

Musical perspectives on composition, sonification and performance

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ABSTRACT

This paper is an attempt to analyse the relation between sonification and music through a short enumeration of case studies. Four pieces have been used to clarify this relation and to understand how the different functions and purposes of music and sonification can be preserved while combining both functions together.

1. INTRODUCTION

A recent (and accurate) definition of *sonification* ([1, p.9]) reads

Sonification . . . seeks to translate relationships in data or information into sound(s) that exploit the auditory perceptual abilities of human beings such that the data relationships are comprehensible.

Thus, sonification is a scientific activity which relates to *auditory display* picking up from this latter field all the research and analysis carried out on sound perception.

Music is instead one of the oldest and most pervasive known artifacts of human kind. The questions concerning its origins and a precise definition for this activity have known many different stages and highs and lows in reputation among musicologists all along the twentieth century to end up confined in some very specialised branch of evolutionary musicology ([2]). All in all, it is quite difficult to set precise boundaries for music. This is why we will resort to a witty reply given in a now legendary lunch meeting in Cambridge between composer Luciano Berio and linguist Roman Jakobson. The anecdote recounts that Jakobson approached Berio very directly: “*Monsieur Berio, qu’est-ce que la musique?* [Mister Berio, what is music?]”. After some hesitation, Berio replied “Music is whatever is listened to with the intention of listening to music” ([3]). We maintain that this is the best definition that we can get for music in that it encompasses *all* the music we have met and known in life. While been almost useless as a definition in its generality, it does incorporate *one* element that is of fundamental importance: human intention – which is

completely arbitrary, dependent on culture and aesthetics and subject to mood, fashion and social requirements (just to name a few contexts which modify our intentions).

At any rate, it is clear that these definitions of sonification and music will not get us very far in our attempt to decide whether these two activities are related or not. While sonification is quite precisely defined, music’s characterisation boundaries are simply too loose to be of any help in trying to make some sense out of the relationship between the two. Given these definitions of course sonification *can be intended* as music – just as *anything else* can. While the creation of music that can be intended as sonification is more difficult to achieve, and indeed it is hard to find good reasons to do something like that (there are some, as we will see, but they are the exception rather than the rule). Thus, we tend to be wary of such approximate combinations because they hardly add some insight while they seriously risk to contribute to the general “noise” of mundane observation. And by *noise* we do not intend the poetic, musical sound that is often sought and modelled in electro-acoustic music but rather that inconvenience in information transmission precisely cornered by communication engineers.

Perhaps a better solution is to resort to the different *purposes* of sonification and music. True, music may have very different purposes, but at least these can be confined into three broad categories:

- rite,
- entertainment, and
- intellectual speculation.

We are confident that these three categories encompass most, if not all, music activity. On the other hand, sonification has *one* very specific purpose: scientific analysis. A major difference appears at last: music is an arbitrary activity carried out in a generally playful way to stimulate our artistic inclinations (whatever those may be), while sonification implies a thoroughness which can be constantly scrutinised, amended and improved using all the scientific conceptual tooling that we have access to. That is to say, for example, that “bad sonification” will be easily spotted out by accurate scientific analysis, while “bad music” will always be a personal judgement matter.

These considerations were necessary to justify our initial skepticism in accounting for sonification and music as two activities that have something in common besides sound itself. However, because of the generality and ubiquity of

music, it is difficult to rule out relationships simply out of prejudice. Thus we embarked in the endeavour of sketching out some analysis of four real-world cases in which some relationship could possibly be found to see what conclusions could be reached through some actual case studies.

2. REAL-WORLD EXAMPLES

Without claiming to be exhaustive but trying nonetheless to encompass a variety of cases in which sonification and music seem to overlap, we took into account four different contemporary real-world examples – two musical works in which sonification is related to the compositional processes and two in which sonification is part of the performance tools used by composers in a creative way. For the sake of simplicity we will call the first ones “compositional” examples and the second ones “performance” examples.

2.1 Compositional examples

The “compositional” examples are related to two pieces that differ very much in nature and compositional principles: *The Sound of Nasdaq* (2003) by Italian composer Fabio Cifariello Ciardi, and *The Radioactive Orchestra* project (2012) set out by Swedish composer Kristofer Hagbard.

2.2 *The Sound of Nasdaq*, by Fabio Cifariello Ciardi

The Sound of Nasdaq (2003) is the first of a number works by Italian composer Fabio Cifariello Ciardi based on live data coming from financial data streaming available over the Internet. Other works by Cifariello Ciardi which represent variations over the same thematic idea are *The Sound of Xetra* (2003), *ASX Voices* (2004), *NASDAQ Voices* (2005-2010), *A BID match* (2008), *Nasdaq Match 01* (2010) e *Nasdaq Match 02* (2010).

These works are audio-visual installations based on the sonification of real time trading data on the NASDAQ Stock Market. Sounds and images are automatically generated by price and volume variations of a variable number of NASDAQ stocks. Depending on the country hosting the installation, chosen companies may be related with local culture and economy. They aim to establish a multimodal real time landscape of the global economy that can be entered and explored by the audience. The installation uses real-time data accessible through online resources to generate dynamic sonic patterns by means of mapping algo-



Figure 1. A performance of *NASDAQ Voices* (2005, Salerno)

rithms. None of these patterns are pre-calculated and they achieve their behaviour exclusively through data variations. The installation may run in real time during any trading session. For any of the sonified stocks, information such as company name and profile, market capitalisation, and description of the associated sound is available during the performance.

([4]) is a paper that describes the technical details of the software toolkit that generates the actual sounds, while ([5, 6]) concentrate on the musical logic that is behind this family of works.

2.3 *The Radioactive Orchestra*, by Kristofer Hagbard

The Radioactive Orchestra is a complex musical project based on an idea by nuclear physicist Bo Cederwall (KSU – Kungl Tekniska Högskolan) and carried out by Swedish media artist Kristofer Hagbard which is based on the creation of musical patterns using the radiation emission of radioactive isotopes.

The Radioactive Orchestra simulates what happens in an atomic nucleus as it decays from its excited states down toward its ground state. This decay happens in steps between the different energy levels in the nucleus. Each transition corresponds to the emission of a photon, a “gamma ray” which is a characteristic energy equalling the difference in energy between the levels. Every nuclide has its own unique set of excited states and decay patterns, creating its own musical signature, so to speak. Since the microcosmic world is ruled by quantum mechanics, even each decay sequence is unique. It is a stochastic, random process, which leads to virtually infinite variations.



Figure 2. Kristofer Hagbard performing at the Nobel Museum

The Radioactive Orchestra uses information on transition energies and transition probabilities (each decay can often proceed to different lower-lying levels, with certain probabilities that can be deduced from experiments) in order to decide which kind of photon to emit. Its energy (measured in kiloelectronvolts, keV) is converted to an audible frequency in Hertz, mapping pitch to gamma ray energy in a direct form. The composer has further quantised frequencies constraining them to tempered pitches. Several different nuclides can be picked out to produce polyphonic textures.

The algorithms used in *The Radioactive Orchestra* are applied to a variety of different outputs: a record, live music performed with the algorithms, videos explaining the project and a public website (<http://www.nuclear.kth.se/radioactiveorchestra/>) in which anybody can try out these models.

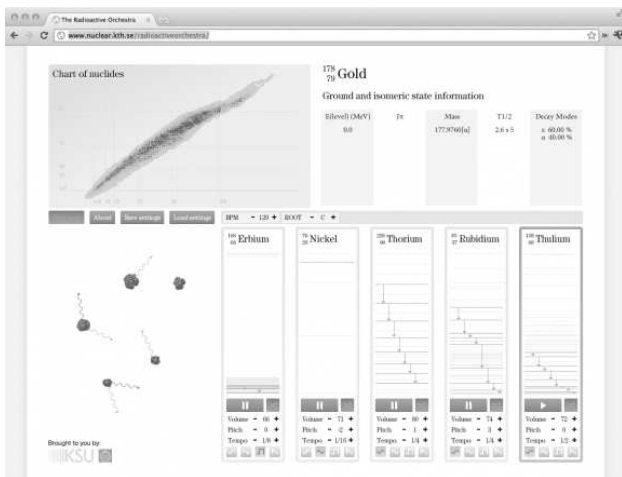


Figure 3. A screen shot of the *The Radioactive Orchestra* website

In addition to its artistic ambitions, this project aims to

fulfil some pedagogical purposes: “the idea is that the connection to music can inspire young people to learn about natural sciences by making one of its most hidden phenomena available in a new way and exposing complexity and beauty in the strange world of the atomic nuclei using music” ([7]).

2.4 Performance examples

Composition is not the only musical activity which has explored the possibilities of connecting data sonification with music production. Most notably, composers and performers have used data coming from 3D tracking of gestures and body postures during performance to contribute to the final musical output of a given piece. We will synthetically describe a couple of cases in this area, emphasising their specific characteristics. Both works are described in ([8]), and both were created using a motion capture system (*Impulse Phasespace*) to track the soloist movements. This system is made out of a variable number of infrared cameras which can detect the movements of the leds that are placed on the body part/object that is being tracked. Both works call for the tracking of hand movements; these happen to move laterally or vertically at both sides of the instrument. In both cases the performer had a pair of gloves, which featured 4 leds each. The so-called rigid body tracking modality was used: each hand was considered as a unique rigid body defined by a matrix of positions of every leds in relation to the first one inserted in the chain of leds. The system detects the center of gravity of that combination through a data triplet (the xyz coordinates) and the accidental occlusion of one of the leds does not affect the continuity of the tracking. The tracking is thus very robust and suitable for live performances. The system can be used with a variable number (> 2) of cameras. Generally speaking, the larger the number of cameras (and so the points of view) the better will be the robustness of the system which will be less sensitive to the particular position which the performer may assume. In live performances however it is necessary to find the best compromise that will allow this robustness without being too invasive from a scenic point of view. In the particular case of the hyperbass flute four cameras were used, placed on two stands placed symmetrically at each end of the instrument in use: one of them at 2.30m from the floor, looking at the performer’s hands from the top, the other on the ground looking at them from the bottom.

2.5 *Ogni Emozione dell’Aria*, by Claudio Ambrosini

Ogni Emozione dell’Aria (2011) is a work for clarinet and live-electronics by Italian composer Claudio Ambrosini. In *Ogni Emozione dell’Aria*, both hands of the clarinet performer are tracked by a real-time motion capture system in order to control the live electronics processing. The score

calls for specific movements of the player (i.e. opening arms) and the movement data captured by the system is used to map the position of sound in space and to add expressive intentions and new layers to the composition. In this work, each hand is seen as a single independent body: the left hand controls the location and movement of sound in space while the right one is connected to timbral effects (i.e. *harmonising*, non-linear distortion, etc.). Performance gestures are thus available to the composer who selects them and notates them precisely in the score in order to replicate performances in a deterministic way. At the same time, these new compositional parameters (gestural movements) preserve the natural inclination of musical expression to be adapted to individual performance aesthetics (what is generally called *musical interpretation*).

Delving into technical details, the live-electronics processing has been made using MAX/msp where two main signal processing strategies have been developed: *Dissolution_A* and *Dissolution_B*. *Dissolution_A* refers to the spectral processing of the clarinet sound through a threshold FFT. Every spectral band is resynthesized when its amplitude is inside a given range delimited by two threshold values (upper and lower). The bands that are resynthesized can have an altered amplitude envelope (through the application of an attack and a decay transient); its pitch can be altered too through transposition. A ring modulation with a 3 kHz carrier can be further added to the altered sound, filtered with the same frequency cut-off through a second-order low pass filter. The sum of these two signals is then filtered by a highpass shelving filter which can enhance or attenuate the high frequency zones.

A particular example of *Dissolution_A* is shown in Figure 4: in this case, the right hand is controlling while the left one is playing. The X value of the right hand is controlling

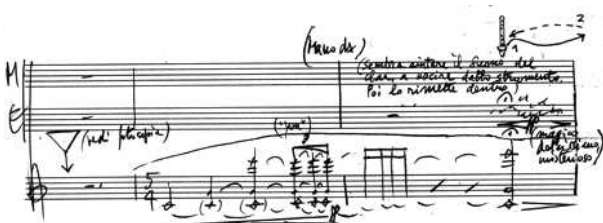


Figure 4. *Ogni Emozione dell'Aria*, score at page 6. Here *Dissolution_A* is used: “The right hand seems to help the sound of the clarinet to come out and then back in again”.

the output level, the Y value is controlling the transposition, the Z value is controlling the left-right spatialization and the M value (its modulus) controls the front-rear spatialization. The X value of the right hand is controlling the output level, In *Dissolution_B* the clarinet sound is granularized through an FFT. The spectrum is first transposed and then reduced to a sequence of sound grains realised with an random selection of a few spectral bands which is renewed with a period of 72 ms (micro-Mel). An example

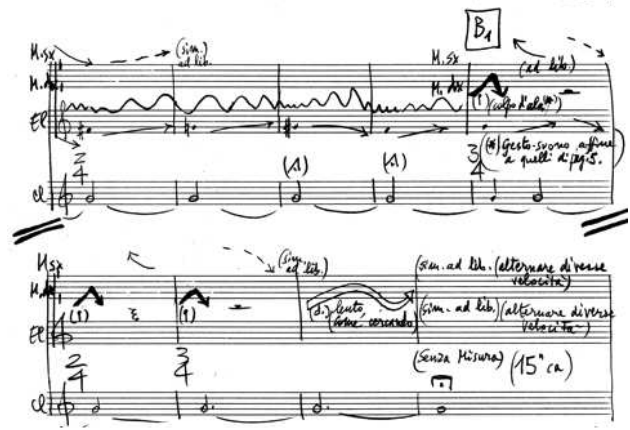


Figure 5. *Ogni Emozione dell'Aria*, score at page 9. Here *Dissolution_B* is used.

of *Dissolution_B* is shown in Figure 5. Here both hands are controlling the sound of a long note as explained in Tab.1.

The movement of sound in space is also a really important part of the sound processing: the sound of the contrabass clarinet is placed in space as if it was a point on a Cartesian plane with axes left-right and front-rear. The right-left dimension is managed through a linear mapping between gesture and result, while the front-rear control is constructed with a so called “rubber band algorithm”. The gesture sends the sound away to the rear position; the sound comes back slowly to a rest position unless there are new upcoming sounds creating a new tension sending it again far away. Performance gestures are thus available to the composer who then selects and notates them precisely in the score in order to replicate performances in a deterministic way.

Therefore, *Ogni Emozione dell'Aria* succeeds in transforming sonification in genuine musical processes (a complete video of the performance at the *Sound and Music Computing* conference in Padova can be found in [9]).

2.6 Suono Sommerso by Roberto Fabbriciani

The genesis of this work began when noted Italian flute player Roberto Fabbriciani intended to explore the expressive possibilities of the hyperbass flute. This instrument was invented by Fabbriciani in the eighties following suggestions by composer Luigi Nono. The peculiar property of the instrument is to be able to play very low frequencies, around 20-30Hz. It is a very large instrument made by plastic pipes and it can be tuned to just one note at a time. That is the main way it has been scored for in large orchestral works, where it was used as a sort of pedal note or choir (cf. for example *La Pietra di Diaspro* by Adriano Guarnieri). The player only needs to hold the instrument

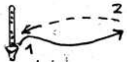

Composer annotation	Motion Capture and Live Electronics
<p>The right hand seems to help the sound of the clarinet to come out and then back in again</p>  <p>(cf. Figure 4)</p>	<p>Right hand: X: <i>Diss.A</i> output level Y: <i>Diss.A</i> transposition Z: space Left-Right M: space Front-Rear</p>
<p>The right hand is again moving the sound “out” of the instrument, but then it moves it also to a higher pitch before going back.</p> 	<p>Right hand: X: <i>Diss.A</i> output level Y: <i>Diss.A</i> transposition Z: space Left-Right M: space Front-Rear</p>
<p>Both hands are controlling the sound, since the performer is playing a long note and carrying the instrument with his knees. (cf. Figure 4)</p>	<p>Right hand: Y: <i>Dissolution.B</i> level Z: <i>Diss.B</i> reverberation level; Ring level</p> <p>Left hand: X: <i>Diss.A</i> output level Y: <i>Diss.A</i> transposition; space Left-Right Z: space Front-Rear</p>

Table 1. *Ogni Emozione dell’Aria* sonification mappings

with his hands, all the sound he is producing is coming from the air of his lungs and can hardly be rapidly modulated. Roberto Fabbriciani wanted to explore the possibilities of having such an instrument as a solo player, able to be expressive and intense. In order to do so, a motion capture system has been used to detect the positions of the hands that could control some live processing which adds several layers of spectral expansion, distortion, and pitch transposition. Other specific gestures are used to move sound in space through a spatialization system. ([10]) is a short excerpt of this work which illustrates these concepts. In this case, data sonification represents a true instrumental extension which augments the capabilities of a specific instrument, thus making it suitable for solo performances and recitals. The hands movements have been associated with pitch, timbre and spatialization controls. The right hand movement was associated to pitch and timbre control.

The movement of the right hand along the X axis (high-low pitch): sound transposition in a two-octave range. The played note can be transposed one octave up (the hand is moved to the right) or one octave down (the hand is moved to the left). The movement of the right hand along the Y axis (low-high) controls the timbral brightness. The played note is unchanged (low position) and becomes brighter if the hand is placed higher. The movement of the right hand along the Z axis (rear front): sound inharmonicity. The played note is unchanged (behind position) and becomes more inharmonic while moving the hand forward (towards the public). The movement of the left hand was associated to the control of the sound spatialization. The movement of

the left hand along the X axis (right-left) controls the left-right spatialization (from the point of view of the listener).

The movement of the left hand along the Z axis (rear-front) controls the front-rear spatialization. The right foot is used to push a pedal that activates a bank of delay lines that extend and multiply the sounds. This bank is made by 5 delays with feedback with the following delay times: 3, 3.8, 4.7, 6.3, 7 seconds. ([10]) is a short excerpt of this work which illustrates these concepts.

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3. DISCUSSION

We will now proceed to shortly analyse these examples maintaining the separation between composition and performance because they introduce different aspects of the interaction between sonification and music. We will leave some overall remarks which apply to both domains for the paragraphs at this section (cf.3.3).

3.1 Compositional examples

The interesting musical qualities of the *NASDAQ* pieces are strongly related to the specific medium-to-large scale time dimension of most financial stock entries. Very synthetically, the nature of these data set and their progress relates easily and strongly with musical voicing and contrapuntal devices such as thematic reiteration, canonic imitation and sequencing. Furthermore, the timing is highly “musical”: the variation rate is highly dependent on transactions that imply human reaction times to some extent, thus resulting in medium-to-large scale evolution patterns that relate strongly with musical form and development. Furthermore, these evolution patterns are clearly interlocked over different time-scales, thus turning into particular cross-scale similarities that are so close to musical structure (e.g. augmentations, diminutions, etc.). It is important to notice that in this case the data is able to provide the time structure and evolution completely autonomously from human intervention, leaving the “compositional freedom” to operate on specific aspects, such as the choice of timbre to assign to each stock and the global *tessitura* range of the work. That is to say that the stock market data has some intrinsic “musical qualities” – musical time in the first place, and thematic imitation as a more subtle characteristic – which can be put on display with no transformation whatsoever. This means, in turn, that the “sonification function” is not jeopardised by compositional decisions and that it

may still be taken up for display purposes independently from the compositional purposes of the installation. At the end of the day, these are the characteristics that make the *NASDAQ* works musically interesting and convincing in the first place. The deep environmental and varied connotational universe that financial markets generate on most people add a welcome interesting programmatic layer to the music – but this layer would be fairly senseless without the strongly musical structure described above. It is unfortunate that a 2–3 bars excerpt does not convey any musical sense because the *NASDAQ* works unfold on fairly large time scales: the *NASDAQ* works can be only enjoyed in their live setting, when stock markets take place with all their numerical roughness.

The Radioactive Orchestra case offers a very different scenario: the data (photon decay happening at atomic level) has no relation whatsoever with the macrocosmic world of human perception in which music takes place. Thus, the composer(s) must inevitably resort to a large number of wide–stretched translations and transpositions to extract some musical sense out of it. In the end, what is left of the original data is some sort of “musical signature” which is indeed unique for every isotope; however, such “musical signatures” are, in themselves, too short and too simple to gain an interesting musical status of some sort (they can hardly be called *leit-motives* because of their lack of structure and variability). The short excerpt presented in



Figure 6. A transcription of a brief *The Radioactive Orchestra* excerpt created using four different isotopes

6 shows the density of these cellular repetitions outlining their short–lived existence (both in physics and in music, although transposed to a different time–scale). So the only choice the composer is left with is to reiterate such signatures over and over (in a completely artificial and simulated way, because the time dimensions in which those decays actually happen are completely unrelated to musical time space), possibly picking some timbral configuration out of an (arbitrary) transposition of the emitted light spectrum. All the other parameters (starting pitch, tempo, rhythmic structure, etc.) are arbitrarily chosen by the author(s). In this context the functions of data sonification are completely lost and the piece carries a purely musical

signification (if any). The fact that the same set of data can produce radically different musics (there is even a yearly contest for web produced music) reinforces this overall impression. Inevitably, the “programmatic” content of music (i.e. using music to make a sonic display of nuclear physics processes) ends up being much stronger than the musical message itself, since for most people the notion of “what is nuclear physics” is quite mysterious while equally tempered melodies carried out on (mostly harmonic) synthesised percussive sounds are indeed more commonly palatable.

3.2 Performance examples

When it comes to performance, it should be noted that “true” sonification of instrumental gesture is already a well–established technique that is used for several applications, ranging from physiotherapy (cf.[11]) to instrumental pedagogy (cf.[12, 13]). However, when sonification is used in performance its usage boils down to three fundamental schemes:

1. the sonification of non–instrumental gestures which augments the actual playing
2. the sonification of extra–instrumental gestures, added by the composer to enhance the polyphony of the piece
3. the direct sonification of specific instrumental gestures

The hyper–bass flute improvisations by Roberto Fabbriani (cf.2.6) clearly fall into case n.1: the hyper–bass flute is an instrument that needs only the mouth to be played, while the hands remain free from (direct) performance duties. Fabbriani can then use his hands (tracked by motion capture) to control the overall live–electronics processing of the sound. The sonification establishes here a strong visual (and causal) connection to the resulting sound which is a far better option both for the performer and the public than a separate live–electronics performer idly sitting at a console moving faders and pushing buttons.

Ogni Emozione dell’Aria by Claudio Ambrosini belongs instead to category n.2. The form of the piece is divided in sections, and the instrumental writing is designed to allow the performer to take turns as to which hand is actually playing the keys of the instrument, while the other is kept free to add a further contrapuntal voice in the performance. In the last section the performer does not need the hands on the instrument at all, thus adding two other sources of voicing in the music. Of course, in this case sonification enables the composer to add a metaphorical and dramaturgical layer through these gestures; in the case of *Ogni Emozione dell’Aria*, the sonified gestures build up to represent the wings of a flying bird – while continuing to serve musically through the sonified capture of the wrists’

movements.

The third case is more common in the music literature: it can be found, for example, in pieces by Adriano Guarnieri or in the improvisations by Giancarlo Schiaffini on trombone. This latter instrument actually provides a good case in point for case n.3, because the gestural component of its instrumental playing (i.e. the movement of the *coulisse*) is particularly well suited for tracking and successive processing.

3.3 Overall remarks

Though incomplete and undoubtedly un-systematic this short enumeration of case studies clarifies one important point: if we attempt to combine together sonification and music, it means that we accept the challenge to preserve both functions and purposes (i.e. sonification *and* music). In the four examples that we have described above, only the first one (Cifariello Ciardi's *The Sound of Nasdaq*) can actually be considered successful in this endeavour. The many performances of this piece and its descendants are certainly not the only indicators for this success: the interest of the financial world for this piece as a useful tool to monitor the stock market when the visual channel is already saturated with information means that the work has been successful in combining both musical and sonification functions.

The other three works *make use of sonification practices and tools* but their purposes are strictly musical – they would not be used as a scientific display of any sort simply because they do not fit any particular scientific criterion in their construction. We could probably repeat the experiment with sonification displays which might have a “musical bend” but it is foreseeable that the end result would not change (though opposed in sign), because the purposes of music and sonification are substantially different.

It is interesting to clarify, then, *what* it takes to obtain a successful result in combining together sonification and music: the data needs to have some “musical” qualities which must lend themselves to an easy mapping into a musical work; while just about anything today can be transformed into a sound event, the “archetypal” characteristics of music (imitation, motivic development, counterpoint, etc.) and their proper “musical timing” are actually the critical aspects to make it “palatable as music” of some sort. If the mapping is not straightforward enough, it loses the possibility of being fed back into the sonification function.

4. CONCLUSIONS

This paper intends to be a contribution to the controversial debate regarding the boundaries of two specific disciplines, namely sonification and music composition. Our intention was not to give a definitive answer to whether or not these two disciplines do actually have anything in common, but rather to try to enumerate the conditions under which such communion can take place replacing a naïve generalisation with some sort of preliminary elaboration and observation.

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