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# Analyzing Electronic Music. Uncovering the Original Conditions of Production

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MODERN MUSICOLOGY AND THE COLLEGE CLASSROOM

# TEACHING ELECTRONIC MUSIC

## CULTURAL, CREATIVE, AND ANALYTICAL PERSPECTIVES

Edited by BLAKE STEVENS



### 3 Analyzing Electronic Music

#### Uncovering the Original Conditions of Production

*Marc Battier*

After over seventy years of an existence rich in innovations, electronic music remains an elusive object for analysis. Numerous attempts have been made, including several quite elaborate systems of representation and paradigmatic fragmentation, but many of these methods have been unable to convince the musical and the musicological communities, so that, in turn, new approaches keep arriving.

For many, because a large fraction of electronic music production is purely aural and lacks scores, works in this domain are considered with the same regard as recordings of non-notated extra-European music or of improvisations. To compensate for the lack of scores, some sort of visual representation is considered necessary before any serious analysis can take place. Indeed, musical analysis has traditionally given a large place to aural perception, and it is understandable that when notation does not exist, a system of representation can be invented in its place to give analysis precious temporal and spectral information.

At present, this general approach, which is based on hearing, has developed through the use of research in the domains of signal analysis and perception. The scientific world of acoustics, signal processing, and psychoacoustics has identified a large number of sound descriptors. Music analysts have taken advantage of these recent discoveries by integrating them into graphical representations. Furthermore, once the audio recording, descriptors, and representation are juxtaposed in a software program, other digital tools can be applied to further investigate aspects of a piece or to compare several versions of the same piece. Software such as Pierre Couprie's EAnalysis, an annotation tool that is able to incorporate the data output of analysis software such as Sonic Visualiser, can be coupled with other methods to make the use of descriptors meaningful within the framework of a musical analysis. This field of research has progressed rapidly during the past few years.

However, electronic music can hardly be compared with recordings of other forms of non-notated music. This is because composers have usually paid significant attention to specific aspects made possible by the use of artificial sounds and electronic technology, including timbre,

morphology, time behavior, texture, and other parameters. All of these categories have taken on new meaning in the development of this music. This is why musicologists and students in musicology should gain some familiarity with the technologies of electronic and computer music. This type of knowledge is particularly important in approaching specific works. The conditions under which a composer produced a piece are quite relevant in providing information about the material and its processing, as well as the treatment of space and the possibilities and limitations of the technology at the time of production.

This chapter illustrates how an understanding of the conditions in which a piece was realized informs the meaningful analysis of electronic music. These conditions become guides to delve into the creativity of composers facing particular environments. What were the choices available to composers, how familiar with the technology were they, were there assistants to help guide them, and if so, how did these conditions shape their work? Questions like these, and many more, address the production aspect of a piece of electronic music and go beyond the description of its sonic surface. Along these lines, the chapter also considers some of the analytical approaches outlined earlier.

### Electronic Music and Its Ever-Shifting Environments

When Pierre Schaeffer embarked on a systematic quest to define methods of turning noises into musical sounds in 1948, no one could have guessed that *musique concrète* would lead to a major field of musical creation. Before the birth of electronic music in Paris, there had been many isolated attempts at introducing noises into the orchestra. As early as 1913, the Italian Futurists envisioned ways to create machines (in fact realized by Luigi Russolo with his *intonarumori*) that would mimic the sounds and noises of modern city environments: the roars of the tramways and the trains, the rumbles and hisses of factories, and the trepidation of urban life. Edgard Varèse translated the modern urban environment of his adopted home of New York City by exploring new expressive possibilities of percussion instruments as well as sirens in *Ionisation* (1931). Varèse also explored the potential of setting up a research laboratory that would help composers experiment with new sonic possibilities, including electronic sounds. Although his efforts may not have received support from existing laboratories, it was one of the first attempts to link music, science, and technology.

In his work at French Radio in the 1940s, Schaeffer inhabited a space that allowed for just this type of sonic experimentation. He devised techniques of processing sounds closely derived from his use of phonograph records, given that for the first few years, magnetic tape recorders were unavailable in the Paris studio. These techniques included speed change, time reversal by playing the disc backward, and above all the practice of

the “closed loop” (*sillon fermé*), which occurs when the stylus goes back and repeats the same passage, whose duration is around 1 second. It may occur on damaged records, but here it was intentional, as repetition, for Schaeffer, tended to obliterate the semantic or referential content of the recording.

As soon as the studio became equipped with tape recorders, Schaeffer, with the engineer Jacques Poullin, conceived a device to transpose recorded sounds: the *phonogène*, which is a modified tape recorder designed to produce musical results. It could be operated with a twelve-note keyboard, or, in another version, with a lever that could continuously vary the speed. The effect of the keyboard *phonogène* can be heard in Schaeffer’s 1958 work *Étude aux allures*. At 2 minutes into the piece, a passage is entirely produced by the device: a resonance is variously transposed to create a sort of melody at times interrupted by percussion sounds. Listening to this passage, it is easy to imagine Schaeffer playing the keyboard of his *phonogène* (Figure 3.1).



Figure 3.1 Pierre Schaeffer at the *phonogène*

The *phonogène* is described in patents obtained by Schaeffer in France, the United States, and Germany. Schaeffer also mentions it in his 1952 book, *À la recherche d'une musique concrète (In Search of a Concrete Music)*.<sup>1</sup> Its effects are also documented in letters from Pierre Boulez to John Cage, as Boulez was a student of Schaeffer in 1951–52 and composed two short studies in the radio studio.<sup>2</sup> They were subsequently premiered at a festival of electronic music in May 1952 in Paris (see Figure 3.2). The impact of the technology available in the studio is essential: Boulez played with the various ratios of transposition allowed by the *phonogène*, which he described in great detail in these letters. The audio quality of his two studies is not high, but the explanation of the use of the studio equipment enables the listener to understand how these pieces were conceived and realized. Only an understanding of the technology used by Boulez can reveal the compositional processes of those two short studies. This remark can be applied to the study of most electronic music, if one wants to go beyond a vague description of what is heard.

The collaboration in the Paris studio between an engineer (Poullin) and a composer (Schaeffer) is emblematic of the collaborative environments

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Figure 3.2 “Deux concerts de musique concrète,” May 21 and 25, 1952, in the festival “L’Œuvre du XXème siècle”

in other studios. As composers were introduced to new technological surroundings, it became important to provide them with personnel who could understand musical issues and, at the same time, operate the various electronic devices in a creative manner. During the 1950s, in the electronic music studios in Cologne and Milan, it was radio technicians who provided this service. In fact, the Italian composer Luciano Berio who, with Bruno Maderna, created the Studio di Fonologia Musicale at Milan Radio in 1955, wrote a memorandum intended for invited composers in which he exhorted them to work with the technicians, because only they could operate the machines. Composers brought musical ideas, and technicians realized them and inscribed them on magnetic tape, the recording medium of the time. In fact, film footage from the studio at the end of the 1950s shows that in reality, composers took a more active part in experimentation. In creating electronic music, new ideas and inspiration often come from a direct contact with devices. However, the technology of the time was not designed initially for musicians; the machines were conceived for the radio. They were expensive, delicate, complicated, and required trained technicians to maintain and operate them, so Berio's recommendation was not far-fetched. During the 1950s, there were few possibilities for composers to create electronic music; in Europe as well as in Japan, they often had to use radio studios, because it was only there that suitable equipment was available. In order to fully understand the works that were realized in this early period of the field, it is critically important to study these environments. For instance, because the devices available in a radio studio were not conceived to be used creatively by composers, technicians and sometimes scientists, such as Alfredo Lietti in Milan, designed specific machines for musical use.

In addition to the *phonogène*, another important device created for musicians during the 1950s is the tempophone, which was realized for the Cologne studio and the Swiss studio of Gravesano. It allowed the pitch of recorded sounds to be transposed without changing their duration. This is because if a sound is played by a disc player at 45 rpm, changing the speed to 33 rpm will transpose the sound down but will also dilate the time, so that everything becomes slower and lower. To avoid this, Anton Springer designed first a time regulator to achieve the effect of transposing a sound without changing its duration and then a time and pitch regulator to manipulate the duration and the pitch of a recorded sound independently, with alterations up to 25%. This can be heard quite clearly in a piece by Herbert Eimert, *Epitaph für Aikichi Kuboyama* (1958–62), in which some sounds seem stretched, an effect obtained by the use of the tempophone.

In North America, electronic music developed more slowly because of the lack of national radio stations, which were common in other parts of the world. Brave composers had to either use a private studio, such as John Cage, who worked in the studio of Louis and Bebe Barron in New York City to compose his *Williams Mix* in 1952, or set up a studio in a

university, as Vladimir Ussachevsky and Otto Luening did at Columbia University the same year.

Differences between the technical equipment available in America and that of other countries contribute to explaining the various routes taken by composers. It was in the United States and Canada that the first synthesizers were conceived, apart from some experiments in Russia that were only discovered later. Their rapid diffusion contributed to a trend toward “mixed music,” in which electronic sounds are mixed with live instruments. While “tape music,” or music composed on a recording medium, was still practiced (and still is), mixed music was produced by composers who did not specialize in electronic music but who could find electronic music studios in their institutions.

The implantation of studios in universities in North America had another side effect. It was in the United States that computer music emerged. Although originally conceived in an industrial research institution by Max Mathews—the Bell Telephone Laboratories in New Jersey—it was further developed in universities that were equipped with large computers: MUSIC IVB (1967) and MUSIC 360 (1969) at Princeton University, MUSIC 11 at MIT (1973), and Cmusic at the University of California, San Diego (1980). In Europe, access to computers for creative work was much more limited and only started to appear in a few places during the 1970s, but it spread rapidly. It was in France, for instance, that the Max programming environment, now used all over the world, was first designed and used in 1987.

The possibilities and limitations offered by studio equipment at any given time should be taken into account when approaching an historical work of electronic music, as new technologies appeared frequently and altered the modes of production. This is easier said than done, as documentation from the time is scarce: many documents were discarded when they became obsolete by the lack of space to house them, or simply because they had been replaced by more recent ones. Thus, a large fraction of knowledge of past environments cannot be retrieved. Fortunately, some publications offer snapshots of the technical equipment of the main studios at a given moment of their history.<sup>3</sup> Some devices were thoroughly described, and documentation can also be found in patent offices, which are now frequently accessible online. This is the case with Schaeffer and Poullin’s *phonogène* and, of course, for many electrical and electronic musical instruments of the first half of the twentieth century. Scholars nonetheless struggle to locate pertinent documents, as was the case for Jo Langton Hutton, who sought to understand the working environments of the four composers she studied in her doctoral dissertation.<sup>4</sup> As these composers were from different countries and times, understanding their equipment proved to be a challenge.

These examples show that the environments in which composers work to create electronic music, be it with tape recorders or with computers, is



ever-changing. This makes it even more important to assess the technology available at any given time, not forgetting the stylistic milieu in which musicians evolved. For instance, we may extend beyond the formative period of the Groupe de recherches musicales (GRM) in the 1950s to consider how evolving studio technology and practices have shaped the work of subsequent composers in the studio:

From the 1960s to the 1970s, composers at the GRM became liberated from Schaeffer's strict requirements of making short studies that experimented with musical objects. For instance, Luc Ferrari became interested in sonic landscapes and recordings that were only minimally edited—a departure from the notion of the Schaefferian sound object. The arrival of analog synthesizers in the studio brought about significant changes, including François Bayle's replacement of the old musical object with the notion of the sound image made of flowing energy, a concept that can be clearly heard in Bernard Parmegiani's groundbreaking work, *De Natura Sonorum* (1975). Along the same lines, Guy Reibel became attracted to live interaction with “sound bodies” and even wrote about them and the creation of instruments.<sup>5</sup> His work *Variations en étoile 2* (1969), for percussion and tape, is an effective example of this interactive approach.

The GRM became equipped with a mini-computer Digital PDP11 in the late 1970s. Rather than using existing software such as MUSIC V, it was decided to develop programs closer to the practice of composers in the studio. The principle of processing sound through a variety of effects allowed composers, until then working with magnetic tape and analog gear, to access and make use of digital techniques. Eventually, a digital sound processor, Syter, was built and used by many before its algorithms became a set of plugins (GRM Tools), now widely used in electroacoustic music. The digital approach marked a departure from work with analog magnetic tapes: it created new practices and sonic materials, yet retained a particular attention to the quality of sounds inherited from a long-standing GRM tradition.

## Repertoire

It is also important for those who aim at studying and teaching electronic music to know the repertoire as much as possible. When I was a student in the 1970s, this was a difficult task, as this music was rarely available on recordings, and these were few and far between. Now, by using the World Wide Web, a wealth of music can be easily accessed. Exploring the repertoire can be facilitated by consulting databases listing musical works in certain areas or within a given period. For instance, British musician and musicologist Hugh Davies made a comprehensive compilation of works up to 1967 in his *Répertoire international des musiques électroacoustiques/International Electronic Music Catalog*, published by the ephemeral *Electronic Music Review* and reprinted by the MIT Press

(1968), now available online.<sup>6</sup> For Latin-American electronic music, it is recommended to consult the collection gathered by Ricardo Dal Farra at the Langlois Foundation in Montreal.<sup>7</sup> For East Asia, the EMSAN database lists music from China, Japan, and South Korea.<sup>8</sup> Maintained in Germany, the International Documentation of Electroacoustic Music is a user-generated, collaborative database of works.<sup>9</sup>

### Advent of Live Electronic Music

If the production of electronic music in the 1950s was rather sparse, it was in part because of limited access to equipment. This situation triggered the development of analog synthesizers during the 1960s, when individual musicians and composers working in schools or in private centers turned to engineers to help create affordable electronic music systems that, in essence, could replace the expensive machines used in radio stations and research universities. On the East Coast of the United States, for instance, Herbert Deutsch, a professor at Hofstra University, asked Robert Moog, known for his production of theremins, to develop an affordable system with basic electronic music components such as voltage-controlled oscillators and a voltage-controlled amplifier. This happened in 1964, and it marked the beginning of the development of the successful Moog modular synthesizers.

On the West Coast at around the same time, Morton Subotnick and Ramón Sender, two composers affiliated with the San Francisco Tape Music Center (SFTMC), approached a young engineer, Donald Buchla, to conceive and build a comprehensive system. The goal was to come up with something that would spare composers from having to spend hours cutting and splicing magnetic tape, as was the case at that time given the center's struggle to acquire suitable equipment and its reliance on tape manipulation to create works. Buchla provided a complete system, which he called the Modular Electronic Music System. Although it was also based on voltage-controlled modules, it was quite different from the Moog synthesizers, as shown in a 1966 advertisement pamphlet (Figure 3.3). It had a variety of synthesis and, above all, processing units, such as a ring modulator and a frequency shifter, a voltage-controlled mixer, a number of different sound generators, a sequencer, and a unique touch-sensitive keyboard. Another unit, the "proximity detector," allowed for the connection of antennas for gestural control in the manner of the theremin. Buchla's device was clearly meant for studio work as well as for real-time performance on stage.

The unique sound quality of the Buchla system can be heard in Morton Subotnick's early electronic works. When the SFTMC moved to Mills College in 1966, he left for New York City, where he was commissioned to compose full-length pieces for LP releases. He exclusively used his Buchla system to compose *Silver Apples of the Moon* (1967), *The Wild*

## THE MODULAR ELECTRONIC MUSIC SYSTEM

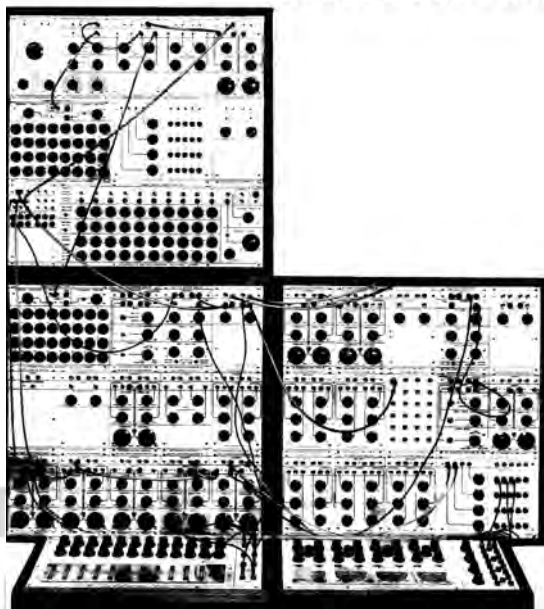


Figure 3.3 Buchla pamphlet, 1966

*Bull* (1968), and *Touch* (1969). Other pieces followed, all of an experimental nature.

The structural differences between the Moog synthesizers of the first years and the Buchla systems explain why they fit different types of music. The former was quickly adopted by pop and jazz artists, while the latter appealed to adventurous and experimental sound designers and composers such as Suzanne Ciani, who, like Subotnick, remained faithful to the Buchla systems after discovering them in the late 1960s.

### The Case of John Chowning's *Stria*

A scholar who has studied in depth the original conditions of production of computer music is the Italian musicologist Laura Zattra. The reader will find in the bibliography some of her publications that deal with this question. Zattra applies philological techniques to the analysis of extant computer music scores and program listings. A striking example of her work can be found in her study of John Chowning's *Stria*,

a computer-generated work realized at Stanford University's Center for Computer Research in Music and Acoustics (CCRMA) in 1977. Neither of the two recordings of the work was perfect in Chowning's judgment, and he expressed the wish to recreate a version closer to his initial intention. Zattra begins her article by describing her methodology:

This article starts from the assumption that musicology needs methods borrowed from philology for studying computer music. The analysis of the creative and revision process that John Chowning carried out in the realization of *Stria* (1977) is made possible by textual criticism and interpretation based on digital and audio sources, sketches, and oral communications.<sup>10</sup>

In the same issue of the *Computer Music Journal*, two researchers, Olivier Baudouin and Kevin Dahan, describe their recreations of *Stria*. Each author started with archives provided by the composer, consisting of fragments of program listings written in an obsolete language, SAIL (Stanford Artificial Intelligence Language), and portions that were generated by MUSIC 10, a version of Max Mathews' MUSIC IV written for the Digital PDP 10 computer at Stanford. As Chowning puts it,

It is a story of . . . how they rehabilitated a piece of music given a program with some missing code and missing data, two different sound recordings, and my memory (aided by fading notes and drawings) of what I had done more than 30 years ago.<sup>11</sup>

The task for Baudouin and Dahan was thus very difficult. Despite the composer's help, they faced conflicting program listings written in an old language derived from ALGOL. This is where Zattra's philological approach is revealed to be effective, as they had to find the versions that seemed to correspond to the recordings of the piece. Chowning evokes these difficulties and this philological method by describing

their carefully analyzing my not-very-clean code written in an old language, . . . carefully analyzing the existing recordings and inferring what I must have done so they could faithfully recreate a critical lost version of the program and its data—and finally, creating *Stria* anew.<sup>12</sup>

For this project, Baudouin used the popular Python programming language and Csound (a popular sound synthesis language derived from MUSIC IV) for the sound generation. To understand the sound synthesis listings written in MUSIC 10, he used a manual I wrote in 1982 for that language when I was at IRCAM, the music research institute founded in Paris by Pierre Boulez in the 1970s. In his article, Baudouin describes the

necessary trade-offs caused by the differences in the languages used at Stanford then and those of today. Dahan took another route and, after careful analysis of the extant sources, chose to transcribe the SAIL code into the Ruby language, and the MUSIC 10 scores into Csound. One notable problem Dahan encountered was the lack of reliable sources for the ending of the piece. He had to resort to musicological analysis to find a suitable solution, which seems to have worked, as it is this version that Chowning often prefers when performing *Stria*.

The reconstruction of *Stria* illustrates the difficulties in salvaging older computer sources to port (or adapt) them to latter-day software. It also shows that for pieces created with computers, care has to be taken to keep the program listings and scores. This is rarely the case, however, and Zattra has shown through her philological work that this presents a significant obstacle in studying older pieces. From the 1960s to the 1980s, most musical works created with computers were programmed. Composers used flavors of MUSIC IV (such as MUSIC 360, MUSIC 10, MUSIC 11, or, as of 1985, Csound), or MUSIC V and its newer incarnation, CMUSIC. During the 1990s, approaches to computing started to change in favor of real-time systems that involved a dose of interaction. Hence, written programs became more elusive, as one could change parameters on the fly with gestures. Although it was still possible to preserve traces of all the actions, doing so was rare. Experimentation, fine-tuning, and changes to the programs were frequent, such that it became increasingly difficult to keep track of the final versions of works. With software like Max and Kyma, real-time interactive approaches no longer required writing lines of codes.<sup>13</sup> Programs that do rely on lines of instructions, such as SuperCollider or Csound, which are both real-time programs in current use, opened the door to live coding, a popular practice in which musicians write instructions that are immediately converted into sounds.<sup>14</sup>

Music combining instruments and electronics (mixed music) started to depend on real-time devices during the 1980s, with machines such as GRM's Syter and IRCAM's 4X. At the same time, the arrival of Musical Instrument Digital Interface (MIDI) technology, which was conceived in the mid-1980s as a real-time way of controlling digital synthesizers through keyboards or computers, allowed for the rapid development of gestural control systems, including gloves, motion sensors, video and infrared capture of movements, and so on.<sup>15</sup> These systems rarely leave written traces, and composers must find innovative ways to notate the actions in their scores.

### Computer Music Designers

The problems that arose with the progress of computer music toward real-time interactive systems have made the documentation of recent pieces quite delicate. To approach these challenges, a number of elements in addition to audio or video recordings can be useful. First and foremost,

many composers are still helped in their creative work by musical assistants or computer technicians. This is the case at IRCAM: while this institute encourages young composers to learn techniques such as Max for real-time operations and sound synthesis software elaborated at IRCAM and OpenMusic for computer-assisted composition operations, a number of older composers invited to create pieces are provided with musical assistants, as was the case with the British composer Jonathan Harvey in his work at the institute.

For many years, these assistants were called “tutors,” but today they are known as “computer music designers” (in French, *réalisateurs en informatique musicale*). Zattra has studied their role and practices, which is an important step toward understanding their function as creative partners of the composer, even if, in the end, the latter is solely responsible for the work. Places where musical assistants had a determinant role can be traced back to Cologne in 1958, when Karlheinz Stockhausen worked on his piece *Kontakte*, for four-channel tape, piano, and percussion. He was assisted in the studio by Gottfried-Michael Koenig, who later moved to establish a computer music studio in the Netherlands and developed an influential practice of computer-assisted composition. The role of assistants was also quite important in the case of Italian composer Luigi Nono, who was for some time director of the Milan studio and produced a number of complex pieces involving real-time processing of sounds, including multichannel spatialization.

## The Visualization of Music

One of the earliest software programs designed for the visualization of electronic music was made around 1994 at the instigation of François Bayle, then director of the GRM. Its name, Acousmographe, is derived from the concept of “acousmatic music,” the term chosen by Bayle for tape music that has no visual component. The absence of visual stimuli was a potential barrier for people who were not accustomed to electronic music performed from tape, including students. A graphical representation of the events in a work, which of course did not have a score, helped listeners follow its narrative. The Acousmographe software offered, from its debut, a palette of signs, shapes, and colors that the analyst could annotate with text. A cursor moves in time so that it is always possible to know exactly the visual position of what is played. This software, twenty-five years later, is still produced and made available by the Institut national de l’audiovisuel (INA), the parent company of the GRM. The set of graphical shapes is quite extensive and enables the user to place graphical elements corresponding to what is heard on a time window and to add textual annotations. Figure 3.4 is an illustration of a graphical analysis of a piece by François Bayle, “Polyrythmie,” a movement from the larger composition *Vibrations composées* (*Composed Vibrations*, 1973–74).

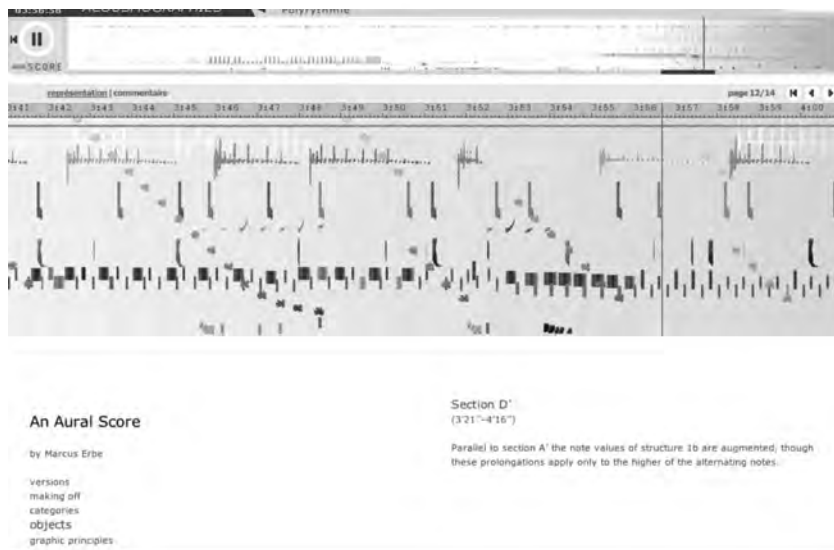


Figure 3.4 Acousmographe representation of François Bayle, “Polyrythmie,” from *Vibrations composées*, 1973–74

Another visualization approach was developed by French researcher Pierre Couprie, currently a professor of music at the University of Evry. His first program, *iAnalyse*, was designed in a way similar to the Acousmographe. Programmed for the Apple Macintosh, and now freely distributed on the App Store, this program also offers a large gamut of graphical shapes and the ability to add textual notes (see Figure 3.5 for a representation of an excerpt from Parmegiani’s *De Natura Sonorum*). Any kind of music can be entered into it. If a piece has a score, the pages can be added, so that the music flows with the score.

Couprie created a second program, *EAnalysis*, derived from the first and with added capabilities. It was commissioned by De Montfort University in Great Britain and was mostly aimed at creating visual illustrations of electronic music. Although no longer being developed or updated, a particularity of this program is that the display can be arranged in horizontal layers, each one receiving a different type of information, although everything is shown in sync with the music. For instance, one layer may display a sonogram, and another may receive annotations and comments; the program is also able to read analyses produced by the British program *Sonic Visualiser*, IRCAM’s *Audiosculpt*, GRM’s *Acousmographe*, and even *Avid Pro Tools* sessions. A typical use of *EAnalysis* is to display analyses, which show various sound descriptors produced by *Audiosculpt* or *Sonic Visualiser*. In any case, as with any software, the user must verify the program’s compatibility with their own computer system.

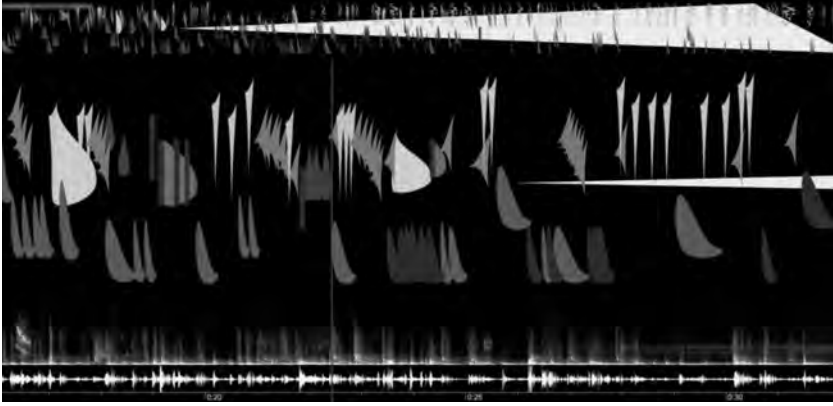


Figure 3.5 Representation of “Ondes Croisées” by Bernard Parmegiani realized by Pierre Couprie

Whether the animation produced by Acousmographie or iAnalyse is analytical or descriptive, having a visual representation, possibly with textual or graphical annotations, is an effective way to introduce electronic music to any audience, particularly one with no previous knowledge of it. This approach may go against the idea of acousmatic music, which consists precisely in sound diffusion without visuals. One may respond, however, that to ensure the proper impact of acousmatic music, certain conditions have to be met: the quality of the diffusion, preparation of the audience, and, possibly, prior verbal presentation, as is often the case. These conditions may not always be possible to meet, particularly when presenting this music to young audiences, for whom visuals will certainly assist in listening. Animations may reinforce the abstract sounds coming out of the loudspeakers and provide visual cues to guide perception.

## Conclusion

Access to teaching tools for electronic music has been rendered easier through the vast amount of music available on the internet, although not necessarily with the required audio quality. These include archives, databases, and websites of resources, including Ubuweb<sup>16</sup> and the various sites gathered by Barry Truax in the Sonic Research Studio.<sup>17</sup> With many other documents accessible online, as well as published books on electronic music (some of which can be considered excellent), it is possible to gather sufficient information for teaching. In addition, digital humanities tools such the visualization software presented earlier help in creating dynamic and vibrant presentations. In the end, of course, listening to as many pieces as possible and having students get acquainted with them are must.



Especially critical is an understanding of the conditions of production. Knowing which technology was available where and when a piece was produced and how the composer possibly found innovative workarounds with the inherent limitations of the devices all informs our way of listening to electronic music. It does not take away any of the charm, poetry, and interest of the music, but it gives us a more thorough grasp on how it was composed. In this respect, publishing a complete score gives access to Karlheinz Stockhausen's second electronic study, *Studie II* (1954), by highlighting the realization process.<sup>18</sup> One can understand the obstacles of producing a piece from sine waves with a rigorous compositional layout under difficult conditions: the Cologne studio was not designed for Stockhausen's approach, and he had to fight for his ideas of composing from only sine waves, when the studio was equipped with expensive electronic keyboard instruments, Harald Bode's Melochord, co-designed with Werner Meyer-Eppler, and Friedrich Trautwein's Monochord, that both produced rich spectra. This was precisely what Stockhausen rejected, as he wanted to compose the sound themselves.<sup>19</sup> Not having proper equipment was a huge challenge, and yet this study became a landmark of the electronic music repertoire. If a detailed score had not been made available, it would certainly not have had the impact it has had. Indeed, Stockhausen is one of the few composers to have produced scores for his electronic works: some are aimed at describing the production process, as with *Studie II*, or are realization scores, as with *Kontakte* (1958–60), *Telemusik* (1966), and *Oktophonie* (1991), to mention only some tape pieces.

All of the aids offered today by digital tools and ready access to documentation and the repertoire make it possible to gather a wealth of information on electronic music. This information encourages us to have a critical view of the existing literature that recounts its history, as some popular books are not exempt from approximations and mistakes carried over from previous writings. Our knowledge of the development of electronic music is now much more informed thanks to thorough research that has emerged over the past few years. Electroacoustic music studies is now an established field, and we can be hopeful that it will lead to a better understanding of what motivated composers of the past as well as those of the present.

## Notes

1. Pierre Schaeffer, *In Search of a Concrete Music*, trans. Christine North and John Dack (Berkeley, Los Angeles, and London: University of California Press, 2012), for instance at 174 and 181.
2. See Jean-Jacques Nattiez, ed., *The Boulez-Cage Correspondence*, trans. Robert Samuels (Cambridge: Cambridge University Press, 1993), 181ff.
3. See, for instance, *Répertoire international des musiques expérimentales: studios, œuvres, équipements, bibliographie* (Paris: Service de la recherche de la Radiodiffusion-Télévision française, 1962).

4. Jo Langton Hutton, "Beyond the Instrumental: Systems, Objects and Space in the Work of Beatriz Ferreyra, Teresa Rampazzi, Éliane Radigue and Delia Derbyshire" (PhD diss., University of Surrey, 2020).
5. Guy Reibel, *L'homme musicien: musique fondamentale et création musicale* (Aix-en-Provence: Edisud, 2000).
6. Hugh Davies, *International Electronic Music Catalog*, accessed November 13, 2020, <https://archive.org/details/InternationalElectronicMusicCatalog/mode/2up>.
7. Ricardo Dal Farra, "Latin American Electroacoustic Music Collection," accessed November 13, 2020, [www.fondation-langlois.org/html/e/page.php?NumPage=556](http://www.fondation-langlois.org/html/e/page.php?NumPage=556).
8. EMSAN (Electroacoustic Music Studies Asia Network) Project, accessed November 13, 2020, [www.ums323.paris-sorbonne.fr/EMSAN/](http://www.ums323.paris-sorbonne.fr/EMSAN/).
9. "International Documentation of Electroacoustic Music," (EMDoku), accessed November 13, 2020, [www.emdoku.de/en](http://www.emdoku.de/en).
10. Laura Zattra, "The Assembling of *Stria* by John Chowning: A Philological Investigation," *Computer Music Journal* 31, no. 3 (2007): 38.
11. John Chowning, "*Stria*: Lines to Its Reconstruction," *Computer Music Journal* 31, no. 3 (2007): 23.
12. Chowning, "*Stria*: Lines to Its Reconstruction," 23.
13. For Max, consult Alessandro Cipriani and Maurizio Giri, *Electronic Music and Sound Design: Theory and Practice with Max 8* (Rome: ConTempoNet, 2019), and for Kyma, consult Jeffrey Stolet, *Kyma and the SumOfSines Disco Club* (Self-published, n.p., 2011).
14. See Richard Boulanger, ed., *The Csound Book: Perspectives in Software Synthesis, Sound Design, Signal Processing, and Programming* (Cambridge, MA: The MIT Press, 2000).
15. Marcelo Wanderley and Marc Battier, *Trends in Gestural Control of Music* (Paris: IRCAM, Centre Pompidou, 2000) [electronic book].
16. "UbuWeb," accessed November 13, 2020, <https://ubu.com/>.
17. "The Sonic Research Studio," accessed November 13, 2020, [www.sfu.ca/sonic-studio-webdav/](http://www.sfu.ca/sonic-studio-webdav/).
18. Karlheinz Stockhausen, *Studie II, Score* (Kürten: Stockhausen Verlag, 1954), [www.stockhausen-verlag.com](http://www.stockhausen-verlag.com).
19. Elena Ungeheuer and Oliver Wiener, "Between Mass Media, Entertainment Electronics and Experimental Music: Harald Bode's Melochords in the Intersection of Many Interests," *Musique, Images, Instruments* 17 (2018): 166–91.

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