Unchartable territories?
A study involving *Stria*, brainwaves and some other things…

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Introduction

For a number of reasons, this paper is quite special: it will not follow a traditional structure and it will – uncommonly – be strongly based on personal experiments, perceptions and visions. Yet it will try to address some fundamental elements which I think are to be taken into account if we are going to pursue the digital music dream Max Mathews, Jean-Claude Risset and John Chowning had back at Bell Labs in the 1960s.

It is not preposterous to say we all have a number of ideas we carry along for a very long time, possibly since childhood, and for some reasons 'stick' with us. As a matter of fact, one of my personal dreams is being able to produce music – actual sounds – directly by "thinking" it. What sounded like science fiction only twenty-some years ago is now almost within our reach. For now a lot of us are still considering such ideas as mere fantasy – and to a certain extent, it is. However this is a line of research that is currently fast developing, as there are still many aspects to take into account, to register, to analyze and to research.
Trying to always keep contact with the music, I will discuss here some aspects of the research I have undertaken: from ideas to sounds, how to use our brain (activity…) to make music, and what it may change (or not) in the way we "think" music.

1) Ideas/sounds/the rest…

Just for the sake of it, wouldn't it be interesting to know what Berlioz, for example, would be thinking if we were to describe him what we're actually able to do right now? Composing (and listening and rehearsing) for a large orchestra without having to leave home, inventing new sounds and new instruments without dealing with instrument makers, or experimenting with alternative instrument playing techniques without damaging the instrument… or the instrument player in the process (see Figure 1). I bet he would probably be interested in some of these aspects (by judging the numerous comments and criticisms in his treatise, for example on the "relative efficiency of wind players" (Berlioz, 1843)), but he would probably look at us quizzically. Yet we can do all that now, and we can do even more!

Figure 1: *Un concert à mitraille et Berlioz* – "Heureusement la salle est solide, elle résiste !" - Grandville, 1846

a) On the limitations of the body

Despite being trained as a classical pianist, which should have given me a relatively decent motor control – having been subjected to some of Charles-Valentin Alkan's *Etudes* in my last years of practice – I always found it difficult to link body movements to electroacoustic music diffusion or computer music "interpretation". If we are to follow Marvin Minsky's terminology, the different

"agents" at work in this particular "task" do not, in my case, form a coherent "society" {Minsky, 1985). Claude Cadoz terms this particular mapping between gestures and computer-generated sounds "energetic continuum" (Cadoz, 1999), suggesting a transformational approach to sonic creation.

This, in my opinion, simply doesn't work. When I compose, arrange, tweak, distort or recreate works of electroacoustic and computer music, I like to have the *articulations* between sound objects, structures, or *beings*, to be precisely defined; I fear this is not within the reach of mapped gestures. This is due, possibly, to the *distance* that lies between sound "ideas" (and the effort and precision needed to make them *emerge in time* (Dahan, 2006) and the control of these ideas: ideas generate gestures, which are then mapped to an approximate control flow; control data is in turn mapped to "musically meaningful" symbolic data, which is interpreted by the computer and turned into discrete sound signal, to be finally transmitted as sound through loudspeakers (see Figure 2).
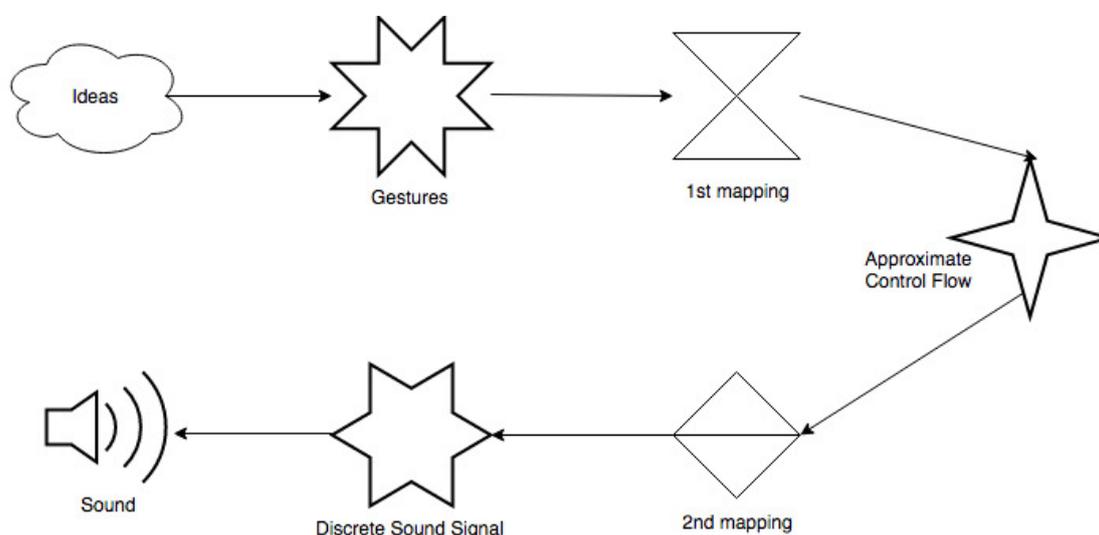

Figure 2: Typical creation chain in Computer Music

Of course, there is simply no way we can get rid of these approximation-inducing (sometimes (beautiful) "error"-inducing) steps when composing, designing sound, or making music – without technology, at some point, many composers in the history of Music encountered difficulties of some sort with copyists, performers, not to mention tinnitus or deafness... To a certain extent, maybe all these problems are "interfacing issues" as well.

b) On the limitations of electroacoustic music

The other, probably conflicting (or even schizophrenic), aspect is related to the flexibility we enjoy and seek when playing to instrumental music – a particular sensation which is very different to that we experience when diffusing electroacoustic music. This flexibility – even *plasticity* – of a scored work probably lies within the accumulation and interaction of all the small deviations

that performers add to musical lines, while maintaining sufficiently strong characteristics so as not to make the whole work lose its identity or meaning. And this opens way for long debates, which won't end before long – hopefully something we are all thankful for as music scholars!

So it looks like we are stuck with a terrible dichotomy: either we endlessly listen to the *exact* same piece (when contemplating the 0 and 1s of the digital sound file[1]) or we endure the tortuous approximate *renditions* (due to imprecise gestures and movements) of an elaborate "ideal" compositional structure (which we might never fully understand or appreciate, thanks to the aforementioned limitations and successive weak links in the chain[2]). I think this would be rather bleak if our 21st century technology could not help us in composing electroacoustic music that could be interpreted – rather than merely "performed". There is also the problem of preserving works of digital music that may be lost due to deteriorations.

c) On the preservation of electroacoustic music

One of the first answer to that is to take advantage of this modern technology and "renew", "reconstruct" or "redo" fixed music works – after all they were and still are "products" of technologies. This is possible if a) the compositional process has been thoroughly documented (up to and including the precise gestures used during the establishment of the fixed media source); b) there is access to all materials used for the composition (that includes "original" sound files, but also source code for sound-synthesis based composition); and c) there exists copies, equivalent or functionally superimposable alternatives to hardware and software solutions originally used. In the case of *Stria*, all these aspects were present in 2007, so reconstructions were made possible. I won't elaborate further on this, since this has been widely documented (Dahan, 2007) (Zattra, 2007).

An interesting side-effect (and something that have shocked some[3]) is that *Stria* entered another dimension due to the diffusion of its complete source: both its *genotype* – the source code for musical events – and its *phenotype* – the actual sound synthesis source code – were suddenly available to everyone. Beyond the historical interest of enabling the preservation of this masterpiece, the ontological status of *Stria* definitely changed: *where* exactly is the work? There

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[1] Of course there are a variety of elements – notably psychological – that will change the specific reception of each instance of a work – however I am not going to elaborate further on that...

[2] See for examples works of the so-called *hyper-complexity* compositional technique (Ferneyhough {zoter}), which aim at inducing as much tension as possible in the chain of rendition.

[3] There were several conservative, but instructive and interesting, reactions on this idea of sharing at the premiere of the reconstructed version at the International Computer Music Conference 2007, that surprised us...

have been multiple versions of it, each reflecting a possible approach to *Stria*[4]. The question that has been put directly into evidence here – and this is probably the most fundamental question for most of our knowledge – is: what exactly are we working on? The interesting fact here is that we are working organically *with* the artwork, not *on* it.

d) Expanding *Stria*

The next step was, almost logically, to use this possibility and the particular plasticity of *Stria* to experiment on.

Fortunately, by using EEG monitoring devices, it is possible to gather meaningful information on emotional responses and states. As we all know, music composition and performance always is a highly emotionally engaging human activity, whether considered from the listeners' perspective or the practitioners' point of view. However, mostly due to motor activities and related cortical zones activation, it is very difficult to examine the similarities and differences between emotional engagements related to one activity, the other, or compounded activities (such as improvisation). Once this information has been captured, we can then exploit it by using it as control data providing temporal, conditional or interpretative cues to the musical system. In our case, we could tentatively say that it may permit to "perform" *Stria* – or any work of fixed music for which we have sufficient data.

Related to this issue is that careful situational analysis of compositional processes and habits suggest that composers may exhibit more creativity when subjected to resistive tensions, notably when engaging with technology, while musicological analysis of electroacoustic and improvisation-related works prove the existence of particular tension/release mechanisms that can be mapped to specific temporal cycles (it is obvious, for example, in the works of Barry Eaglestone). These mechanisms closely recall observations made by cognitive scientists that focused on computational modeling of audition in the context of tonal music (specifically, Edward Large provided an interesting approach, neurodynamics of music perception (Large, 2010)). Implications of these various observations are numerous, and impact several parts of musical studies. In particular, examining the relations between cortical motor activities, temporal aspects of music and cognitive processes in composition and improvisation in the framework of electroacoustic music would provide an interesting test bed, since results would not have to be strictly interpreted within the restricted context of tonal, beat-based music. Since music thinking is a complex domain relying both on perception and action, I decided to explore the field of emotional and cognitive engagement through the design and development of an empirical system whose ultimate goal is to be used in electroacoustic performance control,

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[4] There are at least four different *fixed* versions we worked on that have been used in concerts: the original reconstructed version played at ICMC2007, the corrected version produced in 2009 with the correct END section, a version in 2010 which altered the filters after discussions with Andy Moorer and an 8-channel version made during a stay at CCRMA in 2012.

by means of gathering and analyzing the cortical electrical activity (known as EEG).

Approaches of music composition and performances have of course already been described, however until recently, only rarely in the context of electroacoustic music (most psychological studies are using the context of tonal music); moreover, related (notably esthetical) issues were not raised, which is a key point in our experiments.

2) Some hardware aspects and some experiments

There have been several studies on the subject of Brain-Computer Interaction (BCI) related to Music. Eduardo Miranda's studies since the early 2000s on using different electroencephalography (EEG) devices in order to analyze and then conduct music (Miranda, 2010). Several researchers (e.g. (Sloboda, 2004), (Juslin, 2008)) have been working on analyzing what was going in the brain of musicians when playing and/or listening to music. I won't develop further into these aspects, since literature is fairly well known.

Up until recently, there were a lot of limitations regarding the use of EEG devices in music or musicological research: the expensive nature of these devices was one of them, the impracticability of such systems another, and it was consequently nearly impossible to use them in "natural setting" experiments, with the headsets being moved around, and subjects being able to move their heads naturally.

Since 2010, several solutions are available on the market, which gives reasonably good results with minimum limitation: I have been using an Emotiv Epoc headset. This headset allows experiments to take place without being subjected to a lab-stress environment, by providing them with a complete freedom of movement: which is an important aspect, since it has been determined that motor cortical areas play an important part when playing, listening and/or composing music (Popescu, 2004). There are, of course, important limitations on the hardware itself: the non-invasive nature of the headset makes it very sensitive to poor contact with head scalp, and the possibility of free movement is double-edged since acute reading may not be possible in case of large head movements – there is however a XYZ-gyro channel giving spatial information on the head position. All in all, the system performs well, and gives 14-channels output, with electrodes located using the usual I10-20 reference system, all that wirelessly: much like the "traditional" EEG systems, without the 2 meter long cables hanging behind the head cap.

One of the most interesting aspects opened by the possibility of retrieving and exploiting neuronal data in a musical environment is to be able to gain a better understanding of the action/perception feedback loop at work during musical practice, restitution or composition. Since the evidence of this feedback loop has already been established (Pfordresher, 2006), it was decided to explore several aspects of this loop in an experimental setting.

One of the feature of the Emotiv Epoc software environment is its already preprocessed data flow: while it is possible to have access to raw EEG readings, it is easier to exploit what is called "Cognitiv" and "Affectiv" data flows. "Cognitiv" data roughly corresponds to neuronal activity in specific motor cortical areas, while "Affectiv" data is said to correspond to emotional states. These are serious limitations when trying to design factual, scientific, psychological or neuroscientific experiments, but when designing an experimental system for control of electroacoustic music diffusion, it is sufficient (roughly, it corresponds to signals you get when using tuned filters on specific sensors). Consequently the first experiments used, in turn, "Cognitiv" data and "Affectiv" data: the headset generates streams of information which is turned into OSC packets that are used in a Csound orchestra in order to modulate the frequency of a sine oscillator, or various elements of a filter bank altering a noisy source. The immediate interest is to manipulate data in real-time to alter sounds coming from the software environment, creating a database containing both musical parameters and data evolution in time. Another interesting derivation of this experiment consisted in using it in a musical setting, by generating sound synthesis elements in an improvisation with other musicians. From there two paths are clearly possible: (a) using *conscious* actions (i.e. activating motor cortical areas *without actually performing the gesture*, e.g. thinking of the movement) in order to modulate the sound and (b) using *unconscious* information (i.e. mental states, feelings, emotions) to modulate these sounds.

(a) Experiments were conducted by programming very simple sound synthesis instruments that could be modified and controlled in real-time by cognitive data. This choice was dictated by the possibility to decorrelate sound synthesis design from any reference to real-time conception: it was crucial to be able to gather information as precise as possible without having to worry about "perceived" influence of mental states on sound evolution. In this respect, it was evident from the start that sounds had to be a continuous, if we were to be able to gather interesting data from the experiments. There is a significant lag between a) detection of cognitive data, b) sending to the OSC server and Csound client and c) modification of the synthesis parameter(s). The initial sound algorithm is a white noise source filtered by several resonant filters, with EEG data continuously modifying the frequency and bandwidth. As such, the sound varies from almost unfiltered white noise to almost pitched sound, depending on data acquired. Of the numerous modifications that can be applied to the sound to be tested, several were implemented (time modifications, mental states disturbances testing by introducing randomized events...). All in all, these experimentations are less interesting: the results are highly predictable.

(b) Experiments that include dealing with unconscious – or emotional – states are far more interesting to us: being able to reproduce electroacoustic works, and interpreting them just by being "subjected" to it. Note that the software may be modified in order to modify any recorded music, given sufficient information. However what is even more interesting is the case of *Stria*…

3) *Stria* and brainwaves…

There are a number of elements that can be easily modified in *Stria*: for example, we have access to expression-related parameters (the frequency or amplitude of a vibrato, the quality of a resonant filter, and so on – including the infamous "skew" parameter…), but also to aspects pertaining to the general execution of the work, amongst which first is time. I am not advocating the use of EEG in order to introduce a *rubato* in electroacoustic music[5]; however, as we all experienced this fleeting moment when we *felt* like a particular sound *had to* last a quarter of a second longer: this is exactly what the system permits.

The greatest challenge is to be able to find boundaries within which modifications are "tolerable". In other words, identifying the criterions that permit to produce maps that correspond to the territory being charted: if we are listening/controlling/interpreting *Stria* using this system, there are very limited – if any – on its territory (form, structure and events are preserved); however the map will vary.

Of course, there are still a number of elements to be examined in order to provide a comprehensive software solution for emotional control of computer music environments and performance, to be used in the diffusion of an electroacoustic work. The long-term goal is to use this setup in order to control the diffusion (both spatial and temporal) of an electroacoustic work, whether it comes from a sound synthesis code or from multichannel sound files. For now, we are using works made in Csound, but due to the use of the OSC platform, works programmed in several other computer music environments could be modified to use this as a "super-instrument" dedicated to electroacoustic works diffusion: it could be implemented in any language and controls various environments, using OSC callbacks in return. What is needed is another, more robust EEG system (in terms of system performance, but also construction); there are several newer portable options available nowadays.

But what is even more interesting to me – other than the technical aspects and challenges – is the fact that such a system, and approach, changes the way we react to electroacoustic music, going from "fixed music" to "music that can be changed just by emotionally responding to it": this allows a listener to fully engage with it, and go so far as to modify elements, in a way that is similar to that of a musician interpreting, say, a Beethoven sonata, *but without any body mediation or instrumental expertise*. This opens up possibility for electroacoustic music to be enjoyed and appreciated by more people. And this somehow brings me back to my initial point: being able to "think music aloud". There may also be a social consequence to that: we could be able to "show" to one another "how" we perceive a particular piece of music.

I actually have several "versions" of *Stria* "as felt by" …

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[5] Even if I have run experiments on it – and it sounds good!

Conclusion

I would like to conclude by quoting one of my favorite thinkers, Gregory Bateson, which quite fits right here, and can help explain in retrospect the rather esoteric title I came up with:

"We say the map is different from the territory. But what is the territory? Operationally, somebody went out with a retina or a measuring stick and made representations, which were then put on paper. What is on the paper map is a representation of what was in the retinal representation of the man who made the map; and as you push the question back, what you find is an infinite regress, an infinite series of maps. The territory never gets in at all. [...] Always, the process of representation will filter it out so that the mental world is only maps of maps, ad infinitum." (Bateson, 1976).

Acknowledgment

Bibliography

Bateson, Gregory, "Form, Substance and Difference" in *Steps to an Ecology of Mind*, Chicago Press, Chicago, 1976.

Berlioz, Hector. *De l'instrumentation*. La Gazette Musicale, 1843.

Cadoz, Claude. "Continuum Énergétique Du Geste Au Son - Simulation Multisensorielle Interactive d'objets Physiques." In *Interfaces Homme-Machine et Création Musicale*, edited by Hugues Vinet et François Delalande, 15. HERMES, 1999.

Dahan, Kevin. "Computer Music Enaction." In *Proceedings of the ICMC 2006 Conference*. San Francisco: ICMA, 2006.

Dahan, Kevin. "Reconstructing *Stria*." In *Proceedings of the ICMC 2007 Conference*. San Francisco: ICMA, 2007.

Juslin, Patrick, and Daniel Västfjäll. "Emotional Responses to Music: The Need to Consider Underlying Mechanisms." *Behavioral and Brain Sciences* 31 (2008).

Large, Edward. "Neurodynamics of Music." Edited by M. Riess Jones, R. R. Fay, and A. N. Popper. *Springer Handbook of Auditory Research* 36 (2010).

Minsky, Marvin. *The Society of Mind*. New-York: Simon and Schuster, 1985.

Miranda, Eduardo R. "Plymouth Brain-Computer Music Interfacing Project: From EEG Audio Mixers to Composition Informed by Cognitive Neuroscience." *International Journal of Arts and Technology* 3, no. 2/3 (2010).

Pfordresher, Peter Q. "Coordination of Perception and Action in Music Performance." *Advances in Cognitive Psychology* 2, no. 2–3 (2006).

Popescu, Mihai, Asuka Otsuka, and Andreas A. Ioannides. "Dynamics of Brain Activity in Motor and Frontal Cortical Areas during Music Listening: A Magnetoencephalographic Study." *NeuroImage* 21, no. 4 (April 2004).

Sloboda, John. *Exploring the Musical MindCognition, Emotion, Ability, Function*. Oxford University Press, 2004.

Zattra, Laura. "The Assembling of *Stria* by John Chowning: A Philological Investigation." *Computer Music Journal* 31, no. 3 (2007).