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## Feedback on the creation of a scientific show using immersive sound

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### ABSTRACT

*This presentation is devoted to feedback on the creation of a scientific show produced in collaboration between two acoustic laboratories, musicians and a loudspeaker manufacturer. The aim of the show is to simply explain sound perception to a wide audience using an immersive sound system. The presentation focuses on the creative process (including scenario writing, musical compositions, choice of technical solutions for the audio rendering) and the compromises made between scientific rigor and the artistic aspect. The various phases of the work carried out over almost two years are explained in order to formalize the creative process and the need to find a specific method that is suitable for both artists and scientists.*

### 1. INTRODUCTION

Arts and science projects can cover a wide range of topics and themes, combining creativity with scientific methods. Projects involving the arts and sciences can be realized as concerts, festivals, or exhibitions. They cover a variety of subjects, including ecology, biology or quantum physics. Certain projects, like those that explore immersive sound [1] or the connection between music and the brain [2], are devoted to sound and music.

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The relationship between acoustics and music is extremely old [3], and music remains a very good candidate to explain acoustics in a different way than the traditional teaching approach used by scientists. This encourages musicians and scientists to collaborate and to develop arts and science projects dedicated to different aspects of acoustics or sound, for example inform pupils about the danger of sound played at high levels [4].

In a different initiative, musicians and acousticians from Le Mans University in France worked together to develop a novel idea for presenting acoustic concepts to a broad audience, which included adults and students. This project, dubbed "scientific concerts," was launched in 2009 and uses art, primarily music, to demonstrate the physics of musical instruments as well as the physical properties of sound, such as intensity, pitch, and timbre. These shows allow the audience to alternate between concentration and entertainment as two scientists (who are also musicians) and three musicians use a combination of scientific talks, live demonstrations, and musical interludes to illustrate acoustic concepts.

The concept of the "scientific concert" has evolved recently to incorporate the use of spatial sound to enhance both the realism of auditory scene and the immersive experience for the audience. This gave rise to the idea of creating a "scientific concert" that highlights various aspects of human hearing. This paper details the process of creating and presenting this scientific concert at the sound- focused "Le Mans Sonore" science and art festival [5].

## 2. DESCRIPTION OF THE PROJECT

The project's planning and execution are covered in this section. It begins with the scientific aspects and concentrates on the approach taken to facilitate cooperation between scientists and artists. The project's timing constraints were a serious limitation. During the project, which began in March 2022 and had to be completed by January 2024, participants could only meet a few times per year, each session lasting a few days.

### 2.1. Initial idea

2019 saw the introduction of RESSAC, a new art and science festival by the University of Brest in France, which aims to showcase various sound-related activities and promote art and science in general [6]. The initiative detailed in this paper, a collaboration between two French research institutions, began in 2021 with a proposal from the director of the RESSAC festival. These institutions are the Acoustic Laboratory of Le Mans (LAUM, UMR 6613, Institut d'Acoustique - Graduate School (IA-GS), CNRS), which works on various physical aspects of acoustics and supports the Ophonius art and science project, and the sound perception team of the Lab-STICC (Laboratoire des Sciences et Techniques de l'information de la Communication et de la Connaissance CNRS, UMR 6285) in Brest. In 2009, the Ophonius initiative "scientific concerts" was founded with the goal of combining science and art to explain the fundamentals of acoustics. With the assistance of three professional musicians, it is carried out by two acoustics teachers-researchers who are themselves musicians. Given that the "scientific concerts" addressed the physical characteristics of sound in the two previous projects [7], it appeared logical to build a new project led by Ophonius and the sound perception team that focused on the principle of hearing and how sound is heard (such as auditory scenes, the anatomy of the ear, and the perception of frequency, intensity, and timbre).

### 2.2. Scientific aspects

The project's initial phase was to provide each member of Ophonius with a fundamental understanding of hearing, the same terminology, and nearly the same level of scientific education for musicians and acousticians. To get ready for this, the project's multiple performers attended a two-day lecture on hearing (learning phase at time  $T_0$  in figure 1). The lectures covered the same

material as those given to students pursuing audio bachelor's and master's degrees, which made them challenging for musicians who are not usually exposed to such material (sound localization, auditory scene analysis, perception of intensity, pitch, and timbre). Despite this, the musicians were very interested in these topics and engaged in the session, demonstrating that these kinds of sessions could be held in music schools.

As the session was coming to an end, it was agreed to work with a scientific referee from the sound perception team, whose role was to confirm the proposals made by Ophonius members.

### 2.3. Art and science

The creative process began as soon as the scientific details were understood and the various performers could converse with each other without difficulty. This procedure was broken down into three stages:

- brainstorming, called creative phase, where a ton of ideas came to light,
- structuring, where the final scientific contents were specified, structured and finally arranged in a scenario,
- realisation phase during which the scenography was designed and built, the audio system was tested and the entire show finalized.

The entropy of these three phases as perceived by the team is displayed in figure 1 as a function of time, but it has not been properly quantified.

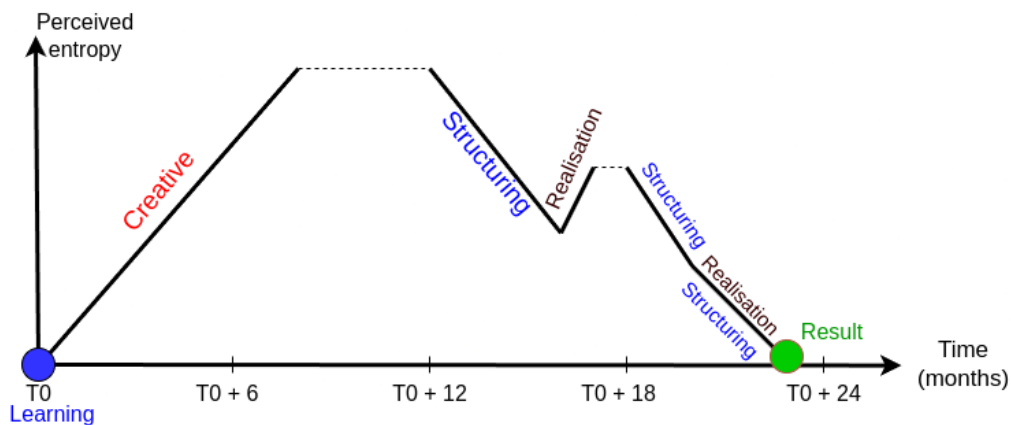


Figure 1: View of the perceived entropy of the three different phases along time.

**Creative phase** Unlike the previous two projects [7], which included live music excerpts, experimental live demonstrations, and scientific presentations with slides on a screen, the goal of the brainstorming session was to come up with a new concept. Scientists and artists came up with a number of thoughts to create a new idea, presuming that the stage would be transformed into a laboratory and that the two scientists would be researchers rather than teachers.

Scenography concepts were evaluated using basic objects or audio systems in three sessions that spanned eight months and nearly eight working days combined. At the end of this period, the various actors proposed general scenography ideas, the use of a voice-over, the use of large physical objects on stage to illustrate different phenomena, the use of a spatial sound system to illustrate space perception, fewer oral presentations, lab experiments on stage, etc. These contents were codified into an unorganized text, called draft. It was a list of numerous items that were essentially repeated across the various sessions. Musicians also decided to compose specific music to illustrate specific scientific contents (masking effect, sound level, perception of space).

During the brainstorming process, an ethical challenge arose: given that the show is about sound perception, is it feasible to conduct formal perception tests with the audience in real time? If yes, how can we conduct these experiments? As it was not possible to guarantee the anonymity during the tests, it was decided to avoid doing formal perception tests.

**Structuring phase** Following the brainstorming phase, it became apparent that the methods used during the brainstorming phase could not result in a speedy and effective organization. As a result, it was decided to divide the project into two teams: one for the scientific aspects (contents, organization) and one for the music (compositions, rehearsals). This made the project rather challenging for scientists who are also musicians.

The scientific referee and the scientists-musicians collaborated to determine the main scientific themes and to develop a scientific scenario that clarifies the concepts for a general audience. To specify the audio system to be used, the scientists-musicians worked with an audio company that develops a spatial audio processor, that is comparable to WFS (wave field synthesis) in its basis [8]. The scientists-musicians took into account the most significant recommendations made by the artists throughout the creative process, focusing exclusively on concepts that appeared more than once in the draft.

Finally, they provided a script with chapters that blended science, music, and scenery (table 1) at the conclusion of the first period (figure 1,  $T_0 + 16$  months). They also provided general guidelines for the performance after consulting with the referee and the audio company, determining that a trained audio engineer was necessary. These parameters included the necessity to keep the audience in the dark as much as possible to intensify the listening experience, laboratory experiments conducted on stage, a spatial sound system, and the development of electroacoustic compositions between chapters.

Aim	Scenery	Music
1- Perceive space		spatial sounds + voice over Marching band
<i>Transition</i>		<i>Electroacoustic composition</i>
2- Anatomy of the ear	Giant ear (Fig. 2)	
<i>Transition</i>		<i>Electroacoustic composition</i>
3- Sound level	Real time sound level meter	specific musical composition illustrating increasing sound level
<i>Transition</i>		<i>Electroacoustic composition</i>
4- Frequency definition	Giant simplified tuning fork	
5- Spectrum definition	5 giant tuning forks	
<i>Transition</i>		<i>Live music and real time spectrum</i>
6- Time envelope	String to represent the envelop	recorded music that is played backwards and forwards
<i>Transition</i>		<i>Live music introduced by time inverted sound</i>
7- Fletcher curve Demonstration of masking	Physical giant octave band analyzer	Recorded sine waves at different levels
<i>Transition</i>		<i>specific musical composition with masking effect</i>
8- Perception of space	Giant head	playing music around
<i>End</i>		<i>specific musical composition with spatial effects</i>

Table 1: Structure of the script provided at the end of the first structuring phase (kept for the following of the project).



Figure 2: View of the items that symbolize the human ear, including the pinna, ear canal, cochlea, ear drum, ossicles in two dimensions, auditory nerves and brain.

**Realization phase** Nearly in the middle of the project, the realization phase began following the structuring phase, which was finished to reduce the amount of information generated during the creative phase. There were two sessions for the realization phase: a short one that happened between  $T_0 + 16$  and  $T_0 + 17$  months, and a longer one that happened at the end of the project. The following tasks were completed during these two realization phases:

- test the scenario live and gather input for potential future improvements,
- finalize the scenario—which included voice over, item usage, experiments, music, and explanations—between  $T_0 + 20$  and  $T_0 + 22$  months (1 month before the deadline).

Then, effort was put into the sound aspects in order to:

- Check the spatial audio quality of the sound system. In order to determine whether 24 small sized loudspeakers in a medium-sized room could be employed, the WFS based Sonic Emotion Wave I processor [9] was first used ( between  $T_0 + 16$  and  $T_0 + 17$  months).
- Choose a spatial audio renderer for the final presentation. The FletcherMachine [8] was employed to get the required result and needed two days of installation (Figure 3). This system, in its Traveler version, enabled to use a loudspeaker setup consisting of :
  - a main frontal system based on 5 Adamson CS7p point source loudspeakers hanged above the stage front
  - a front field system consisting of 7 Adamson CS7p laying on stage floor and arranged in horizontal mode thanks to its rotatable waveguide, with a spacing of 2 meters, allowing for lowering the auditory image
  - a surround system consisting of 12 Adamson IS5c small sized loudspeakers with a spacing of 2.3 meters between sources.
  - 4 Adamson CS119 Subwoofers for the low frequency range.
- Select an easy to use Digital Audio Workstation that fit the needs in terms of real-time management of sound creation and spatial effects. Usine Hollyhock [10] was chosen. Usine

and mixing console audio outputs fed the FletcherMachine inputs with MADI format, then spatially treated audio outputs fed the loudspeaker system in AVB Milan format. In the end, the loudspeakers system needs a little time to be installed and tuned but remains simple.

- Create the electroacoustic music pieces with spatial effects that would be used to break up the "chapters."
- Record the different voices providing the final and temporary voice-over. For the audio demonstration, record the various sounds.

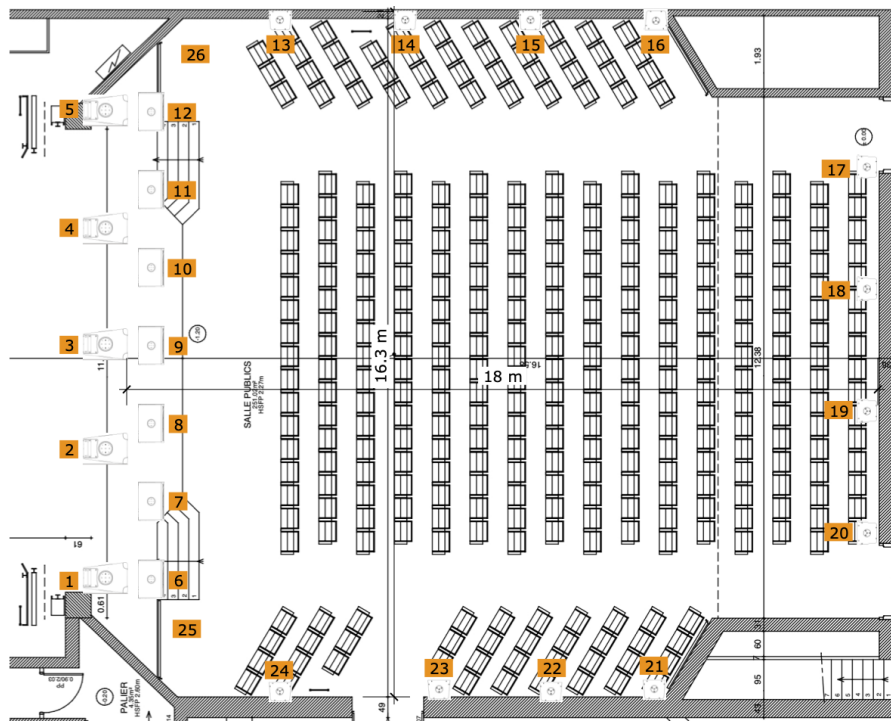


Figure 3: View of the implementation of loudspeakers with the Fletcher machine.

More specifically, in order to quantify the auditory threshold curve and demonstrate masking effects as presented in table 1 at step 7, an experiment was conducted with the use of a large format analyzer. This spectrum octave band analyzer was constructed in this experiment utilizing paper rolls on eight vertical bars; each bar representing one octave and each roll represented three deciBels (figure 4). Since different people a priori perceive different sound levels when pure tones are played, it was challenging to determine the sound level represented by each roll of paper in order to obtain a realistic auditory threshold curve while conducting experiments with a real audience.

Ultimately, the effort focused on the scenography, specifically on the creation and assembly of objects. Both the enormous head and the enormous human ear (see figure 2) were made to be readily transported and moved around the stage. Additionally, five giant tuning forks, the largest of which was almost 80 centimeters in length (vibrating length of 50 cm), were designed using Comsol and built using a water cutting machine (figure 5).

### 3. RESULTS

At the end of this 22 months time, the project was exhibited to a big audience (500+ combined people) and pupils (almost 500) in the scope of Le Mans Sonore 2024, a cultural event for the general public that combines art and science [5]. The informal comment from the audience was very encouraging. An important fact is that the experiment performed to assess

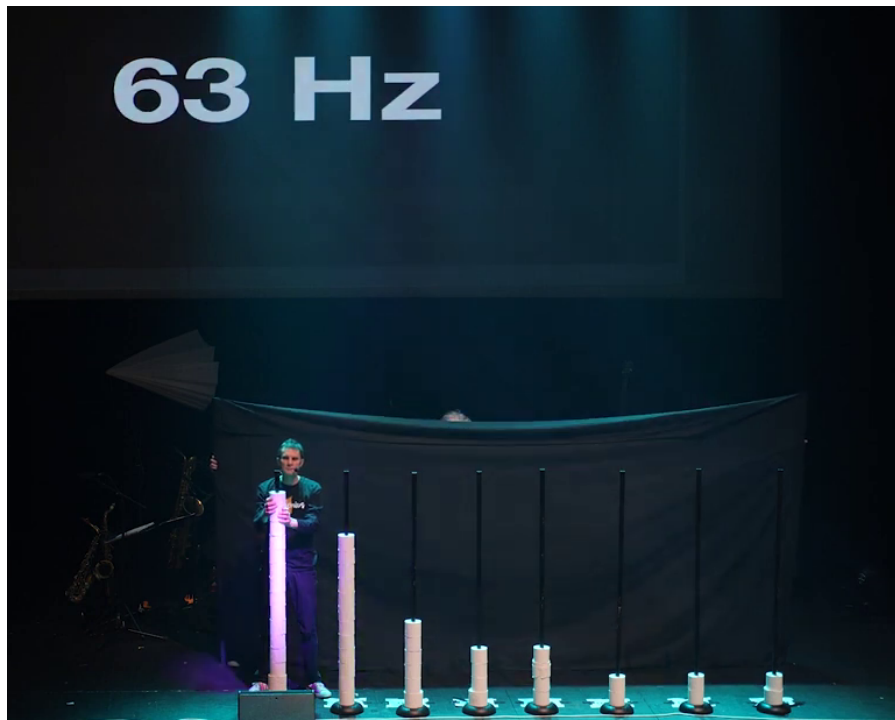


Figure 4: Giant octave bands analyzer to quantify experimentally auditory threshold.

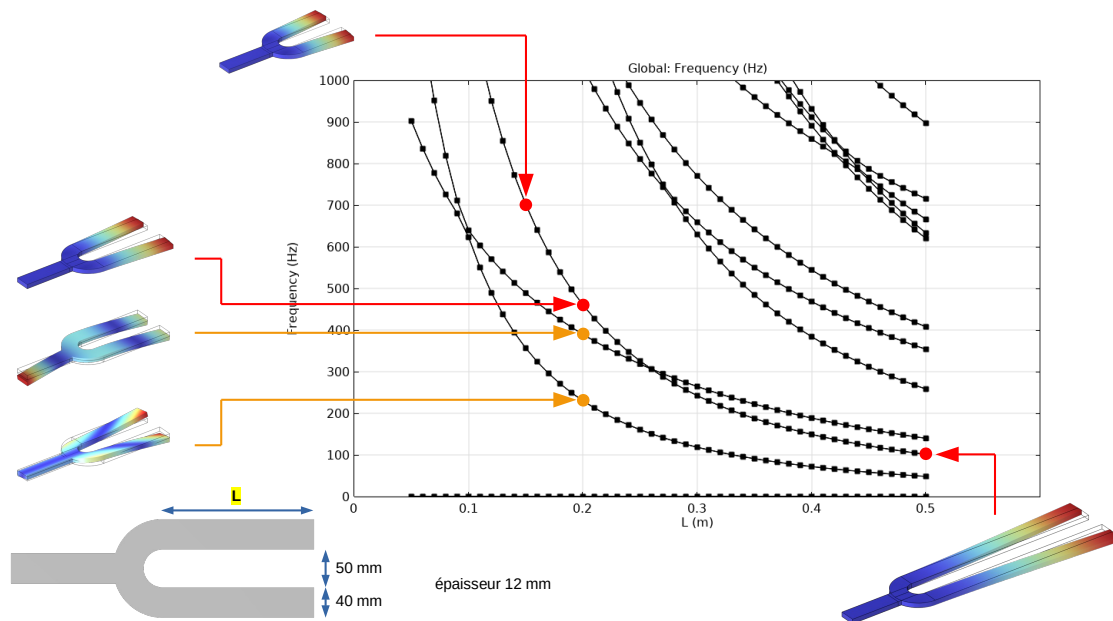


Figure 5: Tuning fork design using Cmsol

the hearing threshold allowed us to distinguish between pupils and adults, with pupils hearing at lower levels. The usage of a spatial and immersive sound system gives good results, despite the fact perceiving the spatial naturalness wasn't spectacular for the audience as the performer's voices and acoustic sources remained in the frontal area. Only the sound design pieces exhibited a strong spatial information. We nevertheless were able to properly demonstrate the effects of diminishing direct over reflected sound ratio when an acoustic source is moving away in a reconstructed room acoustics thanks to the FletcherMachine virtual acoustics engine.

Finally, the scientific substance that is presented in the program is significantly less than that which was provided throughout the training phase. Many topics, such the perception of intensity



and inner ear (hearing cell) function, have not been covered. This demonstrates that there must be some compromise when communicating scientific information to a broad audience. An alternative strategy would have involved turning a scientific idea—like the frequency coding of hearing cells, for instance—into an artistic work of art that employs the frequency coding paradigm to produce novel sounds.

#### 4. CONCLUSION

This paper describes the process of developing an art and science presentation, namely a scientific concert on sound perception. Based on 15 years of experience and around 100 such concerts, it was completed in nearly two years with scientists-musicians, scientists specialized in perception, musicians, technicians (light, mechanics), and a company and audio engineers specializing in 3D sound. The entire process was broken down into numerous phases with a lot of back and forth: brainstorming, idea structuring, script and musical writing, object creation, voice-over writing and recording, staging and light composition, and finally performance. It requires a diverse set of skills, including acousticians who specialize in hearing, musicians, composers, technicians (lighting, mechanics), and audio engineers. The show was well-received, thanks in large part to its innovative visual and audio elements, but it has limitations in terms of the scientific knowledge that can be conveyed to the public. For scientists, the creative process has an impact on teaching, resulting in the first simplification of complicated phenomena and the generation of ideas for student projects, for example. Such projects are also appealing to prospective students. The future plan is to spread this idea to many concert halls, which may necessitate a lightening of the electroacoustic system (for example, octophony), which needs to be investigated.

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