian, et al. 2013. "Tracking production strategies: Identifying compositional methods in electroacoustic music". *Journal of Music, Technology & Education* 6 (3): 323–336.

Ojanen, Mikko. 2014. "Electroacoustic concert and happening performances of the '60s and early '70s in Finland". *EMS Proceedings and Other Publications EMS14-Electroacoustic Music Beyond Concert Performance.*

Otondo, Felipe. 2007. "Recent spatialisation trends in electroacoustic music". In *Proceedings of the Electroacoustic Music Studies Conference.*

– . 2008. "Contemporary trends in the use of space in electroacoustic music". *Organised Sound* 13 (1).

– . 2018. "Recent spatialisation trends in electroacoustic music".

Patton, Kevin. 2007. "Morphological notation for interactive electroacoustic music". *Organised Sound* 12 (2): 123–128.

Pennycook, Bruce. 1997. “Live electroacoustic music: old problems, new solutions”. *Journal of New Music Research* 26 (1): 70–95.

Rataj, Michal. 2010. “Electroacoustic Music and Selected Concepts of Radio Art”. *Saarbrucken: PFAU-Verlag.*

Rhea, Thomas. 1972. “The Evolution of Electronic Musical Instruments in the United States”. PhD thesis.

Smalley, Denis. 1996. “The listening imagination: listening in the electroacoustic era”. *Contemporary Music Review* 13 (2): 77–107.

Stavropoulos, Nikos. 2006. “Multi-channel formats in electroacoustic composition: Acoustic space as a carrier of musical structure”. In *Proceedings of the Digital Music Research Network Conference, London, UK.*

Stead, Michelle. 2016a. “Learning to listen: the construction of listening in electroacoustic music discourse”.

Stead, Michelle Melanie. 2016b. “Learning to Listen: The Construction of Listening in Electroacoustic Music Discourse”. PhD thesis, Western Sydney University (Australia).

Stockhausen, Karlheinz, and Jerome Kohl. 1996. “Electroacoustic Performance Practice”. *Perspectives of New Music* 34 (1): 74.

Stollery, Pete. 2013. “Capture, manipulate, project, preserve: A compositional journey”. *Journal of Music, Technology & Education* 6 (3): 285–298.

Swendsen, Peter Vinding. 2009. “The Threshold of Electroacoustic Music and Dance: A Compositional and Theoretical Exploration of Contemporary Choreo-Musical Practice”. PhD thesis, University of Virginia.

Terrien, Pascal. 2013. “For a Didactical Approach to Electroacoustic Musics: The example of Metallics by Yan Maresz”. *Organised Sound; Cambridge* 18 (2): 161–169.

Therapontos, Nasia, and Dimitrios Savva. “Electroacoustic Musiccomposition In The Music School Of Nicosia”: 5.

Truax, Barry. 2003. “Homoeroticism and electroacoustic music: absence and personal voice”. *Organised Sound* 8 (1): 117–124.

– . 2008. “Soundscape Composition as Global Music: Electroacoustic music as soundscape”. *Organised Sound; Cambridge* 13 (2): 103–109.

Tsabary, Eldad. 2009. “Which Aural Skills are Necessary for Composing, Performing and Understanding Electroacoustic Music, and to what Extent are they Teachable by Traditional Aural Training?” *Organised Sound* 14 (3): 299.

Vine, William. 2010. “Avoiding Extinction in the Instrument Zoo: A Taxonomical and Ontological Approach to Developing an Understanding of the Ecosystem of Electroacoustic Instruments”. *Organised Sound* 15 (2): 167–177.

Waters, Simon. 2007. “Performance Ecosystems: Ecological approaches to musical interaction”. *EMS: Electroacoustic Music Studies Network*: 1–20.

Weale, Rob. 2006. “Discovering How Accessible Electroacoustic Music Can Be: the Intention/Reception project”. *Organised Sound* 11 (2): 189.

Whistlecroft, Lisa. 2013. “Displaying the beauty: The beachcomber-bowerbird approach to composition”. *Journal of Music, Technology & Education* 6 (3): 299–310.

Wittje, Roland. 2013. "The Electrical Imagination: Sound Analogies, Equivalent Circuits, and the Rise of Electroacoustics, 1863–1939". *Osiris* 28 (1): 40–63.

Woloshyn, Alexa. 2017. "Electroacoustic Voices: Sounds Queer, and Why It Matters". *Tempo; Cambridge* 71 (280): 68–79.

Young, John. 2004. "Sound morphology and the articulation of structure in electroacoustic music". *Organised Sound; Cambridge* 9 (1): 7–14.

– . 2013. "Notes, sounds, outsides and insides: Perspectives on pitch in acousmatic music". *Journal of Music, Technology & Education* 6 (3): 255–274.

Suggested Books and Book Chapters

Accaoui, Christian. 2001. *Le Temps Musical.* Desclée de Brouwer.

Agon, Carlos, et al. 2011. *Mathematics and Computation in Music: Third International Conference, MCM 2011, Paris, France, June 15-17, 2011. Proceedings.* Springer.

Aikin, Jim. 2003. *Software Synthesizers: The Definitive Guide to Virtual Musical Instruments.* San Francisco: Backbeat Books.

Alexander, Peter Lawrence. 2001. *How MIDI Works.* Milwaukee, WI: Hall Leonard.

Alperson, Philip. 1994. *What Is Music? an Introduction to the Philosophy of Music.* Rev. ed. University Park: Pennsylvania State University Press.

– . 2012. "Die Instrumentalität Der Musik". In *Collected Work: Vollkommenes hält sich fern: Ästhetische Näherungen. Series: Studien zur Wertungsforschung, No. 53*, 16–45. Wien: Universal Edition.

– . 2014. "Music and Morality". In *Collected Work: Ethics and the Arts*, 21–32. Dordrecht: Springer.

– . "Music As Philosophy". In *Collected Work: What is music? An Introduction to the Philosophy of Music*, 193–210. University Park: Pennsylvania State University Press.

Andersen, Christian Ulrik, and Soren Bro Pold. 2011. *Interface Criticism: Aesthetics beyond the Buttons.* Aarhus University Press.

Anderson, H. Emerson. 1960. *Electronic Organ Handbook.* Indianapolis, IN: Howard W. Sams.

Angliss, Sarah, ed. 2013. "Mimics, Menaces, or New Musical Horizons? Musicians Attitudes toward the First Commercial Drum Machines and Samplers". In *Material Culture and Electronic Sound*, 95–130. Washington, DC: Smithsonian Scholarly Press.

Audissino, Emilio. 2017. "Film/music Analysis I: Music, Gestalt, and Audiovisual Isomorphism". In *Film/Music Analysis*, 95–124. Springer.

Azzara, Christopher D. 2002b. *The New Handbook of Research on Music Teaching and Learning.* New York: Oxford University Press.

Bacon, Tony. 2000. *Fifty Years of Fender.* London: Balafon.

– . 2002. *Fifty Years of the Gibson Les Paul.* San Francisco: Backbeat Books.

Bailey, Derek. 1992. *Improvisation: Its Nature and Practice in Music.* British Library National Sound Archive.

Barrett, Natasha, ed. 2007. "Trends in Electroacoustic Music". In *The Cambridge Companion to Electronic Music*, 232–255. Cambridge, UK: Cambridge University Press.

Bell, Charles. 2017. "MicroPython Hardware". In *MicroPython for the Internet of Things*, 59–124. Springer.

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

Bergsland, Andreas. 2010. *Experiencing Voices in Electroacoustic Music.* Norges teknisk-naturvitenskapelige universitet. Institutt for musikk.

Bianchini, Riccardo, and Alessandro Cipriano. 2000. *Virtual Sound: Sound Synthesis and Signal Processing; Theory and Practice with Csound.* Rome: Con-Tempo.

Bilbao, Stefan. 2009. *Numerical Sound Synthesis: Finite Difference Schemes and Simulation in Musical Acoustics.* Hoboken, NJ: Wiley.

Biles, Jeremy, and Kent L Brintnall. 2016. *Negative Ecstasies: Georges Bataille and the Study of Religion.* Oxford University Press.

Birnbaum, David, et al. 2017. "Towards a Dimension Space for Musical Devices". In *Proceedings Of The 2005 Conference On New Interfaces For Musical Expression*, ed. by Alexander Refsum Jensenius and Michael J. Lyons, 3:211–222. Cham: Springer International Publishing.

Blackwell, Tim. 2007. "Swarming and Music". In *Evolutionary Computer Music*, 194–217. Springer.

– . 2008. "Swarm Granulation". In *The Art of Artificial Evolution*, 103–122. Springer.

Blesser, Barry, and Linda-Ruth Salter. 2009. *Spaces Speak, Are You Listening?: Experiencing Aural Architecture.* MIT Press.

Bonus, Alexander, ed. 2014. "The Grove Dictionary of Musical Instruments". In *Mobile Phone*, 3:487. New York: Oxford University Press.

Borgo, David. 1999. *Reverence for Uncertainty: Chaos, Order, and the Dynamics of Musical Free Improvisation.* University of California, Los Angeles.

Boulez, Pierre. 2018. *Music Lessons: The Collège De France Lectures.* Faber & Faber.

Braasch, J., et al. 2011. "A Spatial Auditory Display for Telematic Music Performances". In *Principles and Applications of Spatial Hearing*, 436–451. World Scientific.

Bregman, Albert S. 1994. *Auditory Scene Analysis: The Perceptual Organization of Sound.* MIT Press.

Brend, Mark. 2005. *Strange Sounds: Offbeat Instruments and Sonic Experiments in Pop.* San Francisco: Backbeat Books.

Bridgers, H. E., and F. J. Biondi. 1958. *Transistor Technology.* Vol. 1. Van Nostrand.

Brinkmann, Reinhold. 1979. *Improvisation Und Neue Musik. Acht Kongress-referate*. Veröffentlichungen des Instituts für Neue Musik und Musikerziehung Darmstadt. Mainz: Schott Musik International.

Brown, Andrew R. 2015. "Engaging in a Sound Musicianship". In *The Child as Musician*, ed. by Gary E. McPherson, 208–220. Oxford University Press.

Brown, Jason W. 2010. *Neuropsychological Foundations of Conscious Experience*. Les Editions Chromatika.

Butler, David. 1992. *The Musician's Guide to Perception and Cognition*. Vol. 1. Macmillan Reference USA.

Butler, Mark J. 2014. *Playing with Something That Runs: Technology, Improvisation, and Composition in DJ and Laptop Performance*. Oxford University Press.

Buzzarté, Monique, Tom Bickley, and Pauline Oliveros. 2012. *Anthology of Essays on Deep Listening*. Kingston: Deep Listening Institute.

Cadoz, Claude. 1999a. *Les Nouveaux Gestes De La Musique*. Parenthèses.

– . 1999b. *Musique, Geste, Technologie*. Editions Parentheses.

Cardew, Cornelius. 1974. *Stockhausen Serves Imperialism, and Other Articles: With Commentary and Notes*. Latimer New Dimensions.

Carson, Barry, ed. 2000. "Vintage Synthesizers". In *Combo Organs of the'60s*, 250–262. San Francisco: Miller Freeman.

Cassidy, Aaron, and Aaron Einbond. 2013a. *Noise in and As Music*. University of Huddersfield Press.

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

Chase, Mildred Portney, and Mildred Portney-Chase. 1988. *Improvisation: Music from the inside Out*. Creative Arts Book Company Berkeley, CA.

Chion, Michel, and TRANSLATOR. 1994. *Audio-vision: Sound on Screen*. Columbia University Press.

Choksy, Lois. 2001. *Teaching Music in the Twenty-first Century*. Prentice Hall.

Chomsky, Noam. 2017b. *Requiem for the American Dream: The 10 Principles of Concentration of Wealth & Power*. Seven Stories Press.

Clarke, Eric. 2005. *Ways of Listening: An Ecological Approach to the Perception of Musical Meaning*. Oxford ; New York: Oxford University Press.

Close, Frank. 2018. *Antimatter*. Oxford University Press, USA.

Cobussen, Marcel. 2003. *The Omnipresence of Improvisation*.

– . 2017. *The Field of Musical Improvisation*. Leiden University Press.

Cohen, Paul R., and Edward A. Feigenbaum. 2014. *The Handbook of Artificial Intelligence*. Vol. 3. Butterworth-Heinemann.

Colbeck, Julian. 1996. *Keyfax Omnibus Edition*. Emeryville, CA: MixBooks.

Collins, Nicholas, and Nick Collins. 2010. *Introduction to Computer Music*. John Wiley & Sons.

Collins, Nick, et al. 2013. *Electronic Music*. Cambridge University Press.

Collins, Nicolas, ed. 2007c. "Live Electronic Music". In *The Cambridge Companion to Electronic Music*, 38–54. Cambridge, UK: Cambridge University Press.

– . 2007d. *My Favorite Things: The Joy of the Gizmo*. MIT Press.

– . 2017. "Live Electronic Music". In *The Cambridge Companion to Electronic Music*, 2nd ed., ed. by Nick Collins and JulioEditors d'Escrivan, 40–57. Cambridge Companions to Music. Cambridge University Press.

Colwell, Richard, and Carol Richardson. 2002. *The New Handbook of Research on Music Teaching and Learning: A Project of The Music Educators National Conference*. Oxford University Press.

Comajuncosas, J. M. 2000. *Wave Terrain Synthesis with Csound*. The CSound Book: perspectives in software synthesis, sound design, signal . . .

Cook, Nicholas. 2013. "Beyond Music: Mashup, Multimedia Mentality, and Intellectual Property". In *Collected Work: The Oxford Handbook of New Audiovisual Aesthetics. Series: Oxford Handbooks in Music*, 53–76. New York: Oxford University Press.

Cope, David. 1991. *Computers and Musical Style*. Vol. 6. Oxford University Press Oxford.

– . 2000. *The Algorithmic Composer*. A-R Editions, Inc.

– . 2015. "Algorithmic Music Composition". In *Patterns of Intuition*, ed. by Gerhard Nierhaus, 405–416. Dordrecht: Springer Netherlands.

Cox, Christoph. 2007. *About Time*. New York.

Crowder, Robert G., and Mark A. Pitt. 1992. "Research on Memory/imagery for Musical Timbre". In *Collected Work: Auditory imagery*. Hillsdale: Erlbaum.

Crozier, W. Ray, and Antony J. Chapman. 1984. *Cognitive processes in the perception of art*. Advances in psychology. Amsterdam: North-Holland.

Dahlhaus, Carl. 2000a. "Was Heisst Improvisation?" In *Collected Work: Allgemeine Theorie der Musik. I: Historik–Grundlagen der Musik–Ästhetik. Series: Carl Dahlhaus: Gesammelte Schriften in 10 Bänden, No. 1*, 405–417. Laaber: Laaber-Verlag.

Dahlhaus, Carl, Hans Hildenbrand, and Philippe Albèra. 2004. *Essais Sur La Nouvelle Musique*. Genève: Contrechamps.

Davies, Hugh. 2001a. *Electronic Instruments*. Oxford University Press.

– . 2001d. *Electrophone*. Oxford University Press.

– . 2001e. "Electrophone". In *Oxford Music Online*. Oxford University Press.

– . 2002. *Sounds Heard: A Potpourri of Environmental Projects and Documentation, Projects with Children, Simple Musical Instruments, Sound Installations, Verbal Scores, and Historical Perspectives*. Soundworld Publishers.

De Furia, Steve, and Joe Scacciaferro. 1987a. *The MIDI Resource Book*. Pompton Lakes, NJ: Third Earth Publishing.

– . 1987b. *The MIDI System Exclusive Book*. Pompton Lakes, NJ: Third Earth Publishing.

Dean, Roger. 1989. *Creative Improvisation*. Milton Keynes England ; Philadelphia: Open University Press.

Dean, Roger T. 2009. *The Oxford Handbook of Computer Music*. Oxford University Press.

DeLone, Richard, and Gary E. Wittlich. 1975. *Aspects of Twentieth-century Music*. Prentice Hall.

Dennis, Brian. 1970. *Experimental music in schools: Towards a new world of sound.* Oxford University Press.

Desolneux, Agnès, Lionel Moisan, and Jean-Michel Morel. 2008. *From Gestalt Theory to Image Analysis: A Probabilistic Approach.* Interdisciplinary applied mathematics v. 34. New York, NY: Springer.

Deutsch, Herbert A. 1993. *Electroacoustic Music: The First Century.* Miami: Belwin Mills.

Dimarogonas, Andrew. 1996. *Vibration for Engineers.* Prentice Hall.

Dittbrenner, Nils. 2007. *Soundchip-musik: Computer- Und Videospielmusick Von 1977–1994.* Osnabrück, Germany: Electronic Publishing.

Dobbs, Teryl L. 2014. ""No Actual Teaching"". In *The Musical Experience*, ed. by Janet R. Barrett and Peter R. Webster, 294–308. Oxford University Press.

Donhauser, Peter. 2007. *Elektrische Klangmaschinen: Die Pionierzeit in Deutschland Und Österreich.* Vienna: Böhlau Verlag.

Drymonitis, Alexandros. 2015. *Digital Electronics for Musicians.* Berkeley, CA: Apress.

Duckworth, William. 2005. *Virtual Music: How the Web Got Wired for Sound.* New York: Routledge.

Dusman, Linda. 2000. "No Bodies There: Absense and Presence in Acousmatic Performance". In *Collected Work: Music and gender*, 336–345. Urbana: University of Illinois Press.

Eby, Robert L. 1953. *Electronic Organs: A Complete Catalogue, Textbook and Manual.* Wheaton, IL: Van Campen.

Emmerson, Simon, and Leigh Landy. 2016. *Expanding the Horizon of Electroacoustic Music Analysis.* Cambridge University Press.

Filsinger, Mark H. 2013. *Novice Music Teachers Learning to Improvise in an Improvisation Professional Development Workshop.* University of Rochester.

Flood, Lauren. 2016a. *Building and Becoming: DIY Music Technology in New York and Berlin.* Columbia University.

Freeman, John. 2010. *Blood, Sweat & Theory: Research through Practice in Performance.* UK: Libri Publishing.

Freitas, Franck, Malek Bouyahia, and Karima Ramdani. 2011. *Sex Sells, Blackness Too? Stylisation Des Rapports De Domination Dans Les Cultures Populaires Et Postcoloniales.* Bordeaux: Ed. Seteun.

Friedman, Melvin J. 1955. *Stream of Consciousness: A Study in Literary Method.* Vol. 44. Yale University Press.

Galambos, Robert. 1962. *Nerves and Muscles.* Vol. 25. Anchor Books.

Garud, Raghu, and Peter Karnoe. 2001. *Path Dependence and Creation.* Psychology Press.

Gewartowski, James W., and Hugh A. Watson. 1965. *Principles of Electron Tubes: Including Grid-controlled Tubes, Microwave Tubes, and Gas Tubes.* van Nostrand.

Glinsky, Albert. 2000. *Theremin: Ether Music and Espionage.* Urbana: University of Illinois Press.

Goodman, Steve. 2012. *Sonic Warfare: Sound, Affect, and the Ecology of Fear.* MIT Press.

Gopinath, Sumanth, and Jason Stanyek. 2014. *The Oxford Handbook of Mobile Music Studies.* Oxford: Oxford University Press.

Gopinath, Sumanth, et al. 2014. "The Mobile Phone Orchestra". In *The Oxford Handbook of Mobile Music Studies, Volume 2*, ed. by Sumanth Gopinath and Jason Stanyek. Oxford University Press.

Gordon, Edwin. 1970. *Experimental Research in the Psychology of Music.* University of Iowa. Studies in the psychology of music, v. 6-. Iowa City: University of Iowa Press.

Graesser, Hanno. 1998. *Design Und Technik Der Elektrischen Streichinstrumente/electric Violins: Design and Technique of Electric Bowed Stringed Instruments.* Frankfurt: Verlag Erwin Bochinsky.

Green, Lucy. 2017. *How Popular Musicians Learn : A Way Ahead for Music Education.* Routledge.

Grimshaw, Jeremy. 2011a. *Space Exploration, Part 2: Mormon Cosmology and the Well-tuned Piano.* Oxford University Press.

Gruhn, George, and Walter Carter. 1994. *Electric Guitars and Basses: A Photographic History.* San Francisco: GPI.

Hall, Tom. 2009. *Free Improvisation: A Practical Guide.* First Edition edition. In collab. with Lennie Peterson. Boston, MA: Bee Boy Press.

Hallam, Susan, Ian Cross, and Michael Thaut. 2011. *Oxford Handbook of Music Psychology.* Oxford University Press.

Haraway, Donna. 2013. *Simians, Cyborgs, and Women: The Reinvention of Nature.* Routledge.

Hargreaves, David, Dorothy Miell, and Raymond MacDonald. 2012. *Musical Imaginations: Multidisciplinary Perspectives on Creativity, Performance and Perception.* OUP Oxford.

Harris, Tony. 2016. *The Legacy of Cornelius Cardew.* Routledge.

Hegarty, Paul. 2007. *Noise Music: A History.* Bloomsbury Academic.

Holmes, Thom. 2012. *Electronic and Experimental Music: Technology, Music, and Culture.* Routledge.

Hopcke, Robert H. 2013. *A Guided Tour of the Collected Works of CG Jung.* Shambhala Publications.

Hopkin, Bart. 2009. *Making Musical Instruments with Kids: 67 Easy Projects for Adults Working with Children.* Pap/Com edition. Tuscon: See Sharp Press.

Horn, Delton T. 1988. *Digital Electronic Music Synthesizers.* Blue Ridge Summit, PA: Tab Books.

Hosken, Dan. 2015. *An Introduction to Music Technology.* New York: Routledge.

Houlgate, Stephen. 2007. *Hegel and the Arts.* Northwestern University Press.

Hugill, Andrew. 2018. *The Digital Musician.* Routledge.

Humphrey, Robert. 1958. *Stream of Consciousness in the Modern Novel.* Univ of California Press.

Ilomäki, Lotta. 2011. *In Search of Musicianship: A Practitioner-research Project on Pianists' Aural-skills Education.* Studia musica 45. Helsinki: Sibelius Academy.

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

Johnson, Bridget, Jim W. Murphy, and Ajay Kapur. 2013. *Designing Gestural Interfaces for Live Sound Diffusion.* Ann Arbor, MI: Michigan Publishing, University of Michigan Library.

Jordà, Sergi. 2017. "Interactivity and Live Computer Music". In *Collected Work: The Cambridge Companion to Electronic Music. Series: Cambridge Companions to Music, 2nd ed.* 86–103. Cambridge: Cambridge University Press.

Jostad, Drew Beecher. 2016. *The Use of Subjective Volume Adjustment As a Behavioral Elicitation Method for Audio Quality Listening Tests.* University of Colorado at Denver.

Jung, Carl Gustav. 2014. *The Structure and Dynamics of the Psyche.* Nachdr. The collected works of C. G. Jung, eds.: Herbert Read ... ; Vol. 8. London: Routledge.

Kane, Brian. 2014. *Sound Unseen: Acousmatic Sound in Theory and Practice.* Oxford University Press.

Karczmarczuk, Jerzy. 2005. "Functional Framework for Sound Synthesis". In *Practical Aspects of Declarative Languages*, ed. by Manuel V. Hermenegildo and Daniel Cabeza, red. by David Hutchison et al., 3350:7–21. Berlin, Heidelberg: Springer Berlin Heidelberg.

Kartomi, Margaret J. 1990. *On Concepts and Classifications of Musical Instruments.* Chicago studies in ethnomusicology. Chicago: University of Chicago Press.

Kemmis, Stephen, Robin McTaggart, and Rhonda Nixon. 2013. *The Action Research Planner: Doing Critical Participatory Action Research.* Springer Science & Business Media.

Kendrick, Lynne, et al. 2011. *Theatre Noise: The Sound of Performance.* Newcastle-upon-Tyne, UNKNOWN: Cambridge Scholars Publishing.

Kent, Corita, and Jan Steward. 2008. *Learning by Heart: Teachings to Free the Creative Spirit.* 2nd edition. New York, NY: Allworth Press.

King, Andrew, Evangelos Himonides, and S. Alex Ruthmann. 2017. *The Routledge Companion to Music, Technology, and Education.* Taylor & Francis.

Laloy, Louis. 1904. *Aristoxène De Tarente Et La Musique De L'antiquité.* In collab. with Robarts - University of Toronto. Paris, Société française d'imprimerie et de librairie.

Landy, Leigh. 1991. *What's the Matter with Today's Experimental Music?: Organized Sound Too Rarely Heard.* Psychology Press.

– . 2009. "Sound-based Music 4 All". In *The Oxford Handbook of Computer Music.*

– . 2012. *Making Music with Sounds.* Routledge.

Lazzarini, Victor. 2009. *A Distortion Synthesis Tutorial.* na.

Lehrmann, Paul, and Tim Tully. 1993. *MIDI for the Professional.* New York: Amsco.

Leighton, Taigen Dan. 2004. *The Art of Just Sitting: Essential Writings on the Zen Practice of Shikantaza.* Simon / Schuster.

Leman, Marc. 1993. “Symbolic and Subsymbolic Description of Music”. In *Music Processing*, 119–164. Oxford University Press.

– . 2008. *Embodied Music Cognition and Mediation Technology*. MIT Press.

Levinson, Jerrold, and Philip Alperson. 2015. “What Is Temporal Art?” In *Collected Work: Musical concerns: Essays in philosophy of music*, 155–169. Oxford: Oxford University Press.

Lévi-Strauss, Claude. 2013. *Myth and Meaning*. Routledge.

Lewis, George E., and Benjamin Piekut. 2016a. “Introduction: On Critical Improvisation Studies”. In *Collected Work: The Oxford handbook of critical improvisation studies, vol. 1. Series: Oxford handbooks, (Number of volumes: 2)*, 1–35. New York: Oxford University Press.

Libin, Laurence. 2018. “Musical Instrument”. In *Oxford Music Online*. Oxford University Press.

Linson, Adam, Chris Dobbyn, and Robin Laney. 2013. “A Parsimonious Cognitive Architecture for Human-computer Interactive Musical Free Improvisation”. In *Biologically inspired cognitive architectures 2012*, 219–224. Springer.

Madison, D. Soyini. 2018. *Performed Ethnography and Communication: Improvisation and Embodied Experience*. Routledge.

Madsen, Clifford K. 1969. *Experimental Research in Music*. Prentice-Hall contemporary perspectives in music education series / Charles Leonhard, editor. Prentice-Hall.

Manning, Peter. 2001. *Institut De Recherche Et Coordination Acoustique/musique*. Vol. 1. Oxford University Press. Visited on 12/28/2018.

– . 2013. *Electronic and Computer Music*. Oxford: Oxford University Press.

Marchetti, Lionel, Christian Zanési, and François Bayle. 1998. *La Musique Concrète De Michel Chion: Essai*. Rives: Metamkine.

McSwain, Rebecca, ed. 2002. “The Social Reconstruction of a Reverse Salient in Electrical Guitar Technology: Noise, the Solid Body, and Jimi Hendrix”. In *Music and Technology in the Twentieth Century*, 186–198. Baltimore: Johns Hopkins University Press.

Metcalfe, Janet, and Lisa K. Son. 2012. “Anoetic, Noetic, and Autonoetic Metacognition”. In *Foundations of Metacognition*, ed. by Michael J. Beran et al., 289–301. Oxford University Press.

Miell, Dorothy, Raymond MacDonald, and David J. Hargreaves. 2005. *Musical Communication*. OUP Oxford.

Mills, Roger, and Kirsty Beilharz. 2014. “The Network Unveiled: Evaluating Telemusical Interaction”. In *Interactive Experience in the Digital Age*, 109–122. Springer.

Miranda, Eduardo. 2001. *Composing Music with Computers*. Focal Press.

– . 2012. *Computer Sound Design: Synthesis Techniques and Programming*. Oxford: Focal Press.

Miranda, Eduardo R., ed. 2007. “Cellular Automata Music: From Sound Synthesis to Musical Forms”. In *Evolutionary Computer Music*, 170–193. London: Springer.

Miranda, Eduardo Reck. 1998. *Computer Sound Synthesis for the Electronic Musician*. Butterworth-Heinemann.

– , ed. 2017. *Guide to Unconventional Computing for Music*. Springer International Publishing.

Miranda, Eduardo Reck, and John Al Biles. 2007. *Evolutionary Computer Music*. Springer.

Moore, Adrian. 2016. *Sonic Art: An Introduction to Electroacoustic Music Composition*. Routledge.

Naumann, Joel, and James D. Wagoner. 1985. *Analog Electronic Music Techniques in Tape, Electronic, and Voltage-controlled Synthesizer Studios*. New York: Schirmer.

Neukom, Martin. 2013. *Signals, Systems and Sound Synthesis*. Bern, Switzerland: Peter Lang.

Newmarch, Jan. 2017. "Raspberry Pi". In *Linux Sound Programming*, 537–545. Springer.

Nilsson, Nils J. 2014. *Principles of Artificial Intelligence*. Morgan Kaufmann.

Nyman, Michael. 1999. *Experimental Music: Cage and Beyond*. Cambridge University Press.

Odin, Steve. 2001. *Artistic Detachment in Japan and the West: Psychic Distance in Comparative Aesthetics*. University of Hawaii Press.

O'Neill, Brian, et al. 2011b. "A Knowledge-based Framework for the Collaborative Improvisation of Scene Introductions". In *Interactive Storytelling*, ed. by Mei Si et al., 7069:85–96. Berlin, Heidelberg: Springer Berlin Heidelberg.

Ord-Hume, Arthur W.J.G., et al. 2001. *Recorded Sound*. Vol. 1. Oxford University Press. Visited on 12/28/2018.

Orton, Richard. 1981. *Electronic Music for Schools*. Cambridge University Press.

Pan, Tianhong, and Yi Zhu. 2018. *Designing Embedded Systems with Arduino*. Springer.

Park, Tae Hong. 2010. *Introduction to Digital Signal Processing: Computer Musically Speaking*. Hackensack, NJ: World Scientific.

Phillips, Scott L. 2013. *Beyond Sound: The College And Career Guide In Music Technology*. Oxford University Press.

Pinch, Trevor J., Frank Trocco, and T. J. Pinch. 2009. *Analog Days: The Invention and Impact of the Moog Synthesizer*. Harvard University Press.

Pinch, Trevor, and Karin Bijsterveld. 2012. "New Keys to the World of Sound". In *The Oxford Handbook of Sound Studies*.

Pinksterboer, Hugo. 2009. *Tip Book: Keyboard & Digital Piano; the Complete Guide*. Milwaukee, WI: Hal Leonard.

Pinkston, Russell. 1999. *Example of Wave Terrain Synthesis Instrument*. University of Texas.

Pressing, J. 1984a. *A History of Musical Improvisation to 1600*. Keyboard.

Puckette, Miller. 2007. *The Theory and Technique of Electronic Music*. Hackensack, NJ: World Scientific.

Pulkki, Ville. 2001a. *Spatial Sound Generation and Perception by Amplitude Panning Techniques*. Helsinki University of Technology.

Reynolds, Simon. 2013. *Generation Ecstasy: Into the World of Techno and Rave Culture.* Routledge.

Roads, Curtis, et al. 2013a. *Musical Signal Processing.* Routledge.

Roberts, Eric. 2008. *The Art & Science of Java: An Introduction to Computer Science.* Boston: Pearson/Addison Wesley.

Romero, Juan J. 2008. *The Art of Artificial Evolution: A Handbook on Evolutionary Art and Music.* Springer Science & Business Media.

Rothenberg, David. 2002. *Sudden Music: Improvisation, Sound, Nature.* University of Georgia Press.

Rowe, Robert. 1993. *Interactive Music Systems: Machine Listening and Composing.* MIT Press.

– . 2004. *Machine Musicianship.* MIT Press.

Samagaio, Frank. 2002. *The Mellotron Book.* Vallejo, CA: ProMusic.

Sauer, Matthias. 2008. *Die Thereminvox: Konstruktion, Geschichte, Werke.* Vol. 13. Osnabrücker Beiträge zur systematischen Musikwissenschaft. Osnabrück, Germany: Electronic Publishing.

Sauer, Theresa. 2009. *Notations 21.* Mark Batty Pub.

Saunders, James. 2009. *The Ashgate Research Companion to Experimental Music.* Ashgate.

Sawyer, R. Keith. 2011. *Explaining Creativity: The Science of Human Innovation.* Oxford University Press.

Schaeffer, Pierre. 2002. *De La Musique Concrète À La Musique Même.* Mémoire du livre.

– . 2016a. *A La Recherche D'une Musique Concrète.* Le Seuil.

Schaeffer, Pierre, et al. 1967. *Solfège De L'objet Sonore.* INA.

Schafer, R. Murray. 1967. *Ear Cleaning; Notes for an Experimental Music Course.* BMI Canada.

Schon, Donald A., and Vincent DeSanctis. 1986. *The Reflective Practitioner: How Professionals Think in Action.* Taylor & Francis.

Schrader, Barry, and Jon H. Appleton. 1982. *Introduction to Electro-acoustic Music.* Englewood Cliffs: Prentice-Hall.

Schrader, Barry, and Marc Battier. 2013. *Electroacoustic Music in the United States.* Vol. 1. Oxford University Press.

Sear, Walter. 1972. *The New World of Electronic Music.* New York: Alfred.

Shepard, Brian K. 2013. *Refining Sound: A Practical Guide to Synthesis and Synthesizers.* Oxford: Oxford University Press.

Sine, Wesley D. 2011. "Organization Science". In *In Search of Research Excellence,* **by** Ronald Mitchell and Richard Dino. Edward Elgar Publishing.

Smalley, Denis. 2010. "Spectromorphology in 2010". In *Collected Work: Denis Smalley. Series: Portraits polychromes, No. 15,* 89–101. Paris: Institut National de l'Audiovisuel/GRM.

Smirnov, Andrej. 2013. *Sound in Z: Experiments in Sound and Electronic Music in Early 20th Century Russia.* London: Koenig.

Smith, Benjamin D. 2011. *Telematic Composition.* University of Illinois at Urbana-Champaign.

Smith, Richard R. 1987. *The History of Rickenbacker Guitars.* Anaheim, CA: Centerstream.

Solis, Gabriel, and Bruno Nettl. 2009. *Musical Improvisation: Art, Education, and Society.* University of Illinois Press.

Solis, Jorge, and Kia Ng. 2011a. *Musical Robots And Interactive Multimodal Systems.* Vol. 74. Springer.

– . 2011b. *Musical Robots and Interactive Multimodal Systems.* Berlin: Springer Verlag.

Southworth, George Clark. 1966. *Principles and Applications of Wave-guide Transmission.* Van Nostrand.

St John, Graham. 2004. *Rave Culture and Religion.* Routledge.

Stenström, Harald. 2009. *Free Ensemble Improvisation.* ArtMonitor dissertation, no 13. Göteborg: Academy of Music / Drama, Faculty of Fine, Applied / Performing Arts, University of Gothenburg.

Sternberg, Robert J., and Scott Barry Kaufman. 2011. *The Cambridge Handbook of Intelligence.* New York: Cambridge University Press.

Sun, Cecilia. 2012. *Experimental Music.* Vol. 1. Oxford University Press.

Suzuki, Daisetz Teitaro. 1991. *An Introduction to Zen Buddhism.* Grove Press.

Thompson, Walter. 2006. *Soundpainting: Workbook 1. Workbook 1.* Walter Thompson.

Tobias, Evan. 2017. *Re-situating Technology in Music Education.* Ed. by S. Alex Ruthmann and Roger Mantie. Vol. 1. Oxford University Press.

Todd, Peter M., and D. Gareth Loy. 1991. *Music and Connectionism.* Mit Press.

Toiviainen, Petri. 2000. "Symbolic AI Versus Connectionism in Music Research". In *Collected Work: Readings in music and artificial intelligence. Series: Contemporary music studies, No. 20*, 47–67. Amsterdam: Harwood Academic.

Toop, David. 2013. "New and rediscovered musical instruments rediscovered." In *Collected Work: Material culture and electronic sound. Series: Artefacts: Studies in the history of science and technology, No. 8*, 259–270. Smithsonian Institution Press.

– . 2016. *Into the Maelstrom: Music, Improvisation and the Dream of Freedom: Before 1970.* Bloomsbury Publishing USA.

Trynka, Paul. 1995. *The Electric Guitar: An Illustrated History.* Chronicle Books.

Trynka, Paul, and Tony Bacon. 1996. *Rock Hardware: 40 Years of Rock Instrumentation.* San Francisco: Miller Freeman.

Trynka, Paul, and Keith Richards. 1993. *The Electric Guitar: An Illustrated History.* London: Virgin.

Tsitsos, Bill. 2013. *Groove Music: The Art and Culture of the Hip-hop DJ.* Taylor & Francis.

Tymieniecka, Anna-Teresa. 2002. *Phenomenology World Wide: Foundations - Expanding Dynamics - Life-engagements, a Guide for Research and Study.* Springer Science & Business Media.

Vail, Mark. 2000a. *Vintage Synthesizers.* San Francisco: Miller Freeman.

– . 2000b. "Vintage Synthesizers". In *Linn LM-1 Drum Computer*, ed. by Mark Vail, 289–293. San Francisco: Miller Freeman.

– . 2014. *The Synthesizer: A Comprehensive Guide to Understanding, Programming, Playing, and Recording the Ultimate Electronic Music Instrument.* Oxford University Press.

Van Der Rest, Nathan Andre Peter. 2014. *A Unified Curriculum for the Teaching of Electronic Sound Synthesis.* University of Colorado at Denver.

Wade, Bonnie C. 2004. *Thinking Musically: Experiencing Music, Expressing Culture.* Oxford University Press New York.

Walsh, Stephen. 1991. *The Time of Music: New Meanings, New Temporalities, New Listening Strategies.* JSTOR.

Ward, Brice. 1975. *Electronic Music Circuit Guidebook.* G/L Tab Books.

Weium, Frode, Tim Boon, and Brian Eno. 2013. *Material Culture and Electronic Sound.* Artefacts: Studies in the history of science and technology. Washington, D.C.: Smithsonian Institution Press.

Whitehead, Alfred North, and Jean Douchement. 1957. *The Concept of Nature.* Vol. 5. Springer.

Wick, Robert L. 1997. *Electronic and Computer Music: An Annotated Bibliography.* Westport, CT: Greenwood.

Wilber, Ken. 2002. *The Spectrum of Consciousness.* Motilal Banarsidass Publ.

Williams, Sean, ed. 2013. "Stockhausen Meets King Tubby's: The Transformation of the Stepped Filter into a Musical Instrument". In *Material Culture and Electronic Sound*, 159–184. Washington, DC: Smithsonian Scholarly Press.

Wilson, Scott, David Cottle, and Nick Collins. 2011. *The SuperCollider Book.* The MIT Press.

Winckel, Fritz. 2014. *Music, Sound and Sensation: A Modern Exposition.* Courier Corporation.

Wishart, Trevor. 2016. *On Sonic Art.* Routledge.

Wittje, Roland. 2016. *The Age Of Electroacoustics: Transforming Science And Sound.* The MIT Press.

Xambó, Anna, et al. 2013. "Video Analysis for Evaluating Music Interaction: Musical Tabletops". In *Collected Work: Music and human-computer interaction. Series: Springer Series on Cultural Computing*, 241–258. London: Springer.

Young, Gayle. 1989. *The Sackbut Blues: Hugh Le Caine, Pioneer in Electronic Music.* Ottawa, ON: National Museum of Science / Technology.

Young, Rob. 2001. *The MIDI Files.* London: Prentice Hall.

Zölzer, Udo. 2008. "Audio Effects Generation". In *Handbook of Signal Processing in Acoustics*, ed. by David Havelock, Sonoko Kuwano, and Michael Vorländer, 785–796. New York, NY: Springer New York.

Index

This work is about Electroacoustic Music, Improvisation, and Performance; the three areas are studied and explored in a combined and holistic manner. The text includes discussions on sonic improvisation and listening modes, the contributions of the electroacoustic genre to modern musicianship, an exploration of a collection of electronic instruments as tools for musical performance and a set of pedagogical activities designed to systematically address the essential questions (the elements) for becoming a sound performer integrating technological means with musical expression.

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