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## Sonaging<sup>1</sup> the workspace: a user-centric workshop.

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### ABSTRACT

*The Laboratoire d'Expériences du Bureau (LEB) is designed as an experimental, educational and experiential space for workspace designers. Its purpose is to provide a better understanding of the implications of design choices on the likely sound experience of people at work. Equipped with a set of mobile acoustic devices, an sound ambience generator software and a multi-channel sound system, it reproduces a range of sound phenomena and immerses listeners in a range of sound ambiances in a work situation. Users are helped to gradually become aware, through sound experience, of the implications of their design choices. The process is part of a research approach to the design of sound devices based on the ideation of new paradigms and modelling hypotheses. This article intends to present the key concepts of the project, how it differs from other comparable approaches, its state of progress as well as the limits and difficulties encountered.*

### 1. INTRODUCTION

In 1989, the French office furniture manufacturer CLEN introduced the concept of the Office Space Laboratory, a workspace dedicated to experimentation in situ, at its factory in Saint-Benoit-La-Forêt in Touraine. Since 2000, CLEN has increasingly designed and manufactured acoustic products, notably through its subsidiary Manade, and has faced growing challenges in providing relevant answers to the complex questions posed by managing the auditory experience at work. Since then, this field has become extremely competitive, while the solutions proposed often remain debatable. At best, they conform to current standards, which, even though they have recently progressed towards better alignment with activities, are not always well understood. In 2020, the CLEN Group partnered with the CRD ENSCi - ENS Paris-Saclay to create the [S'entendre] Chair, a collaborative research framework in experience design for shared workspaces, with the aim of designing and modelling alternative approaches to improve the "sound experience"<sup>4</sup> experience at work. Among other exploratory research and development efforts, we have designed and modelled an Acoustic Workshop in the new LEB premises in Rueil Malmaison. This project and the questions it raises are the subject matter of this article.

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<sup>1</sup>'Sonaging' or 'Soundgining', a neologism for the sound equivalent for imagining. [1]

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<sup>4</sup>Stands here for the experience of sound audition as well as sound expression

## **2. PROJECTING THE SOUND EXPERIENCE**

In response to CLEN's initial request for a space dedicated to the presentation of its acoustic products, the [S'entendre] research team proposed the creation of an immersive space allowing customers to project themselves into the sound experience. The issue of acoustic comfort in office spaces is a subject that has long been explored by acousticians and planners, especially as it is now associated with a transformation of spaces, which are both more open [2] and more 'agile' in their ability to accommodate different activities and heterogeneous work schedules [3]. Faced with these transformations and the multiplication of technical solutions on offer, we thought it would be interesting to test a device that would differ from a demonstrator in that it would be both adaptive and immersive, allowing us to work on the acoustics and sounds of a space through the experience and feeling of sound, and to go beyond the notions of discomfort and noise [4] which are all too often the only criteria associated with the acoustic problems of workspaces. The immersive space would therefore make it possible to project a sound experience, rather than a technical solution associated with discomfort, and thus to instill in designers and planners a culture of working with space through sound, beyond noise. Experiencing the sound in different usage configurations, materials or fittings could also provide a more 'embodied' understanding of acoustic studies. Additionally, this approach enhances comprehension of solutions proposed, which are sometimes difficult to implement due to the lack of knowledge and tools for those involved in workspaces. In this respect, the notion of sound experience that we discuss here takes on its full meaning as a design tool.

### **2.1. Acoustic tools : history and innovation**

The roots of modern acoustics can be traced back to the study of space and furniture. Wallace Sabine, in his early experiments, discovered that increasing the amount of cushioning led to a decrease in reverberation time. His combination of experimentation and experience paved the way for advancements in acoustics, initially through experimentation and later through measurement. Today, additional tools are available to tackle new challenges. Our design aims at facilitating the exploration of the impact of various choices (furniture, usage patterns, materials, spatial configurations) on the acoustic environment of a flexible space. The objective is not only to offer a practical tool for understanding the acoustics of spaces but also an experimental platform for testing, exploring, and evoking specific acoustic effects in real-life scenarios.

## **3. THE HYPOTHESIS OF AN IMMERSIVE SPACE**

We are therefore working on the hypothesis of i) a device which would make it possible to transmit a 'sound culture' based on sensitive experience, ii) to address the stakeholders in the various professional environments who are interested in workspaces, iii) to go beyond the notion of absorption which currently prevails over other issues, in order to address the notion of sound experience at a finer granular reading level.

### **3.1. The sound ambiances at work**

To better understand 'sound ambiances' in workspaces, we need to clarify some key ideas about how we perceive and interact with sound in relation to space. For example, we can experiment with sound 'effects', such as 'coupling' [5], to manipulate the connection between space, use, and material precisely. Similarly, by categorising acoustic links between spaces [6], such as 'articulation' or 'inclusion', we can better understand how sound affects our environment. These insights can guide us in designing office spaces that express specific sound intentions, using tools like sound models to articulate our expectations effectively.

### **3.2. Labels, absolute standards and activity-based standards**

Due to their limited exposure to noise, workspace users are not protected by acoustic regulations, which mainly target direct health issues, like long-term or high-level noise-induced deafness (above 85 dB). Developers strive to adhere to labels and standards as much as possible. The GIAC 2018 Single Acoustic Indicator (IUA [7]) assesses the quality of the sound environment in indoor spaces, taking into account the properties of the premises (background noise, saliences, reverberation) and the type of activity. Voluntary standards, like NF S31-080 (2006) and NF S31-199 (2016), set performance criteria for offices and open-plan areas based on activity types. NF ISO 22955 (2020) provides an international guide for open-plan office acoustics, considering a large set of activities. It distinguishes 4 types of activity: communication with the outside world, collaborative work, slightly collaborative work, (where concentration is required) and reception of the public, as well as 2 situations of uncertainty: not yet known activity and several activities in the same space. However, field observations reveal fluctuating noise levels and silence needs over time, often leaning towards uncertain activity situations due to rapid changes. This trend has increased considerably with the recent spread of teleworking and hybrid working, which significantly upset the balance of sound at work. Activity Based Working (ABW) and the Flex Office "Anytime, Anywhere, Any device, Any content" are reshuffling the deck even further, encouraging us to anticipate needs more effectively. 'Working environments are very often the response to a need at a given moment in time' [8]. Activity-based and flexible working models, as noted by Bertier, require anticipatory design, considering evolving organisational needs. Pillon [9] emphasises the complexity of aligning activities with pre-designed spaces, highlighting the challenges of integrating dynamic sound experiences into design responses. Acoustics now play a central role in development projects, yet no universal solution exists, leading to the proliferation of temporary solutions like pods. To provide more sustainable solutions, we therefore hypothesise that involving workspace users in design decisions and enabling designers to project themselves into the experience are crucial.

### **3.3. Other immersive experiences for workspace design**

Many acoustic laboratories focus on measuring properties, mostly absorption and insulation, rather than providing immersive sound experiences for non-experts. For example, the Finnish Institute of Occupational Health, Indoor Environment Laboratory: Turku University of Applied Sciences (TUAS), collaborates with manufacturers to measure and improve furniture. Educational tools exist, but are often private. The Ecophon Saint-Gobain Laboratory offers a simulation tool for modifying acoustics based on materials, and a educational web tool called 'The Lab' [10] which provides a knowledge base on acoustics issues and enables user to compare different spaces (hospitals, classrooms, offices, etc.) with or without absorbent coverings (walls and ceilings). Terms like 'experience lab' or 'living lab' denote spaces for experiential demonstrations and design. Saint-Gobain Recherche's Domolab (2011-2016) offered the opportunity to hear the effects of acoustic materials inside micro-architectures created by Sismo designers. The tools of Ircam's Acoustic and Cognitive Spaces team, like the Spat, focuses on the analysis and auralisation of sound scenes. Manufacturers showcase acoustic demos on their premises or at events like Workspace Expo [11]. The Italian manufacturer Caimi YouTube videos show the effectiveness of its Snowsound products and as other companies, such as CLEN, have created its own tools for calculating RW acoustic attenuation or RT reverberation time. Most of these demonstrators maximise the differences between resonant and absorbent spaces to highlight the absorption efficiency of the products, but they rarely include acoustic measurements, and do not take account of usage contexts and individual variations. Variable acoustics have long been used in theatres and auditoriums, thanks to removable curtains and other techniques and materials allowing to modify the absorption coefficient of walls and furniture [12]. There are 3 main approaches: variable absorption, room volume variation and active control. These methods

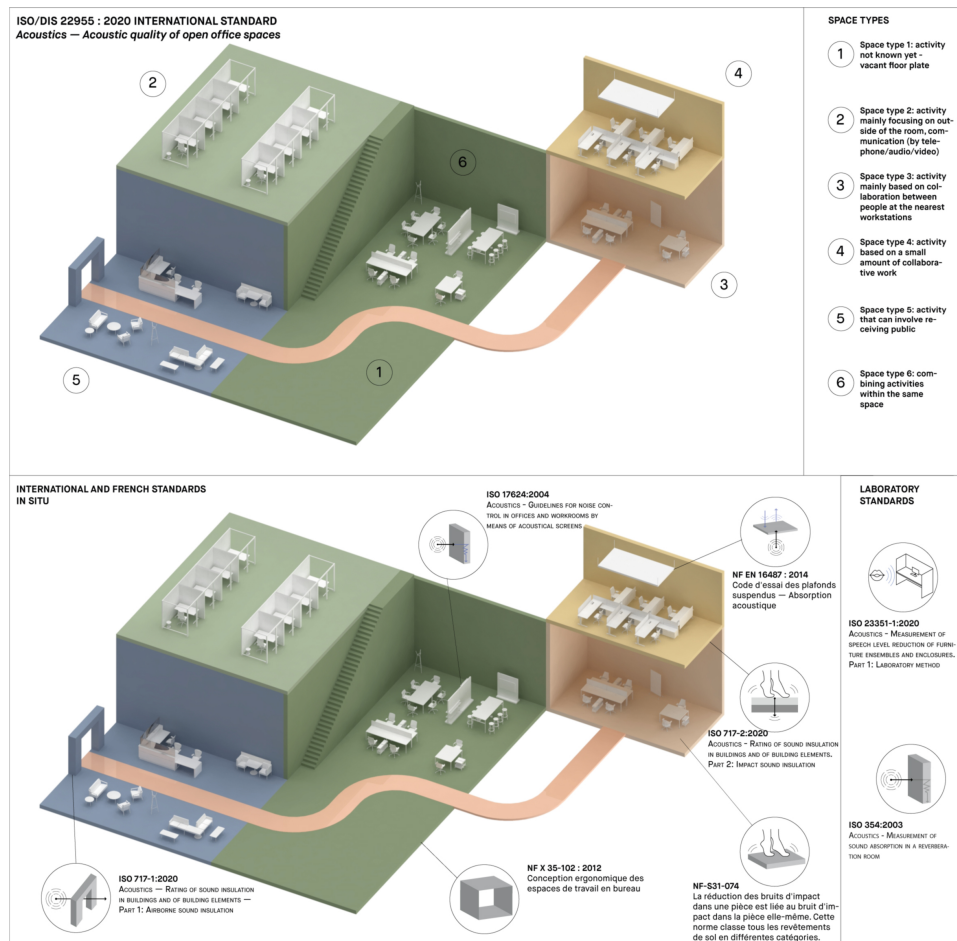


Figure 1: Two visualisations of a typical workspace model. : 1. model of a typical workspace meeting the requirements of the ISO/DIS 22955 standard. 2. on the same model, the different acoustic design standards.

generally offer adaptable solutions, though they're typically costly and reserved for high-value spaces, mainly auditoriums and laboratories. For example Ircam's 'Espace de Projection' is the largest concert venue that has been entirely equipped with rotating 'periact' acoustic variable prisms with 3 faces (absorbent, semi, resonant) since 1978. Therefore, our goal is to offer tailored solutions that address the challenges of workplace sound experience, closely mirroring real work scenarios.

### 3.4. Everyday acoustic reality

Manufacturers and workspace designers typically address acoustic issues in two ways: through simplified, accessible approaches aimed at a wide audience (e.g., Baux's book of acoustics, Buzzi space RT60 app, Abstracta's acoustic guide and VR tool), or through quantitative studies on materials. However, in many cases, manufacturers tend to focus solely on testing and promoting absorption as the primary criterion (see Figure 2).

This classification and presentation of acoustic issues tends to standardise experience, reducing it to a restricted list of situations, often characterised by opposing scenarios and focusing solely on absorption as a solution. Although useful for grasping the extremes and limits of each context, these representations capture only a fraction of authentic situations, or what might be termed 'everyday acoustic reality'. This is based on an experience lived in situ, in a space and not in a laboratory. It allows us to understand, through embodied experiences,

MAKE	TOOLS	MEANS	CRITERIA
Baux	ELEMENTS OF POPULARIZATION	STANDARDS, SCIENTIFIC DATA	ABSORPTION (tested), DIFFUSION CHAMBERS
Acoustic Pearls	MEASURING TOOLS	STANDARDS, SCIENTIFIC DATA, SIMULATION	ABSORPTION (tested), NOISE SHEILDING
Abstracta	ELEMENTS OF POPULARIZATION	STANDARDS, SCIENTIFIC DATA, AUGMENTED REALITY	ABSORPTION (tested), DIFFUSION (tested), ATTENUATION (tested)
Kinnarps	ELEMENTS OF POPULARIZATION		ABSORPTION (tested)
Slalom	TUTORIALS	STANDARDS, SCIENTIFIC DATA	ABSORPTION (tested)
Baresque		STANDARDS, SCIENTIFIC DATA	ABSORPTION (tested)
BuzziSpace	ELEMENTS OF POPULARIZATION MEASURING TOOLS	STANDARDS, SCIENTIFIC DATA	ABSORPTION (tested), DIFFUSION, ATTENUATION
Caimi	MEASURING TOOLS	STANDARDS, SCIENTIFIC DATA, IMMERSIVE INSTALLATION, VIDEO	ABSORPTION (tested)
Casando	ELEMENTS OF POPULARIZATION	STANDARDS	ABSORPTION (tested)
EchoJazz		STANDARDS, SCIENTIFIC DATA	ABSORPTION (tested)
Götessons	MEASURING TOOLS	STANDARDS, SCIENTIFIC DATA, VIDEO	ABSORPTION (tested)
Impact Acoustics		STANDARDS, SCIENTIFIC DATA	ABSORPTION (tested)
Zilenzio	TUTORIALS	STANDARDS, SCIENTIFIC DATA, VIDEO	ABSORPTION (tested)
Acoustic Facts	TUTORIALS, ELEMENTS OF POPULARIZATION MEASURING TOOLS	STANDARDS, SCIENTIFIC DATA, AUGMENTED REALITY	ABSORPTION (tested), DIFFUSION, ATTENUATION (tested)

Figure 2: Comparative table of methods for testing and promoting the acoustic efficiency of products for office spaces (14 brands studied)

a set of concepts that enable us to project ourselves in the search for an appropriate solution. Additionally, experiencing sound in the presence of others introduces variability and facilitates shared understanding. Thus, we aim to export this phenomenological, cognitive, and social approach on an immersive device.

Exploring real-life situations and aiming for a comprehensive grasp of experienced acoustics reveals the challenge of representing all configurations and their numerous associated scenarios. Contrary to our initial assumptions, we moved away from 'typical' and linear scenarios and now prioritize crafting diverse and adaptable sound ambiances. The aim is to create the conditions that make a sound ambiance emergence probable or possible [13] rather than trying to 'create' a virtual one out of nothing. This approach facilitates the realisation of specific sound set-ups as needed, tailored to various situations as well as integrating perception and context in the constitution of these sonic configurations.

Although not a long-term workspace like an office, a sales area still fosters communal interaction for sharing, learning, and exchanging experiences. Thus, questions can be addressed by adjusting the space in real-time, presenting scenarios, simulating acoustic effects and implementing improvements. This necessitates swift adjustments, akin to theatre settings. While theatre serves as a metaphor, it has inherent limitations. Nevertheless, these constraints offer unique characteristics and opportunities for improvement.

The concept of ambiance, and by extension that of acoustic ambiance, is largely shaped by the variability inherent in an environment. Making this variability possible, while maintaining both a technical and a practical framework, was therefore one of our major challenges. Instead of striving for false stability, we focused on identifying the unique characteristics of each environment or configuration. This aspect will be elaborated further in section 3.4., particularly concerning the sound situation simulator.

### 3.5. The LEB Acoustic Workshop

The LEB caters to professional customers, space planners, specifiers and buyers, providing them with the chance to view products in the showroom, customise them, and test them out through simulation. Based on our analysis, we proposed establishing an experiential Acoustics Workshop to complement the offer.



Figure 3: The LEB Acoustics Workshop in a resonant acoustics situation and with absorber panels. (Design Valentine Maupetit - Marie Simon-Thomas)

#### 4. PROCESS AND RESEARCH THROUGH DESIGN

Design research can be defined as the art and science of conceiving and formalising hypotheses from a user-centric perspective. This approach, as defined by Frayling [14] differs from other forms of research related to design, research 'in', 'on' or 'for' design, such as 'project', 'anchored' or 'creation' research [15]. Here, the design project is at once subject, field and objective. The key idea was to create an experiential laboratory where we could get close to real working conditions, while actively adjusting the conditions of the sound experience. In this way, our research embodies the 'through design' approach, integrating and evaluating hypotheses in real time.

##### 4.1. The first stages

The first material device installed was a set of absorbent panels sliding on the walls and enabling the acoustics of the room to be modulated by manually increasing the equivalent absorption surface (see Figure 3). With these panels in place, we could then measure the variation in reverberation time (TR) between the folded and unfolded positions (see Figure 4).

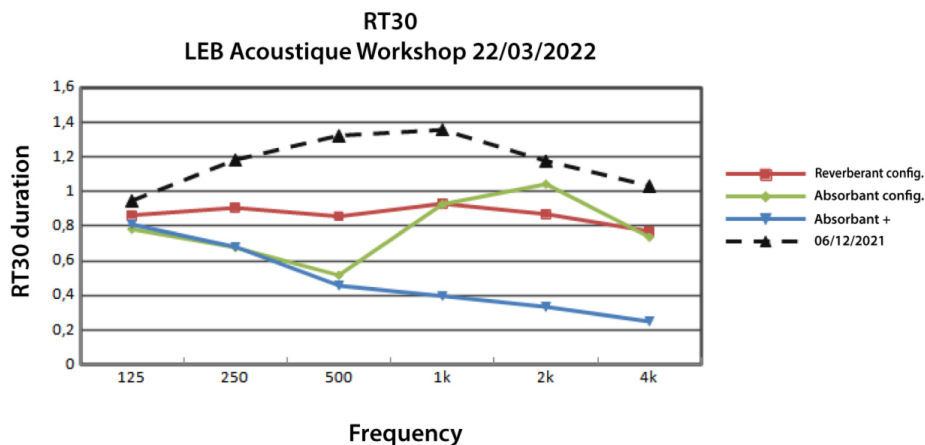


Figure 4: The TR30 averaged over the frequencies 400-1250 Hz is 0.89, 0.72, 0.43 and 1.34 seconds for the 4 configurations respectively. The NF S 31-080 standard recommends values of 0.6 seconds for collective offices (Hugo Dujourdy 2021-2022).

Despite not matching the performance of other competing demonstrators like Caimi or Ecophon, the difference observed remains easily noticeable to the ear, and visitors readily acknowledge the impact of the absorbent panels, even when only partially deployed.

However, the green curve "ie absorbent curve" in Figure 4 reveals a notable flaw in the high frequencies (2 kHz), attributed to a flutter echo between the bare floor and ceiling. Paradoxically, this flaw appears to worsen with the deployment of absorbent panels, becoming more audible as other reflections are greatly attenuated. This easily detectable flaw in the room's centre serves as evidence to visitors that acoustic solutions are seldom straightforward, and remedies may inadvertently introduce side-effects, potentially leading to additional issues.

The following step involved creating a user's guide, providing a simple, step-by-step tool accessible to all and minimising the need for expert mediation. This guide aimed to empower LEB staff to assist customers autonomously with the device, following a predefined path of experiments. These experiments included acoustic tests to demonstrate specific features audibly (such as sound effects, configurations, or acoustic categories), visualisations, simplifications, and the operation of hardware devices installed in the LEB.

#### **4.2. Reflection on variable acoustics**

From this point onwards, we designed a set of complementary absorbent acoustic elements that could be easily modulated according to use, configuration and user choices, and not just fixed "acoustic treatments": flexible floor, ceiling, wall and opening treatment devices to observe the effects of strong contrasts, and to design and show variable acoustic products that could respond to evolving situations at work, as well as giving users a better ability to control their sound experience.

#### **4.3. Iterations and transformations**

When we presented the first version of the Acoustic Workshop guide to the CLEN staff, we realised that it had become a lengthy sequence of actions and learning processes, leading to a strong sense of linearity that overshadowed the flexibility of the real-life experience we aimed to offer. This rigid structure proved challenging to align with the unpredictability of sales situations, such as time constraints, customer expectations, and sales targets. Consequently, we abandoned this restrictive version in favour of a set of open tools integrated into the same user interface and a series of relatively independent scenario units. This evolution allowed a better accessibility, continuous visibility of the measurement tools, the ability to simulate sound situations beyond the predefined scenarios, and the flexibility to address and resolve unforeseen acoustic issues in the room, as needed during demonstrations.

#### **4.4. The LEB Acoustics Workshop today**

The "Acoustics Workshop," situated in the basement of the new Clen Showroom, offers visitors the opportunity to experience quickly the acoustic effects associated with various variables (furniture, materials, uses, and spaces) in an office layout. This spatial set-up is enhanced by an electro-acoustic system that reproduces sounds from a working environment, placing visitors in different scenarios. Depending on the duration of their visit, customers can explore one or more 'visit scenarios'. To assist visitors in understanding the presented acoustic effects, an interactive digital application has been developed, allowing them to conduct a series of acoustic and cognitive experiments and tests in situ.

#### **4.5. Spatial features (booth, adjoining room, materials)**

Towards the rear of the workshop, there's a small recess (2x1m), referred to as the "box," utilised for testing the contrast between a small resonant space and one where two sides are covered with



absorbent material. This straightforward yet common test is conducted in pairs: one person inside, the other outside, then the roles are reversed. Adjacent to the workshop, there's a larger room demonstrating the 'coupling effect' [5] and comparing sound experience with and without acoustic panels deployed in front of the opening. On the opposite side of the workshop, there's a small hall leading to the staircase, toilets, and other rooms, where a loudspeaker is installed to broadcast various distant sound activities (i.e discussions near the coffee machine, printer noises, traffic, or sounds from adjacent offices).

#### 4.6. Tools

Today, the Acoustics Workshop provides the following tools :

- 1 Resonant acoustic environment of the empty space:
  - The space, measuring approximately 25 m<sup>2</sup>, is designed like an office with 2 workstations.
  - Concrete walls covered with plasterboard.
  - Rapidly deployable variable acoustic devices, including sliding absorber panels offered by the manufacturer Manade.
- 2 Measurement tools:
  - Continuous LAeq measurement and TR (reverberation time) measurement for easy comparison of situations and putting feelings and measurements into perspective.
- 3 Multi-channel broadcasting system:
  - An 8-channel sound diffusion system for playing sounds:
    - Local diffusion in the adjoining office.
    - Surround sound within the office (4 channels).
    - In the large adjoining room.
    - In the adjacent space.
    - On a mobile loudspeaker.
- 4 Sound situation simulator:
  - A software tool for simulating sound scenes, including presets corresponding to activity categories in the ISO/DIS 22955 standard (e.g., call centre, collaborative work).
  - The simulator can also enhance the resonance of broadcasted sounds and virtually expand the sound space.
  - Additionally, the tool provides a set of test signals for hearing and characterising the space's response.

#### 4.7. Scenarios

A series of usage scenarios and demonstrations have been designed to respond to a range of situations and make the most of the 'Acoustic Workshop'

- 1 reverberation
  - a Show the reverberation in its bare state
  - b Listen to the reverberation
  - c Experience reverberation as a concentration and discussion activity
- 2 absorption attenuation
  - a Experience absorption as a concentration and discussion activity
  - b Listen to absorption/attenuation (with white/pink noise on loudspeaker)
  - c Show absorption close to the source and further away

- d Compare with/without baffles (white noise/spoken voice)
- 3 isolation coupling
  - a1 Assemble/listen to/experience the muffled ambience (option 1)
  - a2 Edit/listen to/experience partial isolation (option2)
  - b Listen to the coupling effect and how to reduce it

Each of the scenarios can be carried out with or without broadcasting a ‘sound situation’.

#### 4.8. Measurements

The device also includes real-time measurement tools that are continuously active, allowing for the objective assessment of situations and comparison with simple tools (see Figure 5). To ensure high-quality measurements integrated into the developed software application, we use a calibrated measurement microphone paired with a digital audio interface to enable the computer to receive the signal. The signal is then adjusted using a weighting filter to convert dB SPL into dBA and then an absolute correction is applied to align the level with that of a professional sound level meter. However, there is a margin of error of  $\pm 3\text{dB}$  depending on the situation, which does not significantly affect the experience, as the measurements are taken relatively (for comparison purposes) rather than absolutely. The application then provides a continuous intensity measurement (in dBA) as well as a Laeq over a specified time period. Additionally, we’ve created a simple reverberation time measurement tool that assesses the ambient sound level and then measures the decay from an impulse. It’s important to note that this measurement tool is primarily useful for comparing situations (such as the deployment of devices, presence of specific furniture, empty spaces, etc.), as the variability of situations (position relative to the microphone, background noise level, spatial configuration) and sources (e.g., clap, burst, balloon, etc.) make it challenging to achieve laboratory-level measurements.

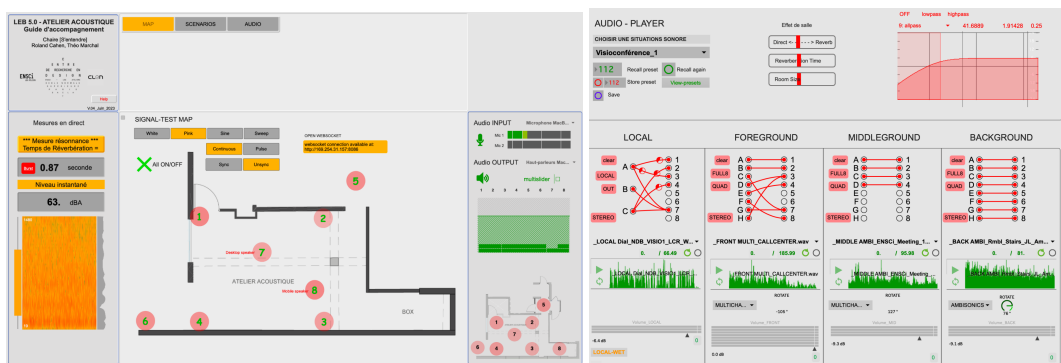


Figure 5: Sound situation simulator user interface

#### 4.9. Sound situation simulator

The sound situation simulator developed using Max MSP offers a default set of typical scenarios, including a reception hall, meeting room, call centre, noisy office, telephone call and conversation, informal proximity discussion, informal meeting, impromptu visit by the manager, individual videoconference, hybrid videoconference, music broadcasting, and professional dialogue at the coffee machine. Each scenario is composed into four levels:

Local (1st level): Features intelligible speech, workplace sketches, dialogues, monologues, videoconferences, telephone calls, etc. These texts were written, performed by actors, and recorded in multichannel format, and can be positioned independently in the space.

Foreground (2nd level): Recorded with various activities, weakly intelligible or unintelligible speech, groups working, movement, and noises from keyboards and devices. These ambient sounds were recorded in ambisonics and are spatially placed for broadcast to create believable scenes. Each field recording reflects different types of acoustics, interior soundscapes and expressions, based on a typology of common sound found in workspaces.

Middleground (3rd level): Features workspaces ambience recorded in ambisonic format, offering distant ambiances characteristic of the premises.

Background (4th level): Includes background noise such as outside soundscape, mechanical noise, flow pipes, traffic, and various types of continuous noise.

#### **4.10. Fun concentration exercises**

In addition, visitors who are not experimental subjects but clients, are offered concentration exercises involving calculation, visual tasks, and memorization. These gamified exercises not only allow visitors to immerse themselves in a sensory experience but also to feel and compare their discomfort during tasks requiring concentration. While the cognitive effects of Irrelevant Sound Effects (IREs) in Open Plan Offices (OPOs) are well-studied, measuring them requires experimental conditions that are too restrictive for our purposes [16]. Therefore, we have abandoned the idea of using cognitive tests to measure the experience, opting instead to use them as tools for user projection. Although the negative effects of irrelevant speech on concentration and memory have been well-documented [17], they are challenging to measure over short periods [18]. However, projecting oneself into the long term allows for a subjective assessment by asking, "Would you accept this situation in the long term?" While subjective, this approach engages both customers and prescribers, enabling them to form opinions based on experience. Therefore, we have chosen to retain these concentration exercises to help visitors to project themselves into more extended periods of use and compare them with their own situations.

### **5. CONCLUSIONS AND LIMITATIONS**

The Acoustic Workshop is now operational in the CLEN showroom. However, since its setup, various limitations have been noted, encompassing technical, theoretical, and human aspects. It's important to address these limitations up to date (*jan 2024*) to inform future iterations of the system or similar setups.

#### **5.1. Physical and technical limitations**

The Acoustic Workshop faces constraints related to space, materials, and usage due to its in situ nature. Complete control over sound and acoustics within the dedicated space proves challenging despite testing various configurations. This unpredictability may discourage usage, as there's a fear of not having sufficient control over the outcomes of choices made regarding sound, equipment, or space.

Moreover, the measurement tools provided aren't calibrated to offer absolute values but rather facilitate comparison of situations and configurations. This presents a challenge in explaining and presenting these values as relative, especially to non-expert users who may misinterpret criteria such as decibels or reverberation time, particularly when they serve as qualification criteria for devices sold. Furthermore, achieving a balance between the tool's flexibility to accommodate diverse demands and its robustness for sustained, potentially non-expert use poses a significant limitation. Compromises are necessary to meet professional context requirements, leading to constraints in the tool's final version, as detailed in section 4.3.

## 5.2. Limits to use and mediation

Use of the LEB currently requires the presence of someone trained in its use, if only to understand the different possible ways of using it, as mentioned above. At the moment, CLEN's employees are not yet very keen to use the digital tools or haven't found how to integrate it in their sales strategy. The choice of offering a real, immersive space means that we need to plan for the management of any 'unforeseen events', whether in terms of choices, behaviour or sounds in the space makes the management more challenging, requiring staff to react and explain accordingly. This demands not only training but also a genuine interest and familiarity with the subject matter.

Finally, the proposal of variable acoustics implies the installation of movable or transformable devices, which appeared to be difficult to install in sufficient numbers to be able to vary all the parameters. This limitation is explained by the function of the space in which the products presented must be able to be sold, leaving little room for the very specific devices or prototypes needed to modify certain acoustic parameters.

## 5.3. Theoretical limitations

The various limitations identified lead us to go beyond human and technical considerations and question the very principle of the system. It would make sense to set up a prolonged period of observation in optimal conditions for the immersive experience in order to evaluate the benefits of the system more systematically and regularly, despite the logistical obstacles mentioned above. Indeed, the effectiveness of such a tool has yet to be demonstrated in the context of a sales and demonstration area that goes well beyond the scope of research or education.

## 5.4. Final comments

In the course of this research, the Acoustic Workshop of the Office Space Laboratory (LEB) has demonstrated its potential as a tool for exploring the sound environment of workspaces. Despite the technical and human challenges encountered, it offers a promising route to a richer understanding and more considerate design of professional sound environments. In particular, the focus on sound through immersive experience, which allows us to go beyond the caricatured examples often encountered in the field, by integrating the nuances and complexity of sound and spatialities. The significance of such a device lies in its ability to sensitise users to the nuances and variability of the sound ambiance, thereby promoting a more discerning and informed approach to acoustic design. This is crucial in recognising the substantial impact that the acoustic environment can have on the well-being, productivity, and overall experience of employees in the workplace. The limitations found in using the LEB Acoustic Workshop highlight the need for training and engagement of stakeholders, along with the development of more adaptable and user-friendly devices with improved acoustic capabilities. These enhancements would enable wider and more efficient use of the laboratory, making the advantages of acoustic immersion available to a broader audience. The LEB's Acoustics Workshop is currently only a tool in its launch phase, which needs to be approved and improved upon, but it has great potential to provide new levers for the acoustics of offices, by placing the human experience at the heart of the design process. The prospect of using lived experience in a creative and thoughtful way to guide the design of workspaces offers a promising path for further exploration of the subject.

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## REFERENCES

1. Roland Cahen. Kinetic Design: From Sound Spatialisation to Kinetic Music. In Richard Kronland-Martinet, Sølvi Ystad, and Mitsuko Aramaki, editors, *Perception, Representations, Image, Sound, Music*, volume 12631, pages 517–530. Springer International Publishing, Cham, 2021.
2. Patrick Chevret, Laurent Brocolini, and Thomas Bonzom. Clefs de lecture de la norme NF ISO 22955 (2021) “Acoustique -Qualité acoustique des espaces de bureaux ouverts”. *NS 375 NOTE SCIENTIFIQUE ET TECHNIQUE DE L'INRS*, 2022.
3. Nadia Heddad. Espace, Travail et numérique. Le cas du travail en flex office. *Activités*, (18-2), October 2021.
4. Jean-François Augoyard. *Entretien Sur Écoute Réactivée*. 2001.
5. Jean-François Augoyard and Henry Torgue, editors. *A l'écoute de l'environnement*. Editions Parenthèses, Marseille, 1995.
6. Grégoire Chelkoff. *Prototypes Sonores Architecturaux - Articulation, Limite et Inclusion*. CRESSON, Grenoble, 2003.
7. GIAC Indicateur Unique de Qualité des ambiances sonores dans le bâtiment. <https://iua.giac-acoustique.org/#iua>.
8. Marc Bertier and Nicolas Cochard. Chapitre 4. L'activity based working. In *Espaces de travail, Management / Leadership*, pages 59–76. Dunod, Paris, 2021.
9. Thierry Pillon. Théorie et pratique du flex office. *Office et Culture*, (64):44–50, June 2022.
10. Ecophon. <https://www.ecophon.com/fr/the-lab/>.
11. Workspace expo. <https://www.workspace-expo.com/>.
12. Tyler Adams. *Sound Materials: A Compendium of Sound Absorbing Materials for Architecture and Design*. Frame, Minneapolis Amsterdam London, 2016.
13. Jean-Paul Thibaud. Une approche pragmatique des ambiances urbaines. page pp. 145. Editions A la Croisée, 2004.
14. Christopher Frayling. Research in art and design (Royal College of Art Research Papers, vol 1, no 1, 1993/4). 1994.
15. Geneviève Raïche-Savoie and Claudia Déméné. La pluralité de la recherche en design : tentative de clarification et de modélisation de la recherche-action, de la recherche-crédation et de la recherche-projet. *Sciences du Design*, 16(2):10–29, 2022.
16. Manuj Yadav, Markus Georgi, Larissa Leist, Maria Klatte, Sabine J. Schlittmeier, and Janina Fels. Cognitive performance in open-plan office acoustic simulations: Effects of room acoustics and semantics but not spatial separation of sound sources. *Applied Acoustics*, 211:109559, August 2023.
17. Krist Kostallari, Etienne Parizet, Patrick Chevret, Jean-Noël Amato, and Edith Galy. Irrelevant speech effect in open plan offices: Comparison of two models explaining the decrease in performance by speech intelligibility and attempt to reduce interindividual differences of the mental workload by task customisation. *Applied Acoustics*, 161:107180, 2020.
18. S. J. Schlittmeier, J. Hellbrück, R. Thaden, and M. Vorländer. The impact of background speech varying in intelligibility: Effects on cognitive performance and perceived disturbance. *Ergonomics*, 51(5):719–736, May 2008.