University of Antwerp

ARIA

Music and Performing Arts

Composing with Piezo

PhD thesis submitted for the degree of Doctor of Arts at the University of Antwerp to be defended by Daniela Fantechi

Supervisor(s):
prof. Wim Henderickx
prof. Erik Myin

Mentor:
prof. Jonathan Impett

Antwerp, 2022

Contents

Introduction

Composing with piezo is the title of my research which concerns the composition of instrumental music implemented with a specific use of piezoelectric microphones - low cost and low fidelity[1] contact microphones. During the research process, I explored a peculiar use of this technology not only to disclose and amplify the instrumental sound but also to produce otherwise unheard sounds, through a reinterpretation of some instrumental gestures, such as glissando, tapping, scraping, etc, produced by playing with the microphone directly on the instrument. Mainly because of the non-linear quality of unprocessed piezoelectric microphones, which thus present limits and different degrees of controllability and predictability - their introduction in my compositional work changed the relationships with the instrumental sound matter, bringing to question different aspects of my compositional approach. Therefore, during the whole research process, I looked for frameworks, theories, and examples, to understand and bring focus to my evolving compositional practice.

The opening chapter of my thesis starts by investigating the history of the contact microphone and the way it has become a cultural object. I consider diverse artistic experiences in the time window from the '60s to the '80s, when contact microphones began to be a widespread technology. From then on, the use of contact microphones has become common in a huge and diverse range of artistic experiences, most of them related to sound art and experimental music. The low cost of piezoelectric elements and their robustness are the main practical reasons for the spread of piezoelectric disks, whose technological features have been curiously kept as they were in the '80s, while at the same time, different applications of piezoelectricity underwent a remarkable development.

The second chapter addresses what kind of changes and interferences the introduction of piezoelectric microphones brings into the instrumental sound system. I start by observing the kind of impact the use of piezoelectric microphones on acoustic instruments has on the listening experience, which I defined as a "stethoscopic form of listening". In fact, comparing the piezoelectric microphone to a stethoscope, the listening experience can be understood as a form of mediate and technical listening, which brings to develop a different understanding of the sound matter framed by the piezo. I then address the role of the piezo within the instrumental system, from an ecological perspective, taking into account the complexity of the feedback network between the instrument and the performer, and the alteration of the usual perceptual habits. I finally consider

1 Due to its irregular frequency curve piezoelectric microphone used without some form of equalization presents a “low-fi” sound quality. Actually, its response extends from the infrasonic to ultrasonic, which makes this kind of microphone quite accurate, if used with the proper form of equalization. The deliberate choice of abstaining from using any form of equalization in my project has to do with aesthetic reasons that I will explain later on.

how the introduction of piezo allows for the building of new instrumental systems, that becomes a relevant aspect of the compositional practice.

The third chapter highlights some relevant concepts that have emerged from my practice and have become operational within the development of my research. Most of them come from different disciplines such as compositional theory, electroacoustic theory, media theory, sociology, and media history. Working with piezo brought me first of all to consider the importance of framing the sound during the compositional process: this allowed me to better understand the properties and the intrinsic potentialities of the material I would deal with. So, I dwell on the relevance of a few spectromorphological concepts, concerning the understanding of instrumental sound matter and its shaping through the definition of different instrumental sound gestures, which inhabit various temporal dimensions. I go on by focusing on the quality of sonic intimacy, considering how the use of piezo tends to bring to the foreground a different perception of the proximity of sounds. I then address the role of notation in getting control over the definition of sonic ideas and the general progress of the work. I finally consider the role that memory has within the compositional work in anticipating and storing sonic ideas, taking advantage of the concept of the archive, borrowed from media theory.

The fourth chapter is dedicated to the main artistic outputs of my research. For each work, I will explain the technical setup, the context for which the piece has been written, and the compositional practice. Every piece tells something different about the use of the piezoelectric microphones and the way they have interacted and interfered with the embodied practices and habits implied in each instrumental system. But also about how piezoelectric microphones have influenced my relationship with musical material, allowing me to develop a more conscious compositional approach.

The text of these four chapters is supported by many examples from my artistic practice - with the exception of chapter one, whose examples are referred to the different mentioned authors. Concerning the examples, images are included in the text, while all audio examples, videos, pdf documents, scores, etc., can be found on the research catalogue (www.researchcatalogue.net) in the published exposition "Composing with Piezo", by Daniela Fantechi. The thesis is then completed by four appendices, mentioned in the text.

1. *Contact microphone: a cultural object*

Introduction

Piezoelectric microphones, a special kind of contact microphone, constitute the core of the presented research project. A contact microphone is a microphone that senses audio vibrations through physical contact with a solid surface or immersion in liquid, and converts them into an electric signal. It is an old, often inexpensive technology that has stimulated the creativity of several generations of musicians and sound-artists, precisely because of its peculiar property of activating a different way of listening. Contact microphones have been widely used to turn everyday objects into "musical instruments", as an alternative to synthesis for sound effects. Sonic exploration of the acoustic characteristics of different objects uncovered new ways to conceive sound material while revealing a different perception of the materiality of sounds. A contact microphone can be intended as a cultural object if one takes into account the connections and relationships arose between musicians and composers that have used this technology, even if with different purposes and aesthetics.

1.1 Brief historical overview

The history of the contact microphone is related to the history of piezoelectricity, since most contact mikes have made with piezoelectric materials.[2] The discovery of piezoelectricity is attributed to Pierre and Jacques Curie, who published in 1880 the first experimental demonstration of the connection between piezoelectric phenomena and crystallographic structure in the article titled *Développement par pression de l'électricite polaire dans les cristaux hémièdres à faces inclinées.* They experimented with measurement of the surface charges of crystals of tourmaline, quartz, topaz, cane sugar and Rochelle salt, when subjected to mechanical strain. This phenomenon was soon named "piezoelectricity" (from the Greek word πιέζειν piezein = press, squeeze) [See Appendix 1]. In order to distinguish it from other scientific phenomenological experience such as

2 Other kinds of contact microphones are electromagnetic, employing the same principle of a guitar pickup, with the difference that electromagnetic contact microphones include a metal diaphragm to transduce any physical vibration into a distortion of the electromagnetic field, while the guitar pickup is merely a coil detecting the field distortions induced by the vibrating ferric material of the string.

"pyroelectricity" (electricity generated from crystals by heating), or "contact electricity" (friction generated static electricity). The following year Gabriel Lippman deduced mathematically from fundamental thermodynamic principles the inverse piezoelectric effect (mechanical strain results from the injection of an electrical field). Based on experimental observations the Curie brothers confirmed the converse effect in 1882. In the following years, the European scientific community worked interactively to establish the core of piezoelectricity: the identification of 20 natural classes of piezoelectric crystals on the basis of asymmetric crystal structure, the reversible exchange of electrical and mechanical energy, and the usefulness of thermodynamics in quantifying complex relationships among mechanical, thermal and electrical variables. The first monograph on piezoelectricity and the relevant crystallography was *Lehrbuch der Kristallphysik*, published in 1910 by Woldemar Voigt's, the book became the standard reference offering the understanding which had been reached. Nevertheless, it took a while to develop from the scientific theory concrete technological applications, also because the mathematics required to understand the phenomenon of piezoelectricity was still quite obscure.

The first practical applications of piezoelectric principles appeared during World War I, as ultrasonic submarine detectors, most famously sonar, based on research done between 1916 and 1917, by the French physicist Paul Langevin (previously a doctoral student of Pierre Curie) and the British/Canadian Robert William Boyle. An electric pulse was sent to a piezoelectric crystal, which produced high-frequency mechanical vibrations that were transmitted through the water. Upon encountering an object, these signals reflected back. A second piezoelectric sensor detected this reflected energy and converted it back into an electrical signal. The distance from the ultrasonic source and the reflecting object was determined by the elapsed time between transmission and reception. This technology was of strategic importance in both world wars. Years later musicians and sound-artists began using underwater microphones (hydrophones) with far more peaceful intentions. The trickle-down of sonar technology stimulated the development of many other kinds of piezoelectric devices. After World War I, more familiar piezoelectric applications – such as microphones, accelerometers, ultrasonic transducers, bender element actuators, phonograph pick-ups and signal filters – were invented and put into practice. During World War II, isolated research groups in the U.S., Japan and the Soviet Union replaced naturally-occurring crystals with ferroelectrics – new discovered artificial materials, that exhibited stronger piezoelectric properties; these were incorporated into more powerful sonars, ceramic phono cartridges, piezo ignition systems, the sonobuoy (sensitive hydrophone listening and transmitting buoys for monitoring ocean vessel movement), miniature sensitive microphones, and ceramic audio tone transducers.

An intense development of materials and devices proceeded, dominated by industrial groups in the U.S. who secured an early lead with strong patents. In U.S post-war companies maintained strict policies and secrecy habits resulting from the development of this field during the war. Consequently, the attempts to develop other applications and build a market for piezoelectric devices were not very fruitful. In contrast, the open-policy atmosphere in Japan encouraged several companies and universities to collaborate, providing a context for the creation of new knowledge, new applications, new processes, and new commercial market areas in a coherent and profitable way.

After World War II, Japan dominated the international market for piezo materials, manufacturing several types of piezoceramic signal filters that addressed needs arising in television, radio and communications equipment, as well as piezoceramic igniters for natural gas/butane appliances. The market for piezoelectric applications continued to grow, with the emergence of audio buzzers (such as those in appliances and smoke alarms) and ultrasonic transducers (used in motion detecting intrusion alarms and early television remote controls). More recently, piezoelectric technology has been applied in the automotive domain (wheel balancing, seatbelt buzzers, tread wear indicators, keyless door entry, and airbag sensors); computers (microactuators for hard disks, piezoelectric transformers); a wide range of other commercial and consumer devices (inkjet printing heads, strain gauges, ultrasonic welders, smoke detectors); and medical, biomedical and bioengineering applications, including insulin pumps, ultrasound imaging and therapeutics, piezoelectric and biomedical implants with associated energy harvesting.

1.2 Musical applications

Piezoelectric innovations played an important role in the development of electronic music, especially in the experimental scene from the late 1950s onward. One of the main reasons can be found in the possibilities unfolded by amplification, as Michael Nyman observes:

> Amplification may reveal a previously unheard, unsuspected range of sounds, drawn out of the hitherto mute or near-mute instrument of whatever nature, bringing about both quantitative and qualitative changes in the materials amplified. (Nyman, 1999, p.92)

As Nyman suggests, an amplified sound — a sound transduced from the acoustical to the electronic domain — is perceived differently not only because quiet sounds can be made very loud, but more significantly because the proximity of a microphone captures different features of the sound source, that were previously unheard. This shift in perception is even stronger when the microphone is a contact mike. Vibrations picked up directly from a surface sound different from the same vibrations after they travel through the air. The resonant material acts as a filter, and the contact microphone picks up the objects "inner sound", like a heartbeat heard through a stethoscope. Through piezoelectricity, composers and musicians started to grasp the full potential of amplification, as a creative tool.

1.3 *Cartridge Music* by John Cage and *Apple Box* by Pauline Oliveros

John Cage was one of the key figures in the musical application of contact mikes and extreme amplification, as exemplified in his work *Cartridge Music* (1960). *Cartridge Music* is an early work of live electronic music, in which all sounds are produced by the means of the amplification of very small sounds, primarily using piezo-ceramic phono-cartridges from record players. Performers replace the needle of the cartridges with different twigs, pipe cleaners, springs and other thin objects, to manipulate the objects (by scraping, plucking, etc.), and elicit different sounds, which are amplified and sent to the speakers. *Cartridge Music* has an open form. The score consists of a number of transparent sheets, and the patterns drawn on them provide only the means to determine a time structure. Each performer has to superimpose the transparencies and work out the time structure by observing the ways in which the drawn lines and patterns on the sheets intersect. The choice of objects and means of manipulation are left entirely to the musicians. The phono-cartridges act as contact microphones, used to explore different objects to uncover new sound materials and reveal the unexpected richness of amplified "microsounds".

Cartridge Music embodies several concerns that, over the following years, would become axiomatic in much experimental electronic music. One of the most evident, as already noted, is the role of amplification in the production and discovery of previously unheard sounds. The sound production, moreover, is strongly connected with gestures performed on everyday objects, instead of traditional instruments. Finally, *Cartridge Music* is representative of a certain DIY approach to electronic systems – in 1960 few could afford oscillators and tape recorders, but everyone seemed to own a record player that could be "hacked" to play this piece. These concerns were all already present in

Cage's work before *Cartridge Music.* As Nyman points out "Cage's *Cartridge Music* had its roots in his pre-war *Imaginary Landscape No.1* (1939) which introduced a number of proto-electronic instruments, and, more relevantly perhaps, in the category of 'amplified small sounds' of *William Mix* (1952)." (Nyman, 1999, p.90). Indeed, Cage had experimented amplification before *Cartridge Music,* as in *Imaginary Landscape No. 2 (*1942) in which both instruments and electronic devices are amplified through contact microphones. And he had already imported "foreign" objects into the concert hall: an early example can be *Living Room Music* (1940), in which Cage invites musicians to use "any household objects or architectural elements as instruments, e.g: 1st player — magazines, newspaper or cardboard; 2nd player — table or wooden furniture; 3rd player — largish books; 4th player — floor, wall, door or wooden frame of window" (Cage,1940, *Living Room Music*, Peters Edition); other examples can be *Imaginary Landscape n.4 ,* composed for twenty-four performers operating on twelve radios, or *Water Music* (1952), for a solo pianist using also radio, whistles, water containers, and a deck of cards. But with *Cartridge Music* especially, Cage pointed out a different way of conceiving electronic music, without using the equipment of the electronic studios, but inventing and adapting portable electronic devices for improvising or performing indeterminate music (Nyman, 1999 p.89). *Cartridge Music* exerted a profound influence on the younger generation of composers who started making electronic experimental music in the 1960's.

Many concerns embodied by *Cartridge Music* appear, for example, in one early work of Pauline Oliveros, the *Apple Box* piece. In this work, Pauline Oliveros (1932-2016) uses wooden boxes in which apples have been stored as resonators for other kinds of objects. Every apple box is prepared with various objects, and it is amplified with contact microphones. The performers are asked to improvise with the content of the boxes.

> The material played will always sound via the resonance properties of the apple box, since the contact microphone is attached to it. The apple box together with its contact microphones functions as a kind of filter, amplifier and reverb, giving the different types of material a similar sound colour, resembling, in effect, the resonance body of an instrument, and producing a unity in sound colour similar to that achieved by an instrument, emphasized by the use of contact microphones or electromagnetic pickups (similar to the ones used in the Neo Bechstein, or in electric guitars) for amplification. (Van Eck, 2017, p.111)

Thanks to the amplification of contact-microphones everyday objects are turned into new instruments. The amplification enables the production of previously unheard sounds, allowing for an exploration of everyday sounds in the context of the musical performance.

1.4 David Tudor - Composers Inside Electronics

With regard to the development of live electronic music, the artistic mate of Cage, David Tudor was truly a pioneer: after a pivotal role as a virtuoso pianist in the development of the post-war musical avant-garde, Tudor became one of the first live electronic performers, with a very personal approach to electronic technology, strongly influenced by his collaboration with Cage. After assisting in the development and performances of *Cartridge Music,* Tudor continued to experiment with similar setups in other pieces by Cage, such as *Music for Amplified Toy Pianos* (1960) and *Variations II* (1961).[3] For each of these pieces, Tudor used a set of phono cartridges to amplify the piano sounds. He gradually acquired the knowledge and confidence that enabled him to design his own electronic circuits for use in conjunction with the cartridges, and he came into his own as a composer (as distinct from performer) of electronic music.

In the early '70s another group of musicians – *Composers Inside Electronics* – expanded Tudor's "hands-on" way of working with electronic means. The group came together on the occasion of a workshop that Tudor gave in 1973, around his composition *Rainforest,* in the "New Music in New Hampshire" conference in Chocorua, NH. In the same conference there were workshops by David Behrman, Gordon Mumma, Frederic Rzewski and several others. John Driscoll, Paul De Marinis, Phil Edelstein, Linda Fisher, Ralph Jones, Martin Kalve, and Bill Viola were among the people attending Tudor's workshop. As John Driscoll remembers:

> David was holding a workshop on the idea of *Rainforest* and of processing signals acoustically, through an acoustical transformation. So he introduced us to this idea of taking a sculptural object and putting a transducer on the object, holding directly to it, and vibrating the material. It's very common now, but at that time it was not. The idea was, what you were trying to do, was to find the signal that the object like to resonate at. So it's almost like the idea of tickling somebody. If I tickle on your shoulder, nothing... but if I find that spot, then it explodes. With the object its the same concept. You try to get the sound material that excites the resonant node of the object and then the object does all of the processing. [...]In the second part of the concept, in order to hear better the subharmonics in particular, we used contact microphones on the object and re-amplified the signal that was in the material. *Rainforest IV* always used contact microphones as well. The same object would have a contact microphone attached to it, that would go back to an amplifier and then then the signal would go to a regular loudspeaker. You would hear it acoustically in the space, but if you put your ear against the object you hear it quite differently because then you hear inside the material. The contact microphone brought out those sounds that were in the material, so it was almost

3 For further info see: Iddon, Martin (2015). *John Cage and David Tudor, Correspondence on interpretation and performance*, Cambridge University Press, pp.187-186.

a reflection of the signal that was heard in the air, but it had a different harmonic content.[4]

Rainforest was originally conceived by Tudor in 1968 for choreography by Merce Cunningham, and by 1973 the piece had already been performed in several different versions. When Tudor was asked to give a workshop in the conference "New Music in New Hapshire", he felt that he was finished with the *Rainforest* concept. Therefore he considered offering it to the early-twenty composers, who were taking part in the workshop (see Tudor, 1984). But, as Driscoll recounts, during the workshop the piece took a slightly different form because of the idea of using bigger objects.

> The original version used the same principles as *Rainforest IV*, but the real difference was that he used a table-top with small objects put on the table. In the very beginning, David made very specific electronics using a feedback oscillator that changes over time, as the source material. In the original *Rainforest* the acoustic output of those smaller objects was not very audible, but the signal that was sent to the loudspeakers was quite loud. So that the idea for the original one is that you are hearing the amplified object through the loudspeaker system, but not hearing the object itself.[5]

What was previously a table-top setup, designed for road performances with the Merce Cunningham Dance Company, expanded into a large-scale set of sounding objects. During the workshop each participant experimented with transducers attaching them to any of object that could be found around the small converted farm/inn. As Bill Viola recalls someone even "blew out two transducers by trying to resonate the bathroom plumbing under the toilet" (Viola, 2004, p.49). At the same time, there was a workshop with Gordon Mumma and David Behrman on building electronic circuits, in which most of the circuits used to perform *Rainforest IV* were built. At the end of the workshop the piece was performed in the town of Chocorua, NH. Here a new and larger scale version of the piece was presented, with objects such as a wagon wheel, a wine barrel, bed springs, etc., suspended in order to resonate freely, creating an environment of sounding sculptures through which the audience could walk. After the workshop, this new version of Tudor's piece – later called *Rainforest IV*[6] – was subsequently performed over 125 times, in more than 45 cities.

---

4 Skype interview with John Driscoll (25 March 2019). For the complete interview see Appendix 2.
5 Ibid.
6 As Driscoll explains, the performance of Composers Inside Electronics has been called *Rainforest IV* only in 1980 or 1981, when the group wanted to publish an album and there were problems in terms of recordings rights, because Tudor had already released an album called *Rainforest.* Previous versions of *Rainforest* were confused historically, because Tudor never really made distinctions between different realizations. For a historical reconstruction see the article by John Driscoll and Matt Rogalsky 'David Tudor's "Rainforest": An Evolving Exploration of Resonance', – Leonardo Music Journal, vol. 14.

The group was officially dubbed *Composers Inside Electronics* in 1976, when Tudor was invited to the *Festival d'Automne*, in Paris. He wanted to have musicians from the Chocorua workshop assist him on *Rainforest* (in the course of the festival they also performed Cage's *Cartridge Music*, works of Takehisa Kosugi, and pieces by various members of the ensemble). The name *Composers Inside Electronics* was chosen to represent Tudor's ideas, around which the group was shaped. As Driscoll observed:

> David felt strongly that at the time music focused on the idea that you have a musical concept and then you find the instruments to realize it. He felt that it should be the reverse of that. You start with an instrument, you explore it and that suggests the music that you make. So that was the reason behind the name *Composers Inside Electronics,* the ideas started inside the electronics and then became musical. The instrument suggests the music. […] When he was building his electronics it was never the conventional use of the electronics. He was making this no-input mixing, and for him this was just a new concept to generate sounds. In the early '60s, nobody had computers, few people had access to the labs of electronics, and nobody had synthesizers. David explored that world trying to use electronics to make the music he was interested in.[7]

In the beginning, crystal phonograph cartridges were used as contact mics in *Rainforest*'s realizations. Tudor was familiar with them from his work with Cage on *Cartridge Music*. Driscoll remembers the Astatic 12u (fig.1.4.1), which had a hole to insert the needle, that was replaced by a piece of steel wire, in order to have a less fragile contact point. Materials for DIY projects were available from electronic surplus dealers, as well as from hobby retailers such as Radio Shack, and manufacturers such as Electro-Voice (fig.1.4.2), Kent, Astatic, Barcus Berry. Later, the kind of phonograph cartridge like the Astatic 12u became hard to find. So while collecting old cartridges in various electronics shops, the group started experimenting with other kind of contact-mics, such as throat-microphones and for bone transducers (that are put against the jaw to drive sounds into the head), both usually used for people with hearing difficulties (at that time Driscoll was living in Washington, next to a school for the deaf).

7 Skype interview with John Driscoll (25 March 2019).

Fig 1.4.1. Astatic12u. Photos © John Driscoll.

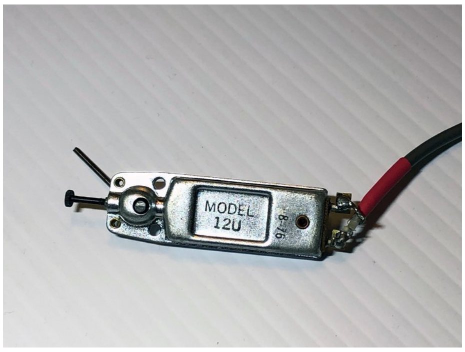
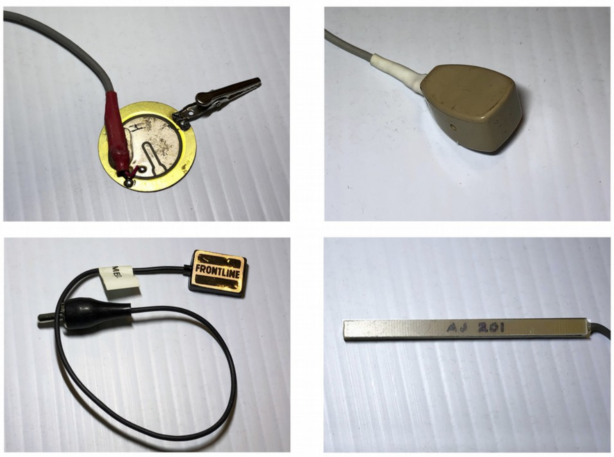


Fig.1.4.2 Contact microphone 805-*ElectroVoice*. Picture from *Electro-Voice* Catalogue (1957). In the catalogue the microphone is described as: "Contact- For guitar, banjo, any vibrating-string instrument. Hi-Z . Sealed crystal. Chromium finish. 15- foot cable. List Price ...$20.00".

Their collection (fig.1.4.3) included also "disk-cutters heads" (devices made for cutting records, used in reverse as a microphone), as well microphones used for listening to the heart-beat of a foetus.

Fig.1.3. Different contact microphones from the collection of John Driscoll. Clockwise from top left: small throat mike; piezo piano pickup; homemade piezo pickup; Frontline pickup. Photos © John Driscoll, used by permission.



When piezo disks became available they were included in the collection, even though Driscoll preferred the phono-cartridges for their richer sound:

> The problem with the piezo disks is that they usually have a centred resonance frequency. Whereas the cartridges were made to have a curve and when you put a reverse curve in your pre-amplifier then it brought out a lot of the bass and they have a much warmer bass sound than the piezo-disks, that tend to be a little more towards the higher frequencies. Each kind of microphone needed a specific pre-amplifier, with a specific circuit. Also, there's impedance difference. So you have to match the impedance better for each of a different kind, so we were trying many kinds of microphone pre-amplifiers, based on which kind of contact-microphone it was. The throat mics didn't have to have a different equalization, it goes through a regular microphone pre-amp as long as the impedance was matched. And those were the lower impedance, while the piezo has a quite higher one.[8]

1.5 Richard Lerman

Richard Lerman is another artist who contributed significantly to the research on the musical use of contact microphones. He began experimenting with different kinds of contact microphones in the mid '60s, using them to record "sounds and vibration in bicycles, wind harps, plants, boat anchor ropes, rocks, cactus thorns, heat expansion in metal, spider webs (with limited success), attached them to many kinds of self-built and traditional musical instruments, and even used them as loudspeaker drivers to induce sound into metal and glass sculpture".[9] Lerman was studying at Brandeis University in Waltham, Massachusetts, while Alvin Lucier was running the electronic studio (with Anthony Gnazzo). When Lucier left Brandeis, around 1965, Lerman became by default the technical director of the studio, "vastly unprepared but really curious".[10] During that period, John Cage and David Tudor were often around, as well as Gordon Mumma, from whom Lerman learned to solder. Lerman remembers Tudor telling him something like: "Richard, if you want to do electronic music, you have to learn some electronics." Lerman took these words seriously, he experimented thoroughly and, "early in the game", was using piezo disks both as microphones and loudspeakers (or – as he puts it – "soft speakers"). The first versions of his piece *Travelon Gamelon* (1977) used "phono cartridges between fender washers, housed in the plastic box [the cartridges]

8 Ibid.
9 In *A Guide for working with Piezo Electric Disks to introduce Children to Issues of Acoustic Ecology and Sonic Creativity* <http://www.public.asu.edu/~rlerman/PDF%20Files/Children%20&%20Piezo%20disks.pdf > accessed 15 April 2019.
10 Email from Richard Lerman (26 September 2018).

were packaged in".[11] Suggesting the percussive and metallic sound of a gamelan orchestra, the sound in *Travelon Gamelon*[12] is produced by rhythmic movements of bicycles, captured by contact mics. But even protected in plastic housings, the cartridges were fragile and often broke. So Lerman started experimenting with piezo materials:

> I was researching a lot of different sources about phono cartridges and discovered that ceramic cartridges (EV 81T's) were piezo devices and were usually made from something like barium titanate. Seeing the word "piezo" with "disks", maybe from a company in Mass called Meshna Electronics, I started buying up different kinds of disks. These were much easier to work with than with the phono carts. So I began using the piezos probably in '78 / '79 or so. They were much more rugged once I figured out the best way to solder them. I began in earnest to work with the disks and to construct preamps for them using various op-amps that were around.[13]

Travelon Gamelon was performed also in Europe in 1979 for the Muzicki Biennale Zagreb, in Lerman's first trip to Europe. In 1981, encouraged by his friend John Driscoll, he applied to the "Spiel und Klangstrasse" festival in Essen (Germany), run by the percussionist Michael Jüllich.[14] There he met Godfried Willem Raes – a Belgian artist who has worked extensively with piezoelectricity–, who was participating in the same Festival. And in September of the same year [15] Lerman performed for the first time at Raes's venue called *Logos* – a space in Ghent, active for experimental music since 1968.[16]

1.6 Godfried Willem-Raes

The composer and performer Godfried Willem Raes, founder of Logos – a Belgian-based research and production centre for experimental music – is well known for his work as an instrument-maker: over a few decades he created a huge Robot Orchestra, combining experimental instrument design with several kinds of musical interfaces, such as wireless gesture control, real-time sound analysis, microwave radar, acceleration sensors, pyro detectors, light sensors, brainwaves, EEG and ECG, etc. Interestingly, his research has also been deeply committed to the study of piezoelectricity, focusing mostly on the use of piezoelectric elements in Ultrasound systems, although he also

11 Ibid.
12 http://www.sonicjourneys.com/PDF%20Files/NewTravelonGamelon.pdf last access 12 June 2022.
13 Ibid.
14 Email from Richard Lerman (12 May 2019).
15 <http://users.telenet.be/stichtinglogos/concerts/concerts1981.html>last access 24 June 2019.
16 <http://users.telenet.be/stichtinglogos/concerts/concerts1968.html> accessed 24 June 2019.

realized many works using piezoelectric microphones to amplify objects.[17] Since the mid-'60s he started experimenting and researching on piezoelectric materials, with piezo elements such as seignette salt, a very hygroscopic material that deteriorates rapidly with humidity, used at an early stage for contact microphones, cheap headphones, crystal radios. Already from his childhood Raes got access to components coming from the research department at Philips, in Brussels, where a friend of his parents worked as engineer. At the end of the ‘70s, when piezo disks became available, he continued researching, making circuits to preamplify their signal, in order to correct their impedance and to eliminate their resonant frequency. Raes collected also many books with data about piezoceramic materials, while contacting factories that produced piezo. Since the mid-'70s, Raes started exploiting piezos in his artistic projects with ultrasound, working especially in the range between 20kHz and 70kHz. He started then to build piezoelectric-based systems acting as gesture sensors, using them for reflection and for measuring people's movements as radar devices, in a doppler setting. Early in the '80s, one of his major results has been the *Holosound* production, which exists both as performance, as installation, and as concert version. The main idea of this work relies on translating the movements of the performer, or of the audience, into sounds within a dynamic multi-dimensional system. A frequency-modulated ultrasound emitter is placed in a specific point and directed towards (at least) three ultrasound receivers, placed on the four corners of an imaginary tetrahedron (all angles 60 degrees). From the receiver, the signal goes to a demodulation circuit to bring the signal back to the audio realm. The three signals from the ultrasound receivers are used also as inputs for special magnetic transducers connected to a given set of changeable objects (e.g. long springs and metal chimes up to three meters) inducing them to vibrate. In installations more receivers can be used, all related to the same ultrasound emitter (a *Holosound* component is shown in fig. 1.6.1). Objects such as keys, or broken glasses, can become audio sources: since their frequency spectrum is rich in many inaudible ultrasounds, little movements such as touching the keys produce strange noises, due to the fact that the system allows the translation of these ultra-high frequencies into the audio realm.

Raes used piezoelectric technology in many other projects in a very creative way. In his early work, he built, for example, a monochord in which he used both an electromagnetic transducer and two piezos in order to amplify the string. The choice of using two diverse types of microphone is based on the possibility of exploiting their different properties: the electromagnetic microphone works better for the bass frequencies, while the piezos are very good for scratching sounds, and for high sounds in general. So the monochord has two outputs: one for the two piezos - that are mixed

17 A whole interview with Godfried Willem-Raes is in Appendix 3.

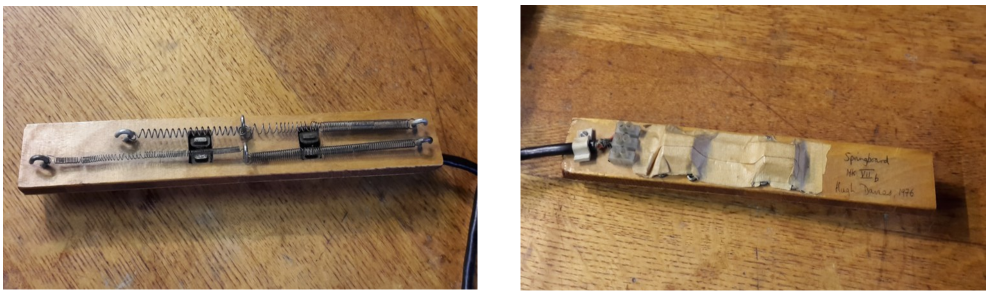
internally - the other for the microphone with the magnetic transducer, which comes from an electric guitar (fig.1.6.2). The two pre-amps are contained in two different circuits - one for the piezo and one for the magnetic transducer, and the two signals are then mixed externally.

Fig.1.6.1 Holosound component: four piezos encapsulated in silicon with their preamplifier in the black box.

Fig.1.6.2. Monochord.

Between the '60s and the '80s Raes' work was deeply connected with the experimental music scene: at Logos, in Ghent, he hosted the most relevant experiences of that time, getting in touch with many interesting musicians, such as Richard Lerman and Hugh Davies. Raes still owns an original Hugh Davies Springboard, bought from the English composer in 1974 (fig.1.6.3).

Fig.1.6.3. Springboard by Hugh Davies, owned by Godfried Willem-Raes. Photos taken at Logos Foundation by the author (20/03/19).



1.7 *Mikrophonie I* by Karlheinz Stockhausen and the *Feedback Studio*

While the experimental scene was growing, exploring electronic music means, the research was going on within the more institutional contexts of the radio studios such as WDR (Köln, Germany), ORTF (Paris, France), Studio di Fonologia (Milano, Italy), BBC Studio (London, UK). In the 1940s, Pierre Schaffer had already started the Groupe de Recherches Musicales at the Radio Diffusion Télévision Française (RTF), where worked for almost ten years. A few years later, Karlheinz Stockhausen worked in the WDR studio in Cologne, and Luciano Berio was among the founder of the Studio di Fonologia in Milano, in which Cage spent almost a year, composing Fontana Mix (1958). In these contexts, electronic works were mostly recorded onto tape.

Karlheinz Stockhausen explored live electronic processing with his pivotal work, *Mikrophonie I* (1964), first premiered on December 9th, 1964 in Brussels. The piece is the result of Stockhausen's experiments, in the summer of 1964, on the large tam tam that he had previously bought for *Momente*. As the only sound source, the tam tam is excited with objects of different materials, such as glass, cardboard, metal, wood, rubber and plastic. All performed actions are amplified with a highly directional microphone and then processed in real-time. The six performers are divided into three symmetrical groups: the first two play different actions with various objects on the tam-tam, the second two manipulate the microphones, while the third pair modulate the microphones' sound with a filter and a potentiometer. In the score[18], Stockhausen specifies different degrees of distance of the microphone from the tam-tam surface and from the point of excitation generated by the object used to play the instrument. Those parameters affect the clarity and the timbre of the sound, in much the same way physical location affects the sound heard through a contact mike. The difference between the sound input of the actual source, and its output through the loudspeakers, has been defined by Stockhausen the "microphonic process" (Maconie and Stockhausen, 2010, 78). Not even in the previous twelve years spent working in the electronic music studio, Stockhausen experienced such an unusual sound world. Maybe as a direct consequence, with the help of Jaap Spek, the technician at Cologne's WDR radio, Stockhausen had started to use contact microphones (fig.1.7.1)[19] to amplify metal and string sounds in many pieces of the same period, such as *Mixtur* (1964), *Prozession* (1967), or *Kurzwellen* (1968).[20] The latter two were performed several times by

18 "One of the most elaborate scores for movements with microphones ever written", as Cathy Van Eck observed in her work *Between air and electricity* (Van Eck, p. 96).

19 These contact mics might have come from the WDR Studio – as most of the equipment Stockhausen used.

20 *Mixtur* (1964) is a piece for orchestra, 4 sine-wave generators and 4 ring modulators, in which contact mics have to be used to amplify percussion instruments and double basses, as specified in the performance notes. *Prozession* (1967), is for tam-tam with microphonist, viola (amplified with contact mic), electronium, piano; and *Kurzwellen* (1968), is for

the composer and violist Johannes Fritsch, who was part of the Stockhausen Ensemble (1964-1970), together with Rolf Gehlhaar. Fritsch and Gehlhaar continued to experiment with contact mics also after they left Stockhausen's group and formed the *Feedback Studio* (active between 1971 and 2001). Gehlhaar remembers Fritsch using a piezoelectric contact microphone model by Schaller[21] for his piece *Partita* (1966) for amplified viola and tape delay:

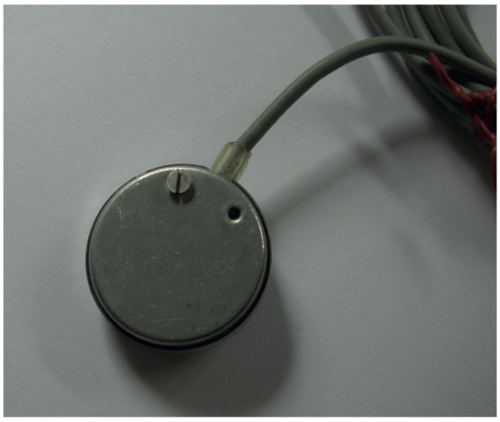
> Normally, when he played, he had the microphone attached either to the bridge or to the soundboard very close to the bridge. The position varied with what quality of sound he wanted to produce - on the bridge, brighter, sharper sound; on the soundboard, slightly more muffled, rounder sound. He was a very good player and his performances of *Partita* and contributions to the performances of *Prozession* and *Kurzwellen* by Stockhausen were of the highest quality. The Schaller contact microphone was very useful for installations and theatrical applications, where, for example one could be attached to the clinking chains that an actor was wearing as a part of his costume. In this context we did have to be careful due to their very high impedance. Consequently, the extending cable, its routing and the amplification had to be electronically very correct, otherwise a lot of noise and hum would be generated. Or several could be attached to the stage floor, to amplify footsteps for particularly dramatic effect. In the Feedback studio we experimented a lot with the contact microphone and various instruments as well as surfaces in our installations of the early 70s, where we would turn whole rooms and all the objects with them into musical installations. For this purpose I often found the contact microphone too sensitive or difficult to employ. I began to research other ways of amplifying objects, for example by hanging them on steel strings passing over an electromagnetic guitar pickup. This produces very interesting sounds. Another technique I developed for installations, was to employ piezoelectric emitters as microphones by placing small weights on them, one edge on the piezo, the other on the object to be amplified. This works very well.[22]

Fig.1.7.1. Contact microphone used by Stockhausen Ensemble. Photos © Sean Williams

tam-tam with microphonist, viola (amplified with contact mic), electronium, piano, 4 shortwave radios.According to Sean Williams (Email, 02 February, 2019) the contact microphone of Fig.4 could be of the same kind used by Fritsch for his viola in the performance of *Prozession*, *Kürzwellen*, *Hymnen* (with soloists), *Spiral*, *Pole*, and various pieces from *Aus den Sieben Tagen*. In all cases, the contact mic signal was processed through a Maihak W49 Hörspielverzerrer (band-pass filter) and then usually two volume faders - one for each speaker.

21 Schaller contact microphones are still produced today. The most popular model is the Schaller Oyster S/P <https://www.thomann.de/gb/schaller_oyster_723.htm > accessed 13 May 2019.

22 Email from Rolf Gehlhaar 28 April 2019.

1.8 Hugh Davies

The British composer and live electronics pioneer, Hugh Davies (1943-2005), invented more than 130 concert instruments, sound sculptures, and site-specific installations – many of which made use of different kinds of contact microphones. His work was strongly influenced by his experience as Stockhausen's assistant, between 1964 and 1966. This collaboration started because of a book Davies was writing about the German composer – that at the end has never been published. Quite significant was Davies' close involvement in *Mikrophonie 1*, having participated in its first performances under Stockhausen's direction. These were the same performances where Fritsch and Gehlhaar were playing, so it's highly possible that Davies was aware of their experiments with contact mics as well. After the period spent in Cologne, Davies maintained a working relationship with Stockhausen lasting several years. He continued to correct his scores and he performed many of his works in the UK. Before going back home, Davies lived also in Paris and New York, working on compiling the *Répertoire international des musiques électroacoustique* or *International Electronic Music Catalog* (RIME), published in 1968. When he returned in the UK he founded the electronic music studio at Goldsmiths College, which he directed until 1986. Four years before, Davies had set up a small studio at the Oxford University, helped by Daphne Oram, a former mentor of Davies, especially while he was still a student.[23] When Davies came back to the UK in 1967 he began building his own instruments, recycling everyday objects, putting contact microphones on them, and bringing to the foreground sounds that are not usually part of the realm of musical sounds. The role of amplification, as well as the use of everyday objects in *Mikrophonie 1*, had a profound effect on Davies, marking the point from which he left the electronic music

23 For further info see also Palermo 2015, op.cit.

compositions based on tape, to develop his own personal research in live electronic music. In doing so, the influence of Stockhausen was balanced by that of Cage and Tudor,[24] especially in regards to the low-fidelity aesthetics and DIY ethos employed in realizing his instruments, as well as the freedom to combine more diverse sound sources. Relying on Raes' statements, Davies worked mostly with magnetic transducers, that he extracted from old headphones or old telephones, and used them as pickups. It seems that Davies was used to collect hundreds of these old things from flea market, as confirmed by Fiorenzo Palermo:

> The first magnetic pick up he used was around 1969 and came from ex-RAF microphones, which he claimed had been used in Spitfires during the Second World War. Subsequently, when the supply of these diminished (he got them from stores in Denmark Street in London), he turned to old telephone handset earpieces or headphones used by the military or by telephone operators. I don't think Hugh built his own microphones, but rather salvaged and repurposed them. Nonetheless, I have found in my research that in the occasion of a performance of "Sternklang" by Stockhausen in Bonn in 1980 Hugh played an A clarinet with a self-made contact mike and pre-amplifier".[25]

In 1968 Davies produced one of his first successful self-contained instruments, the *Shozyg I* (fig.1.8.1), which consists of the last tome of the encyclopedia – volume 13, which includes entries from "Shoal" to "Zygote", thus from "Sho" to "Zyg" – whose pages had been hollowed out to make space for objects mounted on its inside back cover. The objects inside – a ball-bearing, three fretsaw blades of different length, and two different springs – were grouped in two areas, and each group is amplified by a piezoelectric pickup, chosen according to its filtering characteristics. The objects were played using fingers, fingernails, screwdrivers, needle files, toothbrushes, small electric motors, etc.[26] According to Palermo, Davies had begun using piezoelectric microphones "at least since the establishment of the Goldsmiths Electronic Music studio in 1967, which had two piezos in its initial equipment, and he used these to amplify all kinds of object (combs, broken light bulbs, springs), then recording *Galactic Interfaces* as a result".[27] In other works, Davies used magnetic pickups instead, as in *Concert Aeolian Harp,* built from eggslicers: fine fretsaw blades were mounted in parallel on an aluminium frame, which would have then been fixed to a stand. The contact microphones were placed on the edges of the aluminium frame, perpendicular to the blades. The performer should then blow on the fretsaw blades, recalling the sound of an Aeolian harp. (see

24 In admitting their influence, Davies recalls a remarkable Concert in London (November 1966) given by Cage, Tudor, and Mumma during a visit by the Merce Cunningham Dance Company. During this concert they might have performed also *Music for Amplified Toy Pianos* (1960). [See Davies, 2001].

25 Email from Fiorenzo Palermo (25 May 2019).

26 For a more detailed description and pictures see Palermo 2015, op.cit.

27 Email from Fiorenzo Palermo (25 May 2019).

Palermo 2015, pp.191-192). Exploiting the means of amplification Davies brought to the fore sounds that were previously part of background noise, complying with the Cageian aesthetic of ‘small sounds’. The *Shozyg 1* is a good example of Davies' way of building small, compact, and portable instruments, fulfilling the need for immediacy and accessibility. In fact, Davies called the *Shozyg 1* a “*musique concrète* synthesizer” (Palermo, 2015, p.166-167), considering both its great sound potentialities and the possibility to perform live-electronic music with it.

Fig.1.8.1. Shozyg I (1968) - self-built electro-acoustic musical instrument by Hugh Davies. © Science Museum/Science & Society Picture Library. For an audio example go to: https://sounds.bl.uk/Classical-music/Hugh-Davies-experimental-music/026M-C1193X0051XX-0001V0 [last access: 23/05/2021].

Between 1968 and 1975 Davies was also a member of *Gentle Fire*. The other members were Richard Bernas, Patrick Harrex, Graham Hearn, Stuart Jones, Richard Orton, Michael Robinson. Curiously the name *Gentle Fire* was originated by consulting the I Ching. The group was inquiring the book about the path they need to take: “hexagram No. 37, the Family, came up – the two trigrams of which are Sun and Li, meaning Gentle Wind and Clinging Fire respectively – indicating clearly to the group that they should continue these activities and supplying the name Gentle Fire”((Davies 2001, p.54). Beside performing a wide range of composition by living composers – such as Stockhausen, Ashley, Cage, Cardew, Feldman, Wolff, etc. –, *Gentle Fire* performed collective pieces, composed by the group between 1970 and 1973, further exploring live processing of sound as well as invented instrumentation. In *Group Composition III* and *IV,*[28] the ensemble shared a single instrument, the *gHong* (invented by Robinson), made up of three suspended metal oven grills, with a wooden crossbar on the fourth side from which four large springs were suspended. Each side of the *gHong* was connected to two contact microphones: a high-quality type, such as a stethoscope or transducer, and a contact microphone with a reduced frequency response. By varying the levels on a mixer for each pair of microphones it was possible to obtain substantial

28 In *Group Composition III* the *gHong* was the only sound source, while in *Group Composition IV* each member chose also another instrument to play.

filtering effects, so that the use of microphones was crucial in the playing of the *gHong*. Apparently the *gHong* was originally meant to satisfy the score instructions of Christian Wolff (see Palermo, 2015, pp.138-140) , where the score instructions read: ‘Construct an instrument, or find something, or use an instrument as part of a construction which can make 5 different pitches, or 11 or 3 different pitches; 6 different qualities of sound (they can be made to depend on the manner of performance), or 2; and which can sustain sounds at least somewhat before they begin to fade’, and the different microphones placed on the instruments allowed for an extension of the sounds produced.

1.9 *The Artaudofoon* – Peter Schat

The idea of amplifying metal sounds with contact microphones was also applied by the Dutch composer Peter Schat (1935-2003). Early in his career, with the help of the sculptor Frans De Boer-Lichtvelt and the technician Jo Scherpenisse, he designed an instrument named *Artaudofoon*. In the '60s Peter Schat was part of a group of politically engaged young composers that included Misha Mengelberg, Louis Andriessen, Dick Raaymakers, Jan van Vlijmen, Reinbert de Leeuw, and Konrad Boehmer, who founded the “Studio voor Elektro-Instrumentale Muziek” - STEIM.[29] Nico Bes – who worked at STEIM as a technician since 1971 – recalls that one of his first experiences with the technology of contact microphones was the *Artaudofoon.*[30] The instrument, as the name suggests, was inspired by the *Theatre of Cruelty* of Antonin Artaud, and consisted of five metal sculptures, whose sound was amplified by contact microphones attached to them. According to Jo Schepernisse[31], Schat used military throat-microphones (used by helicopter-pilots). The history of this huge instrument is controversial. As recounted by Bas Van Putten in Peter Schat's biography, the idea of this project started in 1965, when Peter Schat obtained a grant from the Prince Bernhard Fund. While working on his opera *Labyrinth*[32] he developed the idea of building a huge electro-acoustic percussion instrument, equipped with many “contact microphones, a filter, a modulator, an amplifier and a set of loudspeakers” (Van Putten 2015, p.381). In September 1966 Schat also tried

29 See Otto, Andreas (2008). *Die Entwicklung elektronischer Musikinstrumente am Steim (Studio für elektro-instrumentale Musik) im Amsterdam seit 1969*. (MagisterArbeit), pp.14-15. <https://docplayer.org/2117578-Die-entwicklung-elektronischer-musikinstrumente-am-steim-studio-fuer-elektro-instrumentale-musik-in-amsterdam-seit-1969.html > accessed 18 April 2019.

30 Email from Nico Bes (05 February 2019).

31 Email from Jo Schepernisse (09 April 2019).

32 *Labyrinth* was premiered at the Holland Festival 1966, conducted by Bruno Maderna, who was at that time guest-director at the Concertgebouw in Amsterdam.

to get funding from Philips because the instrument was presenting many technical problems and he had underestimated the costs of the electronic parts. In 1966 Schat received a commission by the Rotterdam Art Foundation to write *Electrocution*, which should have been - in Schat's original idea - a total theatrical work, using the *Artaudofoon* as the percussive instrument, but this work was never written. Nevertheless, in Schat biography, Van Putten mentions the movie *The Gangster Girl* (1966) by Frans Weisz,[33] in which a scene of a concert – filmed in the Kleine Zaal of the Concertgebouw of Amsterdam – features a composition played by the *Artaudfoon* and three double basses (fig.7a, 7b). According to Van Putten, Peter Schat played two roles in the movie: “the Stranger", a guy who falls in love with the gangster's girl, and the role of the conductor of his own music for *Artaudofoon* (Van Putten 2015, pp. 386-389).

The picture from *The Memory of the Netherlands Database* (fig.1.9.1) – an online heritage collection of Dutch historically relevant paintings, drawings, stamps, posters and photographs – was probably taken during the shooting of the movie, since the location looks alike. The *Memory of the Netherlands Database* dates the picture March 14th, 1966, but it does not mention the movie. In the newspaper *San Francisco Examiner* (July 17, 1966) it is possible to find a similar picture, which caption mentions the *Artaudofoon* as the percussion instrument “unveiled last week” (unfortunately the dates do not match perfectly), but without any reference to the occasion in which the picture was taken.

Fig.1.9.1. *Artaudofoon.* Peter Schat standing in the middle. Photos © *The Memory of the Netherlands Database.*

In the scene of the over-mentioned movie,[34] the fragment played in the concert was probably an improvisation or a part of the open-form piece *First Essay on Electrocution* published in 1967 by Donemus.[35] The latter, for violin, guitar and metal percussion instruments (3 players), seems to be a

33 Original title of the movie: *Het gangstermeisj*e. Cast: Wiet Claessen, Walter Kous, Gian Maria Volonté, Astrid Weyman, Joop Admiraal, Kitty Courbois, Joop van Hulzen, Paolo Graziosi.

34 See the published exposition "Composing with Piezo", by Daniela Fantechi in www.researchcatalogue.net for the excerpt from *The Gangster Girl* (1966) [16'30"-18'30" ca.], courtesy heirs Jan Vrijman.

35 See the published exposition "Composing with Piezo", by Daniela Fantechi in www.researchcatalogue.net to consult the score.

work in progress, as can be deduced from Schat's request to settle the fee, unusually written in the score, right before the technical notes.[36] A statement later in the technical notes – “it is the best to use the *Artaudofoon* for the performance […] it is, however, also possible to use cymbals and other metal percussion instruments, the sound of which is scanned with contact microphones”[37] – suggests that Schat was becoming aware of the difficulties in the use of the *Artaudofoon*. Soon, in fact, the project was abandoned and the *Artaudofoon* was forgotten. One part of it is still archived at STEIM (fig.1.9.2).

Fig..9.2. *Artaudofoon* archived at Steim. Photos © Nico Bes.

1.10 Conclusions

The diverse experiences described above indicate the shared interest around the possibilities of amplification and the development of new ways of experiencing sound through the use of contact microphones. The period between the '60s and '80s was one of lively circulation of ideas. Long before the internet made this kind of sharing effortless, international festivals and concerts were the main occasions for musicians to meet and share each other's work and technical research. American composers travelled throughout Europe, bringing new ideas from the New World. Cage and Tudor were among the earliest visitors, and had a profound effect. Tudor in particular played a central role, acting as a bridge between American and European communities. Since the 1950s he had premiered many works by composers including Stockhausen, Maderna and Boulez, building strong connections with the European avant-garde.[38] At the same time, he often toured with Cage,

36 “Here is the composition written as result of your commission. I hope that you will in the near future pay the second half of my fee, namely 750 guilders, into my transfer account (No. 122,747) Thank you very much.” (In Schat, Peter (1967) *First Essay on Electrocution,* for violin, guitar and metal percussion instruments (3 players). Donemus [score]).

37 Idem.

38 He premiered, for example, Stockhausen's *Klavierstück XI*, on April 22nd, 1957, in New York – with the great

introducing new music from other American composers as well. It is worth noting, that in this lively period, the premiere of *Cartridge Music* took place in Germany at Mary Bauermeister's Cologne atelier, on October 6th, 1960, with performers such as the Naim June Paik, Hans G. Helm, Benjamin Patterson, William Pearson, Kurt Schwertsik, Cornelius Cardew, alongside Cage and Tudor, and avant-garde composers such as Stockhausen present in the audience.[39]

In such an interconnected community, the exploration of new possibilities of amplification contributed to changes in perspectives and practices of music making. Because of its relevance to this process, a technological object such as the contact microphone became a cultural object, contributing to the cross-pollination between different artistic disciplines. As John Driscoll noted, Tudor's idea of turning upside down the role of the instrument in the process of music creation has a profound influence on the development of experimental music. The instrument is no longer the means to realize a musical idea, but it is itself the starting point of a whole creative process. And the possibility of amplifying what previously belonged to the realm of the inaudible encouraged a new perspective, contributing to more creative approaches in the development of DIY practices and collaborative works. In this context the gradual shift of David Tudor from being the representative pianist of the avant-garde music, to embracing a personal and experimental way of dealing with electronics, seems to exemplify the path of a musical movement enriched by experimentalism, especially through personalities like Hugh Davies and Richard Lerman, and the intense activity of collectives such as *Gentle Fire, Feedback Studio, Composers Inside Electronics*.

Since the '80s, the use of contact microphones has become common in a huge and diverse range of artistic experiences, most of them related to sound art and experimental music, and strongly based on improvisational performance practices. My own personal approach, as I will explain further in the following chapters, shares with these experiences the application of DIY techniques, but it brings them into a context of compositional notational practice, in which the intentionality of gestures remains a central research aspect.

---

disappointment of Steinecke, who had agreed before on having the world premiere in Darmstadt a few months later – , and Maderna's *Piano Concerto*, on September 2nd, 1959, with the Symphonic Orchestra *Heissischer Rundfunk*. See: Iddon (2013), pp.181-183.

39 Iddon (2015), p. 166.

Main References

Adlington Robert. *Composing Dissent: Avant-garde Music in 1960s Amsterdam.* Oxford University Press, 2013.

Callister, Jr, Willian D. *Materials Science and Engineering. An Introduction,* John Wiley & Sons. Inc., 2007.

Cage, John. *Living Room Music*, Peters Edition, 1940.

Cage, John. *Cartridge Music*, Peters Edition, 1960.

Davies, Hugh. "Gentle Fire: An early approach to live electronic music", Leonardo Music Journal, 11 : 53-60, 2001.

Driscoll, John and Matt Rogalsky. "David Tudor's "Rainforest": An Evolving Exploration of Resonance", Leonardo Music Journal, vol. 14, *Composers inside Electronics: Music after David Tudor* : 25-30, 2004.

Fullemann, John and David Tudor. "An Interview with David Tudor by John Fullemann in Stockholm, August 31, 1984". www.davidtudor.org/Articles/fullemann.html.
(last access: 16/05/2019)

Iddon, Martin. *New Music at Darmstadt: Nono, Stockhausen, Cage, and Boulez,* Cambridge: Cambridge university Press, 2013.

Iddon, Martin. *John Cage and David Tudor, Correspondance on interpretation and performance*, Cambridge University Press, 2015.

Kuivila, Ron. "Open Sources: Words, Circuits and the Notation-Realization Relation in the Music of David Tudor", Leonardo Music Journal, vol. 14, *Composers inside Electronics: Music after David Tudor* : 17-23, 2004.

Lerman, Richard. *A Guide for working with Piezo Electric Disks to introduce Children to Issues of Acoustic Ecology and Sonic Creativity*. Available at: http://www.sonicjourneys.com/PDF%20Files/Children%20&%20Piezo%20disks.pdf (last access,13/03/2019)

Lerman, Richard. *Travelon Gamelan,* 1977.
Score availble here: http://www.sonicjourneys.com/PDF%20Files/NewTravelonGamelon.pdf [last acces: 12/05/2019]

Manbachi, Amir and Richard S C Cobbold, 'Development and application of piezoelectric materials for ultrasound generation and detection', in *Ultrasound,* 2011: 1–10.

Mooney, James. 'The Hugh Davies Collection: live electronic music and self-built electro-acoustic musical instruments, 1967–1975', Sound and Vision, 7, 2017.

Mooney, James. “Hugh Davies's Electronic Music Documentation 1961-8”, Organised Sound, 20 (1), 2015 : 111 – 121.

Mooney, James. “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 (IFIMPAC), 12-13 March 2015, Leeds College of Music.

Mooney, James. “Internationalisation and historicisation in Hugh Davies’s international electronic music catalog: a position paper -OR- Hugh Davies: international electronic music champion”, in: The Eighth Biennial International Conference on Music Since 1900, 12-15 Septempber 2013, Liverpool, UK. (Unpublished)

Nyman, Micheal. *Experimental Music: Cage and Beyond*, Cambridge : Cambridge University Press, 1999.

Otto, Andreas, *Die Entwicklung elektronischer Musikinstrumente am Steim (Studio für elektro-instrumentale Musik) im Amsterdam seit 1969*. (MagisterArbeit) https://docplayer.org/2117578-Die-entwicklung-elektronischer-musikinstrumente-am-steim-studio-fuer-elektro-instrumentale-musik-in-amsterdam-seit-1969.html (last acces: 18/04/2019)

Palermo, Settimio Fiorenzo. *The Work of Hugh Davies in the Context of Experimental Electronic Music in Britain.* PhD thesis, Middlesex University, 2015.

Raffo Dewar, Andrew. “An in-depth history of the innovative instrument builders and composers that helped revolutionize live electronic music”, Red Bull Music Academy Daily, 2018. https://daily.redbullmusicacademy.com/2018/07/sonic-arts-union-history-and-key-works (last access: 20/04/2019)

Schat, Peter. *First Essay on Electrocution*, for violin, guitar and metal percussion instruments, Donemus, 1996.

Smith, William F. *Scienza e tecnologia dei materiali*, McGraw-Hill Libri, Milano, 1995. (Original title *Foundation of Materials Science and Engineering 2/e*, McGraw-Hill Inc, 1993).

Stockhausen, Karlheinz. Maconie, Robin. *Stockhausen on Music*, Marion Boyars, London and New York, 1991.

Van Putten, Bas. *Alles moest anders. Biografie van Peter Schat*, Uitgeverij De Arbeiderspers Amsterdam – Antwerpen, 2015.

Viola, Bill. “David Tudor: The Delicate Art of Falling”. Leonardo Music Journal 14, 2004, pp. 49–56.

http://www.editionjohannesfritsch.de/index.html (last access: 10/05/19) https://piezo.com/pages/piezo-education (last access: 04/05/2019)

http://www.steampoweredradio.com/pdf/electro%20voice/electro%20voice%201957.pdf
(last access: 12/02/2019)

https://www.geheugenvannederland.nl/en/geheugen/view?identifier=ANP01%3A12912095
(last access: 11/05/2019)

2. Microphones, instruments, performers: ecosystemic considerations

Introduction

In the previous chapter, I have considered diverse artistic experiences in a quite narrow time window, from the '60s to the '80s. From then on, the use of contact microphones has become common in a huge and diverse range of artistic experiences, most of them related to sound art and experimental music. The low cost of and the easy availability of piezoelectric elements are the main practical reasons for the spread of piezoelectric disks, whose technological features have been curiously kept as they were in the '80s, while at the same time, different applications of piezoelectricity underwent a remarkable development. There is a sort of gap between the technological and scientific progress of piezoelectric devices, and the use of piezoelectric elements for the construction of contact microphones or hydrophones, in the realm of experimental music and sound art. Enormous progress has been made in the direction of micro-size: nowadays piezoelectric devices tend to be built-in electromechanical microsystems, covering a wide range of different applications from automatization to bioengineering and biomedicine. Hence, it is no longer possible to manipulate or hack advanced piezoelectric devices. While piezoelectric elements used to build piezoelectric contact microphones have maintained a hand-size/finger-size, crucial to manipulation. The lack of correspondence between the scientific progress of piezoelectric technology and its adoption in experimental music experiences can be ascribed to the miniaturization of piezo technology and the subsequent loss of physicality and impossibility of a hands-on approach. If some technological upgrades are evident in the comparison between the first experimental experiences and the work of contemporary artists, they consist, above all, in the inclusion of software, controllers, video, and any other kind of implementation of the electronic system. But the technology of piezoelectric disk is basically kept as it was, pointing to the importance of manipulation, and DIY ethic and method.

In the context of contemporary experiences with piezoelectric microphones, my project *Composing with piezo* confirms the use of the old-school technology of piezoelectric microphones (simply *piezos*, from now on). One peculiarity of this project relies on the fact that self-built microphones are used with acoustic instruments, combining rough DIY tools with finely designed and highly perfected traditional instruments. Moreover, piezoelectric microphones are here used both to amplify instrumental sound and to produce otherwise unheard sounds, through a reinterpretation of a few instrumental techniques, such as glissando, tapping, scraping, etc, by playing the instrument directly with the contact microphone. Usually a contact microphone such a piezo is simply placed on the soundboard of an instrument to amplify it, capturing the vibrations of its surface, that are transduced and converted into the electric signal. When, instead, the piezo is used to play the instrument (moving it on its strings, on its surface, etc) its role changes: the piezo provokes sounds while detecting them through the contact with the resonant surface. This stethoscopic use of the piezo calls into question several issues, concerning the usual perception of sound in the listening experience, the instrumental use of microphones, also in relation to the contemporary tendency of extending the usual techniques of instrumental playing, and lastly the role of piezo within the compositional process.

2.1. Stethoscopic forms of listening

A certain use of piezo can be defined as stethoscopic when the movements performed with the contact microphone on the body of the instrument, recall the ones of the stethoscope on the human body. As a clear example, I can refer to my piece for piano and electronics *PianoMusicBox_1*. In this piece two piezos are used – one is given to the pianist for the production of sounds and one is fixed on the soundboard, providing information to the electronics. The piece starts with a few gestures, produced by exploring with the piezo the inner part of the instrument – the soundboard and the strings –, and it gradually moves toward the more familiar piano sound-world, when the pianist finally reaches the keyboard. The pianist's movements with the piezo inside the stringboard of the piano resemble the physician's auscultation with the stethoscope.[40]

This comparison between the piezo microphone and the stethoscope opens up a few considerations on the listening experience. In his book *The Audible Past*, Jonathan Sterne dedicates two chapters to the genealogy of modern techniques of listening, and to the way their meanings changed in relation to three very different cultural contexts in Western Europe and the United States: modern medicine from the 1760s into the 1900s, sound telegraphy from the 1840s into the 1900s, and sound-reproduction technologies between 1876 and 1930. Early in the twentieth century, thanks to the diffusion of the telephone, the phonograph, and the radio, the appropriate techniques of listening became widely spread. And Sterne observes how their development was transposed and elaborated from techniques of listening already evolved during the nineteenth century in the very specific field of medicine. Sterne chooses an advertisement of Brandes of 1925 – in which the use of headphones is encouraged to improve the listening experience – as the endpoint of a series of transformations in practical orientations toward listening that began in the 1810s with the invention and adoption of the stethoscope in the medical diagnosis. Even the iconography of listening linked to early sound-

40 See the published exposition "Composing with Piezo", by Daniela Fantechi in www.researchcatalogue.net to watch an explanatory video excerpt from *PianoMusicBox_1*.

reproduction technologies, especially concerning the use of headphones, points out a direct line of descent from the stethoscope, and the telegraph, to the telephone, phonograph, and radio.

The understanding of listening from a technical, scientific and rational perspective, started when listening entered as the practice for medical examinations of patients. Then, over the course of a century, this practical orientation moved from the specialized realm of medicine to the much larger context of listening to technologically reproduced sound.

Sterne uses the word “technique” making clear the distinction from the term “technology” that could easily fade into the first one.

> Technique connotes practice, virtuosity, and the possibility of failure and accident, as in a musician’s technique with a musical instrument. It is a learned skill, a set of repeatable activities within a limited number of framed contexts. Listening involves will, both conscious and unconscious—perhaps a better word than will would be disposition or even feel. (Sterne, 2003, p.92)

So, techniques of listening come as a learned skill, necessarily resulting from an educational process, "whether institutionalized in professional training or simply accomplished through shared and repeated practice” (Sterne, 2003, p.92). Listening techniques emerged as a distinctively modern set of practical orientations toward sound and listening, and what Sterne presents is a set common to medicine, telegraphy, and sound-reproduction technologies.

First of all, in these contexts listening becomes a technical skill, used toward instrumental ends, which could be developed up to virtuosity. Moreover, listening has been constructed as a rational and discrete activity, ideally separated from other sensory activities. And, once reached the ability to separate hearing from the other senses, listening techniques helped to create a private acoustic space, that can be shaped and transformed. Finally, this private acoustic space comes with a specific content: it is inhabited by sounds that become signs, on the basis of their sonic features and their meanings. In fact, technical notions of listening depend also on the establishment of a code used to describe heard sounds, even if this code borrows its main terms from other sensory experiences, especially from the visual ones.

The emergence of a shared code, in addition to the development of listening techniques, provided prestige and professional ethos, especially in the specific fields of medicine and telegraphy, where the ability of representing listenings were part of professional expertises of both doctors and sound telegraphers. For both professions, an auditory technique is a premise for some form of physical distance and some mediating practice or technology. The faculty of isolating and intensifying hearing, promoted by mediating practices or technologies, was a component of rationalization of listening, which has been turned into a required skill. Medical listening, for example, provided new clear meanings to the interior motions of the human body, and hearing, in medicine, surpassed sight as a diagnostic tool through the use of the stethoscope for over a century.

The invention of the stethoscope is credited to René-Théophile-Hyacinthe Laennec. In 1819, he published the *Treatise on the Diseases of the Chest and on Mediate Auscultation*, in which he explained to physicians the reasons to prefer listening to patients' bodies with the stethoscope, how to listen properly with it, and how to interpret the sounds thus heard. The first models of stethoscopes were monaural instruments. Their shape was cylindrical with an earpiece at one end and a hole at the other that would be placed on the patient's body. These first models looked like an extension of the ear trumpet, which had been in use for centuries, with the main difference that doctors used them not as hearing aids but to augment their auditory abilities. Later, rubber tubing was used to make the middle of the instrument flexible, while around 1850 the binaural stethoscope appeared, designed by Arthur Leared. The binaural model quickly found favour because it provided sound to both ears, further helping physicians to isolate from other sounds and concentrate on sound in their specific auditory fields.

As one of the most enduring symbols of modern medicine, the stethoscope represents a key object in the development of a listening technology, connecting the faculty of hearing to that of reason. The practice of listening to the movements inside the body with the aid of an instrument has been defined mediate auscultation for the first time by the same inventor of the stethoscope Laennec. In his treatise, the term was used in opposition with the practice of immediate auscultation, i.e. the habit of listening to a patient's body with the naked ear, without any instrument to mediate in between. When promoting the use of the stethoscope Laennec insisted on its instrumental role, drawing a clear line between the use of the stethoscope and the one of listening directly to the human body (which is itself also actually conceived as an instrument for listening, as Sterne highlights).

In the construction of modern medical knowledge mediate auscultation becomes central as a discrete, mediated, skilled, and technologized form of listening. Mediate auscultation has soon become a highly structured activity that requires deep knowledge and practice to perfect. Physicians need thorough ear-training and practices in order to turn instrumental listening into a point of access to medical knowledge. The stethoscope has been considered as a means to an end for the enhancement of medical perception. In this context, Sterne observes a rise of empiricism, towards a new emergent understanding of perception and its practice. Physicians have been asked to develop skills of concentration and abstracting in order to direct their attention only to specific sounds that had to be analysed. The stethoscope compensates for some of the insufficiencies of the human ear, but it also helps to isolate the faculty of hearing from the other senses, avoiding conduction of audible vibration by other parts of the body than the ear. Hearing is thus developed toward an ideal autonomous state, separated from the other senses, especially from touch and bone conduction. Hence, the stethoscope helps in creating a physical distance between the subject and the object of the listening experience. The stethoscope permits also to put a frame around some of the heard sounds, providing a clearer distinction between interior and exterior sounds. And this possibility of framing sounds facilitates their understanding, their analysis and diagnosis.

Many aspects associated with listening, listening with technology, and the sounds heard via listening with technology, are enclosed in the practice of mediate auscultation. And, as Sterne points out, most of these aspects have been transposed in the music realm from the very first development of sound-reproduction technologies. For musicians, listening soon becomes a technical skill, used toward instrumental ends. A skill to be developed up to virtuosity. With the introduction of sound-reproduction technologies, listening is understood from a technical and rational perspective. In this context, the microphone can be compared to the stethoscope, considering both of them as an extension of the human ear, as technical objects that enhance the usual listening possibilities. The microphone becomes the instrument to turn listening into a mediated practice.

An explicit comparison between the use of the microphone and that of the stethoscope has been expressed by Stockhausen in *Mikrophonie I*. Here, a condenser microphone is used (rather than a contact microphone), but the German composer clearly explains his intention of using it to fulfil a listening function. Instead of considering the microphone as a rigid and passive recording device to reproduce sounds as faithfully as possible, Stockhausen prescribes to the microphonist actions to be done on the tam-tam, probing "the surface of the tam-tam with the microphone, as a doctor probes a body with a stethoscope", as the composer writes in the preface of the score. The microphone gains a central role in the listening experience, up to the possibility to shape it. Through this very close listening, Stockhausen aims to bring to the front sounds of the tam-tam that otherwise would remain inaudible. Microphones co-operate in the definition and the perception of a peculiar auditory space inhabited by a previously hidden multitude of sounds. A listening experience mediated by such a use of microphones resembles the way doctors learn to restructure their own auditory space through the use of the stethoscope. In this sense, microphones share with stethoscopes the feature of a framing device. In medicine, mediate auscultation helps in distinguishing internal sounds that have a diagnostic meaning, from external ones, that have to be ignored. While in music, the opportunity to shape the auditory space allows for a better understanding of the musical material, and for a discrete and conscious form of listening. Intended as such, listening is oriented to the definition of a private acoustic space, in which each framed sound might assume a different meaning.

Experiences of mediated listening using contact microphones tend to highlight these aspects even more, producing a significant shift in the usual listening perception. When connecting a contact microphone to an object, the vibrations amplified are those of the specific point on the solid surface of the object where the microphone is placed. The contact microphone tends thus to resonate differently at different points of the material. Usually, the sound amplified through a contact microphone contains fewer frequencies and a stronger presence of pitched material, compared to the richer unamplified sound of the object. Moreover, a contact microphone usually has resonant peaks of its own, around certain frequencies. Thus, a process of filtering naturally happens when using a contact microphone. The sound heard will be then the sum of the "filtered" sound of the contact microphone and the unamplified sound of the object itself resonating through the air. This is the main reason why a consistent shift in the usual listening perception happens when using contact microphones. Sound is perceived as much larger and artificial, and the physical distance between the listener and the object of listening is perceptually reduced: sounds within the frame appear closer.

As already mentioned, Cage was among the first to explore sounds that are perceived differently through amplification with contact microphones, and to incorporate these sounds in his own sound material. The most relevant historical example in this sense is *Cartridge Music*. Here piezo-ceramic phono-cartridges from record players were turned into contact microphones and used to explore and manipulate different objects by actions such as scraping or plucking, etc. By performing with phono-cartridges, various sounds are elicited, uncovering different sound qualities of materials and revealing the unexpected richness of a whole set of amplified “microsounds”.

This unusual proxemics of sound is rendered even more evident by a stethoscopic use of piezo, which activates spontaneously a very different way of listening. Amplification becomes clearly audible: due to its irregular frequency response curve the piezo is devoid of features of sonic transparency. The piezo presents, in fact, very specific acoustic properties, such as the pronounced resonant frequency of its own, that confers it a peculiar colour. Thus, working with piezo means to mark even more the sonic presence of a technological tool between the acoustic sound of the resonant object and the human ear.

In most of my works, the musician is asked to perform a few actions with the piezo on the instrument, disclosing a different perception of the instrumental sound. Similarly to the stethoscope, the piezo has to be moved on the instrument's body, on its strings, or on its surface. In this way, the piezo captures the sound in a very close way while activating it, picking it up from different points of the vibrating surface. According to its resonant frequency and the inner resonances of the instrument, the piezo reacts differently at different spots of the instrument. Such stethoscopic use of piezo on the instruments tends to reveal to the human ear very intimate sounds, highlighting the sonic materiality of the instrumental sound, while calling into question the usual habits of the listening experience. Hearing is thus projected in a sort of hyperreality in which the instrumental sound matter is perceived as a fabric looked at through a microscope[41]. The mediation of the piezo facilitates the building of a private auditory space, in which the actions of putting a frame around different sound objects and zooming in on the instrumental sound matter become more straightforward. Such renewed understanding of the sound material comes then to be a pivotal aspect within the compositional process, which can be itself understood as an advanced form of technical listening, as I will discuss more in detail later.

---

41 See the published exposition "Composing with Piezo", by Daniela Fantechi in www.researchcatalogue.net, to listen to the audio example 2.1.1 produced by a piezoelectric microphone rubbed on a string of the violin.

2.2. Instrumentality of piezo: should piezo be intended as a musical instrument?

A stethoscopic use of the microphones foresees its delivery into the hands of the musicians. In my project, as well as in the examples already seen of *Cartridge Music* by Cage, or *Mikrophonie I* by Stockhausen, performers produce significant musical actions through an active use of microphones. *Mikrophonie I* is one of the first cases in which microphonist movements are even accurately notated in the score, as if the microphone has to be considered a fully-fledged musical instrument.

> After finishing the score of *Mixtur* for orchestra and ring modulators, I searched for ways to compose – flexibly – also the process of microphone recording. The microphone, used until now as a rigid, passive recording device to reproduce sounds as faithfully as possible, would have to become a musical instrument and, on the other hand, through its manipulation, influence all the characteristics of the sounds. In other words, it would have to participate in forming the pitches – according to composed indications – harmonically and melodically, as well as the rhythm, dynamic level, timbre and spatial projection of the sounds. (CD booklet Stockhausen-Verlag CD9, pp.17-21)

The manipulation of the microphone through specific actions and gestures assigned to the performer seems to imply for Stockhausen its use as a musical instrument. But, whether a microphone could be actually considered a musical instrument, as Stockhausen seems to state, is a delicate and non-trivial question.

An interesting contribution by Sarah-Indriyat Hardjowirogo addresses the issue of constructing instrumental identity within the context of contemporary music production. The development of phonography, sound-reproduction technology, and all processes of electrification, digitalization, and interconnectedness led to the creation of many new musical instruments. As a consequence of such techno-cultural progress, the understanding of what a musical instrument is has thus been challenged - also because there are evident differences between musical instruments of the 21st century and those of the earlier times, both in terms of appearance, and of technical functionality, playing technique, and sound. In her contribution, Hardjowirogo outlines a few main criteria to shape the concept of instrumentality, which should allow a better understanding of the specific qualities of musical instruments, the connections between traditional and contemporary instruments, and the distinction between musical instruments and other sound-producing devices.

Usually, a musical instrument is defined as any object that produces sound. This definition appears insufficient because of the existence of different categories of objects able to produce sound but commonly not understood as musical instruments. Examples could be all sound reproduction devices - such as radio, cd-player, turntables, etc – or everyday objects originally designed with other purposes, even if often used to produce sound in musical contexts.

Hardjowirogo explains that instrumentality has to be understood as the result of an intentional instrumental use, of certain sounding objects: “an object is not per se a musical instrument (ontological definition) but it becomes a musical instrument by using it as such (utilitarian definition)” (Hardjowirogo, 2017 p.11).

Instrumentality tends to present different degrees, which make some objects appear as more ‘instrumental’ than others, depending on the process of culturalisation undergone, i.e on their regular and extended use as musical instruments, within the context of a specific culture. Instrumentality has therefore to be intended as a dynamic concept, resulting from processes of “cultural negotiation” (Hardjowirogo, 2017 p.12). An object is more or less identified as a musical instrument depending on the degree of shared understanding of its contingent functions. Actions and meanings enabled by the sounding device are more relevant than its physical properties in the construction of its instrumental identity.

> Instrumentality in this sense represents a complex, culturally and temporally shaped structure of actions, knowledge, and meaning associated with things that can be used to produce sound. [...] the term must not be understood as denoting a property an object per se has or has not, but it is rather intended as a means of capturing the instrumental potential of a given artifact. (Hardjowirogo, 2017, p.17)

Taking into account significant literature about the argument, Hardjowirogo starts her preliminary list of criteria of instrumentality, with “Sound Production”, which represents a traditional musicological notion of the instrument, from von Hornbostel and Sachs (1914) on, with a substantial difference between traditional instruments, whose sound is the immediate result of the physical characteristics of the object, and digital musical instruments, whose sonic features are designed independently from the physical ones. “Intention and Purpose” figures as the second criterion; playing a musical instrument always requires both the intention to do so and the purposeful use of something (that can also have originally a different purpose) as a musical instrument. The third cited criterion is “Learnability and Virtuosity”: each instrument requires practice, exercise, and learned skills. This seems to be a valid criterion not only for musical instruments, but for instruments in general, as previously seen when speaking about the stethoscope and mediate auscultation.

“Playability/Control/Immediacy/Agency/Interaction” constitutes the next point in the list. Playability and control imply the immediate reaction of the sounding instrument to the performer’s actions. What might change is the degree of agency ascribed to the instrument, in the interaction between it and the performer. The physical aspect of instrumental performance is addressed by three different concepts of “Expressivity/Effort/Corporeality". The notion of physical action, or even effort, required by instrumental playing is linked with the romantic idea of virtuoso expressivity, which in some cases is kept and searched as a feature also in the design of new instruments, confirming the idea of the musical instrument as a means of musical expression. Next criteria are “Immaterial Features”/Cultural Embeddedness". Both notions imply the cultural negotiation of value and meaning of a musical instrument. The last point of Hardjowirogo's list is “Audience Perception/Liveness”, both important criteria because it is precisely in the context of the performance that the perception of liveness from the audience legitimates the notion of instrumentality.

Understood as the identity of musical instruments, instrumentality is therefore constructed through the interplay of various criteria. The contribution by Hardjowirogo addresses this issue from a quite broad perspective, concerned with the understanding of new and contemporary musical instruments, especially the ones created in the electronic and digital domain. More specifically related to the possibility of understanding microphones as musical instruments is, instead, the perspective offered by Cathy Van Eck, in her book *Between Air and Electricity*. Here, the author's concerns about instruments and instrumentality bring us back to Stockhausen's statement, since the core question of the book is: "Are microphones and loudspeakers musical instruments?" (Van Eck, 2017, p.1)

Van Eck investigates the role of microphones and loudspeakers in contemporary and experimental music. The author starts from observing how, over the twentieth century, microphones and loudspeakers have become an omnipresent technology in music, as well as in everyday life. Since their introduction, many aspects related to music and music-making have changed enormously. On a technological level, high-fidelity has been among the main criteria for the design of microphones and loudspeakers: sound reproduction technology has been developed to become as invisible and sonically transparent as possible. Nevertheless, the presence of microphones and loudspeakers has been brought to the front and questioned by many diverse artistic experimentations. Most of them have worked directly with microphones and loudspeakers, looking for different kinds of interactions with conventional musical instruments, with daily objects, or directly turning microphones and loudspeakers into sounding devices (a long, accurate and very significant list of musical works that have been developing from creative uses of microphones and loudspeakers is given by Cathy Van Eck in her book). In proposing a taxonomy of sounding objects used as musical instruments, Van Eck individuates three main general categories. The first is that of traditional musical instruments, whose primary and main intended function is to produce music. The second includes all devices not usually identified as musical instruments, but whose main function involves sound in several ways, like radios, record players, mixing desks, as well as microphones and loudspeakers. The third category includes all objects not associated with sound at all in their main function, but consciously used within a musical experience, such as glasses, boxes, spoons, tables, bicycles, etc. For the two latter categories the author considers as implicit the intentionality of the composer to bring these objects in the realm of musical instruments, intending them as such. The degree of instrumentality recognized to these objects has to do also with the special treatment they undergo during the performance, as well as the fact that their unexpected use as musical instruments becomes a determining aspect of the musical experience. It is thus easy to observe that some of the above-mentioned criteria such as intentionality, playability of the object and its perception within the performance, as well as the cultural negotiation of its musical value and meaning, emerge as important aspects in the definition of the identity of the musical instrument.

Van Eck's starting question “Are microphones and loudspeakers musical instruments?” resonates as particularly significant in the context of my project, for which I need to articulate the role of piezo, displaying the emerging relationship with the traditional musical instrument, and with the performer.

When Van Eck talks about artistic projects using contact microphones, she outlines two main approaches: on one hand they are used to develop new instruments from scratch transforming daily objects into sound-making devices, on the other, they are used to transform conventional instruments. The first approach relates to all experimental practices of developing new instruments combining everyday objects with contact microphones. As already seen in the first chapter, one of the first examples that fits this category is the work of Richard Lerman, who has spent many years of his research in working with piezo. In *Travelon Gamelon* (1977) he uses piezo to amplify bicycles, obtaining original percussive musical instruments; or, a more articulated example is the work by Hugh Davies, as in the case of the *Shozyg*. Assembling different objects in the cover of an encyclopedia volume, the *Shozyg* becomes a sophisticated musical instrument, able to produce a large variety of sounds, also thanks to the combination of amplification with different kinds of contact microphones and other close miking techniques such as magnetic pickups.

The second approach could be exemplified by the project *Inside piano* by Andrea Neumann. Here the soundboard of a grand piano is amplified by several kinds of contact microphones and all musical actions are diffused through loudspeakers. As Cathy Van Eck explains:

> In Neumann's performances the grand piano has been changed into a different instrument which can only function properly by interacting with microphones in order to obtain a specific sounding result. Elements of the piano which would not normally emit much sound in themselves become audible in this instrumental set-up. What is resisting to sound in a common grand piano might be resonating here and become an essential part of the instrument. The microphones are not fixed at a specific spot, but can be adapted anew between and even during performances. This new instrument focuses mainly on producing many different sonic qualities, in contrary to the conventional grand piano, which is built to produce the same sonic quality but at eighty-eight different pitches. (p.109-110)

In all the examples cited, contact microphones are exploited for their capacity of bringing unperceivable sounds to the front, and giving them a unexpected colour. This is a central aspect also in my research: the peculiar colour of amplification is pivotal and determinant for the artistic value of each work. A big part of my research on sound material and its treatment within the compositional process starts exactly from the specific features of sounds produced and amplified by unprocessed piezo.

Moreover, I share with both above-mentioned approaches the aspect of combining my contact piezoelectric microphones within a certain set-up, that as a whole can be understood as a new musical instrument. However, my project is peculiar because the introduction of the piezo can be interpreted as a sort of invasion of the space of someone else's instrument. In experimenting different combinations and uses of the piezo with various traditional instruments, such as the guitar, the cello, the violin, the piano, etc., I am not playing myself, but I provide the performer with one or more piezos, together with a set of instructions about how to play with them. Therefore, I come to question which role the piezo assumes in these new contexts, and how it actually interferes with the pre-existent and consolidated system of someone else's traditional instrument.

2.3. Alteration of the instrumental system

I should start with considering the dynamic nature of the system consisting of the performer and all the components of the musical instrument. An interesting point of departure is the cybernetic perspective in Herbert Heyde's *Grundlagen des natu rlichen Systems der Musikinstrumente* (1975), very well described by De Souza in his book *Music at hand*. Heyde develops an organology that is grounded in cybernetics, a scientific approach which boomed in the 1950s, which investigates systems in general – technological, biological, psychological, or social – focusing on a system's abstract structure and behaviour, instead of its material properties. Heyde divided into basic categories all the components of an instrument. For example a string or a drumhead are *transducers* which take energy from some *activator*, such as the violinist's or percussionist's hand, and change it to sound. This energy can pass through a *mediator*, such as a bow or a drumstick. *Controllers, resonators* and *couplers* may then modify the signal; other categories of *modulators* and *amplifiers* belong specifically to the domain of electric and electronic instruments. According to Heyde, any musical instrument can be constructed as a subset of elements from the general musical instrument system called *Ganzsystem*. A musical instrument is thus intended as a system of inputs and outputs, which transmits and transforms a signal. Within this perspective, the piezo becomes a component of the system, and it can be intended both as a *transducer* (if hit to produce a sound), a *mediator* (if used i.e. to scrape a string) and an *amplifier* (if simply placed on the soundboard of the instrument, but also in all other cases in which sound is produced through the piezo, which at the same time amplifies it). But more significant is the fact that the piezo, as a functional component of the system, becomes part of a structure of connections between all components, that Heyde calls "energetic, material, and informational couplings". In fact, in Heyde's cybernetic approach to organology the single functional elements involved are less relevant than the whole structure of connections between all components, which is what makes each instrumental system distinctive. The relevance of his perspective lies in the acknowledgment of a certain continuity between the mechanical and the organic: performer and instrument are integrated in a circuit, in which aspects of control and technique can be distributed to the technology.

As De Souza highlights, sound production conceived as the transmission and transformation of energy has not to be considered as a one-way process. Rather the flow of energy in the instrumental system happens in plural directions: actions are converted into sound and sounds give feedback about the actions. The system is interactive, even in the absence of technology. Multisensory feedback participates in shaping both the perception and the production of sound. Auditory feedback is fundamental, for example, for intonation or tuning. But also visual and tactile feedback is essential. Information flows from the touching hand to the touched hand, which finds the resistance of the object as an important tactile feedback. Hence, the connections between playing and listening, and the direct coupling between action and perception, generate a form of cognition based on sensory experience, which is not only embodied, but also ecological, i.e. situated in an environment. Knowledge about sound comes from what and how we listen, we touch, we see, within these interactive systems; and the ongoing feedback relationship between the different agents of each system, whose nature is primarily perceptual, happens within an environment, which is both natural and cultural. This ecological perspective avoids the subject/object duality which reduces the instrument to a physical object operated by a human subject; rather it observes the relationship between the instrument and the performer, taking into account the complexity of the feedback network, as well as practices, repertoires, institutions, social discourse, etc. The instrument has to be seen as “something which comes attached with actions, we must understand the instrument-as-played, not the instrument-as-constructed or -observed.” (Habbestad, 2017, p. 317). So, as a technological object, the instrument comes to the musician not only with its own design, its physical and material features, but with a set of operations or actions that can be performed on it. These possibilities for actions are what J. J. Gibson called “affordances” (Gibson, 1979). In his ecological approach, any object is seen primarily in terms of affordances, as a thing I can use: a chair is seen in terms of the possibility to sit or stand on it. Affordances imply a complementarity of agent and environment.

The musical instrument, as an object, tends to reveal certain affordances while concealing others. It provides the performer with a series of relational features that remains invariant through changes that enable body-sound coordination, its own topography reveals a specific mapping between actions and sound material. Instrumental practice generates distinctive motor and perceptual patterns and habits, in which the performer with her/his body, and the tool, react to each other. The learning by doing process activates a kind of knowledge based on making, in which techniques and technology complement reciprocally. As De Souza observes, the "poietic know-how may belong not only to tool users but also to the tool itself” (De Souza, 2017, p.24), or rather instruments “know” things for their users:

> The piano, for example, “knows” a certain pitch-class collection: the notes of the equal-tempered chromatic scale. But it does not present twelve undifferentiated steps. Instead, it materially highlights

> particular tonal structures endemic to Western music. Its physical opposition of a diatonic white-note scale with intervening black-note semitones corresponds to the notational culture of natural and chromatically inflected pitches, and the resulting pattern of twos and threes functions as a visual and tactile reference point for the player. (De Souza, 2017, p.24)

The process of uncovering, absorbing, and finally, mastering what the instrument "knows" requires time and practice. What usually happens to beginners is to interrogate more experienced performers on their playing techniques. That is the reason why the musical instrument never presents itself as completely neutral: it comes to the performer with layers of embodied practices and idiomatic gestures, specific to different repertoires, genres, historical practices, and traditions. Instruments reveal traces of users' actions, and their idiomaticity is maintained and negotiated within communities, through shared practices, abilities, affordances and perceptual habits. As distinctive musical dialects, instrumental idioms emerge from the interaction between players and instruments, and the latter are shaped in coordination with their development as technical objects, their affordances, and player habits. Idiomatic gestures become part of the vocabulary of the performer, whose sense of agency relies on pre-reflective actions and consolidated motor habits. In fact, the sense of agency - which implies intentionality and awareness about decision-making and control - is experienced more as a general intention, while more detailed decisions are often avoided during the performance because intended as a kind of overthinking. In case of unexpected changes of instrumental affordances, and so of new connections between action and sound, an instrumentalist's sense of agency can be reduced. Alteration of the auditory feedback implies a moment of disruption in the usual feedback network between instrument and performer. In the context of my research, the introduction of piezo can be considered as an element of interference, which alters the established and consolidated connections within the interactive system of the musical instrument.

As already observed, from an ecological perspective, affordances exist independently of the agent's need or skill, even if affordances and abilities are usually co-defined. Technique and technology coevolve in a space of open possibilities, since any tool can always be used in unexpected ways: a chair never forces its user simply to sit in it, but for example, it can offer the possibility to hide behind it or use it to close a door. The same happens within the context of musical instruments, whose technology and technique flexibly coevolve, as elements of each are adjusted or modified. As a composer, I am usually keen to explore instrumental affordances, searching for ways to go beyond the sound possibilities that the instrument has been designed for. Therefore, at least in the first stage of the compositional process, I tend to provisionally assume the role of the performer, trying to play the instrument myself, in order to get a personal experience of its possible affordances, while testing possibilities to distance myself from the established instrumental practice. My attempts have to be understood as a praxis that is shared amongst a larger community of musicians and performers. In each particular historical moment, the adoption of transgressive behaviours has stimulated the creativity of different generations of artists (Barrett, 2014). But in the context of contemporary music, this mode of searching has become almost constant. Many musicians, composers as well as improvisers, tend to extend or to operate at the edges of the sonic possibilities offered by the instrument, changing or forcing its original design features, looking for new means of expressivity. De Souza dedicates an entire chapter of his book *Music at Hand*, to “voluntary self-sabotage”, the praxis of musicians to alter instruments on purpose, as a strategy to “surprise, resist, or provoke its player” (De Souza, p. 83). The author outlines three principal modes of alteration: retuning, preparation, and redesign. Retuning consists in changing an instrument’s pitch mapping, producing unexpected pitches: a praxis quite diffuse among string instrument players. Preparation lies instead in incorporating foreign objects at the site of sound production, in order to produce unexpected sounds, with a certain openness to noise. Indeed, preparation often transforms pitches into complex inharmonic sounds, as in the prepared piano by John Cage, in which preparation produces unexpected noises – metallic or wooden –, turning the piano into a complex percussion instrument. By modifying the body of the instrument, preparation overlaps with the instrumental redesign, which rather consists in reconfiguring the familiar interface of the instrument, by reshaping its known space, while altering its possibilities of interaction.

In cognitive terms, all these different modes of alteration affect the habitual action-sound coupling, and the learned auditory-motor patterns. In perception and memory, sensorimotor integration relies on patterns of co-activation, hence any instrumental modification interferes with the learned connections between body and ear. But such connections are not rigid, and any alteration of the instrumental system tends to activate adaptations and adjustment of instrumental techniques and a dynamical remapping of consolidated motor habits. Therefore any mode of alteration represents an opportunity for the performer to relearn her/his own instrument, and to rethink assimilated instrumental experiences. In such situations, the performer reaches a deeper awareness of her bodily engagement, in listening and feeling the sound differently, while becoming even more conscious of the materiality of the instrument and its potentially endless affordances.

Challenging musical habits is one of the central aspects of the work of Helmut Lachenmann, whose work has been extremely inspiring for my compositional research. Between the late 1960s and 1970s, Lachemann wrote a series of compositions, later defined as *musique concrète instrumentale*, including pieces such as *Pression*, for cello, *Air*, for orchestra and percussion solo, *Dal niente*, for clarinet, *Guero* for piano, and many others. In all these works all physical actions support a very precise conception of sound, without being hidden behind it. Rather the focus is on the physical modes of production of sound, which makes the performer, as well as the listener, aware of the mechanical and energetic conditions in which the sounding result is produced, and so perceived. It is the sound of the instrument itself that shows what happens. For example, in *Pression* for cello, the main focus is on how the bow is moved, in which point of the cello and on which material, with what kind of pressure, if on a string at what distance from the bridge and from the fingerboard, and so on. Lachenmann borrows this way of paying attention to sounds and their mode of production by everyday way of listening, in which objects are shaken or hit in order to know more about their consistence and their material, and each sound, in general, is relevant because full of information about the object itself, and also about the surrounding environment. An important source of inspiration – as Lachenmann recounts in his famous writings *Hören ist wehrlos - ohne Hören* (Lachenmann, 1996) – has been the typical technique of the *musique concrète* of recording everyday sounds on tape and using them in musical collages. Lachenmann has applied this procedure in the realm of acoustic instruments, therefore he defines his compositions *musique concrète instrumentale*. In his work as a composer, Lachenmann explores traditional instruments with the clear aim to develop new performative techniques, forcing the potentialities of the instrument through what is usually defined as "extended techniques". Thus Lachenmann experiments with musical misalignment, pushing against established auditory-motor associations, while looking for a listening experience in which perception becomes aware of itself.

Coming from instrumental music with written scores, my work has been looking to the western tradition of a quite disciplined instrumentality, in which the adoption of extended techniques is understood not only as a transgressive behaviour, but also as a creative opportunity. Indeed, for me, the importance of Lachenmann's work lies primarily in his attempt of activating a different way of perceiving sounds, highlighting their materiality. Within my research, bringing and incorporating the piezo technology into the western tradition of written scores and disciplined instrumentality is similarly a way to question usual perceptual habits, providing a lens for a closer observation of the materiality of sound. The intrusion of the piezo affects the whole process of music-making, not only the production of sound but also its perception, imagination and creation.

One of the first pieces in which I experimented with the use of piezo is *et ego*, for classical guitar and electronics. Here I have explored a quite standard use of piezo: two piezos have simply to be fixed on the soundboard of the guitar (fig.2.3.1) as means of amplification. The hyper-amplification of the instrument immediately determines a big change in the usual sensory feedback relationship with the performer, who thus has to react to a guitar of a different kind: all contacts with the instrument, even the smallest and accidental movements, become audible. In this way, the extension of the instrument back into the body of the performer is strongly perceptible, and demands from the performer another kind of awareness and negotiation with respect to her physicality. While opening up a different perspective on the guitar, this kind of hyper-amplification allows for the discovery of new affordances offered by the instrument. When exploring them on the guitar I discovered the possibility of adopting certain gestures, almost inaudible on an unamplified instrument. In this respect one of the most radical gestures appears for the first time in b. 9 (fig.2.3.2), where the performer is asked to play a glissando with the nail, which would have been barely audible in a usual acoustic situation. Following this, many other sound gestures take advantage of this hyper-amplification the instrument. During the piece, the performer is rarely asked to produce sounds by means of plucking the strings, which is usually understood as the principal affordance of the guitar.

Fig.2.3.1 - Position of piezos on the surface of the guitar in *et ego*

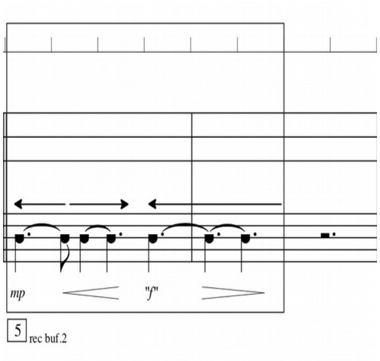


Fig.2.3.2 - *et ego,* bb.9-10.

More often she is asked to treat the guitar as a resonating percussive surface, where different modes of sound production – like hitting, scraping, striking, etc – are activated on various points of the instrument, such as strings, frets, soundboard, generating sounds that are more or less resonant. Some percussive actions have also to be done directly on the surface of the piezos, which become effectively part of the instrument itself: they are no longer just the means of amplification, but they become part of the physical space of action of the performer. Piezos work as interferences and elements of disruption in the usual relationship between the performer and her instrument, and extended techniques allow overcoming the instrument idiomatic constraints by simulating other instrumental spaces and borrowing other instrumental techniques, providing a different perspective on the classical guitar. The performer needs to adapt and tune herself, and her own agency, expressed and manifested in what is often defined as 'expressivity' and 'individual touch', results, as Water suggests,

> not only from the physiology of the player, but the complex feedback into that player's body of vibrating materials, air, room, and the physiological adaptations and adjustments in that body and its 'software' which themselves feedback into the vibrating complex of instrument and room. (Waters, 2007, p.2)

Within this altered system the presence of electronics in relation to the acoustic fact poses some questions about the understanding of its role within what we have described until now as the music-making system. As Waters (Waters, 2007) points out, the engagement with computers and electronics heightens the sense of mutability between the different elements of the system. Waters observes how the computer – with its associated software – is usually considered as an 'instrument'. But in acknowledging its own agency it can be understood as a 'performer', or, in other circumstances, it is addressed as a 'performing or composing environment'. As 'composing environment', I would add, it might be considered as sharing the role of the score – understanding the score for its function of providing a set of instructions that has to be followed during the performance. In the case of *et ego*, as well as in most of my works, the electronics poses a similar sense of mutability, suggesting a multiple role. In the programming of the software, a set of instructions about behaviours and parameters concerning how the sound will be processed is defined in advance. Hence, the electronic part is previously composed. And through the code it partially assumes the role of the score. At the same time, in order to evaluate the code and to control all the parameters that can be changed live, an electronic performer is required, who will contribute in a personal way to the musical result, just as any other kind of instrumental performer would do playing her own instrument. Finally, since the electronics is actually producing sounds, it can also be understood as an instrument itself, or at least as an extension of the acoustic instrument, whose sound is processed.

Nevertheless, besides any effort of fitting the electronics in one role or another, I think it is worth noting how it could be intended as an extra layer of interference. The microphones placed on the soundboard of the guitar impart a very specific sound quality to the recording of the close-captured sound – primarily due to the fact that I have deliberately chosen not to add any processing or equalization to the piezo sound, precisely to highlight the perception of a low-fi sound. Its peculiar sound quality is transferred in the recording and consequently, it affects the way the sound is processed. While enlarging the possibilities of the instrument, the use of electronics interestingly affects further the relationship between performer and instrument. In the specific case of *et ego* – and similarly in other pieces of mine – this is partly due to the fact that most of the recorded sounds – especially in the first part of the piece – are only slightly processed before being reintroduced in the performance in form of playbacks and delays, and this creates multiple layers of similar sounds. By varying and repeating small percussive gestures, the guitar and the electronics contribute together to the accumulation of almost pitchless percussive sounds. This increases the difficulty of recognizing the instrumental or electronic origin of the sound, and at first, that can be confusing for the performer herself (then progressively, during the piece, the percussive pace starts to slow down, leaving space to a slower texture of harmonic sounds, in which the sonic result still depends on the instrumental origin of the sound, filtered through the piezo).

Considering all constraints and constructs in the instrumental system, which evolves as the result of a long process of experimentation and negotiation, the possibility to collaborate with performers becomes very important. First of all, because the performer needs to get familiar with the peculiar technology of piezo, becoming aware of their different usage possibilities and their way of hyper-amplifying the instrument; secondly, because the performer, with her own expertise and engagement, can usually add great value to the results of my experimental moments of improvisation. Through rehearsals and moments of discussion, different performers have provided me with useful feedback about the collected sound material, enhancing the definition of playing techniques and the notation of single gestures.

2.4. *Inside the instrument*

In this context, the act itself of composing strongly relies upon the instrumental system and its evolving features. Indeed, adopting the technology of piezo has changed my personal compositional practice, driving me to a different approach, that slightly resonates with that of David Tudor's "inside electronics", partly described in the previous chapter.

As already mentioned, between the late '50s and the '60s, Tudor was one of the most appreciated avant-garde pianists. As a highly acclaimed pianist, he premiered many works by the most relevant contemporary composers – Pierre Boulez, Earle Brown, Sylvano Bussotti, John Cage, Morton Feldman, Karlheinz Stockhausen, Christian Wolff, among others – often supporting them in the realization of their works. Right when he was at the peak of his career, he started to look for ways to move beyond this role, clearly feeling the need to affirm his own personal musical conception. Hence, he slowly moved, as Goldman aptly says, "from a compositional-based performance practice to a performance-based compositional practice" (Goldman, 2012, p.55). Goldman individuates as a central moment of this transition, his collaboration with Mauricio Kagel on the piece *Pandorasbox*, through which Tudor discovered the bandoneon. So named by the German instrument dealer Heinrich Band (1821-1860), the bandoneon was originally conceived for religious and popular music, then exported by emigrants to Argentina, where it was adopted into the nascent genre of tango. Fascinated by the potentialities of the bandoneon revealed by Kagel, Tudor kept exploring this instrument, firstly commissioning new pieces (to be mentioned its work on the bandoneon with Pauline Oliveros and Gordon Mumma), then elaborating himself his own work, creating one of his first public compositions. In 1966 he presented the multimedia piece *Bandoneon! (a combine)*, at the 9 Evenings of Theatre and Engineering, collaborating with the video-artist Lowell Cross, the sound artist and engineer Anthony Gnazzo, and Fred Waldhauer, a Bell Telephone Laboratories engineer. The work was presented with the following note:

> *Bandoneon! is a combine* incorporating programmed audio circuits, moving loudspeakers, TV images, and lighting instrumentally excited. . . . Bandoneon! uses no composing means, since when activated it composes itself out of its own composite instrumental nature. (David Tudor Papers, Getty Research Institute (GRI) (980039), Series IA, Box 3, Folder 2, in Kuvila 2004, p.17)

As Goldman recounts, in addition to projections of visual patterns responding to the music, already tested a few months earlier in the performance of Lowell Cross's *Musica universalis*, Tudor's piece

for bandoneon included many other elements, like remote-controlled carts bearing loudspeakers that wandered on the stage, and a "vochrome", a set of harmonium reeds fitted with contact microphones, used to filter the bandoneon's signal, thereby triggering various other sonic and visual events. In such a context, composition tends to overlap with instrumentation. By conceiving the instrumental system as an assemblage of a series of different materials, also using different media, Tudor aimed to set up specific conditions for the activation of a unique sonic apparatus. In fact, Tudor did not explicitly claim the role of the composer; rather, he considered himself as a performer, working within an interactive situation, often created collaboratively.
Moreover, the idea that a piece can "compose itself" has to be understood also from the perspective of indeterminate music. From being mainly a performer, involved in the creation of indeterminate works, Tudor got to be mainly a composer of live-electronic works, heavily performance-based.

Anyway, what strikes me most is how Tudor questioned the traditional sense of composition. As Driscoll recounts in his interview (see ch.1.4 /Appendix 2) Tudor did not think about musical concepts that need instruments to be realized, rather about instruments as suggesting the music one could make. Tudor's DIY approach to electronics always sought an unconventional use of it. He explored affordances of all components of the electronic means and of their interactions, in order to reach different musical possibilities. While creating or manipulating a complex, but flexible instrumental system, Tudor challenged its specific musical possibilities. In this sense, the composer aimed to unveil and respond at the same time to instrumental affordances as much as musical ones. Hence, as De Souza points out, "instrumentation is not a mere adjunct to composition. Instrumentation is instead a fundamental part of composition" (De Souza, 2017, p.108).

In my project with piezos I have clearly experienced how the building of the instrumental system becomes part of the compositional practice. The introduction of piezo opens up for many different and potential perspectives on the traditional instrument, requiring the exploration of new affordances, through which new musical ideas might arise. Building the instrumental system means also to understand the role of the piezo, choosing which kind of actions can be done with it on the instrument, at which points of its physical space, on which components, with which kinds of movement, with which kind of energy, and so on. But also to understand how all sound gestures that can be performed with the piezo could be then integrated with other instrumental techniques, which kind of amplification is required, which kind of relationship the instrumental material might have with the electronic means, how the latter should be programmed, and so on and so forth. So, the whole instrumental system becomes, first of all, a source of material, and thus has to be intended as a compositional tool. Indeed, both the identification and the disposition of different sound materials throughout the piece are dependent on the neat understanding of the instrumentation at disposal and on a sensible distribution of its affordances. Thus, during the compositional process, musical constraints are constantly negotiated through instrumental ones and the other way around.

In such negotiation, sound material undergoes a process of definition, in which the perceptual experience of listening fulfils a central role. The mediation of the piezo facilitates the building of a private auditory space, in which I can better frame the instrumental sound matter, trying to become more and more familiar with it, up to the point that I can imagine how to shape it during the piece.
My personal experience finds some points of resonance with David Rosenboom's neuroscientific perspective. Rosenboom clearly explains that musicians are first of all listeners, "who through intensive practice can become hyper-aware of how they parse sound and construct endogenous musical memory engrams". For "master creative listeners", listening can be "elevated to the level of composition" (Rosenboom, 2014, p.2). Compositional processes can be thus understood as advanced forms of technical listening, which comes as a learned skill. Moreover, Rosenboom, assuming the Cage's definition of music simply as "organization of sound" (Cage, 1937), also suggests that "a fundamental form of musical intelligence might be described as active imaginative listening to what each listener chooses intentionally to regard as musical" (Rosenboom, 2014, p.2).
This form of active and imaginative listening matches with my understanding of the compositional practice: through the definition and the exploration of the musical instrumental system, I identify what I intentionally choose to regard as musical, and I build a piece with it. Each work is thus primarily intended as a possible listening experience.

Main References

Barrett, R. *From Experimentation to Construction*. In: Gilmore, B., Crispin, D., editors. A*rtistic Experimentation in Music*, Orpheus Institute Series - Leuven University Press, 2014, pp. 105-110.

De Souza, J. *Music at Hand. Instruments, Body and Cognition*. New York : Oxford University Press, 2017.

Gibson, James J. *The Ecological Approach to Visual Perception*. New York: Psychology Press, 1979.

Goldman, Jonathan. "The Buttons on Pandora's Box: David Tudor and the Bandoneon", in American Music, 30, 2012, pp. 30-60.

Habbestad, B, Carey, J. *Instrumental Modality. On Wanting to Play Something*. In: Bovermann, T., De Campo, A., Egermann, H., Harjowirogo, S-H., editors. *Musical Instruments in the 21st Century. Identities, Configurations, Practices*. Singapore: Springer, 2017, pp. 263-272.

Hardjowirogo, Sarah-Indriyati. *Instrumentality. On the Construction of instrumental Identity*, in *Musical Instruments in the 21st Century. Identities, Configurations, Practice*s, T. Bovermann, A. De Campo, H.Egermann, S-H. Hardjowirogo, S. Weinzierl (eds), Singapore: Springer, 2017.

Heyde, Herbert. *Grundlagen des natu rlichen Systems der Musikinstrumente*. Beiträge zur musikwissenschaftlichen Forschung in der DDR 7. Leipzig: VEB Deutscher Verlag fu r Musik, 1975.

Hornbostel, Erich M. von and Curt Sachs. “Classification of Musical instruments”, translated by Anthony Baines and K.P. Wachsmann, in The Galpin Society Journal, 14, 1961, pp. 3-29.

Kim, J-H., Seifert, U. *Interactivity of Digital Musical Instruments: Implications of Classifying Musical Instruments on Basic Music Research*. In: Bovermann, T., De Campo, A., Egermann, H., Harjowirogo, S-H., editors. *Musical Instruments in the 21st Century. Identities, Configurations, Practices*. Singapore: Springer, 2017, pp. 79-94.

Kuvila, R. “Open Sources: Words, Circuits and the Notation-Realization Relation in the Music of David Tudor”, in Leonardo Music Journal, 14, 2004, pp. 17–23.

Lachenmann, Helmut, Wolfgang Rihm. *Conversazioni e scritti,* edited by Enzo Restagno, Ricordi, 2010. (translated from Lachenmann, Helmut. *Musik als existentielle Erfahrung*, edited by Josef Häusler, Wiesbaden : Breitkopf & Härtel, 1996).

Rosenboom, D. “Active imaginative listening — a neuromusical critique”, in Frontiers in Neuroscience, Auditory Cognitive Neuroscience, The Musical Brain, 8, 2014, pp.1-7. https://www.frontiersin.org/articles/10.3389/fnins.2014.00251/full#h3 (last access: 28/10/2020).

Sterne, Jonathan. *The Audible Past: Cultural Origins of Sound Reproduction*, Durham & London : Duke University Press, 2003.

Van Eck, Cathy. *Between Air and Electricity*, New York, London : Bloomsbury, 2017.

Waters, S. “Performance Ecosystems: Ecological approaches to musical interaction”. In: EMS: Electroacoustic Music Studies Network, Proceedings of The ‘languages’ of electroacoustic music; 12-15 June, 2007; De Montfort University, Leicester, UK. http://www.ems-network.org/spip.php?article278 (last access: 14/04/2020).

3. Framing a personal compositional practice

Introduction

If we understand the act of composing as an active and imaginative form of listening, a composed work is meant to be understood as a proposal for a possible listening experience. In outlining this listening experience, the composer chooses how to organize sound material. The result of her compositional process is usually defined in the final formal structure of the piece, i.e. in the shape that the sound material assumes inside the temporal dimension of the music experience. During my research project, I have been deeply interested in trying to understand how the compositional process develops starting from the instrumental sound matter, and which kinds of relationships happen between the sound material and its organization in a determined form.

3.1 The *window-form*

In his book *Le figure della musica*, Salvatore Sciarrino addresses the need to outline some main concepts on which contemporary music - as well as historical music from which it derives - is based. The words of the title *Le figure della musica* (the figures of music) stand for the main abstract ideas on which composers' choices are based. Sciarrino states that any compositional work does not appear as an undifferentiated stream of sounds. What an attentive listener tends to hear is how sounds are grouped together. Some groups of sounds are more characteristics than others and as soon as they come back the listener recognizes them. Those groups mark different areas of a composition. The formal structure of a piece is built on grouping those recognizable elements in longer sections. So, Sciarrino points out how form arises from the way groups are arranged, according to the personal strategies of the composer. Consequently, musical matter is organized following some key concepts that music shares also with other disciplines. Sciarrino's approach aims to outline those key-concepts of musical construction, in order to get deeper knowledge of general aspects of music-making. The key-figures on which Sciarrino focuses are: *accumulation processes, multiplication, little bang, transformations, window-form.* I have been particularly interested in the window-form, to which Sciarrino dedicates the two last chapters. The window-form is based on the concept of temporal and spatial discontinuity. A first and very basic example of this discontinuity could be a photograph, which breaks the unitary concept of time and space, making possible the coexistence of the past - represented by the picture - within the present. Similarly, Sciarrino speaks about a painting hung on a wall, which can create the illusion of multiple temporal and spatial dimensions. The concept of *window* is borrowed from computer science: working with computers, simultaneous processes are visualized in different windows on the screen, and through these windows space interacts with time.

The sensibility relative to this kind of temporal and spatial discontinuity is implied in our contemporary way of thinking, but it has slowly emerged already before the beginning of the history of photography. Sciarrino, in fact, identifies several examples of this modern sensibility, looking at the art of the past. He mentions, for example, the painting *Ragazzo morso da un ramarro* (1594) by Michelangelo Merisi, named Caravaggio, as an ante-litteram example of a snap-shot (the painting represents a young boy in the moment he is bitten by a green lizard). Among the musical examples for the window-form, Sciarrino mentions the beginning of the IV movement of the *Symphony n.9* by Beethoven. Here, before presenting the main theme, fragments from the previous movements of the symphony emerge from the orchestral texture. Sciarrino considers them not as simple citations, but as real windows that Beethoven opens on other sound worlds.

In a window-form, more or less complex blocks can be assembled through different editing processes. And, since each block is full of different information, the juxtaposition of different blocks can produce a traumatic friction. Unexpected changes from one world to another one allow for multiple connections in our memory. As Sciarrino points out, the way windows appear can also represent the mode of operation of our mind: following a principle of intermittence the psychological path is presented as made of moments of reflection, critique, clarification, and definition of ideas. Through fragments and repetitions a polyphony of relations emerges, combining really near and really far perspectives, which can interact avoiding intermediate levels. A microscopic and macroscopic world coexist. Therefore, a window-form somehow works also as a representation of the recursive process of our mind, which is able to go back and forward from one idea to another one, moving between different temporal and spatial dimensions. This aspect is particularly interesting to address compositional processes, considering the role that memory has in storing or anticipating a specific sound material, while consciously working with it on different time scales. From this perspective, later in this chapter, I will further focus on my own compositional practice, which usually starts from the exploration of the instrumental sound matter, to then get to its understanding, definition and organization within different time levels.

The reason for me to be interested in what Sciarrino has defined as window-form, lies also in its strong connection to the idea of frame. In the previous chapter, I have talked about stethoscopic forms of listening, i.e. listening experiences mediated by the use of the contact microphone, which becomes a sort of framing device. The use of piezos helped me in getting a better awareness of discrete and conscious forms of listening, in which the auditory space can be framed and the attention can be moved to what is inside the frame.

So, I will start by questioning how to understand the instrumental sound matter, framed by contact microphones and intended as the raw sonic stuff, distinguished from the instrumental sound material understood as the result of a process of selection and definition of the same raw sound matter. I will go on to address how the use of piezos interferes with usual habits of listening, especially in terms of how sound is perceived in its projection in space. I will moreover take into account the role of notation in the crucial moments of inscription during the compositional process, as well as its function as a means of sharing ideas and supporting the performers' memory.

3.2. What's in the frame?

Working with piezos challenged my usual compositional approach. A stethoscopic use of this technology on traditional acoustic instruments provokes a new way of listening to the sound matter. As already mentioned the use of piezo facilitates a form of technical listening, which frames the instrumental sounds within a clearer auditory space. The heterogeneous sound matter inside the frame asks for a better understanding in order to be chosen as part of the material the composer can work with. Using piezo I felt the need to better understand the properties of the instrumental sound matter being explored, also in order to understand how these properties could lend themselves to different kinds of manipulation, transformation, and organization.

Therefore one of the first questions in my project has been concerned with the heterogeneous nature of the instrumental sound matter, which would become part of my vocabulary.

In her book *Listening through the noise*, Joanna Demers structures a vast discourse about genres in electronic music since 1980, considering how electronic music has changed the way we listen not only to music, but to sound itself, outlining her perspective on "sound" as material.

> What I mean by material here amounts to the objectified, audible phenomena in electronic music, from notes and rhythms to sound grains, clicks, timbres, even silence; it is, as Adorno puts it, 'what artists work with' (1997, 147). (Demers, 2010, p.43)

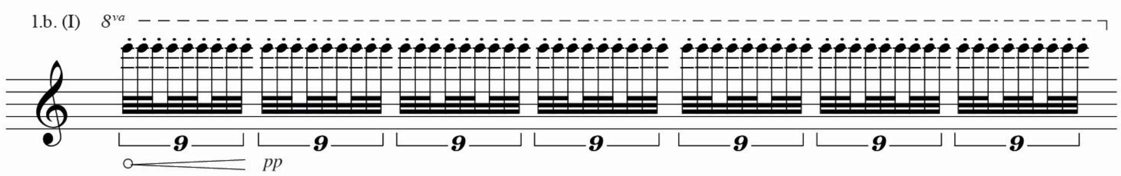
Joanna Demers refers to the heterogeneous material of the composer's work, pointing out how any kind of "objectified, audible phenomena", from pre-existing to newly created sounds, could be intended as material. In fact, if the act of composing can be seen as the practice of organizing sound, the sound itself can be intended as the raw material the composer chooses to work with.

Nowadays composers tend to deal with a wide range of sound possibilities, since any sound can gain the status of musical material. As Curtis Roads observes, referring to Varèse, "the philosophy of organized sound extended the boundaries of accepted musical material, and hence the scope of composition, to a wider range of acoustic phenomena." (Roads, 2004, p.327). Consequently, the composer needs to find strategies to adapt her own work to this wide range of heterogeneous acoustic phenomena, that present different temporalities, different morphologies and different properties. Demers observes that most of the time the discourse about material needs to converge to the activities – construction, reproduction, or deconstruction – that generates it: "As a concept *material* may encapsulate the dual concerns of sound itself and sound generation, concerns that […] are traits held in common among many electronica genres" (Demers, 2010, p.43).

It is interesting to stress this double perspective on sound material. On one hand, Demers takes into consideration the sound material as the “sound itself”, the “objectified, audible phenomenon”, detached from any external semantic content – as in the most significant case of microsound music, addressed in her fourth chapter, in which she observes how the use of minimal particles of material tends to nullify any “external referentiality, converting sound into raw objects” (Demers, 2010 p.70). On the other hand, she considers the sound material from the perspective of its mode of generation, as the product of construction, reproduction, or destruction. She sees it as a malleable material that, in opposition to Schaeffer's formulation of the sound-object, can hardly be separated from its modes of production or from the media on which it is affixed: “material necessarily refers back to its own generation, and so, any discussion of material must include actions and devices involved in its creation” (Demers, 2010, p.43). Any information about the source, actions and devices involved in the mode of production of a specific sound provides knowledge about its potentialities and about the different possibilities to work on it, also in relationship with other sounds.

I have personally experienced that information provided by the mode of production is very important in the process of comprehension and definition of the sound material. Extending Demers' discourse beyond electronic music, I would like to show an example taken from *Prossimo* (2017), a piece for violin and electronics. At the time of composing the piece, among a vast array of materials I collected a specific sound: a fast repeated sound on the first string (fig.3.2.1). In order to identify it as part of my material and to define it, I felt the need to indicate the devices and the actions involved in its production. The action consists of a continuous and fast ribattuto, and the same repeated gesture involves at least two devices: the violin as the resonator – whose resonant body is amplified through a piezo attached to it - and the bow as the exciter. The sound embodies different kinds of information about its mode of production: it is played col legno, on a specific string, in correspondence to a certain harmonic node, with a defined energy level, i.e. dynamics. At the same time, as I will explain later, this sound has been stored as a “sound itself”, as a raw object, suitable for further manipulations.

Fig.3.2.1 – *ribattuto* sound.



In the Italian translation of Helmut Lachenmann's essays there is an interview by Enzo Restagno, in which the composer tells a brief story. When he was a student in Köln, attending Stockhausen's lessons, Henri Pousseur was there to teach, and he asked Lachenmann to name the first sound that came to his mind. He replied: “the barking of a dog”. Pousseur posed the same question to another student, who replied “the sound of a harp”. Then, he asked the twelve present students to develop a scale, that from the sound of a barking dog proceeds to the sound of a harp (Lachenmann, 2010, pp.26-27). Of course, each student came up with a different way to connect these two sounds. Besides observing the evident heterogeneity of these two sounds and how, nevertheless, each student found out her own way to create with them a musical moment, the interesting aspect of this short story lies in Pousseur's request to develop a scale, as the strategy to connect two distant sound-events. The notion of scale implies the notion of direction and movement. Therefore, in my opinion, Pousseur's request assumes that the creation of a structural relationship between two sounds implies the understanding of their potential possibilities of movement, which in turn is linked to the recognition of the development of the internal trajectory of the sound-event itself. Andrea Valle addresses this issue as a matter of internal and external temporality:

> In order to be recognized, audible figures require a nested temporality. On the one hand, the identification of a figure supposes that the figure itself is placed in a context of a temporality that is “external” to the figure. But on the other side, the figure itself is still an object to be appreciated “in real time”, an intrinsically temporal figure which reveals (or at least can reveal) an “internal” temporality. (Valle, 2015, pp.76-77)

The composer, in fact, constantly faces the need to negotiate between the internal temporality of the audible figure or sound-object, and the external one, i.e. the structure to which the former refers. The question of temporality is related to the issue of the time scales inhabited by the sound material. In his book *Microsounds*, Curtis Roads (2004) outlines nine different time scales, specifying for each of them also a chronological range. For example, the “sound object time scale” goes from a fraction of a second to several seconds, the “meso time scale” is usually measured in minutes or seconds, while the “macro time scale” is measured in minutes, or hours, or, in very extreme cases, days. Both the “meso” and the “macro” time scales refer to what has been described above as the external temporality: the “meso time scale” represents the local time in which musical ideas unfold, and processes of development, progression, juxtaposition of different sound objects take place; while the “macro time scale” concerns the notion of form, the architecture of the composition. From the composer's perspective, both these time scales are related to the organization of the sound material. The “sound-object time scale” is instead the time scale of the material itself. In fact, Roads compares the sound object with the note, as the elementary unit of composition in the score, even if he distinguishes the former as heterogeneous and the latter as homogeneous. The heterogeneity of a sound object derives from the fact that two sound objects may not share common properties: they could present different temporalities, different morphologies and different properties. Instead, the homogeneity of a note derives from its static set of properties (pitch, timbre, dynamic, duration) that allows abstraction and efficiency in the musical language. A similar comparison with the note is made also by Denis Smalley, who compares it with the notion of gesture:

> The basic gesture of traditional instrumental music produces the note. In tonal music, notes form a consistent low-level unit, and are grouped into higher levelled gestural contours, into phraseological styles, which traditionally have been based on breath groups. Singers and wind-players, after all, have to breathe. In electroacoustic music the scale of gestural impetus is also variable, from the smallest attack to the broad sweep of a much longer gesture, continuous in its motion and flexible in its pacing. The notion of gesture as a forming principle is concerned with propelling time forwards, with moving away from one goal towards the next goal in the structure – the energy of motion expressed through spectral and morphological change. (Smalley, 1997, p.113)

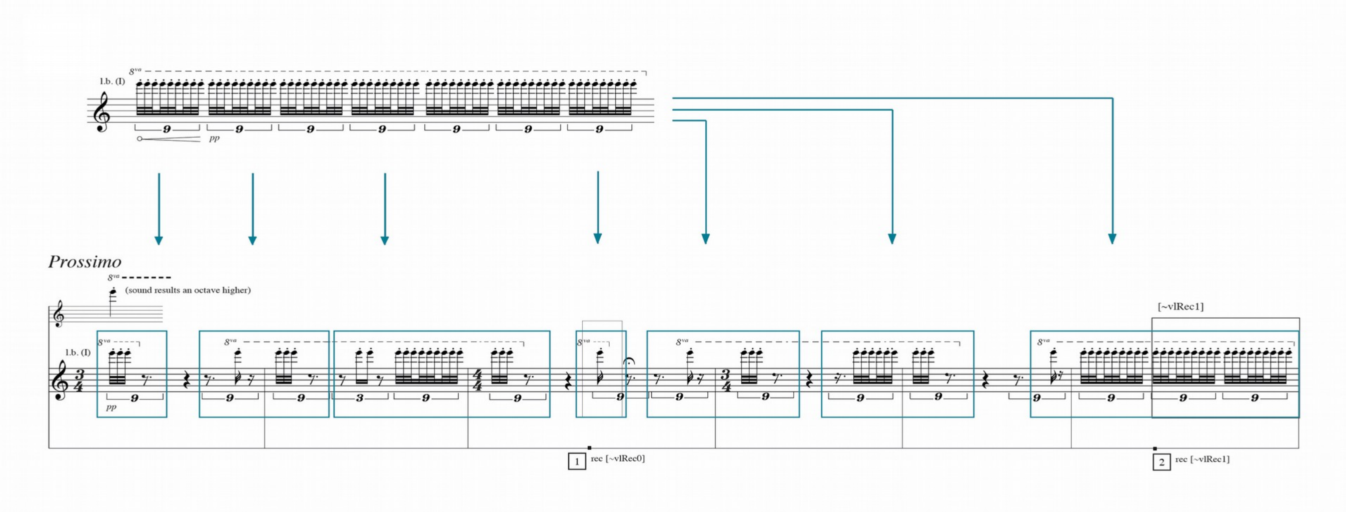
With his theory of spectromorphology Smalley introduces the notion of gesture as a forming principle, considering its conditions of motion. Smalley defines spectromorphology as a descriptive tool based on aural perspective, to study sound changes and transformation over time. The term is derived from the Schaefferian term typomorphology (Schaeffer, 1966). Smalley's approach considers sound materials and musical structures from the perspective of the spectra of pitches and their shaping in time. Spectral and morphological changes over time are the consequences of the activity that generates the sound material:

> Sound-making gesture is concerned with human, physical activity which has spectromorphological consequences: a chain of activity links a cause to a source. A human *agent* produces spectromorphologies via the motion of gesture, using the sense of touch or an implement to apply energy to a sound body. A gesture is therefore an energy-motion trajectory which excites the sounding body, creating spectromorphological life. (Smalley, 1997, p.113)

Similarly, the notion of gesture linked to the aspect of energy is relevant also to Trevor Wishart who makes a clear distinction between the “intrinsic” and the “imposed” morphology of sound (Wishart 1986). The intrinsic morphology concerns the properties of the sounding system, while the imposed morphology relates to the energy input into the system. In order to make this distinction clearer he proposes three sound examples from the category of continuous sounds: a sustained sound of a violin, of a synthesiser, and the one of a bell. According to their physical properties the first two sounding systems – the violin and the synthesiser – require a constant input of energy in order to produce a long sound, whether the bell needs just a single input of energy to resonate for a long time. So, considering any sounding system as gesturally responsive, the definition of the sound material depends not only on the physical properties of the system, but also on the definition of the gesture that shapes its imposed morphology.

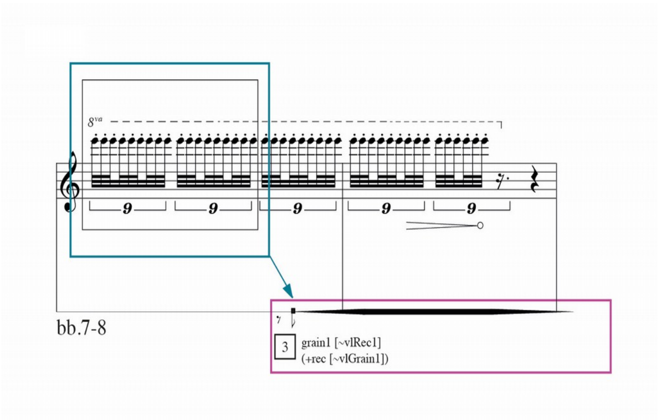
During the compositional process, the composer shapes her own raw matter through a clearer definition of single gestures, choosing for a certain imposed morphology. Going back to the first example of the *ribattuto* sound of the violin, I can observe how it has been shaped throughout the piece. In the first line, it has simply assumed different rhythmical contours (fig.3.2.2).

Fig.3.2.2 – first bars of *Prossimo.*



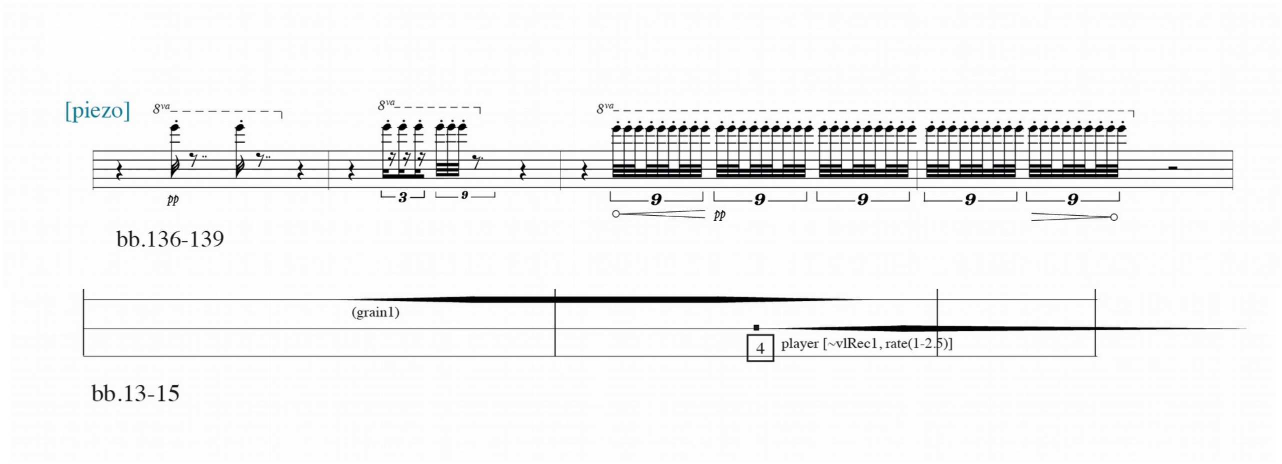
Through simple subtraction operations, the sense of continuity that the material presents at its first stage appears somehow broken. The same feature of continuity is instead reinforced when, at the end of the first line, the *ribattuto* sound is recorded to be electronically processed through a granulator (fig.3.2.3); while, approaching the end of the first part (bb.13-14), the *ribattuto* sound is altered in its pitch through a glissando movement – also in the electronics (fig.3.2.4). Lastly, during the final part of the piece (from b.130), the same sound material appears again, but this time it is played with the piezoelectric microphone and no more with the legno of the bow: one aspect of its mode of production changes since the piezo becomes the exciter. The timbre is therefore affected, even if the material is still very well recognizable[42].

Fig.3.2.3 – *Prossimo* (bb.7-8).



42 See the published exposition "Composing with Piezo", by Daniela Fantechi in www.researchcatalogue.net, to listen to the audio example from 3.2.1. to 3.2.5, the latter produced by a piezoelectric microphone rubbed on a string of the violin.

Fig.3.2.4 – *Prossimo* (bb.13-15).



This opens up a space for at least two different questions: Which kind of manipulation, intervention, transformation does the material afford? How far could a sound material be manipulated while preserving its original "identity"?

It is worth noting that the compositional process includes different moments in which the composer defines the imposed morphology of the sound material she is working on, taking into account which kinds of manipulation, intervention or transformation the intrinsic properties of the material afford or suggest. Within these moments the material is shaped in different gestures, designed through the definition of various parameters: the physical action, namely the movement that has to be done within the physical space of the instrument in order to provide a gestural shape to the sonic idea, the material/tool involved in the actual gesture (the string, the wood, the bow, the piezo, the plectrum, fingers/nails, etc..), as well as the space of the instrument where the action takes place, the quantity of energy – the dynamic – to be put in the action, and lastly, the temporality of the gesture, intended as the internal duration of the sound event or its rhythmic contour. In this way, each gesture becomes more recognizable as a specific sound-event. The temporal dimension that each gesture acquires will be then particularly important to provide information about how sound events will be organized at a structural level, contributing to the creation of a certain sense of motion. As Smalley indicates:

> Gestural music, then, is governed by a sense of forward motion, of linearity, of narrativity. The

> energy–motion trajectory of gesture is therefore not only the history of an individual event, but can also be an approach to the psychology of time (Smalley, 1997, p.113).

Additionally, Smalley observes that if the temporal dimension of a gesture is too loose and stretched in time, the perception of forward motion and linearity gets lost. When the gesture loses its human physicality, the perception of its spectromorphological life will move to the inner details of the sound event; the human scale becomes an environmental one, turning the gestural structure to a textural one. As Smalley again points out, most music shifts between texture and gestures.

> Individual gestures can have textured interiors, in which case gestural motion frames the texture – we are conscious of both gesture and texture, although the gestural contour dominates, an example of gesture-framing. On the other hand, texture-carried structures are not always environments with democratic interiors where every (micro-) event is equal and individuals are subsumed in collective activity. Gestures can stand out in foreground relief from the texture. This is an example of texture-setting – texture provides a basic framework within which individual gestures act. (Smalley, 1997, p.114)

From this perspective, both gesture and texture are considered as forming principles, but the dominance of one above the other will depend not only on the compositional choices but also on the understanding of the sound material. The heterogeneity of sound material can suggest different degrees of segmentation or malleability. It is a composer's task to understand the possible behaviours of the musical material, considering its properties and its affordances.

The concept of affordances brings us back to an ecological approach to perception, developed by Gibson around the '60s. Gibson's ecological approach has been further elaborated, among others, by William Gaver, with a particular focus on the aural domain. Gaver makes a clear distinction between musical and everyday listening. In musical listening, “the perceptual dimensions and attributes of concern have to do with the sound itself, and are those used in the creation of music” (Gaver, 1993, p.1). Musical listening is usually concerned with the determination of timbre, pitch, loudness, and the ways they change over time. An everyday listening instead, takes into account the experience of hearing what is happening around us: which things are to avoid, and which might offer possibilities for action: “the perceptual dimensions and attributes of concern correspond to those of the sound-producing event and its environment, not those of the sound itself” (Gaver, 1993, p.2). The distinction between these two kinds of listening modes is between the kind of experiences, not sounds. It is, of course, possible to listen to any sound either in terms of its attributes or in terms of the events that caused it: hearing the everyday world as music was one of the revolutionary proposals of John Cage, as Gaver points out.

Historically, studies of acoustics and psychoacoustics have been guided largely by the concern of understanding music and sound produced by musical instruments. The latter tend to be more harmonic, compared to the inharmonic or noisy everyday sounds. Moreover, musical sounds tend to have a smoother and relatively simpler temporal evolution, while everyday sounds tend to be more complex. The switch from a musical listening to an everyday one might be relevant in the context of working with a special kind of heterogeneous sound material, such as the instrumental sound matter produced with piezo, since, like everyday sounds, it is more noisy, inharmonic, and more complex. Because of its heterogeneity, the understanding of this specific sound matter could benefit from going beyond the range of physical parameters – such as frequency, amplitude, phase, duration – and considering the perceptual experience from the perspectives of other perceptual dimensions, such as size or force, or energy input into the system.

Gaver's ecological acoustic perspective shares some insights with Smalley's spectromorphological approach, and the concepts of intrinsic and imposed morphology proposed by Wishart. In fact, an ecological perspective takes into account that the pattern of vibrations of solid objects is structured by a large number of physical attributes. The latter can be compared both to the intrinsic morphology of a sounding object and to the gesturally responsive quality of any sounding system. The material is an important intrinsic attribute that has to be taken into account: its internal structure has many complex effects on its vibrations, particularly in the temporal domain. Also the shape and size of a sounding object affect the quality of the sound produced. Size usually determines the lowest frequencies that an object can make, while its shape determines the frequencies and spectral patterns. Different kinds of interaction types – if an object is hit, or scraped, or rolled – impose differences both in the varying of the amplitude over time and the spectrum of vibrations. An impact of hitting, for instance, involves rapid and discrete deformation of an object, while the action of scraping in contrast, involves a continuous input of energy into the system. So, the various kinds of interaction modes might be compared to different gestures, with various levels of energy, that shape the imposed morphology of sound.

All sounds are therefore rich in information about their physical attributes, their modes of generation, and the energy involved in their creation. Focusing on what's in the frame means also training ears to different listening modes, combining forms of musical and everyday listening. Assuming a double perspective, sound material can be understood as “sound-itself”, detached from any external context, but also as the embodied and ecological result of different modes of generations, reproduction, or destruction. This twofold approach contributes to a better understanding of crucial information for the comprehension and the definition of the sound material, as well as to the creation of a more precise aural memory of heterogeneous sound material that the composer chooses to work with.

3.3 Proximity of sound

An ecological acoustic perspective also takes into account all the information about how the sound is perceived in the environmental space. In any amplified context the use of microphones alters the usual perception of both the quality of the instrumental sound and its projection in space. These two aspects are usually taken into account, considering on one hand the already mentioned filtering that any microphone – even the most hi-fidelity one - adds to the instrumental sound quality, and on the other hand how sound is projected in the space through loudspeakers. Their use implies dealing with multiple variables, such as their frequency response, their number and disposition, and their relation to the acoustic responses of the room. All these variables also affect the perception of the distance or closeness of sounds in the space. Finally, it has to be considered that the acoustic instrument itself constitutes a sound source, so the amplified sound projected in the room through loudspeakers adds to to the actual instrumental sound.

All these general considerations are at the basis of any work involving forms of amplification. Even more so in the specific case of my research, which deals with a peculiar form of amplification. As already discussed, the use of piezo enables a form of mediate listening, which demands a strong engagement with different aspects of listening, raising several questions:

- How does the use of piezo interfere with a usual perception of the amplified instrumental sound and of its projection in the space?
- Which kind of listening situation should I foresee in order to allow people to clearly perceive a different proxemics of sound?
- Is space a compositional element?

The hyper-amplification of the instrumental matter through piezos provides a significant shift from the usual auditory feedback. Using piezos implies the most close-miking technique, which picks up the sound of the instrument directly from the vibrating surface of the instrument, isolating it from other sound sources, and minimizing the ambient sound. Moreover, due to their very specific acoustic properties (as already explained in chapter 2) piezos filter the instrumental sound, conferring on it a very peculiar colour, while clearly revealing the sonic presence of the technological tool between the acoustic sound of the resonant object and the human ear. So, the instrumental sound matter amplified and produced with the piezo gains a new sense of proximity. This term has the same root as the word "proxemics", which refers to the study of the human use of space within different cultural contexts. This term was introduced by the anthropologist Edward T. Hall. In his essay *The Hidden Dimension* (1966) Hall developed a theory of proxemics, arguing that human perceptions of space, although derived from sensory apparatus that all humans share, are culturally patterned. Hall observed how different cultural frameworks for defining and organizing space are internalized at an unconscious level, and they can produce misunderstanding within communication in cross-cultural settings. In a similar way, I would argue that the perception of amplified instrumental sounds is internalized at an unconscious level according to a few constant aural habits. The way piezos amplify instrumental sound creates a moment of disruption in this usual perceptual pattern. This uncommon sense of proximity means that the sound produced with piezo is perceived as strikingly close, generating a different proxemics of sounds. Fig.3.3.1 shows bb.198-200 of *Residual*, a piece for ensemble and electronics, in which the cello performs an action involving the piezo.

Fig.3.3.1 – *Residual* (bb.198-200)

In this section, the piezo has to be placed flat on the indicated string, in the position more or less corresponding to the head of the note, here replaced by the straight line. The piezo here has a double function: it tunes the string – as a finger would have done –, and it closely amplifies the movement of the bow. The emergent sound quality is extremely airy, except for the moments in which the bow moves toward the bridge, the pressure increases and the dynamic grows significantly. Here the sound becomes extremely complex and noisy. During one rehearsal I have made a recording of these few bars, both with piezo only and with condenser microphones, which also capture the environmental sound. Comparing these recordings it is extremely clear how close and hyper-real, the piezo sound appears.[43]

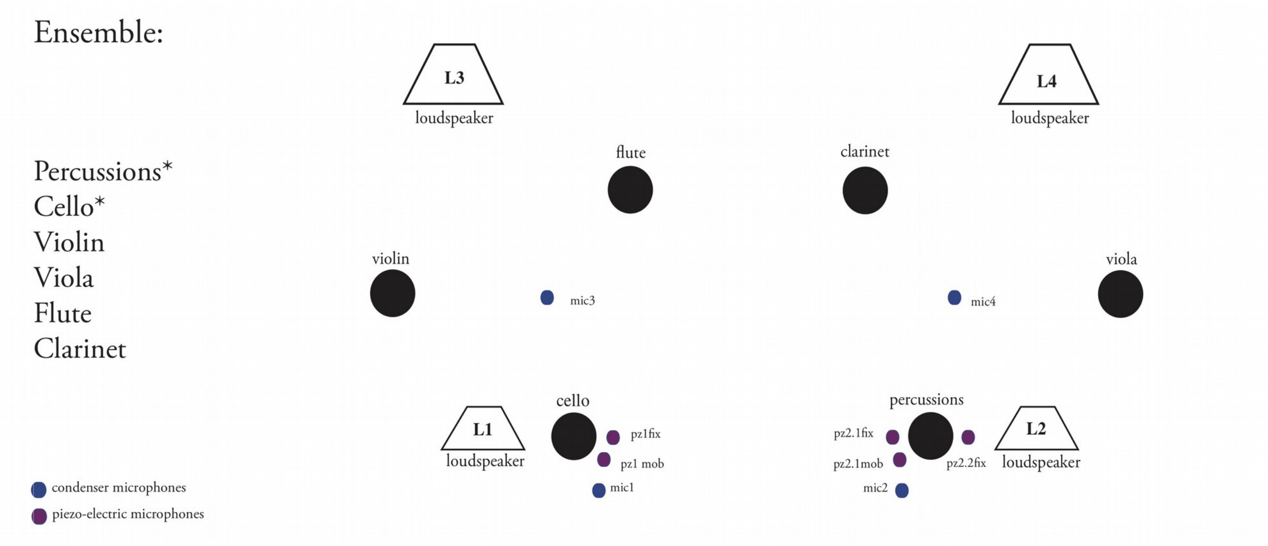
During my work with piezo, this aspect leads me to try different strategies in order to highlight the sense of intimate proximity and the actual changes in the proxemics of sounds. I want to refer here to two different pieces that enacts quite different strategies: *Residual* for ensemble and electronics, and *PianoMusicBox_1,* for piano and electronics. These two pieces present different situations in terms of the kind of amplification and the strategy chosen to project the amplified sound in space.

Residual was commissioned by Hermes Ensemble, and premiered at the Concertgebouw in Bruges, on November 21st, 2019. With this work I have worked with space at a compositional level,

43 See the published exposition "Composing with Piezo", by Daniela Fantechi in www.researchcatalogue.net to listen to audio examples 3.3.1a and 3.3.1b.

exploring the possibility of working on two different planes of sound: one in the foreground, and the other in the background. The cello and the percussion (timpani, marimba, güiro, crotales) are the instruments in the foreground, which act almost as soloists. The cello is provided with one piezo, which has to be used to play different gestures on the instrument, and another which has to be fixed on its body with the purpose of amplification. Concerning the percussion, one piezo has to be fixed on the surface of the timpani, another on the lowest C-key of the marimba and a third has to be used to play the crotales and the güiro. Both percussion and cello are primarily amplified with piezos, although a condenser microphone is added, in order to smooth the color of the piezo. The rest of the ensemble – flute, clarinet, violin and viola – is arranged in a semi-circle behind the soloists and is amplified only with a pair of condenser microphones, with a sort of transparent amplification, i.e a light reinforcement of the instrumental sound. In order to emphasize the perception of these two different planes, cello and percussion are amplified through their own loudspeakers, placed next to them. In this way, both the sound of the acoustic instrument and its amplification are projected in the space from almost the same spot. The rest of the ensemble is instead amplified through a pair of stereo loudspeakers placed behind the ensemble (fig.3.3.2).

Fig.3.3.2 – *Residual* (instruments' disposition)



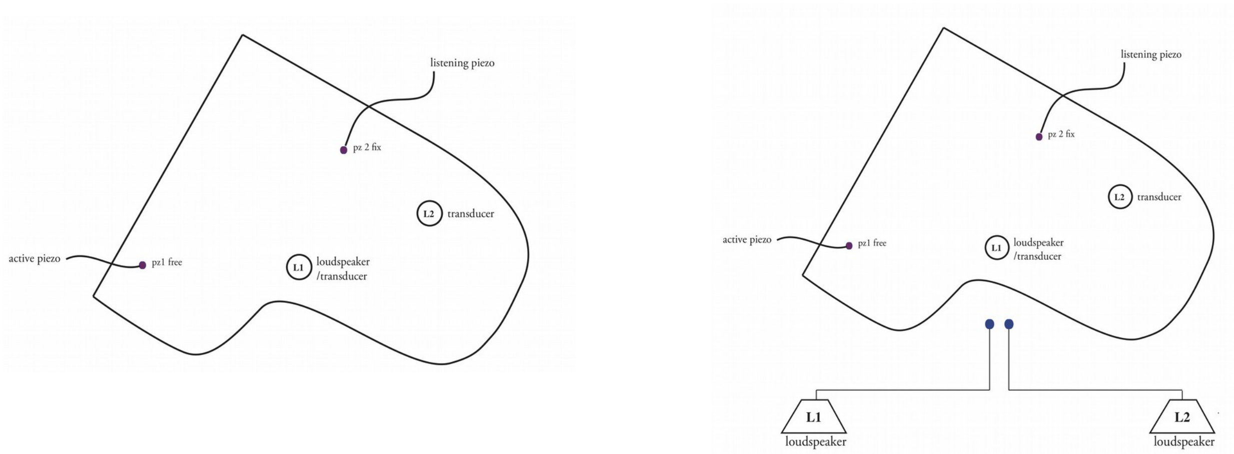
The piece articulates a catalogue of actions and gestures that explore different degrees from almost pitchless to more pitched sounds, sometimes using the sound quality of piezos in order to create similar sounds for the cello and the percussion, as happens, for example, in the first section of the piece. Here the percussionist starts playing on the surface of timpani with a gentle scraping sound, using fingers or nails. The cello enters after a few bars with a rhythmic counterpoint of actions, playing with the bow next to the piezo, which is placed flat on the string in a determined position, producing a quite airy sound that resembles the one of the timpani. A quite unstable and unpredictable materiality of sound emerges from the gestures played with piezos. A similar instability is sought in the sound quality of the ensemble, especially when using harmonic sounds of the strings and airy or multiphonic sounds of the woodwinds.

In the last sections of the piece, the piezo-sounds of cello and percussion are processed electronically. The processed sound is sent to the main loudspeakers, instead of being sent to the more directional loudspeakers of cello and percussion. In this way the electronically processed sounds are clearly distinguishable from the "acoustic" piezo-sounds, and their foreground-quality enters in the background sound plane.

Instead of seeking to highlight different sound planes, foregrounding the different proxemic of piezo-sounds, *PianoMusicBox_1* aims to concentrate on the inner sounds of the instrument and its hyper-materiality. *PianoMusicBox_1* has been written for and in collaboration with the pianist Chiara Saccone, and it was premiered during the festival "Collaborations are More Refreshing than New Socks", at the Royal Conservatoire of Antwerp, on December 4th, 2019. The amplification strategy includes the use of two piezos – one is given to the pianist for the production of sounds and the other one is fixed on the soundboard, providing information to the electronics. The first piezo produces sound while amplifying – and sometimes as input to the live-electronic processes. In addition to the piezos, two transducers are placed inside the stringboard of the piano to create a closed system, in which both the acoustic instrumental and live-processed sound are amplified through the body of the instrument. In this way the piano becomes the only sound source. (In the case of performing the piece in a very big room, a couple of microphones and a stereo set of loudspeakers might be used to reinforce and better project the sound of the piano in the space (fig.3.3.3).

The piece starts with a few gestures, produced by exploring the inner part of the instrument – the soundboard and the strings – with the piezo. The pianist operates different gestures of gentle scraping and glissandos along single strings, or with transversal movements on a certain range of strings, or behind the bridge. In the first sections of the piece sound matter always results from the direct contact of the piezo on the string.

Fig. 3.3.3 – *PianoMusicBox_1* (amplification system)



The materiality of the string emerges clearly. Part of this sound material is recorded through the piezo and it is then played back as it is or after undergoing processes of filtering and granulation. The aim is to enact an intertwined internal dialogue between the processed sound and the live one produced by the pianist. Both layers of sound share similar acoustic features. Moreover, both come out from the piano through the transducers, sharing the same sonorous space. In this way, the perception of dealing with the same sound instrumental matter is reinforced. The listener's attention is so drawn to the same complex and intimate sound world. Only gradually does the pianist reach the keyboard and the piece moves toward a more familiar piano sound-world, but the feeling of proximity and intimacy is maintained by the same colour of the amplification through the piezos and the transducers.

3.4. The Role of Notation

The process of grasping and understanding the differences in quality and proxemics of piezo sounds is a long process which relies on auditory skills of memorization. The role of auditory memory in our experience of music is described very well by Bob Snyder in his book *Music and Memory*

(Snyder, 2000). Here the author addresses the abilities and limits of our memory in the organization, recognition and recollection of sound events. Snyder suggests that our memory is organized on a model consisting of three processes: an early-processing echoic memory, a short-term memory and a long-term memory. Each of these three memories differently processes information that comes to our ears. Each memory functions on a different time scale, that for Snyder loosely relates to a different time level of music organization, called respectively “level of event fusion”, “melodic and rhythmic level”, and “formal level”. Note that these time levels resemble those of the above mentioned definition given by Curtis Road: the “level of event fusion” would correspond to the “sound object time scale”, the “melodic and rhythmic level” to the “meso time scale” and the “formal level” to the “macro time scale”.

Within these processes, acoustic features are extracted from continuous data of echoic memory and then bound together and organized into groupings based on similarity and proximity in perceptual categories, which later becomes conceptual, in long term memory. These different memory processes do not function completely independently of each other. The processes are intertwined in the building and in the actual consolidation of long-term memories. The whole process may be understood as a recursive one, that can occur either spontaneously, or as a result of conscious efforts. The recursiveness lies in the fact that each time a specific sound is heard once more, our memory activates the process of storing more accurate information about that sound, starting from the last aural memory of that specific sound. The recursiveness lies in the fact that each time a specific sound is heard once more, our memory activates the process of storing more accurate information about that sound, starting from the last aural memory of that specific sound. As a composer, getting conscious of the distinction of three processes of memory based on three different time levels has led me to understand the need for iterative listening to the instrumental sound matter, in order for its aural memory to achieve a certain level of definition during the compositional process. Then, as the abstraction of sonic images becomes clearer, the necessity to notate the aural memory of the gestures tested and experienced starts to emerge, in order to find a way to bring the sonic image from its 'inside' time to the 'outside' time of composition. The visual translation of the sonic image becomes, therefore, part of the process of comprehension and acquisition of the sonic material, crucial in turn to its manipulation, transformation and formal organization within the compositional structure.

In the visual translation of any sound image, notation comes into play as a tool for the composer to give a shape to her own aural memory. Auditory imagination is helped to recall different sounds by visual cues, graphically represented with a symbol or a set of symbols. Therefore, notation becomes a means for the composer, as it has been the case for the last few centuries of Western composed music. We can observe with Impett:

> Symbol-manipulation lies at the heart of Western composition. The symbolic representation and manipulation afforded by technology from wax tablet to computer constitute a form of conceptual prosthesis. Virtual, mental quasi-external representations are both more ephemeral and more plastic than their material counterparts. The points at which a current state is externalized constitute a unique signature in the compositional process. (Impett, 2016, p.661)

The uniqueness of this signature lies in the personal set of choices made by the composer herself. This decision-making process requires constant negotiation between the mental representation of each sonic idea and its physical representation in a visual form. Therefore, the process is again to be considered as recursive. It is part of the composer's task then to decide how to translate the sonic image into a visual one. The composer has to choose what features of the sonic image she needs to graphically represent and how. Negotiation within the limits of the visual representation is required to define the amount of information that could be delivered by the notation, in order to define and make clearer specific features of a certain sound event.

In my compositional practice, I've found a personal strategy to specify and integrate the use of piezo in a form of consolidated notation. What I am usually concerned to define and indicate are the aspects corresponding to the same parameters through which I tend to design different sound gestures, i.e. the movement that has to be done within the physical space of the instrument in order to produce the related sonic idea; where the action has to take place, as well as the material/tool involved in the production of sound (the string, the wood, the bow, the piezo, the plectrum, fingers/nails, etc..); the temporality of the gesture, intended as the internal duration of the sound event or its rhythmic contour; and the quantity of energy – the dynamic – to be put in the action.
This attitude is somehow linked to the embodied and perceptual nature of music-making, in which the physical production of sound is understood as tangible, through its situated and embedded experience. But crucial in my personal experience is also the fact that thanks to the graphical representation of the sonic gesture through which the performer produces a specific sound, the mental image of a certain sonic idea becomes clearer and more precise.

In order to define and design the visual representation of different sonic images, I rely on different ways to notate scores. They go from a more traditional/descriptive notation to a more prescriptive action-notation – which is now recognized as a quite established mode, inherited from Helmut Lachenmann's work – to direct description of techniques used through verbal instructions or symbols. The latter are usually explained in detail in the performance notes, so that the score can be less dense and easier to read (see performance notes of *Residual*).

Prescriptive action-notation in particular, indicates mechanical properties of the sound production, such as the direction and the energy of the movements that the performer is asked to do (Ornig, 2013). An example is found in the first bars of *Residual* in which the percussion (timpani) and the cello share similar gestures, which appear similar also in the way they are notated. The notation does not describe the sound result, but the action that the performer has to do. The movements that have to be done are prescribed by lines and arrows which resemble the alternating of right and left hands for the timpani, and the alternating of the direction of the bow of the cello, which is here moving vertically on the string. More detailed info about the space and tool/material involved are given both by symbols and verbal instructions: two different symbols – whose meaning is described in the performance notes – indicate whether the action on the surface of the timpani has to be done with the nails or fingertips, while the fact that the surface is amplified through piezo has already been explained in the preliminary notes. The black diamond-head of the cello indicates instead the approximate position in which the piezo has to be placed on the string – in this case the fourth string, as indicated by the roman number. The rhythmic contour of each gesture is traditionally notated by the alternation of quarter-notes and chromas within each 4/4 bar. The energy to be put in the action is notated with traditional dynamic symbols of *p, mp, mf*, etc and the *crescendo* and *decrescendo* lines.

The attempt to define as precisely as possible the different sound gestures is a recursive process that happens both at a visual and at an aural level. This recursive process of defining and re-defining becomes fundamental in the compositional practice. Through notation, the gestural structure in which the sounding matter is inscribed comes to constitute the starting material of my work, and, once I get a better understanding of the sound material I want to work on, that material tends to reveal its potentialities more easily. Around each sonic image, others come into being, by analogy, symmetry or opposition, through an interplay between the aural memory and the aural imagination. From then on, the work can more easily progress within other time levels, namely within the meso time level in which musical ideas unfold and the macro time level of the structural form of the piece – corresponding to Snyder's “melodic and rhythmic level” and “formal level” –.

Architecture-wise, a piece is usually built by various sonic images differently organized in time, which interweave to produce multiple stratifications or successions of varying temporal dimensions (for examples from my practice see ch.4, especially sections 4.3, 4.7). During the compositional process many decisions are taken simultaneously, constantly zooming in and out between different time-scales of music organization. Compared to the retrospective perception of listening, the composer works in *prospect*, imagining sounds, their succession and combination, though a complex set of operations. As outlined by Impett:

> Composition is a reflexive, iterative process of inscription. The work, once named as such and externalizable to some degree, passes circularly between inner and outer states. It passes through internal and external representations – mostly partial or compressed, some projected in mental rather than physical space, not all necessary conscious or observable – and phenomenological experience real or imagined. At each state-change the work is re-mediated by the composer, whose decision-making process is conditioned by the full complexity of human experience. This entire activity informs the simultaneous development of the composer's understanding of the particular work in its autonomy, of their own creativity and of music more broadly. Environment (culture, technology) and agents (composer, work) coevolve at different rates. (Impett, 2016, p.457)

In my daily practice, again, I rely on notation as a tool to get control over each "state-change" of the work. I got used to constructing on paper a spatial representation of time, to visually represent the macro time level of the formal and architectural structure of the composition. My drafts are usually sketched on paper, following a timeline, placed on top of the score. Timelines are tools that enable me to visualize the disposition and the development of different sound-events in time, the possible relationships between them, and to get an overview of the global form of the piece. Just in a few occasions timelines are preserved in the final version of the score, as in the specific case of *et ego,* (see ch.4.2). The adoption of a timeline reveals a 'left-to-right' reading habit, which comes from the assimilation of traditional notation, as well as from frequent use of sound-editing software, in which the waveform is usually represented in the time-domain.

The representation mode chosen by the composer reflects her personal experience, within her own specific technological and social environment. Since the composer usually operates within the same environment in which the performer acts, it is often the case that performer and composer share similar codes. Hence, the score might be also understood as the interface to share sonic ideas, through their visual inscription, and to provide a set of instructions for the performance of the piece.

The role of notation in supporting mnemonic activities is crucial also for performers, who need to memorize a different way of playing and interacting with her own instrument. Notation supports a shared comprehension through a set of agreed symbols. The possibility to collaborate with performers adds a great value to each project. First of all, it is very important that performers could have the possibility to get familiar with the peculiar technology of piezo, becoming aware of their way to alter the instrumental system by the means of hyper-amplification. Secondly, performers, with their own expertise and engagement, usually enhance the results of my experimental moments of improvisation. Through rehearsals and moments of discussion, different performers have provided me with useful feedback about the collected sound material, enhancing the definition of playing techniques and notation of single gestures.

The way I rely on notation in my compositional practice is almost constant, even if a few exceptions have to be mentioned. *Hidden Traces* is an open-form piece for guitar and electronics, conceived for an exhibition in the Belgian Art Gallery *Be-Part* in Waregem, in April 2019. I was asked to propose a piece that I would have performed by myself. As a composer, I am usually more concerned with writing pieces for someone else. So, this was quite an uncommon request, that led me to adopt what is an unusual solution for me, i.e. the realization of an open-form piece, of about 12 to 15 minutes. The overall control is left to the performer, who has however to follow a certain set of indications, also regarding the formal structure. The technical setup resembles that of *PianoMusicBox_1:* two transducers are placed on the soundboard of the guitar, to amplify both the instrumental and live-processed sound through the body of the guitar. Two piezos are, instead, employed with two different functions. The performer uses the first piezo to play on the strings and on various points of the surface of the guitar, while the second piezo has to be fixed on the soundboard to act as a "listener", providing information for the electronics. *Hidden Traces* has been premiered in Belgium by myself, and then in the UK and in Germany by the guitarist Seth Josel. For this piece, I have never gone through the usual process of notating gestures that I have been experimenting with during the exploration of the instrument; rather, I have focused more on getting control of different electronic processes, which allowed me to improvise with a certain set of predetermined material. As long as I was the only performer of the piece, I relied on my gestural memory to improvise, using just a draft as a reference point, with an approximate timeline for the general structure of events, and some reminders about how the MIDI controller was programmed. Only when there was the occasion to have the piece performed by the guitarist Seth Josel, did I sketch out a more precise set of instructions (see the related section of ch.4), realising that the actual score was, for a large part, already embedded in the code of the software that controls all the electronics processes. During the whole compositional process, in fact, I relied mostly on the software as the main composing environment, rather than on more familiar tools such as pencil and paper. The whole process of externalization of sonic images through their inscription on paper, has been somehow condensed in the programming of the code. Consequently, the final score has come to be a set of textual instructions for the performer, who is asked to be fully aware of all the different electronic processes that she has to control, in order to move freely within an open structure, which has, nevertheless, a few fixed points regarding the succession of different events. In this particular case, I have observed that, more than ever, preliminary work with the performer has been fundamental; in the "score", a large amount of information about possible playing techniques – that are in part left to the expertise and to the personal creativity of the performer – is missing, while the functioning of the system made of piezos, transducers, and various electronic processes, requires certain skills that the performer might have to learn.

3.5. The Role of Memory in Storing, Anticipating and Archiving

As a general and basic premise I tend to understand composition as a discipline of 'organizing sound', as has been suggested by Varèse:

> I decided to call my music 'organized sound' and myself, not a musician, but 'a worker in rhythms, frequencies, and intensities' (Varèse, 1966);

and Cage:

> If the word 'music' is sacred and reserved for eighteenth- and nineteenth-century instruments, we can substitute a more meaningful term: organization of sound (Cage, 1937).

The notion of "organization", can be then understood as referring to the way different sounds are combined within the formal structure of the piece, so within what has been previously defined as the "meso" and the "macro" time scale of music. From the listener's perspective the perception of how the sounds are organized in these time scales happens while the piece is played, so inside the time of the piece itself, or in retrospect, moment after moment during the listening process. Instead the composer has to work in prospect, outside the real-time of the composition, imagining sounds, their succession and combination. Thus it is worth noting how the compositional work happens in another temporal dimension, called the "supra" time scale by Road:

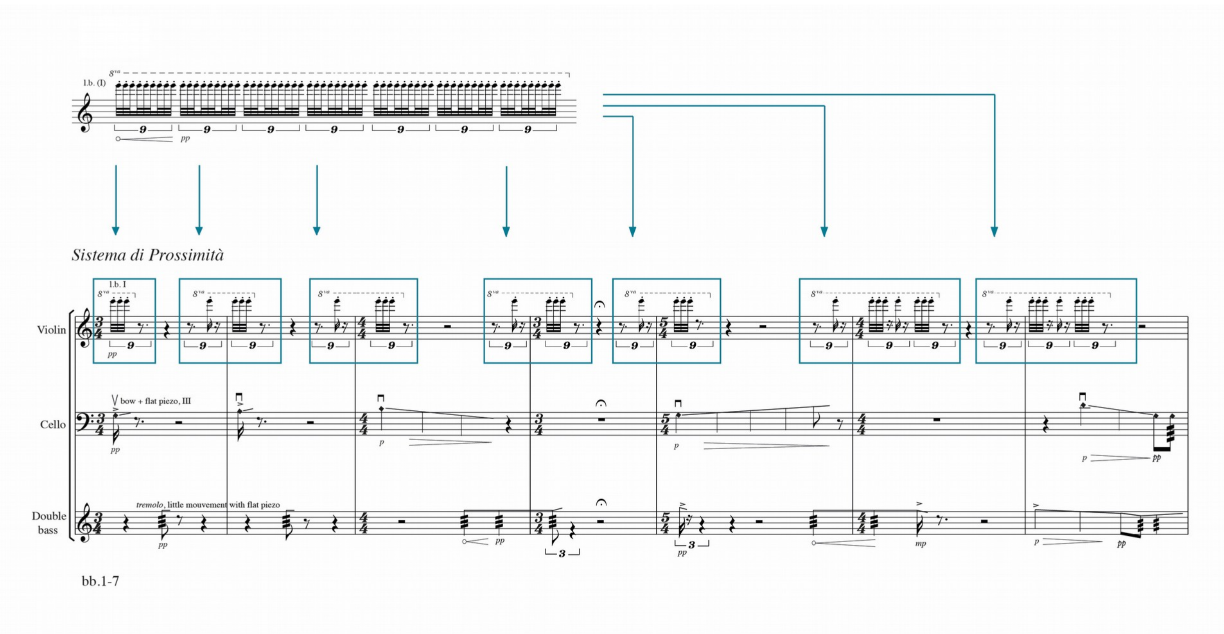
> Composition is itself a supratemporal activity. Its results last only a fraction of the time required for its creation. A composer may spend a year to complete a ten-minute piece. […] The electronic music composer may spend considerable time in creating the sound material of the work. Virtually all composers spend time in experimenting, playing with the material in different combinations. Some of these experiments may result in fragments that are edited or discarded, to be replaced with new fragments. Thus it is inevitable that composers invest time pursuing dead ends, composing fragments that no one else will hear. This backtracking is not necessarily time wasted; it is part of an important feedback loop in which composers refine the work. (Roads, 2004, p.10)

The “supra” time scale of the compositional process is, therefore, a time outside the real one of the musical composition, and Roads refers here to the non-linearity of the whole process. In my opinion, this non-linearity is not only represented by the time spent in experimenting, going back and forward, but also by the way the composer is constantly shifting between different temporal dimensions, zooming in and out within the different time scales inhabited by the sound material. This recursive work on sound, that lies at the core of the compositional process, triggers a feedback loop between the aural memory and imagination: the composer tends to imagine and anticipate the structural relationships between different sound objects that she keeps in memory while rethinking their definition. This mechanism relies strongly on the possibility of creating a consistent memory of the sound material.

In my personal experience, this means creating multiple ways to get continued access to empirical experience of the sound material and to the different ideas about its definition, transformation and manipulation. The possibility to go back as many times as needed to the empirical experience of sound allows for a better understanding of the acoustic features of the sound material that I am working on, and for a constant redefinition of its aural memory. Thus, I have developed a practice of recording moments of improvisation and exploration, as well as rehearsals at different stages of the process. For each different project or piece, I tend to store and catalogue in digital folders and sub folders different recordings, text files with their description, patches for the processing of sounds, notes, sketches, etc. This becomes a sort of personal archive in which I organize the material that I am working with. In this sense, the term “organization” assumes a different connotation referring to the idea of classification and archive. In this larger meaning, "organization" is no more just a matter of combining the material inside the formal structure of the piece itself, but it refers to the organization of the material outside the piece, within the composer's working environment. During the compositional work, the creation and the organization of a personal archive of information is constantly reshaped and updated, so that this act of cataloguing the sound material supports the non-linear approach to the compositional process, providing the possibility to access and navigate through different information at various stages of the process. Furthermore, the existence of such archives allows for the occasional reconsideration and reuse of a certain element of stored material, providing for multiple outcomes.

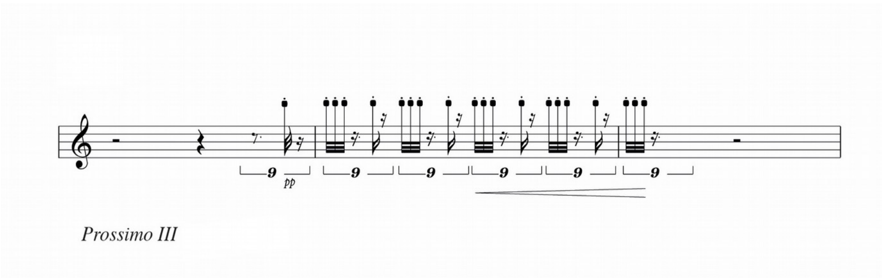
As example I return to *Prossimo* and the *ribattuto* sound of the violin, discussed above. *Prossimo* belongs to the cycle *Sistema di Prossimità,* which consists of four pieces: *Prossimo,* for violin and electronics, *Prossimo II* for double bass and electronics, *Prossimo III*, for cello and electronics, and *Sistema di Prossimità*, for violin, cello, double bass and electronics. Each piece of this cycle can be played separately, or one after each other, seamlessly. In the latter case the reuse of the *ribattuto* sound of the violin, discussed above, is clearly recognizable. At the beginning of *Sistema di Prossimità* (bb. 1-13) the same sound material appears in a specific rhythmical version (fig. 3.5.1), which is the result of a process of subtraction from the original material.

Fig.3.5.1. *Sistema di Prossimità* (first bars).



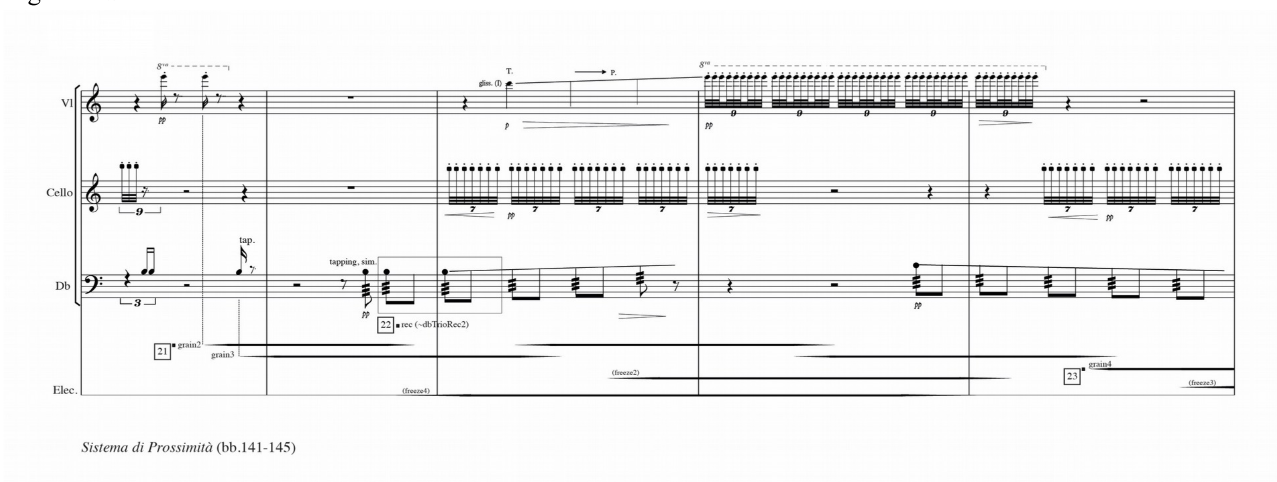
A similar version is assigned to the cello, in the last part of *Prossimo III* (from b.133 until the end of the piece, fig.3.5.2); here the mode of production – with *legno battuto* – is similar, and the derivation from the violin's material is evident, even if the timbre and the dynamics are different due to its transposition on another instrument. This sound in the piece for cello also assumes a structural value: it recalls the one already played in the violin piece and, at the same time, it foreshadows the beginning of the trio.

Fig.3.5.2 *Prossimo III – ribattuto* sound with legno



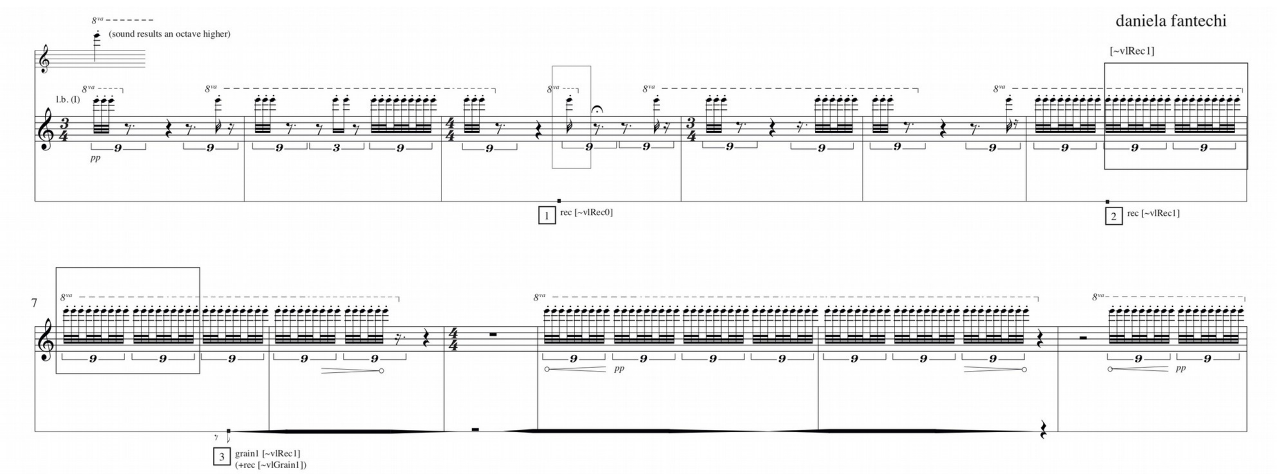
Finally, the *ribattuto* sound comes back at the very end of the cycle, played at the same time by the violin and the cello (from b.134 until the end of *Sistema di Prossimità* – fig. 3.5.3), and, in a slightly different version, by the double bass as well. But here this *ribattuto* appears in its continuous form, and, because it is played by all instruments, the sense of texture implied in its original form is reinforced.

Fig.3.5.3 *Sistema di Prossimità* – bb.141-145.



The creation of a consistent memory of certain specific sound gestures such as that of the *ribattuto*, is generated and supported by the act of storing and archiving. During the compositional process, my attention tends to be focused on a limited number of specific sound gestures, corresponding to the ones stored as recordings of explorations, improvisations and rehearsals. These materials usually come to constitute the basis of the formal construction of my pieces. The same recorded and stored materials are also selected for the construction of the electronic part. In my works I rarely conceive the electronic part with the use of synthesized sounds. Rather the electronic is generated by the processing – such as granulations, filtering, delays – of the instrumental part, recorded during the performance. I usually tend to present a certain sound gesture in the instrumental part, to then record it and promptly process it, creating a dialogue with the instrument. In *Prossimo*, for example, the *ribattuto* sound is the first one to be recorded in the buffer "~vlRec1" and processed (actually the first sound to be recorded is the buffer "~vlRec0", which is just a single hit of the same sound gesture, recorded at the very beginning of the piece, but it is processed only later on). So the buffer "~vlRec1" will be the first one to establish a dialogue with the instrumental part, which is playing similar material (bb.7-8 – fig. 3.5.4).

Fig.3.5.4 *Prossimo* (first bars)



Right after a descending glissando (bb.16-17) is recorded as the buffer "~vlRec2", as well as the sound generated from the gesture of a tremolo done with the flat piezo on the string, recorded as the buffer "~vlRec3" – fig.3.5.5. These buffers, together with the ascending glissando recorded as the buffer "~vlRec4", are processed or simply played back while the violin plays, from b.22, a material similar to the one of buffer "~vlRec3" – fig.3.5.6. The processing of these buffers contributes to creating a certain complexity in the polyphony of events happening between the instrumental part and the electronic one – see ex.4. Through repetition, reinterpretation and transformation, all the material presented until now comes into play. So, in this section a limited series of elements is presented through multiple identities. This process of recognition and differentiation of the sound matter lies at the core of my compositional work and it is enabled by the activation of the aural memory, which allows for working on multiple identities of the same material. Relying on the exploitation of a personal archive, the activation of the aural memory is stimulated in the understanding of the sound matter and of its multiple possibilities of manipulation. Finally, the aural memory comes into play not only in the compositional process but also in the listening experience. During the performance of the piece, it is the listener's memory to be both challenged and guided in the identification and recognition of different instantiations of the same sound material by the constant reinterpretation and re-proposition of a limited series of sonic ideas.

Fig.3.5.5 *Prossimo* (sound gestures recorded as buffers)

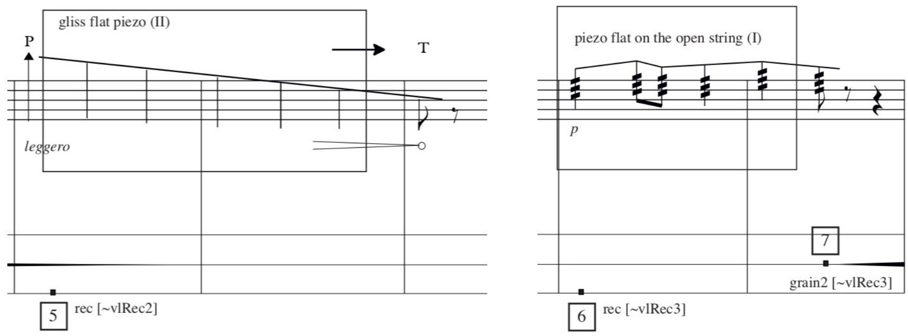
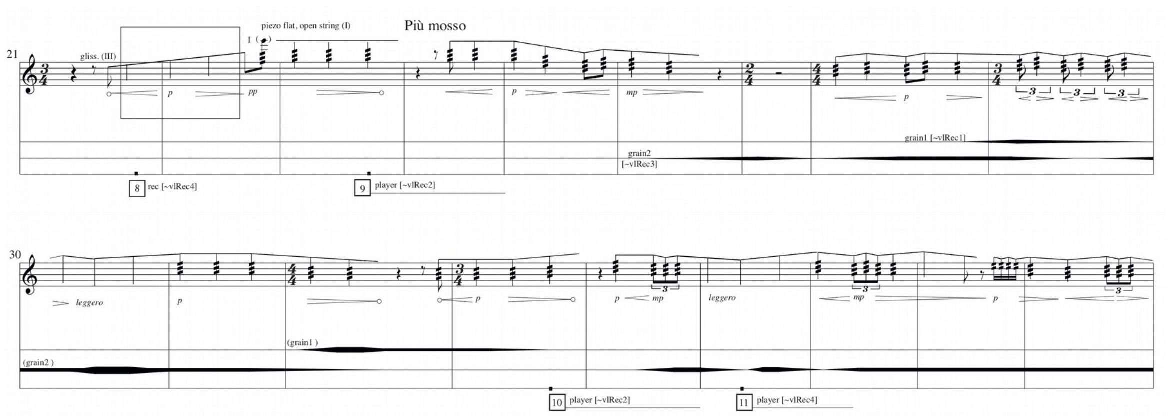


Fig.3.5.6 *Prossimo* (polyphony of events between the violin and the electronic part)



Within this context I found very interesting Patricia Alessandrini's perspective about the role of memory and material, as clearly addressed in her presentation *Memory as Difference, Material as Repetition: a Performative Presentation of Compositional Strategies and Multi-source Interpretative Methods* (Alessandrini, 2015).

Most of her compositional works consist of 'interpretations' or 'readings' of existing repertoire. As it is the case of *Adagio sans quatuor* (2010), which is based on the Adagio introduction of Mozart's “Dissonance” quartet, *Forklaret Nat* (2012), written for the Arditti Quartet and based upon an interpretation of *Verklärte Nacht,* by Arnold *Schönberg,* or *Tracer la lune d'un doigt* (2017), based upon a reading of the Adagio movements of J. S. Bach's violin concertos. Her conscious choice of building a personal relationship with the past by using work of the past is influenced by the idea that material is not something that has to be generated, whether it has to be found and interpreted.

> I feel that as composer I'm actually performing and interpreting the past through different technologies. [...] I'm somewhat of the opinion that nothing is new, or rather that anything new is just a recombination of things that already exist. [...] I try to emphasise and embrace this idea of nothing being new, but where difference is still possible, and this difference comes about through my subjectivity as a performer, as an interpreter of what has come before. (Interview with Nicholas Moroz, 2017)

Most of the pre-existing original materials Alessandrini uses are scored but is not the score that lies at the core of her compositional work. Her method relies in essence on the assembly of electroacoustic maquettes through the layering of various recordings of pre-existing repertoire. The process of superposition highlights the differences between the recordings. In fact, the recordings may be time-stretched proportionally note by note so that, when superimposed, they are synchronized; and the superimposition of these different versions may be subjected to further time-stretching to heighten the subtle variations between them and bring out the artifacts of the phase vocoding. The maquettes are subsequently transcribed into instrumental parts, and they may also provide material for the electronics. Through this process, her instrumental works are started as electroacoustic pieces in order to eventually produce a score, and the identity of the piece is situated in the multiplicity of its practical realization. In such processes, memory provides the possibility of expressivity, in the perception of subtle differences between the various instantiations of the original composition, as well as between the newly composed utterance and the original composition upon which it is based.

More generally, I would therefore observe that memory enhances composers' creativity, beyond the kind of material they tend to use. The possibility of building a strong and consistent aural memory of the sound matter allows understanding where differences are still possible, and exactly through the expression of differences, the artist may get to fully express her own creativity.

According to my personal experience, I can observe how providing the composer with the possibility to have continuous access to her own classified and catalogued sound material, represents a possible model to work on sound. Such a methodological way of collecting sound materials brings the notion of archiving and cataloguing at the core of the "organization" of the whole compositional process. A source of inspiration for this way of working has been the methodological use of archives and catalogues in the work *Systema Naturae* by Mauro Lanza and Andrea Valle a cycle of four co-composed works (2013-2017 – see Appendix 4).
Setting up her own archive, the composer creates a personal database, a physical and digital space

where she stores and redefines sound materials while building and enriching her own aural memory of them. Keeping available access to this database provides a clearer way of developing ideas during the compositional process. Moreover, access to her own personal archive allows for reconsidering already exploited sound materials from new perspectives. For the composer, this is a way of getting deeper knowledge about her own work, and it can also be a convenient and creative way of producing new outcomes. During my research work, gaining this awareness has led me to develop and improve my own habits in building my personal archive. For each new compositional project, I create a specific folder on my computer where I store all different kinds of material - recordings, patches, drafts, scores, etc - with special attention to recordings of my own explorations of different instrumental gestures, as well as of rehearsals with musicians at different stages of the process. These recordings provide me with the possibility of iterative listening which allows me to sharpen the definition of the sonic ideas I am working with. Moreover, the access to these recordings gives me the opportunity to build with them sonic drafts and simulations, using editing software and patches where I can try different processing of the sound material collected.

A declared exploitation of my personal archive is my recent electroacoustic multichannel piece *Tickling Forest* (2020). I deliberately composed this piece choosing material just from my personal archive of instrumental pieces: all the sounds I worked with belong to recordings of instrumental sounds from different previous pieces. Among the sound material I chose to work with, there is also the same *ribattuto* sound of the violin, that for this piece has been processed in various ways, using different granulators and filters (listen to audio ex. 3.5.7– excerpt from *Tickling Forest*).

I tried to keep track of the compositional process that can be summarized as follows:

- All material comes from recordings of sounds used or collected for previous pieces. I chose 19 samples among various recordings made for the following pieces: *et-ego* (for guitar and electronics, 2017), *Prossimo* (for violin and electronics, 2017), *Prossimo II*, (for double-bass and electronics, 2018), *Residual* (for ensemble and electronics, 2019), *PianoMusicBox_1* (for piano and electronics). Each selected sample - from 2'' to 30'' – was stored in a folder named “original Buffers”.
- All samples in “original Buffers” were edited and stored in a new folder as “rendered Buffers”. The editing consisted of selecting the most interesting parts and levelling off the amplitude. [software used: Reaper]
- A few spectral analyses were done while checking some possible filterings. [software used: Adobe Audition]
- According to their acoustic features (thickness, textural or gestural shape, register, timbre similarity, etc..), sounds were grouped together in 8 main groups.

- Sound samples were processed through different granulators and filters. [software used: SuperCollider]
- Working within different groups of sounds, a trial track (from 1' to 3') was created for each group. [software used: Reaper]
- Trial tracks were rehearsed on an 8-channels system in two different sessions (27-28/01/20, 11/02/20) at the Orpheus Instituut, thanks to the precious collaboration of Juan Parra Cancino, responsible for the configuration of the 8-channel system. [software used: Digital Performer].
- A few trial tracks and a few samples were chosen to become the actual material used during the final composition of *Tickling Forest* [software used: Reaper and Illustrator for the score].

The decision of starting from already used material has been triggered by my own theoretical reflection on the notion of archive. During the compositional process, I slowly realized and got confirmation about the actual importance, from the creative perspective, of going back on certain sound materials, taking the chance of better focusing on their nature, and exploiting their potentialities within new musical contexts. Their memory evolves within new utterances, and the archive provides the composer with an environment where letting her own expressivity emerge, through the comprehension of many subtle differences between multiple possible instantiations of the same material. Therefore the setting-up of a work environment based on personal archiving methods contributes not only to enhance the organization within the single compositional process but provides the composer with the possibility of a space of self-reflection. The composer can benefit from her own archiving environment, especially when this is in constant evolution, reflecting the depth of her own personal thoughts and research. The archive becomes the space where memory is built and where processes of artistic self-consciousness are strengthened.

Hence, the notion of archive should be intended not only as a physical or digital space to store and get continued access to the sound material, but also – as Laura Zattra proposes – as a process of self-knowledge and awareness.

> I believe that this awareness, for electroacoustic composers and musicians, may only generate from the concept of archive, an aspect inherent in the very notion of research. Archiving – by artists, composers, musicians, performers, and scholars – is crucial for several reasons. […] I intend archiving not only as a separate entity (one artist's physical archive), but also as a process of self-knowledge, of studying and revealing personal lacks and indicating new possibilities for innovation and experimentation; as an action to find the way through what has been already done. […] Archiving means the necessity for the artist/composer/researcher to maintain his/her own materials (that is their own knowledge, culture and

> practice), in order to become responsible for their own choices, to conduct themselves consciously as artists, to assess their understanding of their own practice, which is the real way to originality and individuality. (Zattra, 2018)

The concept of the archive is therefore to be understood as a dynamic process, which provides composers and artists with a deeper awareness of their own work. And working within this mindset can fruitfully enhance originality and support creativity.

Conclusions

During my research process, I have looked for frameworks, theories, and examples, to understand and bring focus to my evolving compositional practice. In this third chapter, and partly in the second one, I have tried to explain some relevant concepts that have emerged from my practice and have become operational within the development of my research. Most of them come from different disciplines such as compositional theory, electroacoustic theory, media theory, sociology, and media history.

Working with piezo brought me to focus on the quality of sonic intimacy, bringing to the foreground a different perception of the proximity of sounds. Since I often invite the performer to use the piezo like a stethoscope on the instrument's body in order to let the sound matter emerge from a different proxemic perspective, Jonathan Sterne's observations about the importance of the adoption of the stethoscope in medicine and his consequent formulation of the development of a mediate and technical form of listening (Sterne, 2003), resonated particularly to me. I realized that I could read the use of the piezo on acoustic instruments as a “stethoscopic form of listening”. The latter implies the mediation of a technical device - the piezo - and the idea of framing sound, rendering some sounds as interior and others as exterior, marking different spatial dimensions. The same different spatial - and temporal - dimensions that Sciarrino points out in his definition of the window form (Sciarrino, 1998). The similarity between the idea of "frame" and the one of "window" brought me to consider how important could be within the context of any compositional process, the possibility to frame the sound, in order to better understand its properties and its intrinsic potentialities. The awareness of this possibility led me to take into consideration different listening modes, which helped me to get a better understanding of the heterogeneous qualities of the sound matter produced with piezo. All aspects that allowed me for a musical shaping of such sound material, as I will better explain in the next chapter (especially in section 4.3).

I have once more focused on the experience of listening while considering the issue of memory. During my research path, I have started to methodically collect recordings from experimentation with piezo-sounds, and to constantly go back to these recordings during the compositional process. In questioning how memory works in grasping and storing information about sound I have experienced myself the three-strata model proposed by Snyder (Snyder, 2000), in which I saw a direct link to three of the time scales proposed by Roads (Roads, 2004). This theoretical framework allowed me for considering how my compositional process tends to evolve working with different sonic ideas, that respond to different time dimensions. Moreover, it brought me to consider the need to build the compositional work around specific sound materials, which the listener can recognize as repeated occurrences of particular sound within the piece, or as its variations, its evolutions, or simply through the opposition with other kinds of materials – as I have partly explained in section 3.5 while referring to the *ribattuto* sound within *Sistema di Prossimità*, and as I will better explain in the next chapter.

Finally, the discourse about the role that memory has within the compositional work, led me to consider the concept of archive, borrowed from media theory. I recognized this concept as emerging both from my practice and from other experiences, such as that of *Systema Naturae* by Mauro Lanza and Andrea Valle. I have progressively realized how the notion of archiving and cataloguing has become a tool in the organization of my compositional practice. Consequently I have understood the concept of archive also as a dynamic process, which provides me with a deeper awareness of my own work.

All the ideas that I have here summarized, have become conceptual tools within my compositional practice, and, at the same time through these theoretical aspects, I have been able to develop my critical faculties. So, now, I would conclude by asking how these aspects that emerged from my research might usefully contribute to the analysis and the understanding of electroacoustic music. And what kind of implications might they have not only concerning listening, but for practitioners as well, in the hope that these concepts might be useful in the future development of different creative practices within the contemporary context of music-making and of thinking with sound.

Main References

Alessandrini, Patricia. Interview by Nicholas Moroz, *Reinventing Instruments to Reinterpret the Past and Question the*

Present: Patricia Alessandrini in Conversation with Nicholas Moroz, November 2017. http://explore-ensemble.com/patricia-alessandrini (last access 01/02/2022).

Alessandrini, Patricia. *Memory as Difference, Material as Repetition: a Performative Presentation of Compositional Strategies and Multi-source Interpretative Methods,* video of the presentation given at the DARE Conference 2015, at the Orpheus Instituut, Ghent (BE). https://dareconferences.org/presentation/memory-as-difference-material-as-repetition-a-performative-presentation-of-compositional-strategies-and-multi-source-interpretative-methods/#presentation (last access 01/02/2022).

Cage John. *The Future of Music – Credo,* 1937, in Christoph Cox and Daniel Warner (edited by), *Audio Culture, Readings in modern music*, New York : Continuum, 2006, p.26.

Bregman, Albert. *Auditory Scene Analysis: The Perceptual Organization of Sound*, Cambridge : MIT Press, 1990.

Brooks, William. *Sounds, gamuts, actions: Cage's pluralist universe, in Metacage:Essays On And Around Freeman Etudes / Fontana Mix / Aria*, edited by William Brooks, Collected writings of the Orpheus Institute 2, 61-95, Leuven : Leuven University Press, 2009.

Demers, Joanna. *Listening through the noise: the aesthetic of experimental electronic music*, New York : Oxford University Press, 2010.

Emmerson, Simon. *The Relation of Language of Electroacoustic Music*, in *The Language Electroacoustic Music*, edited by Simon Emmerson, UK : Palgrave Macmillan, 1986.

William W. Gaver, "What in the World Do We Hear? An Ecological approach to Auditory Event Perception", in Ecological Psychology, 5 (1) : 1-29, 1993.

Gorelli, Tommaso. "I *Regnum* di Lanza e Valle", (interview), in The New Noise, 06/07/2015. https://www.thenewnoise.it/i-regnum-di-andrea-valle-e-mauro-lanza/ (last access 07/03/2022).

Hornbostel, Erich M. von and Curt Sachs . "Classification of Musical instruments", translated by Anthony Baines and K.P. Wachsmann, in The Galpin Society Journal, 14: 3-29, 1961.

Impett, Jonathan. *Making a Mark: The Psychology of Composition*. In: Hallam, S., Cross, I., Thaut, M., editors. *The Oxford Handbook of Music Psychology*, Oxford University Press, 2016, pp. 661-656.

Lachenmann, Helmut, Wolfgang Rihm (2010), *Conversazioni e scritti*, edited by Enzo Restagno, Ricordi, 2010.

Orning,T. *Pression Revised: Anatomy of Sound, Notated Energy, and Performance Practice*. In: De Assis, P., Brooks, W., Coessens, K., editors. *Sound and Score, Essays on Sound, Score and Notation,* Orpheus Institute Series - Leuven University Press, 2013, pp. 94-109.

Roads, Curtis. *Microsound*. Massachusetts : MIT Press, 2004.

Roullier, Pierre et al. *Mauro Lanza & Andrea Valle Systema Naturae*, Collection A la ligne Ensemble, Champigny sur Marne : 2E2M, 2016.

Schaeffer, Pierre. *Treatise on Musical objects*, translated by Christine North and John Dack, California Studies in 20th Century Music, 2017. (Originally published as: Schaeffer, Pierre. *Traité des objets musicaux : essai interdisciplines*, Paris : Seuil, 1966).

Salvatore Sciarrino, *Le figure della musica*. Casa Ricordi : Milano, 1998.

Smalley, Denis. *Spectromorphology and Structuring Processes,* in *The Language Electroacoustic Music*, edited by Simon Emmerson, UK : Palgrave Macmillan, 1986.

Smalley, Denis. “Spectromorphology: explaining sound-shapes”, Organized Sound, ii/2 : 107-126, 1997.

Snyder, Robert. *Music and Memory, an Introduction*. Cambridge : MIT Press, 2000.

Valle Andrea. “Residual Orchestras: Notes on low profile, automated sound instruments”, in The virtuous circle design culture and experimentation Proceeding of the cumulus conference, paper presented at Summer Cumulus Conference-Politecnico di Milano 2015, June 3rd, 2015. https://iris.unito.it/retrieve/handle/2318/1547460/104873/cumulus-2015-054Experimenting.pdf (last access 07/03/2022).

Valle, Andrea. “Towards a semiotic of the audible”, in Signata, Annales des Sémiotique, Sémiotique de la musique, edited by Aage Brandt and José Roberto do Carmo Jr. Liege : Presses Universitaire, 6, 2015.

Valle, Andrea. [and Mauro Lanza]. “Systema Naturae: shared practices between physical computing and algorithmic composition”, Sound and Music Computing Conference, July 5-8, Espoo, Finland : 391- 398, 2017.
https://iris.unito.it/retrieve/handle/2318/1645065/351641/SMC17_p391.pdf
(last access 07/03/2022).

Varèse, Edgard. “The liberation of sound”, in Perspectives of New Music, vol. 5, n 1, Autumn- Winter : 11-19, 1966.

Wishart, Trevor. *Sound symbols and landscapes*, in The Language Electroacoustic Music, edited by Simon Emmerson, UK : Palgrave Macmillan, 1986.

Zattra Laura, *Is Originality Undetected Plagiarism?,* Text of the keynote presentation at the EMS 2018 (Electroacoustic Music Studies Conference), Florence (Italy), 20 June 2018 – 18:30 - Richelieu Hall.

4. Works

Introduction

In this last chapter, I will present the main artistic outputs of my research. With the exception of a couple of electroacoustic works, all of the pieces presented are compositions for acoustic instruments implemented with the use of piezoelectric microphones. For each work, I will explain the technical setup, the context for which the piece has been written, and the compositional practice. Every piece tells something different about the use of the piezoelectric microphones and the way they have interacted and interfered with the embodied practices and habits implied in each instrumental system. But also about how piezoelectric microphones have influenced my relationship with musical material, allowing me to develop a more conscious compositional approach.

4.1 e*t ego* and e*t ego - Tape version*

et ego, for guitar and electronics, is one of the first pieces that I wrote using piezoelectric microphones. This work was commissioned by the guitarist Pierpaolo Dinapoli. Originating from Venosa, a small village in the Italian southern region of Basilicata, his project was about inviting young composers to write pieces for guitar, pieces that refer to Carlo Gesualdo, Prince of Venosa, one of the major composers of the late Italian Renaissance. *et ego* was composed between fall 2016 and spring 2017, and it was premiered in Venosa, on September 5th, 2017.

At the time of starting its composition, I had just finished *Tenebrae*, a project by the ensemble Blutwurst, that I've been part of since 2011. *Tenebrae* is a collection of five pieces based on some fragments taken from the vocal work *Tenebrae factae sunt*, part of *Responsoria et alia ad Officium Hebdomandae Sanctae spectantia*, composed in 1611 by Carlo Gesualdo da Venosa. The original material is submitted to a process of time stretching that modifies the relations between the melodic lines. In some of the pieces another change occurs, in an almost spontaneous way, through an analog manipulation of the sound on magnetic tapes, where instrumental excerpts produced by the musicians of the ensemble are recorded. The low quality of the tape recording gives a distinctive grain feature to the sound, distorting it and emphasising its transformation.

For *et ego,* I decided to work in a similar way, choosing a small fragment from the famous *Tristis* *est anima mea*, from the *Tenebrae Responsoria*. Here the harmony changes with a peculiar chromaticism, and my first idea was to stretch this moment in time, in order to change its harmonic perception. Since the guitar cannot produce a really long and sustained sound, I relied on the electronics to freeze a few sounds, in order to create a slowly changing texture through their overlapping. At the same time, I started experimenting with two piezo microphones, placed on the soundboard of the guitar to amplify the instrument, allowing for the production of very subtle sounds both on the strings and on the soundboard. I then realized the possibilities opened up by this hyper-amplification, and I started experimenting, treating the guitar mostly as a percussive instrument, producing sounds by hitting, scraping, striking all of its surfaces, from the fingerboard to the soundboard, including the piezos. The hyper-amplification introduced by the use of piezos allowed me the possibility of adopting certain gestures, almost inaudible on an unamplified instrument. And, of course, as already discussed in ch.2.3, in becoming part of the instrumental system, the piezos introduced a big change in the usual sensory feedback relationship with the performer. Embracing her own instrument, the guitarist is facing the introduction of the piezos not only when she has to produce sound directly on their surfaces, but at any time: the whole body of the guitar is hyper-amplified by the piezos attached to it, so even the most delicate contact becomes relevant. After selecting a few gestures as part of the sound material I would have worked with, I have started to record this percussive material and play it back, also changing the rate of reproduction. I then realized how imperfect and noisy these recordings could be. I intuitively perceived them as damaged and ruined by time, and this perception reminded me of the distortion introduced by analog manipulation of the sound on magnetic tapes happening in *Tenebrae*. I, therefore, decided to work on different levels using piezos both to amplify sound and to produce sound (when percussive actions are done directly on their surface) and to record in real-time all the material that is then processed by the electronics. Since all input sounds are recorded through the piezos, what has to be processed already begins with a specific colour, given by the piezos. Moreover, the sound of the two piezos fixed on the soundboard of the guitar can be processed through two different filters (a lowpass filter and a bandpass filter) in order to differentiate their colour. The performance of the piece foresees a stereo amplification, through which the percussive actions produced with the piezos are panned respectively on the right and on the left, according to the piezos' position. *Et ego* starts with a slow percussive pattern made by tapping with fingers on piezos. A first rhythmic fragment is recorded and played back at different rates. The same procedure is applied to some other sound gestures so that all the electronic part is generated from the guitar's sounds. The first part of the piece is developed through an accumulation of gestures, repeated both acoustically and electronically. Each recorded sound is processed following some fixed parameters, such as rate of their reading, and some variable parameters, such as the volume, and the equalization of the piezo microphones. The electronic performer is asked to interpret and somehow phrase the events of the cue list, which are always in dialogue with the acoustic instrument. The phrasing of the delay lines and of the freezes is very important. After the first part, the freezes take more space, and gradually the piece is slowed down to the moment when it holds on to the harmony of Gesualdo, which becomes recognizable, although transfigured. The whole piece is structured as a slow and gradual transition from a first percussive and pitchless section to a richer harmonic texture. The use of piezos allowed for including otherwise inaudible sound gestures, enriching the vocabulary of the guitar, introducing at the same time a significant shift in the auditory perception of the guitar sounds, also through their use in the electronic part.

The performance of *et ego* might be followed by another piece – *et ego - tape version* – that is directly derived from it. Using a few recordings of frozen sounds that constitute the last part of the piece, I realized a fixed-media of approximately 15 minutes. The piece develops a texture of highly reverberated frozen sounds that have to be played back through one or two transducers laid on the soundboard of the guitar (a transducer works in the opposite way to a piezoelectric microphone: it transduces the electrical signal into a mechanical one, sending physical vibrations to the resonant body to which it is placed). So, the whole body of the guitar - the soundboard and the strings - becomes the resonant space through which the piece is propagated. In this way, the piece acquires a different colour each time, thanks to the specific resonance qualities of the instrument used. *et ego - tape version* was premiered at the Turner Contemporary, in Margate (UK) on June 2nd, 2018, during the *Oscillate Festival*.

4.2 *Prossimo*

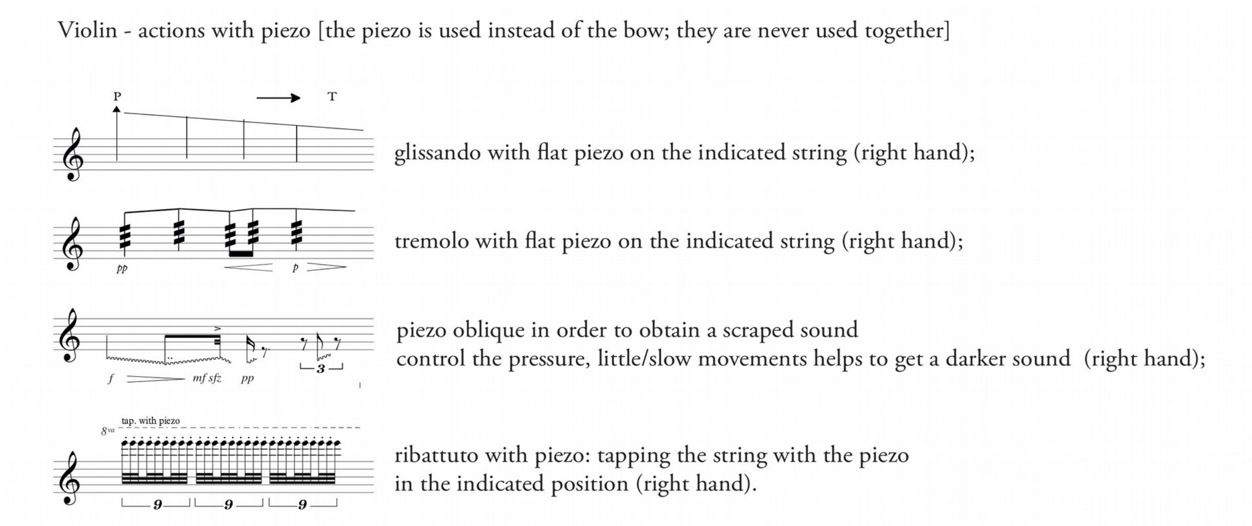
Prossimo, for violin and electronics, was written during the artistic residence St.A.i.R *Styria Artist in Residence Program* by Steiermark - Österreich, in Graz, between February and April, 2017. The piece was written taking advantage of the support of the violin player Lorenzo Derinni, and the electronic performer Davide Gagliardi, both from Schallfeld Ensemble. The piece was premiered at Schaumbad Freies Atelierhaus, in Graz, on April 23rd, 2017.

The technical setup includes the use of two piezo microphones and a condenser microphone. One piezo has to be fixed on the soundboard and is used to amplify the violin sound. Its signal is mixed with the signal of the condenser microphone in order to have a smoother amplification of the violin sound. The other piezo is used by the violinist to make a few sound gestures on the strings. In *Prossimo* I experimented for the first time with the introduction of a piezo microphone as an object that the performer can hold in his/her hands to produce sounds. So, this mobile piezo becomes part of the instrumental system as a mediator, (like a bow or a drumstick, following Heyde's view, see ch. 2.3) which transfers the energy that produces sound from the violinist to the instrument. The sound gestures generated by such a use of the piezo become the most consistent part of the sound material exploited in the composition of the piece. They consist of:

1. glissandos made with the piezo along a specified string. The violinist holds the piezo in her right hand almost flat on the string making a glissando movement from the bridge to the fingerboard (descending movement) or from the fingerboard to the bridge (ascending movement – first gesture in fig. 4.2.1).
2. Tremolo movements made with the piezo placed flat on a specified string. The violinist varies the direction of the movement along the string following the indicated rhythm, within an approximately specified register (second gesture in fig. 4.2.1)
3. Scraped sounds produced with the piezo placed oblique on a specified string. With the piezo in his/her right hand, the violinist has to control the pressure of the piezo on the string, following the dynamic indications, while changing the direction of the movement according to the indicated rhythm (third gesture in fig. 4.2.1)
4. *Ribattuto* sounds produced by tapping the piezo on the indicated position. These sounds resemble the *ribattuto* sound presented at the very beginning of the piece (see ch.3.2), but instead of tapping the string with the bow in the right hand, while the left hand press the string at a specified point, the violinist holds the piezo with the right hand, and taps the string with it, always at the same point (fourth gesture in fig. 4.2.1)

All these sound gestures are the results of a deeper exploration of the possibilities offered by the use of the piezo on the instrument. I spent a lot of time trying all these gestures by myself, recording them, cataloguing and listening back to them, reflecting on their potentialities in terms of sound material. Once I had defined them in a quite precise way, I discussed them with the performer in order to double-check their feasibility. Their execution requires extra effort from the performer, who needs to adjust his/her way of playing in order to be able to get control over these gestures, which imply the use of piezo.

Fig.4.2.1 – Violin sound gestures



The inclusion of these sound gestures as part of the material I would have worked with, raised a relevant question also from the compositional point of view. Working with piezo implies working with a heterogeneous material, which presents a high degree of noise and a lower level of controllability and precision, compared to the sounds conventionally produced by a musical instrument. Therefore, I was keen to find a way to organically combine the sounds produced using piezo, with the sounds produced with the violin. My search for integration between these two different sound worlds started by considering how I could focus on the richness of these sounds and how I could get a certain control over their complexity. Concerning this issue, a real source of inspiration has been for me the work made by Andrea Valle and Mauro Lanza for *Systema Naturae*, a cycle of four works, whose peculiarity lies in the coexistence of traditional acoustic instruments and different setups of remotely controlled electromechanical devices. I have already mentioned this work in ch. 3.5, for the way the two composers worked together on creating a shared database regarding the sound material they were going to use, which presents a similar degree of heterogeneity to that offered by the combination of piezos and instruments. During the compositional process, the creation of such a catalogue offered Lanza and Valle the possibility to assume an instrumental perspective for the electromechanical devices, considering at the same time the use of different kinds of preparation and extended techniques for acoustic instruments, in order to create a more coherent vocabulary of sound material. Thanks to their database they were able to foresee very precisely all potential behaviours, concerning dynamics, spectral contents, rhythmical possibilities, etc, of their material. Therefore, the two composers were able to choose very consistent combinations of sound events produced by very different and heterogenous sound sources. My attempt has been similarly focused on exploiting the piezo sounds through an instrumental approach, i.e. organizing them in rhythmical events, organizing their dynamics, exploiting the richness of their spectra. Concerning the violin sound world, I chose instead to work with rather complex sounds such as harmonic bichords played *molto flautato*, or *ribattuto* sounds played with legno - which add noisy components to the sound. In this way, I tried to reduce the distance between the two sound worlds, so that all the sound material would have presented similar degrees of controllability and harmonic complexity. Finally, the use of electronic processes has also been relevant in this search for integration, helping me in creating different lines of dialogue between all the sound gestures explored through the piece. The electronic part has also been fundamental in providing a certain coherence to the organization of the formal structure. As already mentioned, *Prossimo* starts presenting a single sound gesture which is doubled in the electronic part (bb.1-15). A second section starts with the proposition of two new sound gestures (the glissando and the tremolo movements with piezo) and both of them are recorded and processed back through the electronic part. In the meantime, echoes from the first sound keep appearing in the electronic part (bb.16-41). A third section (bb.42-71) is opened by a new sound event represented by a high harmonic bichord, and it goes on presenting again the ribattutto sound, together with echos from the material of the previous section in the electronic part. During this section, the material of the harmonic bichord is developed through repetition, transpositions, and different elaborations. This third section closes with a sudden, complex, and abrupt *sfz* sound. The resonance of this sound is electronically created with a frozen sound on which a fourth section opens. Here a new material is presented: the scraped low sound produced with the piezo on the IV or on the III strings. Again this material is mixed with granulations of different previous sounds. This darker section closes with a double reprise of the *sfz* sound, electronically sustained by different freezes. Opening with a third repetition of the same sfz sound, the last section gets back to the elements of the bichords of the third section and to the *ribattuto* sound of the beginning. But this time the latter is played with the piezo and it is articulated according to a rhythmical structure of two consequent triplets, or it is combined with an ascending glissando. The hierarchies between recognizable elements change, while the pace of the piece is gradually slowed down and the texture moves to higher registers, becoming lighter and more fragile.

[*Prossimo* performed by Marco Fusi: https://www.youtube.com/watch?v=4lrN7woWeyo, same recording on Score Follower: https://www.youtube.com/watch?v=NjdQw9J75w4]

4.3 *Prossimo II, Prossimo III* and *Sistema di prossimità*

After the composition of *Prossimo,* I decided to go deeper into the exploration of the possibility of using piezo microphones with stringed instruments. I, therefore, decided to create a cycle starting from *Prossimo,* which works as the generative piece. Since the latter was composed in collaboration with the violin player Lorenzo Derinni and the electronic performer Davide Gagliardi, both part of the same ensemble, I decided to proceed with the collaboration with Schallfeld, working on the new pieces together with the cellist Myriam García Fidalgo and the double bass player Margarethe Maierhofer-Lischka.

The cycle has been named *Sistema di Prossimità,* and it includes:

- *Prossimo,* for violin and electronics

- *Prossimo II,* for double bass and electronics

- *Prossimo III,* for cello and electronics

- *Sistema di Prossimità,* for violin, cello, double bass and electronics.

Ideally the four pieces should be played one after each other, seamlessly. Otherwise they can also be played separately. The whole cycle was premiered on December 17th, 2018, at the Royal Conservatoire of Antwerp (BE) during the festival *Experiments are More Refreshing than New Socks*.

The technical setup is similar for each piece of the cycle. Each string instrument is provided with two piezo microphones and a condenser one. One piezo has to be fixed on the soundboard, and the other is given to the player, with the possibility to connect it to a volume pedal, so that each performer could independently control the volume of the piezo by its own.

The last piece of the cycle *Sistema di Prossimità* is literally the sum of the previous three solo works: it was created by the superimposition of the three solo pieces. Starting from the violin piece, I worked simultaneously on the piece for double bass, for cello and on the one for trio. For the composition of these works I rely strongly on the use of a very simple tool: a timeline. As mentioned in ch.3.4, timelines are often part of my compositional practice; when I write drafts on paper I use them to better visualize the disposition and the evolution of events in time, as well as to get a better understanding of the balance between different elements within different sections, the relevance given to certain elements and their hierarchical relationships within each section. So, basically, I proceeded by copying *Prossimo* under a timeline, then I disposed under it other five empty musical staffs (from the top to the bottom): one for the violin as part of the trio, one for the cello as solo, one for the cello as part of the trio, one for the double bass as solo, one for the double bass as part of the trio. In order to provide a certain coherence to the sound material shared between the three string instruments, the sound gestures used for the cello and for the double-bass are derived from the ones of the violin, even if there are a few additions, due to new explorations done on these two instruments. The additions consist of the following sound gestures:

1. The double bass player is asked to hold the piezo stable in an indicated position with the left hand, while with the right hand he/she taps the string repeatedly, touching the fingerboard. (fig. 4.3.1)

2. Both in the double bass part and in the cello part the gesture of the glissando with the piezo (first gesture in fig.1) is elaborated through the addition of the bow: while the left hand makes the glissando with the piezo flat on the string, the right hand bows the contiguous open string (fig. 4.3.2)

3. Similarly, in the cello part, the scraped sound is modified assigning the piezo to the left hand, while the right hand plays the bow on the contiguous open string (fig. 4.3.3).

4. Both the piezo and the bow are used on the same string in alternation or combination: the flat piezo (left hand) does short glissandos, while the bow (right hand) does a vertical movement from the bridge to the fingerboard or vice versa. (fig. 4.3.4).

5. The right hand plays a double stop with the bow: one string is open, the contiguous one is "tuned" by the piezo, which makes some glissando movements along the string (fig. 4.3.5).

6. The right hand plays with legno on the same string where the piezo has been placed at a high point between the bridge and the fingerboard. The resulting sound should be very airy. (fig. 4.3.6).

7. The right hand taps repeatedly with legno on the string where the piezo has been placed at a high point between the bridge and the fingerboard. (fig.4.3.7).

Fig. 4.3.1

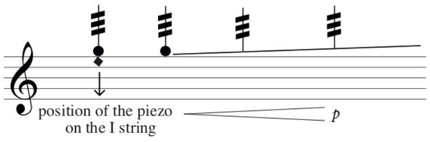


Fig. 4.3.2

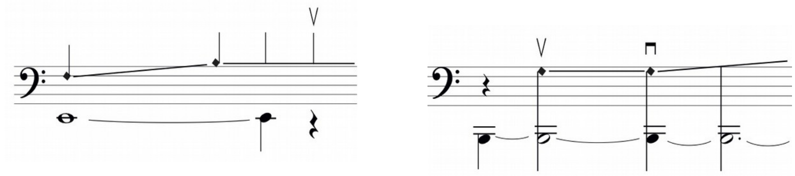


Fig. 4.3.3

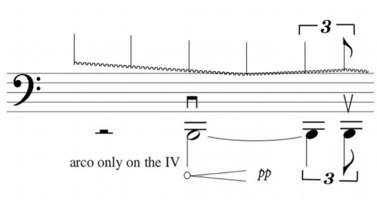


Fig. 4.3.4

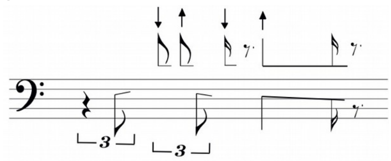


Fig. 4.3.5

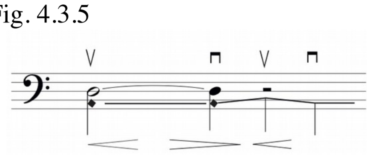


Fig. 4.3.6

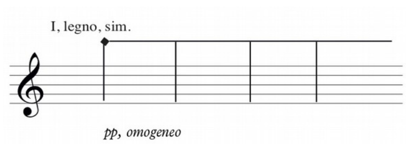
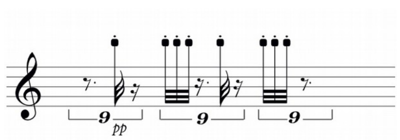


Fig. 4.3.7



All these sound gestures, that expand the sound material of the violin piece, foresee the combination of two different mediators/activators: the piezo and the performer's hand, or the piezo and the bow. Again, all sounds produced with piezo have been organized in rhythmical events, taking into account the definition of their dynamics, and the richness of their spectra. As well as in *Prossimo,* also in *Prossimo II* and *Prossimo III,* all instrumental sounds are posed in a continuous dialogue with the electronic part, which is made by processes on the same instrumental sounds. In *Sistema di Prossimità* the electronic part is much lighter, since most of the dialogues happens between the three string instruments. For the composition of the trio, I relied strongly on some counterpoint techniques as well as on some strategies of subtraction/addition (as partly explained in ch.3.5) through which different combinations, concatenations, or stratifications of one or more sonic gestures contribute to the creation of different relationships, while hierarchies between different elements vary continuously.

The whole cycle of *Sistema di Prossimità* insists on a stethoscopic use of the piezos. In fact, most of the sound gestures performed with the piezo on the strings visually resemble the movements of a stethoscope on the body of the instrument. Acoustically, such a stethoscopic use of piezos tends to highlight the materiality of the instrumental sound and an unusual proxemics of sounds. I have therefore felt the need to approach the sound material from a different perspective. During the compositional process, considering the faculty of the piezo of working as a framing device helped me in understanding the similarities and the differences between the sound material. As discussed in ch.2.1, the mediation of the piezo facilitates the building of a private auditory space, enhancing my own practice of listening. Consequently, I started to be more and more conscious of the importance of storing and cataloguing sound material that has been framed through the piezo, in order to create a direct point of access to the explored and collected material, supporting the process of building a stronger memory of all used sounds.

[*Prossimo II*, performed by Margarethe Maierhofer-Lischka: https://soundcloud.com/daniela-84/prossimo-ii, *Prossimo III*, performed by Myriam García Fidalgo: https://soundcloud.com/daniela-84/prossimo-iii, *Sistema di Prossimità*, performed by Schallfeld Ensemble: https://www.youtube.com/watch?v=5zzUB1kzK4w]

4.4 *Hidden traces*

Hidden traces is a piece for guitar and electronics. It is an open-form piece – approximately 12/15 minutes – written for and premiered at the Belgian Art Gallery *Be-Part* in Warengem, on April 27th, 2019. In *Hidden traces* the sonic world of the guitar is explored through a reinterpretation of some idiomatic actions and sound gestures, revealing the nature of the instrument from a different perspective. The dialogue between the performer and the instrument is mediated by the use of the piezoelectric microphone, which discloses new sound qualities, enriched by some real-time sound processing.

The technical setup consists of two transducers and two piezoelectric microphones. The transducers are placed on the soundboard of the guitar, and they work as loudspeakers to amplify both the instrumental and live-processed sound through the body of the guitar. The two piezos are, instead, employed with two different functions: the first one is used to play on the strings and on various points of the surface of the guitar, while the second one has to be fixed on the soundboard to act as a "listener", providing information for the electronics. Beyond the exploration of new affordances of the guitar through the use of piezo, I was interested in exploiting primarily the resonant properties of this instrument, experimenting with a few electronic solutions that I had never used before. The amplification through the transducers allows for making the guitar body resonate differently, according to the specificities of the sound material provided. Therefore I decided to enlarge the spectrum of sound sources conveyed to the transducers, using four different categories of sound material:

- sounds produced by the actions of the performer;
- sounds produced by different electronic processes on the material recorded in real-time;
- electronically generated sounds (such as sinewaves);
- pre-recorded material.

As already mentioned in ch. 3.4, *Hidden traces* is an open-form piece, for which the performer receives a set of indications regarding the formal structure (see *Hidden Traces* Notes). The latter consists of three main sections and the set of instructions gives information on the timing for using a certain number of pre-determined processes and materials. The piece should start by creating an initial texture of noisy sounds, which has to move gradually towards a polyphony of more pitched sounds, through the possibility of freezing some guitar sounds and playing back different sinewaves, which will differently resonate with the tuning of the strings. The pre-recorded material starts appearing from the middle of the piece, and it consists of human voices that slowly emerge from the sound texture. The pre-recorded sounds are fragments belonging to different radio shows, broadcasted by Radio Ghetto.* The fragments selected for *Hidden traces* are in different languages and their content is never recognizable during the piece. The dynamic and the duration of the reproduction of these "traces" depends on certain parameters of the sound gestures produced by the moving piezo, identified by the fixed one, which "listens" to how the guitar is resonating. The control is therefore left to the performer, who can decide how much of these fragments should emerge from the sound texture.

[*Hidden traces*, performed by Seth Josel: https://www.youtube.com/watch?v=ZIQaR5Kfk_4]

*(note: Radio Ghetto is a project of participated radio, which aims to give a voice to the farmhands living in the rural area around Foggia, in the south of Italy. It has been created in 2012, by the association Rete Campagne in Lotta, to give a voice to the community of rural laborers. All radio shows are directly curated by the people living in these communities, and they host debates, discussions about problems related to migratory experiences, stories of everyday life, music contests, etc).

4.5 *PianoMusicBox_1*

PianoMusicBox_1 is a piece for piano and electronics, written for the pianist Chiara Saccone, and premiered during the festival *Collaborations are More Refreshing than New Socks*, at the Royal Conservatoire of Antwerp, on December 4th, 2019. *PianoMusicBox_1* presents a technical setup similar to *Hidden Traces*, which somehow has worked as a sort of preparatory study for the piano piece. As already explained in ch.3.3 the setup includes two piezos – one for producing sound and the other one to control some of the electronic processing –, and two transducers placed on the soundboard for the amplification. The combination of piezos and transducers allowed me to deal with a unique instrumental system, without the mediation of external loudspeakers: the mediation is in fact that of piezos and of the resonant body of the piano itself.

The composition of this work started around the idea of turning the piano into a sort of music box. I was interested in rendering the mechanical aspects of a music box and its characteristic way to playback well-known melodies. I, therefore, focused on putting into the foreground a few metallic and "mechanical" sounds produced by playing on the stringboard, together with a sort of transfiguration of the piano's idiomatic sound. I have chosen *Dream*, an early piano piece by John Cage of 1948, as the well-known melody that should have been played back from my "piano music box". I have therefore made some recordings of this piece with the piezo, and I have also derived from *Dream* a few harmonies and fragments of melody that the pianist plays during the piece. In this context, the two piezos have been exploited for two different uses. The first piezo has been used to explore the inner part of the piano with sound gestures such as gentle scraping and glissandos produced along the strings, and on different sections of the stringboard, using the piezo again as a sort of stethoscope (see ch.2.1). The second piezo, the one fixed on the soundboard of the piano, has been used to record the instrumental sound. During the piece, this recording is played back through the transducers, therefore it appears extremely filtered, and with a very peculiar colour, primarily conferred by the strong sonic features of the piezo, but also by the fact that it is played back through the resonant body of the piano. Other materials that have been used for the composition of *PianoMusicBox_1* are produced by playing in an ordinary way on the keyboard, where a section in the highest register has to be prepared with patafix, so that the sound result is a sort of stopped sound. In the first section of the piece, the pianist plays always with the piezo inside the stringboard, creating an almost pitchless environment of mechanical gestures. After b.12, the electronics start to record her gestures and play them back, often after processing them through filtering and granulations. This dialogue between the piano and the electronic part grows in intensity, to be then slowed down between bb.75-80. A new section starts at b.81 with the pianist alternating stopped sounds – with an ordinary playing on prepared notes – with glissandos made with the piezo along a single string. The movement of the stopped sounds increases in density between bb.94-105, to decrease again from b.106 on. At b.110 a new gesture appears: a *ribattuto* sound on a single string. This is the last sound played with the piezo, before the pianist approaches the keyboard to play in a very ordinary way. From b.123 on, a few melodic motifs start to emerge while the electronic still echoes previous piezo sounds. From b.136 to the end the electronic start instead to play back the recording of one section of *Dream* by Cage previously made with the piezo; so finally the playback of the recording through the transducers creates a last dialogue with the piano part. The appearance of this transfigured melody from the inside of the piano allows for understanding where the melodic fragments played by the pianist come from. [*PianoMusicBox_1,* performed by Chiara Saccone: https://www.youtube.com/watch?v=BmOFhr2_94U]

4.6 *Residual*

Residual is a piece for ensemble and electronics, premiered by Hermes Ensemble at the Concertgebouw in Bruges, on November 21st, 2019. The ensemble consists of flute, clarinet, violin, viola, cello and percussions. As already mentioned in ch.3.3 – where the technical setup has been explained in details –, cello and percussion act as soloists: they are in the foreground, both using piezos to play, while the rest of the ensemble is arranged right behind them, with a very smooth amplification.

Most of the experimental attempts that I have made during the creative process have been focused on exploring the way piezo could be efficiently used on percussive instruments, specifically on timpani, marimba, crotales and a güiro. Many gestures performed with percussion are then doubled by the cello, with gestures that produce a similar sound quality. The sections of the piece are characterized and shaped by the evolution of a few specific gestures. The first section, for example, is conceived starting from a gentle scraping on the surface of the timpani, which is amplified through the piezo, with fingers or nails. This gesture is moulded by a clear rhythmical structure, which is mechanically repeated by the cello entering at b.13, with a quite a similar pitchless and airy sound, produced by the movement of the bow right next to the piezo, placed flat on the IV string. Starting from b.20, this rhythmical counterpoint is partially imitated by the viola and the violin, which alternate or play together. At b. 44, the first pitched sound appears: the clarinet enters playing a single note in *pp* in a quite high register. From here to b.99 the flute and the clarinet develop a quite heterophonic dialogue, while the string sections and the timpani keep on with the same rhythmical texture of airy sound. From b.92 the tempo is slowed down, progressively the airy sounds thin out, as well as the heterophony between the clarinet and the flute. The violin and the viola are slowly left alone, and they move on to build a new quite fragile heterophony, with high harmonic sounds, played *molto sul tasto* and with very light pressure. This delicate texture is then enriched by the flute, which joins by repeating a few very subtle multiphonics (from b.109), and by the clarinet, which starts playing a few long notes in the middle register (from b.113). The ensemble keeps playing this very fragile texture until b.140, where the tempo is slowed down even more and a new section starts.

The opening of the following section is given to a solo gesture by the cello. With the piezo placed flat on the string, the cello plays quite airy and rather noisy sounds, that are irregularly modulated in pitch by ascending and descending glissando movements of the piezo. These sounds are recorded and processed by the electronics, and played back from the main loudspeakers (see ch.3.3) creating an extra layer of sound. From b.147, the ensemble starts to create a very soft harmonic texture in the background, in which chords morph slowly through the out of phase distribution of entrance and closing of single sounds of each instrument. At b.196 the cello is asked to play with an over-pressure of the bow, drastically increasing the dynamics. Right under this complex sound the marimba begins to play its lowest note with the bow. The wooden materiality of this sound emerges clearly through the amplification of this low marimba key with the piezo. Moreover, the percussionist adds some short sounds played hitting the crotales with the piezo. The over pressured cello sound is then repeated a few times, always framed by complex chords of the ensemble, which include loud multiphonics of the flute and the clarinet. Indeed this section is the most dramatic of the piece, and it fades out at b.213, where the sustained sound of the marimba is left alone. From this point begins the last section of the piece, marked by the focus on a few different gestures. The percussionist alternates the long notes on the lowest C of the marimba, with hitting the crotales with the piezo. The cello keeps on playing airy sounds, whose closing is put in relation with a gesture of the ensemble, consisting of a short airy sounds of flute ad clarinet and a short tremolo of the violin and the viola. In the meantime, the cello begins to introduce percussive actions by tapping the string with the piezo, doubling the crotales. From b.240 until b.258 the cello goes back to the airy sound, shaping it with a rhythmical profile that clearly recalls the very beginning of the piece. From b.259 the cello and the marimba are left alone until the end of the piece (a certain symmetry could be recognized in the fact that both the beginning and the end of *Residual* are assigned to the soloists).

The electronics echoes the low and long tones of the marimba, while the crotales and the cello exchange their percussive sounds, processed through a delay. From b.268 the cello takes back the bow and it starts to dialogue with the electronic echoes of the marimba, playing a double sound on the IV open string and on the III string "tuned" with the piezo. From b.291 the sound of the cello becomes more complex since the piezo has also to be placed oblique on the string, producing a scraped sound. The latter is doubled by the sound of the güiro played with the piezo. On top of an electronic texture created by the overlap of different echoes of the marimba sound, the dialogue between the cello and the güiro closes the piece.

The whole work is formally structured around specific sound materials, whose hierarchies change during the piece according to the repetition or the variations of their occurrences. The way different sound materials are put together by analogy, symmetry, or by opposition tends to guide the listening experience, allowing the listener to recognize some sound gestures and their evolution throughout the piece, while creating an aural memory of them. The development of such a compositional approach has been driven by theoretical questioning about how memory works in grasping and storing information about sound. Different sonic ideas and different sound gestures tend to evolve within different temporal and spatial dimensions. As Sciarrino pointed out when speaking about the window-form (see ch.3.1), more or less complex blocks full of different information can be assembled by producing traumatic frictions and multiple connections in our memory. The polyphony of relations that emerges, combines different perspectives, following a principle of intermittence through which our mind jumps from a temporal window to another, anticipating or remembering the different sonic ideas.

[*Residual*, performed by Hermes Ensemble https://soundcloud.com/daniela-84/residual]

4.7 *Tickling forest*

Tickling Forest is an electroacoustic piece written for an eight-channel surround system. The piece should have been performed in SARC in 2020 by Juan Parra Cancino, but due to the Covid pandemic the performance did not take place. For this reason I decided to make an alternative ambisonic version of the piece, which can be listened to through headphones. As I have briefly described in ch.3.5, the composition of *Tickling Forest* consisted of many different steps, starting from the selection of nineteen different sound materials stored in my personal archive. All these samples come from recordings I made during the compositional process of different pieces, so they are all sounds recorded with piezo and most of them are sounds produced with piezo, specifically on guitar, violin, piano, double bass and güiro. All these samples underwent an electronic process, mainly consisting of filtering and different kinds of granulation. As a result all processed samples present different morphologies, consisting of the combination of different registers, dynamics, material qualities, behaviours, going from a more textural to a more gestural one – when samples have a clear rhythmical profile –, and so on. Consequently, according to their specific features, the processed samples have been organized within a formal structure, following principles of analogy, opposition, transformation, density variation, and so on. The formal structure of *Tickling forest*, unlike most of my pieces, is almost circular rather than linear, meaning that it is not necessary to listen to it from the beginning to the end, but that the piece (almost 10 minutes long) might be repeated in loop, inhabiting the space where it is performed.

A peculiarity of this work is that during the compositional process, I did not produce a score: the project of the piece was created directly in the editing program (Reaper). A scheme of the piece was deduced only after its composition, from the final version of the fixed media. It mostly delivers information about when samples appears and how are they distributed around the eight channel surround system. Movements of the samples are of different kinds: they might be played back as a point from a single loudspeaker, or they can move from a loudspeaker to another one, also making a full circle (clockwise or counterclockwise); they can otherwise move covering a specific angle, or they could be assigned to a stereo pair or to a specific section of loudspeakers. The acoustic space is therefore constantly reshaped by multiple combinations of different sound materials.

The composition of this work has been an important moment of reflection and further research concerning my own practice. It has first of all been relevant, as pointed out in ch.3.5, the attitude of deliberate exploitation of my personal archive, supported by the awareness of the importance of such a methodology of working. It has been moreover important to think about sonorous space from another perspective. In fact, during the compositional process, the formal organization has responded not only to the need of understanding of the implicit or imposed morphological properties of the different sound materials, but it has also followed spatial criteria, considering the trajectories and the quality of the movements of the sound in the space. The aim was to create a listening environment, within which each piezo sound material I was working with, indulges a different proxemics, depending on its own specific characteristics.

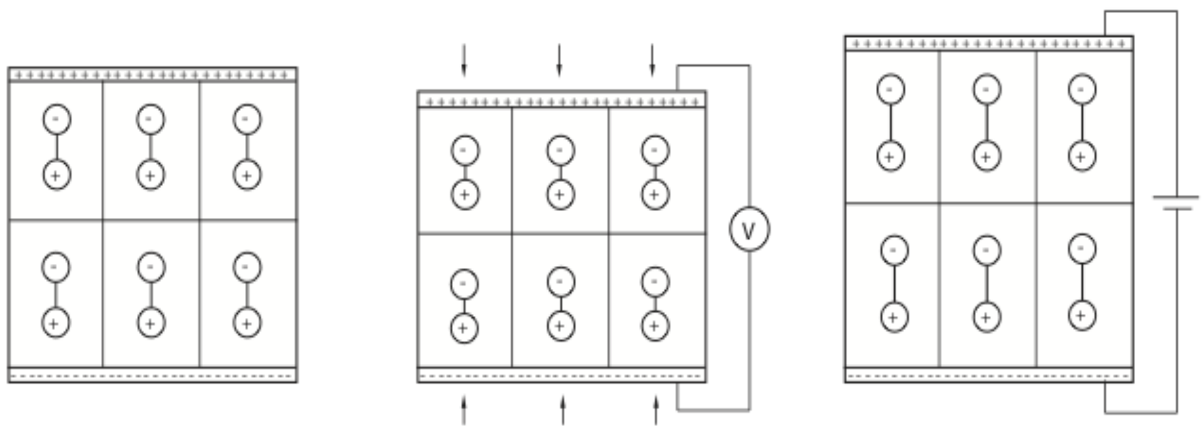
[*Tickling forest* – ambisonic version: https://soundcloud.com/orpheus-instituut/daniela-fantechi-tickling-forest]

Appendix 1

Piezoelectricity

Piezoelectricity or, literally, pressure electricity, is an unusual property exhibited by a few ceramic materials: an electric polarization — the alignment of electric dipoles in a common direction, which gives rise to an electric field that is oriented in this same direction — is induced in the ceramic crystal when a mechanical strain (dimensional change) is imposed on it. The inverse piezoelectric effect is also displayed by this group of materials; that is, a mechanical strain results from the imposition of an electrical field (fig.1).

Fig.1. Compressive and expansive forces applied to dipoles within piezoelectric material.



dipoles within a piezoelectric material

the application of a compressive or expansive force results in a change corresponding to the distribution of dipole moments. This causes a change in the surface charge, which is proportional to the applied force. A voltage is generated when the material is subjected to a compressive stress. Similarly, when a voltage pulseis applied to the surface, a displacement occurs causing an acoustic wave to be generated (inverse piezoelectric effect).

This property is characteristic of materials having complicated crystal structures with a low degree of symmetry. Natural piezoelectric materials include Quartz, Tourmaline, Rochelle Salt, Langasite. Synthetic piezoelectric materials include barium titanate (BaTiO3), lead titanate (PbTiO3), lead zirconate–titanate (PZT) [Pb(Zr, Ti)O3], and potassium niobate (KNbO3). The piezoelectric behaviour of a polycrystalline specimen may be improved by heating above its Curie temperature and then cooling to room temperature in a strong electric field (pooling process). Piezoelectric materials are utilized in transducers, which are devices that convert electrical energy into mechanical strains, or vice versa.

Appendix 2

Skype interview with the composer John Driscoll (member of the collective *Composers Inside Electronics*) – March, 25th, 2019. The following interview appears as the interviewer, Daniela Fantechi, transcribed it.

[John Driscoll participated in the workshop about *Rainforest,* that David Tudor gave in the music conference called "New Music in New Hampshire", in the summer of 1973]

DF: Did he came with John Cage or was he alone?

JD: No, well... There were a number of different composers giving workshops. David was one of them. David Behrman, Gordon Mumma, Frederic Rzewski,... and a few others, I don't remember everybody. David was holding a workshop on the idea of *Rainforest* and of processing signals acoustically, through an acoustical transformation. So he introduced us to this idea of taking a sculptural object and putting a transducer on the object, holding directly to it, and vibrating the material. It's very common now, but at that time it was not. The idea was, what you were trying to do, was to find the signal that the object like to resonate at. So it's almost like the idea of tickling somebody. If I tickle on your shoulder, nothing... but if I find that spot, then it explodes. With the object its the same concept. You try to get the sound material that excites the resonant node of the object and then the object does all of the processing.

DF: What signal was sent to the object?

JD: It could be any type of signal. The only real criteria for the signal was to make that signal so that it excites the resonant nodes. So it's possible to use a signal that the object doesn't like and it does very little, but if you use the signal that it does like, then there's a large transformation.

DF: Was the input signal always electronic?

JB: Yes. It could be either an electronically generated signal, it could be a recorded signal, it could be any kind of signal, but the idea was that it had to be specific to exciting the resonance.

DF: There were contact microphones used as well?

JD: In the second part of the concept, in order to hear better the subharmonics in particular, we used contact microphones on the object and re-amplified the signal that was in the material. *Rainforest IV* always used contact microphones as well. The same object would have a contact microphone attached to it, that would go back to an amplifier and then then the signal would go to a regular loudspeaker. You would hear it acoustically in the space, but if you put your ear against the object you hear it quite differently because then you hear inside the material. The contact microphone brought out those sounds that were in the material, so it was almost a reflection of the signal that was heard in the air, but it had a different harmonic content.

DF: We are now talking about *Rainforest IV*, have you also worked on the previous versions?

JD: Recently we were reconstructing the original one. David did a version for Merce Cunningham, for a dance of Merce's called *RainForest*. That was known as the first one. (Merce's title used the large "F", and David just used the regular "f"... just to confuse this!). They did it in 1968. The original version used the same principles as *Rainforest IV*, but the real difference was that he used a table-top with small objects put on the table. In the very beginning, David made very specific electronics using a feedback oscillator that changes over time, as the source material. In the original *Rainforest* the acoustic output of those smaller objects was not very audible, but the signal that was sent to the loudspeakers was quite loud. So that the idea for the original one is that you are hearing the amplified object through the loudspeaker system, but not hearing the object itself.
Then there are some disputes on what was really called *Rainforest II*. And there was a third version, that was very brief, that David did with John Cage. That one was using John's voice, but there's also another variation that was not using John's voice... So, the variations II and III are confused historically.

DF: Which version was David showing in the workshop in 1973?

JD: The thing you have to realize is that David never really made these distinctions about versions. The very first one was called *Rainforest*, the second and third were called *Rainforest*, and when we started what we called *RainForest IV,* that was also called *Rainforest* for many years. There wasn't a difference between the titles. We've sort of done that because it helps historically defining the different versions. So the version that *Composers Inside Electronics* performed was never called *Rainforest IV* until, I think about 1980 or 1981, when we wanted to put out an album in Berlin and the problem was the recordings rights - David had already released an album called *Rainforest*, so that is when it became *Rainforest IV*.

DF: Did *Composers Inside Electronics* came together before 1973?

JD: No, the group came together for the “New Music in New Hampshire”. That was the starting point of the group. It wasn't really officially called *Composers Inside Electronics* until 1976. In 1976 David was invited by the *Festival d’Automne* to make a large presentation, and he wanted to have this group working with him on *Rainforest* present our own works, as well as to do some others works. We did performances of Kosugi’s *Catch Wave*, of Cage’s *Cartridge Music*, and *Rainforest*. He wanted to have a name for this group and that's when we were sitting down and coming up with this name *Composers Inside Electronics*. It was probably '75/'76, just before we did this *Festival d’Automne,* in Paris.
David felt strongly that at the time music focused on the idea that you have a musical concept and then you find the instruments to realize it. He felt that it should be the reverse of that. You start with an instrument, you explore it and that suggests the music that you make.
So that was the reason behind the name *Composers Inside Electronics,* the ideas started inside the electronics and then became musical. The instrument suggests the music.

DF: Do you think that this idea of “being inside” was also suggested by his very practical way of producing sound, really next to objects, using transducers to make surfaces vibrates?

JD: Well, I think that the concept David had was related to his approach to his music, particularly with his electronics. It wasn't just *Rainforest* alone, but it was the idea that when he was building his electronics it was never the conventional use of the electronics. He was making this no-input mixing, and for him this was just a new concept to generate sounds. In the early '60s, nobody had computers, few people had access to the labs of electronics, and nobody had synthesizers. David explored that world trying to use electronics to make the music he was interested in, and so, I think this idea of *Composer Inside Electronics* really came from that desire.

DF: How many people were in the group at the beginning?

JD: In the beginning it was myself, Phil Edelstein, Linda Fisher, Ralph Jones, Martin Kalve, and Bill Viola. That was sort of the original group with some others, that took part in the workshop, but didn't continue. We were all in our early twenties.
David had this idea that he was finished with the *Rainforest* concept, and he was going to give it away to us to use. I think that the result of the workshop was a surprise for him, because he was using small objects, and then we went out and got these large wagon wheel, big wine barrel, bed springs. The difference was these all needed to be suspended in order to make them resonate and they were quite large. We had this large barn and we were hanging all these objects from the beams of the top. And so, all of a sudden you have this sculptural environment you can walk through, and walk around. I think some of this was a surprise to David, that it took this direction, so we did the performance there in the barn. Going on at the same time, there was a workshop with Gordon Mumma and David Behrman on building electronic circuits. So lot of us were building circuits that

we were going to use to perform with *Rainforest*. What happened was that we did a performance in a town called Chocorua in the state of the New Hampshire. I think David probably thought: “This is now done, the workshop was great, it's over”. A while later a bunch of us said “We would love to perform it again! Would you consider doing it again?” Bill Viola made an arrangement in Syracuse, with the *Everson Museum* to do a performance there, and then Ralph Jones found an opportunity in Buffalo. So, all of a sudden it started to continue, and I'm not sure that at the beginning David thought this was going to grow and become something. That version, the *Rainforest IV,* I think now it has been performed over 125 times, in more than 45 different cities.

DF: *Rainforest* was not the only work of the group, right?

JD: No, particularly later in the 70s we also started to do collaborative works, where one person would have an idea and all of us would perform that work together, rather than just independent works that we would perform ourself. In 1977/78 we did two series of performances in this space in NY called *The Kitchen*, and that was the beginning of this period where we did a lot of collaborative works together.

DF: Which kind of contact microphones were you using in this first period?

JD: At that time we didn't have piezo disks. We were using phonograph cartridges. David was familiar with those from the work with Cage's *Cartridge Music*. These were salt crystal phonograph cartridges from a company called Astatic. They had one called 12u, and that was a model where you have a hole to insert the needle, and instead of the needle we just inserted a piece of steel wire, and then attach the wire to whatever object.

DF: So you don't have too fragile a needle needle?

JD: Yes, and they put out a fairly strong signal, but you would have to use a pre-amplifier. Then they started to get very hard to find because that was the end of the period where people were using regular phonograph needles. There was a period where David and I were searching in all of these electronics shops just to buy all the cartridges we could find.
In the meantime there were other kinds of contact microphones that we used. One of them was a throat-microphone, that was used for people with bad hearing, for the deaf. This was usually just put against your throat, but it could also been put against bone, and there was another one that was made for driving bone, for people with hearing difficulties and you put it right against your jaw and it drives sound into your head. Both worked well for amplifying the objects.

DF: Where did you find them?

JD: You have to realize that most of these could be used either as a microphone, as a loudspeaker. I was living in Washington and there was a school for the deaf nearby and they were using some of these. The other ones we used were devices made for cutting records: “disk-cutters” they were called. They were the opposite, when you are making a record they would actually cut the track, and those could be used in reverse also, for microphones. That was the period, after the cartridges started to disappear, that we were trying to find other contact microphones.
I had one that was used for listening to heart beating on an unborn infant. We had quite a collection of different kinds of contact microphones and David started collecting other ones as well, so it wasn't just the phono-cartridges.

DF: When did you start to use the piezo disk?

JD: That's a good question. I don't remember the exact year. Probably mid '80s...

DF: Did you already know Richard Lerman at that time?

JD: Oh yes, Richard Lerman and I were very good friends. He performed once or twice with us, but not on regular basis. But David and he were also good friends.

DF: Because he told me he was using piezo-disks around '78, for his piece *Travelon Gamelon*...

JD: Yes, If Richard was using piezo around '78, then we were using them also. Because he and I spent a lot of time together. But I prefer the phono-cartridges because they had a much richer sound. The problem with the piezo disks is that they usually have a center resonance frequency. Whereas the phono cartridges used a RIAA frequency compensation. That was a curve for phono-cartridges which used a reverse curve in your pre-amplifier that brought out a lot of the bass with a much warmer bass sound than the piezo-disks which tend to be more biased towards the higher frequencies.

DF: When you were using all these kinds of different contact microphones that you have mentioned, did all of them have different features and needs?

JD: They all needed a form of pre-amplifier, with a specific circuit. Also there were impedance differences. You had to match the impedance better for each of the different kinds, so we were trying a number of different kinds of microphones/pre-amplifiers, based on which kind of contact microphone it was. The throat mics didn't have to use a different equalization, for they went through a regular microphone pre-amp as long as the impedance was matched. The throat mics were lower impedance, whereas the piezo disks had quite a higher impedance.

DF: Which other projects were using these kind of microphones in a quite relevant way?

JD: We were even using them with the piece that Martin Kalve created called *Earthing*. He was using feedback generated where you placed a guitar pickup and a transducer on an object, and as you moved the guitar pickup it would create different feedback nodes. All of us were using contact microphones as amplifiers for objects in other collaborative works. I had a piece called *Ebers+Mole*, that used transducers and contact microphones as well. In that work I used a long piece of thin bamboo, maybe about two meters long, which was suspended at one end, and at the other end had a very fine wire that went 3 or 4 meters long to a suspended phono-cartridge. I used a transducer on one end of the bamboo to drive the signal through the resonating bamboo and through the fine wire to the phono cartridge. I created a rhythmic sound that was transformed by its travel through the bamboo and the vibrating wire.

Appendix 3

Interview with Godfried Willem-Raes — March, 20th, 2019 @ Logos, Ghent (BE)

DF: Can you go back to the first project were you used piezo?

GWR: or the predecessors of piezo! I came in contact with piezo actually in an indirect way. The first piezo element was seignette salt, it was very hygroscopic. If it gets wet it's lost forever. These old elements you won't find them anymore because they wouldn't work. Because of humidity, they deteriorate after a while. But those are the first one that were used as contact microphones, as headphones also, cheap earphones, crystal radios. These are old headphone pieces with seignette salt that are broken actually [fig.1.Old headphones components with seignette salt].

DF: Have you done artistic project with them?

GWR: Yes because we used them as contact microphones at the beginning of Logos, at the end of the 60s. And then only, I think, by the end of the '70s, piezo disks with the copper came. Only at the end of the '70s. We can look it up, this is the book by of one of the producers, and it gives applications of these piezo disks, so if we look at the dates, …'68, but the second edition of '74. And this is the report from the producers, from the factory. I was studying these materials. [fig.2. Books on technical properties of piezo-ceramic material]
The brass-bond piezo were not on the market when this book came out. It just describes the piezo electric material itself, the new ones that are not hygroscopic. As soon as they came out they started experimenting with it. Contact microphones were sort of trivial application, but my research was very much into what you could do with piezos if you go beyond audio, because they are very good for ultrasound. I used them a lot in the range of 20kHz and 70kHz.

DF: As sensors, basically?

GWR: Yes, well gesture sensors, because I use them for reflection and for measuring people as radar devices, actually, in a doppler settings. And I've been using them until recently. Now there are better technology available, with microphones, etc, but at that time piezo was evident.

DF: When have you started with the project on ultrasonic?

GWR: Mid ‘70s I think. ’74/75 must be my first project in that realm. And the first big result was the *Holosound* production, and that was somewhen early in the '80s. So this was a complete artistic full evening production, completely based on ultrasound and ultrasound demodulation. I used piezos a lot. Actually this is a component of it [fig.3. *Holosound* Component]. You see this four piezo encapsulated in silicon, this is the preamplifier. And I attach big springs and metal chimes to it, very long ones, and they get into resonance.

DF: So this is not for the ultrasonic?

GWR: Well, it was driven by the ultrasonic signals from the movements that trigger these things: those are the pickups. It was all a feedback system. The space becomes magic, because you move into the space and the sound changes automatically, because of the ultrasound. And the ultrasound gets demodulated and triggers the objects that I attach here on these piezos.

DF: The use of the springs reminds me some works of Hugh Davies…

GWR: Well, I have an original Hugh Davies here: look [fig.4/4a. Hugh Davies's Springboard. On the back coils are covered with tape] there’s his signature and the date. It’s a real Hugh Davies’ springboard. An original one: I bought it from him ’74. But this is not piezo. Hugh Davies almost never worked with piezo. He was always working with these magnetic transducers, and he gets them from this [fig.5. Old headphones and its inner view]. This is an old headphone, before the Second World War, and what is inside: there is a membrane in here, a very thin steel membrane, and here there are these two coils on the u-shaped magnets, and when you send the signal to it, because of the magnetism, the membrane starts to vibrate, and you can listen to it. But it’s reversible. It’s a perfect microphone. It’s the same microphone used in here. He took them from these old telephones and used them as pickups. You just unscrew it, it’s easy to take it off. It works by induction, this is a permanent magnet, so a metal object that moves in front of the magnet induces an electrical current in proportion to the vibrations of the spring, and you get an electric voltage on the output immediately. The advantage is that is a non contact device because it makes no physical contact with the spring. With the piezo you always have to make a physical contact, you have to attach something to it, whereas this work at a distance: basically it’s the same system of a microphone used on an electric guitar, it’s only much smaller and you can go to tiny object with this. I know Hugh Davies had hundreds of these things because he bought them on the flea markets, always. From headphones, old telephones also had them…

DF: So you have made several installations with this kind of thing: How long were the springs attached to it?

GWR: Around 3 meters.

DF: Springs are attached at these piezos, and what is on the other side?

GWR: There are electromagnetic exciters, coils that brings the spring into motion, excited by the audio. So it's an inductive coil to which you send audio… And all these things are reversible. In fact, if you send electricity to it, you can use it to activate the spring. And if you move the spring you make electricity, you'll get a signal.

DF: Does this project have a title?

GWR: Yes, it was applied in *Holosound*. *Holosound* exists as a performance, as an installation. as a concert version. But I did many things before that. There was also another piece, called *Montage*, with all springs installed in here, and people activate all the things just by moving.

DF: How long have you worked to develop all these ideas and installations?

GWR: Well, it's hard to say, because I'm all the time experimenting in the lab. I think quite long... I did almost nothing else than researching on it, making circuits how to pre amplify good… it was not so straightforward. You cannot use just about any pre-amp: impedance matching is important. Then I'm trying to get rid of the resonant frequency. All these ancient things have an inconvenient in that they have a resonant frequency which generally has a peak between 2 and 3 kHz, which makes it sound very metallic and harsh all the time. The thing is dividing circuits to get rid of this proper resonance of the piezo material.
Inside there's the preamplifier circuit, just with the signal conditioning and the filter to make sure it doesn't sound metallic and behind there's the line-out that goes to the 4 loudspeakers in a quadriphonic set.

DF: Were you also controlling a sort of spatialization?

GWR: Well, it goes automatically in this case (the first piezo goes in the first speakers, and so on).
I have a mixer board, yes. But in principle it goes automatically, depending on the movements of the people and the sensors. In a certain corner you active that speaker there, …

DF: How many sensors do you have?

GWR: Normally it's 3. At first I have many more. But I came to the conclusion that three it's the optimum: one, two, and the third suspended in a tetrahedron, and I always need an emitter. If you do ultrasound work, you have a tetrahedron, you have one emitter and three receivers, and from the receivers you go to a demodulation circuit, a sort of ring modulator, to bring the signal back to the audio realm. But at first I've tried with many more, but they don't bring more information. With a little math you can just derived all the three-dimensional signals with just three transducers. But in an installation piece you are free of course to have as many as you like. I made also installations with many receivers that use just one ultrasound emitter - and it's very magical! - just to amplify things like keys, or breaking glasses, or things like that. You can put keys here and by just touching the keys you make a strange noise. And this is because things as keys and glass have a lot of ultrasounds in their audio spectrum,, which we don't hear, but the system allows to translate that into the audio realm and then it becomes magic, because you have a set keys, you do a "click click" (a small movement) and you hear a very loud sound, and you put them down and it's gone. And you see no microphone!! That's quite magic…We did it last November [2018], there were a lot of festivity for the 50th years of Logos, we did many installations, with old pieces…

Look what I have here, did I show you this? This is massive piezo material [fig.6 piezoelectric element]. All made of piezo-material. It's heavy and very fragile. You cannot touch it because it has a coat of silver and if you touch it, it oxides immediately and then it becomes less sensitive. This is tuned to 65 KHz and gives incredibly high sound pressure level, but you wont' hear it. This can be used as emitter, you cannot use it as a receiver. It comes from a laboratory, this is research material. Philips, all the electronic things that have research department, before that goes into production, have to make prototypes, and all sort of things. You cannot buy it, it's research material, it's not supposed to be for sale.

DF: When did you meet Hugh Davies? Here or in UK?

GWR: I think here, I met him many times. I visited him in England, and that was '73, I'm sure, but I knew him already. He was involved in the experimental scene in England, after he worked for a while as technician for Stockhausen, in the late 60's. I played with *Gentle Fire* - his group - here in Gent, I think it was '71 or something…. But he was also involved in that group around Cornelius Cardew, the *Scratch Orchestra*… I had contact with these people, also with Cardew, etc…

DF: Do you have also projects where you amplify objects?

GWR: Of course. I want to show you something…
Look, this is from '71: It's a monochord [fig.7. Monochord], but look here [fig.8. Monochord details] it has electromagnetic transducer and piezo and two outputs, so you can have both things connected. One out is for the two piezos - they are mixed internally - the other one is for the microphone, a magnetic transducer, from an electric guitar. This is an early application and the bridge is just on the piezos, without touching in the middle. There's a pre-amp in the circuit.

DF: Why do you choose to have two different kinds of microphone?

GWR: Because this one is very good for the bass frequencies, and this is very good for scratching sounds, for the high sounds. So it's a completely different sound core. So you can mix the two signal externally. You can also decide to plug only the piezo, or viceversa. The first model was from '69, but it didn't have piezos. It's also possible that I put piezo disks later, as soon as they came out, but this is the very earlier thing that I did with piezos. You have two preamps - two different circuits - one for the piezo and one for the magnetic transducer.

DF: Which is the project that is more representative or more relevant for you?

GWR: With piezo material *Holosound* is one, and another piece that has a lot of piezo material is *Hex,* which is a sub-miniature robot orchestra. Instruments are all this size and there are a lot of piezos there, all computer controlled. The title *Hex* comes from hexadecimal, the composition is completely coded on a little computer. Originally it was a Sinclair ZX81. *Hex* is made of many boxes with pc boards, with little objects on them, and piezos. And they are directly amplified on the board. Piezos and the board are built together, completely integrated. The objects were driven through the computer with an electromagnetic thing, so you could see the movement of the object. It's a sub-miniature robot orchestra. The sound is amplified and the timbre depends on the tiny objects (little bit of strings, little bit of springs… super tiny things) that are moved.

DF: So did you meet first Hugh Davies and then Richard Lerman?

GWR: Yes I met Richard Lerman a little later (around the '70). He was also working with piezo, as soon as they came out.

DF: There was a whole international scene…

GWR: Everybody used them, David Tudor, in the *RainForest* piece, there were lots of piezos in there. Takehisa Kosugi also used them, in the Cage's production with Merce Cunningham.

This book [a Dutch book on piezoelectricity from 1946] is one of the earliest one, before the piezo-disk, it describes the whole circuitries on piezoelectric materials and their uses as microphones, etc… This is from 1946. This is in dutch, I think it was originally in Dutch, because Philips was working very much on these things. And it was an engineer who wrote this book who worked at Philips. And when the piezo materials came out, then they published these data books on piezoelectric ceramic. This was around the time when disks came out and this is already '82. These books are very rare now [fig.10. Various books on piezoelectricity]. They were not collected by libraries, only by engineers at that time. There are the reports of the factory, experimenting with different shapes, describing the measurement results. I bought them in the early '70s. And this is also interesting: here there's my correspondences with an Hungarian factory that produces piezos… I was at the University between '68 and '75.

DF: Did you get in contact with these factory through the University?

GWR: No, I knew people there, an engineer who worked there, was friend of my parents. So I got, as child already, many components for free, through this guy who was working at Philips. Because he knew that I loved to play with them, to solder them, so I got free components…

The first electric component were given to me when I was a boy, 6 years old, and I got a resistor, from one of the laboratories from University. I was very proud.
I got contact with University people for many things, but University had no production facilities.

DF: Had University contact with those laboratories?

GWR: Not with Philips,.. well the technical high school in Eindhoven had connections because that University was almost erected by Philips, they lived there, there was close connection, but not here in Gent. There was a department of Philips in Brussels, that is where this family member of me worked in the laboratories there… they were working on the development of loudspeakers basically, also with piezos. You know, these piezos, find applications 'til today in cheap loudspeakers… I also made some.

DF: Were you using different piezo material?

GWR: I checked all kind of piezo material that I could put my hands on and see what they are good for. I also have a piezo transducers which were produced for submarines to measure the distance. I have them also - on 200kHz, I have a complete set.

DF: How can you tune a thing like this?

GWR: You cannot tune it. I don't have the machinery. You should cut it. And actually, if you read books on piezo you see that it's a ceramic. That means it's baked in the oven, and you first make them all, shaped them, and you bake them. They solidify and they become this piezo material. So afterwards cutting it generally ruin the piezo. You have to make it right in that shape.

If you take a piezo disk you can tune it but you have to be very careful… you see, if I break it, it's broken! But if I take a grinder and I take off a little bit here [on the edges], I can make it smaller, I can tune them and the pitch goes up…. but you have to be very careful. Big pieces would break.

For the Ultrasonic project, for receivers, I tend to tune them exactly to 40kHz by grinding them off. You have to choose one frequency. You can choose 60KHz, or 65, or whatever, but you have to make sure that all your system is tuned to the same frequency. The emitter and the receivers are both tuned at the same frequency.
With submarine-thing that is around 200kHz… the problem is if you go up in frequency then the range you get through air becomes problematic, because the higher the frequency, the more dampening you get through the air. They use it on boats, because there the medium is not air, but water. Water is a good conductor for Ultrasound. But in air, they have a sensitivity of maybe 20cm…which is what not was I need.

DF: So, is the choice of the frequency also related to the space to be covered?

GWR: Yes, yes.

DF: So you haven't done project with this submarine component material, right?

GWR: No, no, I bought those components to do experiment with.
I know someone who has done project with them, actually, who used these microphones underwater to amplify movements of shrimps in the sea. If you have a decent ultrasound microphone you can get the shrimps' sound. Warren Burt did that. He is a native American, he emigrated 30 years ago to Australia. He lives in Melbourne.

Appendix 4

The exploitation of the idea of catalogue in Systema Naturae*, by Mauro Lanza and Andrea Valle*

Systema Naturae is a complex work, written between 2013 and 2017. It is a four hand composition by Mauro Lanza and Andrea Valle. Though the two Italian composers belong to the same generation, they come from slightly different backgrounds. Andrea Valle (1974) is an electric bass player, who studied composition with Azio Corghi. He is now a researcher at the University of Torino, and many of his projects involve computational control of physical objects, for improvisations, sound installations and multimedia performances. Mauro Lanza (1975) instead, studied piano in Venice and Computer music at IRCAM, and his pieces are now performed by many ensembles for contemporary music. In his compositions, he often seeks to bring together classical instruments with less conventional sound sources (such as toy instruments, noise-makers, physical modelling synthesis). The two composers share a common interest in using less conventional sound sources. In this sense, the peculiarity of *Systema Naturae* lies in the co-existence of traditional acoustic instruments and different setups of electromechanical devices, made up of what might be called “hacked objects”. *Systema Naturae* is a cycle of four works, each one dedicated to a different natural kingdom: *Regnum Animale*, *Regnum Vegetabile*, *Regnum Lapideum* and *Fossilia*. The main reference is to *Systema Naturae* (1735), the important scientific work by Carl Linnaeus, a Swedish botanist, physician and zoologist, who relied on the classification of nature in three kingdoms — animal, vegetable, and mineral — and introduced the binomial nomenclature, i.e. a formal system of naming living beings by genre and species. The latter could be seen as a rationalistic attempt to order the polymorphic appearance of nature, which is not the case of the other references, represented by the Medieval books of bestiaria, herbaria and lapidaria. These were, in fact, heterogeneous collections of miscellaneous animals, plants and stones, multifaceted catalogues of both existing and fantastic creatures with much information and many illustrations and descriptions. In the cycle *Systema Naturae,* the concept of the catalogue is quite central and it could be seen as a model that informs different aspects of the work: first of all its general organization. Hence each *Regnum* is structured as a catalogue, made up of a sequence of short pieces, each one dedicated to an imaginary animal, plant, stone, or fossil. From Table.1 is possible to observe the structure of each *Regnum*. Within the four *Regna* the number of the pieces decreases, while their length increases progressively: *Regnum Animale* collects 28 pieces of approximatively 40" each, *Regnum Vegetabile* has 18 pieces, with a duration between 1'00" and 1'40", *Regnum Lapideum* has 12 pieces between 1'20" and 1'45", and *Fossilia* has just four pieces, where the longest is about 6'.

Tab.1. Structure of *Systema Naturae*

Regnum Animale	***Regnum Vegetabile***	***Regnum Lapideum***	***Fossilia***
approximate duration 20'	approximate duration 20'	approximate duration 19'	approximate duration 14'
28 Pieces – Each piece is between 40"/45"	**18 Pieces** – Each piece is between 1'05"/1'30"	**12 Pieces** – Each piece is between 1'20"/1'45"	**4 Pieces** – Each piece has a different duration
External reference: medieval tradition of Bestiaria Linneaus' *Systema Naturae.* Title are generated starting from the **BINOMIAL NOMENCLATURE**, in Linneaus' *Systema Naturae*	External reference: medieval tradition of herbiaria Linneaus' *Systema Naturae.* Title are generated starting from the **BINOMIAL NOMENCLATURE**, in Linneaus' *Systema Naturae*	External reference: medieval tradition of lapidaria Linneaus' *Systema Naturae* Title are generated starting from the Marbodus Rhedonensis's poem *De Lapidibus*	External reference: For Linneaus *Fossilia* is not the fourth kingdom, rather an articulation of the mineral one. However, the authors choose fossils as an interesting conclusive notion for the cycle
I. Minaeptacta gringi II. Phola reicha III. Taleus photothodecae IV. Zampychis flalutengla V. Cteromelis udivetusi VI. Graphas lopongens VII. Sectiditomys stonisius VIII. Urysilomys hyssii IX. Omysomysomys cacaca X. Pteronulephis urachotrons XI. Ioris casachocii XII. Zamonicomus monica XIII. Nomotaus yansicomolis XIV. Adius geradii XV. Cteromelis melins XVI. Onomys ucetasolanzondaroma XVII. Vinteroicis intermans XVIII. Hoopus lindens XIX. Durophos wienocia XX. Atottotis melitopuma XXI. Wiluscomylanycanonis XXII. Cistomalpha notus XXIII. Acaprimomyda tibie XXIV. Onomys valloruesca XXV. Urophoturonta glistrispus XXVI. Daripessus yantillippicus XXVII. Urochronopus stoniarens XXVIII. Feriocetus petrii	**I. Nononophis janeziarii II. Uelerinea ballus III. Tocactocepia eventaeticans IV. Hipseus lanthicus V. Schinia groumbusia VI. Ferocyclopia erossini VII. Ismosia papanabuis VIII. Ariolactus usteginsiphillemena IX. Hodolindereus hyboalga X. Eralmatus clens XI. Canochia usiva XII. Disia belga XIII. Hipseus valos XIV. Reocerantroma phenaudi XV. Chylicerela eucucta XVI. Melonthora cirencesus XVII. Bindronocereus ligenatos XVIII. Pentochtelacinia xissisiis**	**I. Aligurius II. Gagalida III. Echelechelena IV. Metastontes V. Anionidia VI. Eliteralates VII. Elenion VIII. Chrisopiris IX. Iactopia X. Caracon XI. Gerillidon XII. Alatia**	**I. Hinicinichnia II. Aranichnia III. Seuschylichnia IV. Totalatelonteminchnia**

In each of the four *Regna*, traditional ensemble instruments are integrated with a different set of electro-mechanical devices, made of what might be called “hacked objects”. After their creation, all these electro-mechanical devices have been named, classified and grouped in different families, partly following the existing taxonomy defined by Hornbostel and Sachs – which classifies instruments as idiophones, chordophones, aerophones, and electrophones – and partly following other criteria such as time responsivity (which is related to the temporal behaviour of the object and to its capacity to provide a fast attack and a fast delay, to allow complex rhythmical organization), control behaviour (distinction between objects with a discrete behaviour - on/off - or continuous one), presence or absence of pitch, and so on. This classification represents another aspect related to the idea of cataloguing. Moreover, at an early stage of the compositional process, the two composers worked on the creation of a database, in which they collected a large number of recordings of every single electromechanical device and recordings of instrumental sounds – including sounds produced with particular extended techniques –. All recordings have been analysed and catalogued on the basis of their possible dynamics, spectral contents, rhythmic behaviours, and so on. During the compositional process, this database has been exploited to pursue a smart use of the spectral contents of sound in building and combining different sound events. The two composers have systematically used simulations to provide a testing environment, supplying constant feedback on the compositional process. Their shared database has been constantly updated with spectral information, gathered from audio analysis tools, and used to feed algorithmic compositional environments - such as SuperCollider on Andrea Valle's side, and OpenMusic, on Mauro Lanza's side - in which accurate simulations of the pieces were created. In this way, the two composers maintained thorough control over the richness and the complexity of the sound material they were working with.

Main References

Fantechi, Daniela. *Systema Naturae, by Andrea Valle and Mauro Lanza, experimentation as starting point of a piece of "acoustic computer music"* – 2018 – Atti del Convegno "EMS18: Electroacoustic Music: is it still a form of experimental music?" – EMS Network. http://www.ems-network.org/spip.php?article451 (last access 07/03/2022).

Gorelli, Tommaso. *I Regnum di Lanza e Valle*, (interview), in The New Noise, 06/07/2015. https://www.thenewnoise.it/i-regnum-di-andrea-valle-e-mauro-lanza/ (last access 07/03/2022).

Roullier, Pierre et al. Mauro Lanza & Andrea Valle Systema Naturae, Collection A la ligne Ensemble, Champigny sur Marne : 2E2M, 2016.

Valle Andrea. "Residual Orchestras: Notes on low profile, automated sound instruments", in The virtuous circle design culture and experimentation Proceeding of the cumulus conference, paper presented at Summer Cumulus Conference-Politecnico di Milano 2015, June 3rd, 2015. https://iris.unito.it/retrieve/handle/2318/1547460/104873/cumulus-2015-054Experimenting.pdf (last access 07/03/2022).

Valle, Andrea. “Towards a semiotic of the audible”, in Signata, Annales des Sémiotique, Sémiotique de la musique, edited by Aage Brandt and José Roberto do Carmo Jr. Liege : Presses Universitaire, 6, 2015.

Valle, Andrea. [and Mauro Lanza]. “Systema Naturae: shared practices between physical computing and algorithmic composition”, Sound and Music Computing Conference, July 5-8, Espoo, Finland : 391- 398, 2017.
https://iris.unito.it/retrieve/handle/2318/1645065/351641/SMC17_p391.pdf
(last access 07/03/2022).