AURA project: enjoyment of the auralisation experience by different target groups

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Modern technologies have become a familiar feature in experiencing our cultural heritage. With the AURA (Auralisation of acoustic heritage sites using Augmented and Virtual Reality) project, music and opera houses in Berlin, Florence and Lviv opened up to the potentials of auralisation for music performing arts and establishments. AURA reached out to the European music community and offer a wide range of opportunities of building new audiences, new business models, new performance practices and exciting new aural experiences. Also, it aims to create a model for cross sectoral collaboration to foster creativity and to promote European heritage in new ways. The present article describes the procedures applied by Vie en.ro.se Ingegneria project partner to engage different target groups, make them experience auralised models of the three theatres and assess their perception through a questionnaire designed ad-hoc for each group and through the participation in round tables discussions. The main outcomes from the analysis of the collected data are reported, together with the structure of video tutorials implemented to ensure a wide dissemination of results.
Keywords: auralisation, immersive experience, virtual reality, acoustic, theatre, music, cultural heritage

Progetto AURA: fruizione dell'esperienza immersiva dell'auralizzazione da parte di diversi gruppi target
Le nuove tecnologie sono utilizzate sempre più di frequente per la fruizione del patrimonio culturale. Con il progetto AURA (Auralisation of acoustic heritage sites using Augmented and Virtual Reality), i teatri d'opera e musicali di Berlino, Firenze e Leopoli hanno potuto sfruttare le potenzialità che l'auralizzazione offre alle arti dello spettacolo e alle istituzioni musicali. AURA si rivolge alla comunità musicale europea alla quale offre un'ampia gamma di opportunità per attrarre nuovo pubblico e creare nuovi modelli di business, nuove performance e nuove entusiasmanti esperienze sonore. Si propone inoltre di sviluppare un modello di collaborazione intersettoriale al fine di promuovere in maniera innovativa la creatività e il patrimonio europeo. Il presente articolo descrive le procedure applicate dal partner del progetto Vie en.ro.se Ingegneria per coinvolgere diversi gruppi target, far loro sperimentare esperienze immersive virtuali nei tre teatri e valutarne la percezione attraverso un questionario elaborato ad-hoc per ogni gruppo e attraverso la partecipazione a tavole rotonde. Vengono inoltre riportati i principali esiti ricavati dall'analisi dei dati raccolti e presentati i video tutorial sviluppati per dare ampia diffusione ai risultati.
Parole chiave: auralizzazione, esperienza immersiva, realtà virtuale, acustica, teatro, musica, patrimonio culturale

1 | Introduction

Modern technologies are increasingly used for the enjoyment of cultural heritage. In fact, theatre and musical performances are by their nature "immersive" and this feature can be achieved thanks to the auralisation technique which creates virtual soundscapes starting from 3D-models recreating the sound environment of a real space. This allows to propose an immersive experience in which the user can move around in space and experience how the architecture influences the sound.

The AURA project is led by the Berliner Gesellschaft für internationale Zusammenarbeit mbH, in collaboration with academic partners from the Hochschule für Technik und Wirtschaft in Berlin, the Departments of Architecture and Industrial Engineering of the University of Florence and the Lviv Polytechnic National University, supported by musical institutions such as the Konzerthaus in Berlin, Vie en. ro.se. Ingegneria s.r.l. from Florence, a partner with extensive practice in involving people in immersive experiences and evaluating their perception, the Lviv Tourist Development Center of Lviv and Magnetic One of Ternopil.

Auralisation technology is continuously evolving in sync with computational possibilities and has proven its value for different acoustic-related disciplines and multiple potential

applications. As an illustration, auralisation is gaining momentum in the archaeology field since it enables the reconstruction of the acoustic of past venues and heritage sites [1], [2]. Also, several modelling methods are available in architectural acoustics for the purpose of simulating sound in modelled environments [3]; recent developments have focused on ways to better integrate auralisations in architect workflow [4] and to complement it with immersive virtual reality technologies [5]. Despite these developments, the application of auralisation to deliver a multisensory experience to performers and audience, in the fields of music and theatre, is still in its infancy. Introducing auralisation as a cultural experience and a tool to be used by the culture industry and assessing the opportunities it offers is the innovative approach taken by the AURA project.

The AURA project aims to promote auralisation in the field of cultural heritage and performing arts. Particularly, the AURA Project aims at setting immersive experiences of three European theatres, investigated as case studies. Auralised 3D models are expected to offer a wide range of opportunities to build new business models, new performance practices and exciting auditory experiences. In this way, AURA aims to create a model of cross-sector collaboration to foster creativity and promote European heritage in new ways.

Among the project activities, collecting the future users' feedbacks, such as the point of view of musicians, designers and theatre-goers, has a crucial role for the implementation of the tool. Indeed, assessing audience experiences gives a key for understanding how and in what conditions auralisation can represent a rich and exciting alternative to the immersive nature of the live performance.

This latter aspect is particularly relevant to understand how young people, who are the age group least likely to attend theatres, perceive the theatre experience. Additionally, the experts' and technicians' opinion is considered important for a meticulous comparison between the real and the virtual experience and for the definition of a model which can better fit the reality.

The main aim of the paper is to assess audience experience of AURA innovative auralised 3D models. In what follows, a brief introduction on the development of the models for the three European theatres carried out by project partners is presented. The paper then focuses on the sessions of immersive experiences designed by Vie en.ro.se Ingegneria S.r.l. Adopted methods to collect data – a questionnaire administered to the participants and round table discussions – are illustrated and results are reported and commented. Video tutorials, implemented to disseminate project's results to different target groups, are also presented.

2 | The immersive experience

2.1 | The definition of three virtual environments

The three theatres which have been modelled and simulated in virtual reality are:

- Teatro del Maggio Musicale Fiorentino (Florence, Italy);
- Konzerthaus (Berlin, Germany);
- Lviv National Academic Opera and Ballet Theatre named after Solomiya Krushelnytska (Lviv, Ukraine).

The theatres differ in terms of architecture style and period of construction as well as acoustic features. They are characterized by different volume, number of seats and reverberation time, which affect their acoustic performance.

The synergic collaboration between the University of Florence and the HTW Berlin University of Applied Sciences resulted in the definition of three application for the simulation of virtual reality. Following theatres surveys, the Department of Architecture of the University of Florence has developed the visual 3D models of the inside, whereas the HTW dealt with the implementation of the auralisation process. The combination of these two aspects makes the experience of immersion inside the theatre realistic.

Fig. 1 – Inside view of the 3D model of the "Konzerthaus" in Berlin

Visualizzazione dall'interno del modello 3D della Konzerthaus di Berlino

Thanks to the definition of 3D visual and acoustic models, the three theatres have been implemented in a specific software (Unity) and three applications for personal computers have been set.

For an easier control of the user experience, some significant listening points have been defined (e.g., in the first row, on the balcony, on the stage).

As regards the audio simulation, the orchestra plays the 4th part "Golliwogg's Cakewalk" from "Children's Corner", a composition by Claude Debussy.

The following sections present the procedures and methods applied by Vie en.ro.se Ingegneria project partner to engage different target groups (general public, technicians and experts), making them experience the auralised models of the three theatres and collecting their feedbacks through a questionnaire and through the participation to round tables discussions.

2.2 | Sample definition

Users' experiences and the analysis of their perceptions have been diversified in order to understand how categories of audiences can differently be influenced by the proposed tools and to collect distinct feedbacks on potential improvements and applications.

Three groups of subjects have been identified: i) General Public (students from high schools and general non-expert public); ii) Technicians (architectural designers, acoustic designers, students of engineering and architecture); iii) Experts (musicians, singers, conductors, actors, expert audience).

In order to reach and engage a broad number of participants, several actions were put in place using a wide range of tools and messages tailored to the addressed category. Specifically, the sessions of AURA immersive experiences were disseminated through the social media accounts (e.g., LinkedIn) of Vie en.ro.se Ingegneria (Figure 2).

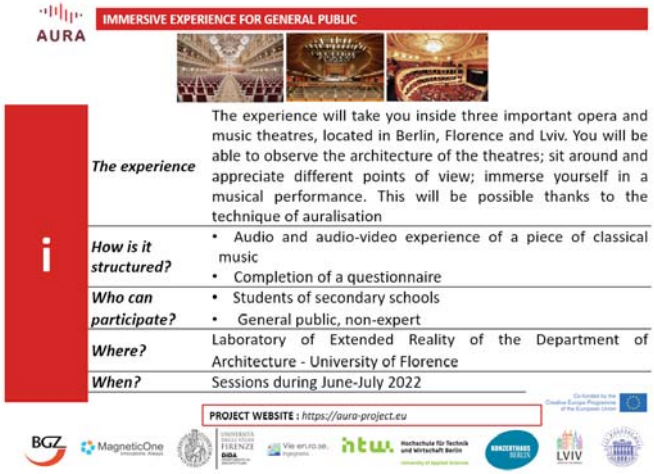

Fig. 2 – Leaflet designed to promote the AURA immersive experiences

Volantino redatto per promuovere le esperienze immersive del Progetto AURA

Additionally, the experiences were promoted through emails and phone calls to Florence music schools, to the Florence music Conservatory as well as to the acting schools. Voluntary participants have also been identified during academic courses of the University of Florence.

The immersive experiences took place between the months of May 2022 and October 2022 in the LXR Laboratory of Extended Reality of the Department of Architecture at the University of Florence and have been organised in eight sessions.

2.3 | General public experience

Participants are divided in small groups of maximum 4 people and accompanied in the Laboratory where the technical supervisor briefly describes the subsequent phases of the experience (Figure 3).

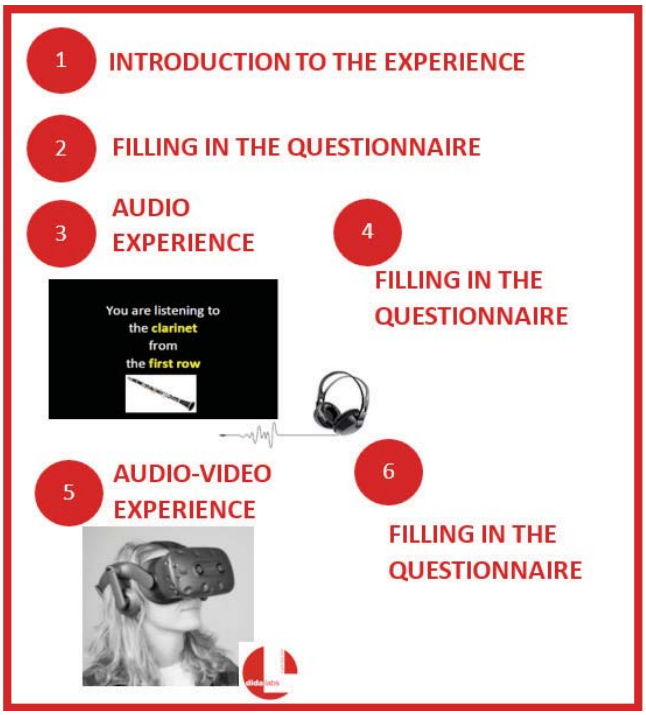

Fig. 3 – The experience's phases for General Public

Le fasi dell'esperienza per il Pubblico generico

The questionnaire is created using Google forms, and participants are given the possibility to fill-in the set of questions on their mobile phones.

The structure of the questionnaire consists of 30 questions divided into six main sections.

The first part of the questionnaire includes:

- Section A, regarding personal information (5 questions).
- Section B, focusing on personal habits related to theatre attendance (10 questions).

The second part is composed of one section:

- Section C, with a single matrix question, focusing on the evaluation of the audio experience.

The third part includes three sections:

- Section D, concerning the evaluation of the immersive audio-video experience (6 questions).
- Section E, focusing on the comparison between the immersive audio-video experiences in the three theatres (3 questions).
- Section F, concerning future developments (5 questions).

The questions included in the questionnaire are closed-ended or multiple-choice. The questions related to the characterization of the samples and their assessment of different kinds of music performances are designed drawing on a literature review and surveys deployed by projects in the field of performing arts. We especially review recent projects, scholarly sources and reports by musical and theatre institutions which mainly aim to i) collect robust data on audiences including demographic profile and booking behaviours [6], [7]; ii) identify audience' motivations to attend arts and music performances [8] and iii) explore benefits people enjoy from music, barriers to concert attend-

ance as well as strategies to creatively engage audiences [9], [10].

2.3.1 | The audio experience

Before starting the audio experience, participants are asked to answer to the questions included in the first part of the questionnaire (sections A and B).

For the audio experience, the technician provides stereo headphones to the users. Participants listen to the music piece by Debussy auralised in the Konzerthaus in Berlin.

The two minutes audio track consists of different instruments playing inside the theatre and in different listening positions (e.g., listening to the whole orchestra from the stage, or to the clarinet from the first row). The description of the content of each part of the audio track, which consists of the playing instrument(s) and the position in the theatre from which each participant was listening to it, is displayed on the PC monitor. At the end of the audio experience, participants answer to Section C of the questionnaire.

To engage youth participants, an Audio Interactive Game is also designed. Students are asked to listen to an audio track and recognize the instrument playing and understand how close to the orchestra he/she is listening to it. The interactive quiz is implemented in Microsoft Forms; the correct answer is displayed on the screen as soon as the answer is given by participants.

2.3.2 | The audio-video experience

In order to make participants test the audio-video experience, the technical supervisor provides an Oculus – a virtual reality headset that allows to play the audio and the 360° space view of the theatres – to each of them and runs the Apps of the three theatres so that users listen to the auralised audio tracks (the Debussy piece played by the whole orchestra) and visualize the corresponding space in the Oculus (Figure 4).

Fig. 4 – Audio-video experience using Oculus
Esperienza audio-video con Oculus

Participants lead the experience and independently choose the listening positions within each of the three theatres (e.g., on the stage, front rows, balcony seats etc.) (Figure 5).

Fig. 5 – The audio-video experience (visualization from the stage position)
Esperienza audio-video (visualizzazione dal palco)

At the end of the experience, participants are asked to answer the third part of the questionnaire.

2.4 | Technicians and experts' experience

The experience designed for technicians and music experts slightly differs from the one carried out with the general public, in order to suit the peculiar characteristics of the sample categories. The main variation deals with their participation to round table discussion and with the structure of the questionnaire.

The structure of the questionnaire administered to technicians consists of i) section A, with 5 questions on personal information and ii) section B, with 6 questions on habits regarding theatre attendance and on professional experience. The questionnaire for experts consists in i) section A, with 5 questions on personal information and ii) section B, with 10 questions on theatre attendance habits and professional experience.

2.4.1 | The audio experience and the audio-video experience

Before starting the audio experience, participants are asked to fill in the entire questionnaire. The audio experience is carried out as described in section 2.2.1 for the general public's sample group. In this case, the Interactive game is not performed. The audio-video experience is carried out as described in section 2.2.2.

2.4.2 | Round table discussion

At the end of the audio-video experience a round table is organized: participants are divided into small groups (up to 5 persons). Two specific canvas – one for each participants'

sample group – are elaborated and displayed on a screen and printed to facilitate the discussion on specific topics (Figure 6). Suggestions, comments and ideas are collected by the staff conducting the experience.

During the round tables with technicians, the following aspects are touched upon:

- other potential applications of auralisation in their field;
- utility of the tool for the choice of materials in a designer project;
- benefits of the tool in the field of architectural design;
- added value compared to traditionally used tools;
- specific benefits for acoustic designers;
- Music experts are instead asked to discuss and give their feedbacks on the following topics:
- previous experiences with immersive technologies;
- benefits of listening from different points of the theatre;
- benefits of knowing the architecture and acoustics before the performance;
- benefits of activating/deactivating different instruments;
- utility for a specific type of theatre or performance;
- effectiveness of the tool in attracting new audience.

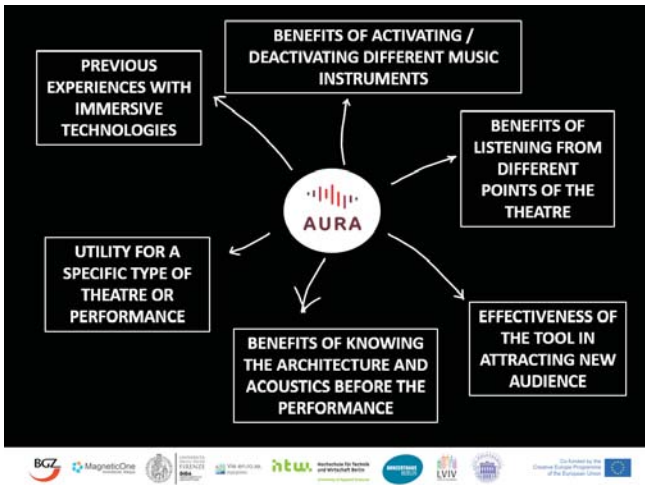

Fig. 6 – Canvas for round tables (Experts)
Schema per le round table (Esperti)

3 | Analysis of collected data

The total number of participants to the AURA immersive experiences was 155, which corresponds to the same number of collected and completed questionnaires distributed as follows:

- 70 questionnaires by the general public;
- 41 questionnaires by technicians;
- 44 questionnaires by experts.

Additionally, field notes of the round table discussions with a total of 85 participants (technicians and experts) were collected and analysed.

3.1 | Results for general public

Demographic profile and habits related to theatre attendance
The number of female participants is greater than the male one (44 versus 26). The majority of the respondents is in an age range between 18 and 40 years and has at least a high school diploma. As regards their occupation, the largest group (65%) corresponds to students.

The sample group is composed of a majority of non-theatre-goers. Less of 10% of the subjects attend a music performance more than 5 times a year. The great majority of respondents (80%) usually enjoys music using streaming platforms. Instead, "Enjoying music at theatre" is the option chosen by just 3% of the sample. When comparing it with the question "Why you go to music theatre?", the motivation indicated with more frequency was: to listen to a richer, louder, more real sound (31 out of 70).

3.1.1 | *Audio and audio-video experiences*

As regards the results concerning the audio experience, 93% of the participants declared that the audio experience met their expectations – at least "moderately".

When asked to assess the audio-video experience in the three theatres, 32% of the participants indicated that had perceived significant acoustic differences when listening from different points of the theatre. 47% of the respondents perceived acoustic differences in a moderate way (Figure 7).

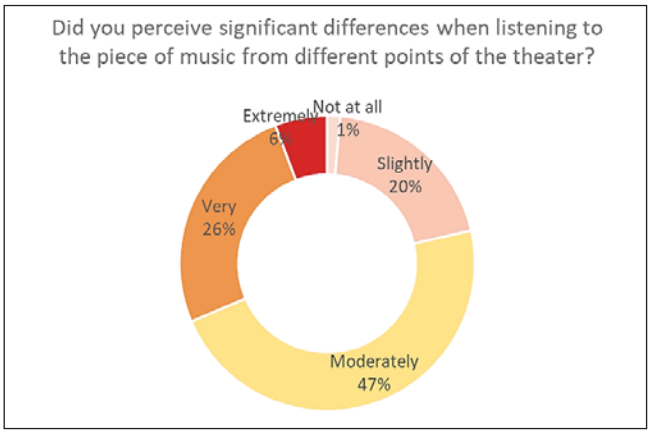

Fig. 7 – Perceptions of acoustic environment
Percezione dell'ambiente sonoro

According to a great majority of participants (66%), the possibility to listen to the piece of music from positions which are usually difficult to access (e.g., the stage) or less affordable (e.g., the first rows) is an added value compared to the real experience.

The Berlin Konzerthaus was selected by the majority of participants as the theatre where they had the most enjoyable audio-video experience.

The immersive experience was mainly defined as "evocative" and "enjoyable".

3.1.2 | *Future developments*

Notably, 66% of the participants claimed that their willingness to go to the theatre increased after the experience (Figure 8), demonstrating the potential of the tool to attract new theatre audience.

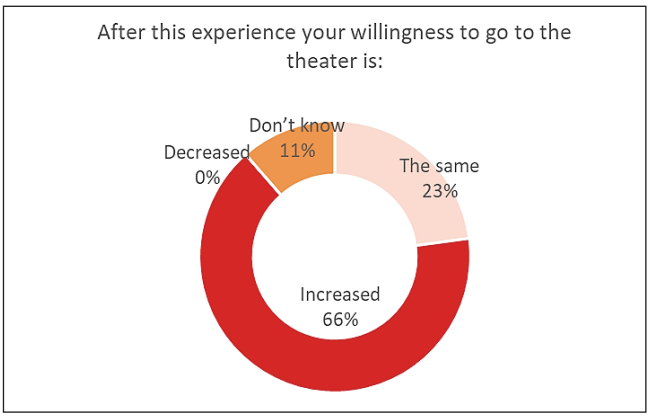

Fig. 8 – Willingness to go to theatre
Desiderio di andare a teatro

Figure 9 shows that the general public is extremely interested in having at home the kind of immersive experience like the one enjoyed at the laboratory. Furthermore, respondents identified the possibility of attending a performance when it is not possible to go to the theatre or the theatre is far from home as significant potentials of the auralisation tool (Figure 10).

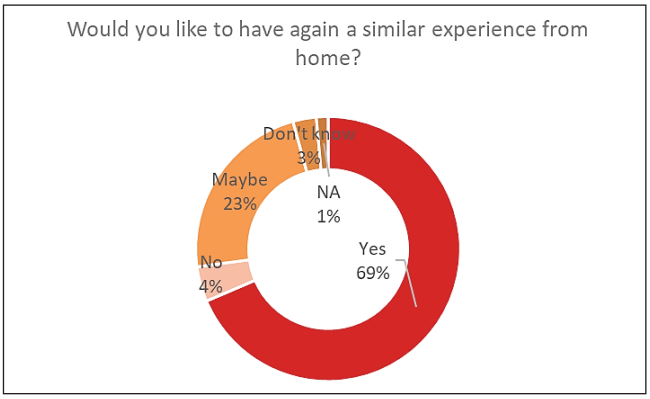

Fig. 9 – Immersive experience from home
Esperienza immersive da casa

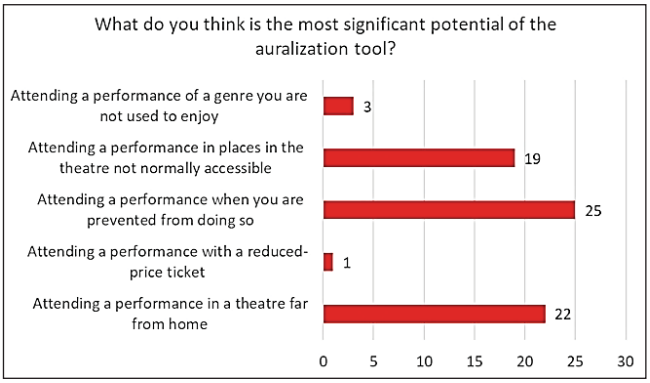

Fig. 10 – Potentiality of the auralisation tool
Potenzialità dell'auralizzazione

3.2 | Results for technicians

Demographic profile and habits related to theatre attendance
The sample is equally distributed by gender and the majority of the respondents is in an age range between 26 and 40 years. Participants are mainly architecture or engineering students (42%), architects (24%) and designers (24%); whereas only 5% of the sample is made up of acoustic designers. 7% of the sample has already dealt with acoustical and 5% with architectural design or requalification of a theatre.

63% of participants enjoy cultural events more than 6 times a year. However, technicians rarely enjoy live streaming or attend in-person music shows.

3.2.1 | *Round tables*

Architects agreed that the immersive tool is useful during the design process as it allows to test ideas, evaluate the performance of materials not only aesthetically but also acoustically and enables a complete perception of space.

The main benefit identified by acoustic designers deals with the acoustic simulation provided by the auralisation technique that allows to show design results to the clients for a better understanding and enjoyment of the designed spaces. Before they are built.

Participants suggest the following additional potential applications of auralisation in their field:

- To provide a virtual reality experience of urban parks and soundwalks.
- To offer alternative way to visit archaeological sites through a virtual reproduction of ancient sites.
- To give the possibility to join events in indoor and outdoor environments (e.g., fairs, exhibitions).
- To check construction sites.
- To design acoustic barriers.

3.3 | Results for experts

Demographic profile and habits related to theatre attendance
The majority of the respondents (66%) is in an age range between 41 and 65. Half of the sample is composed by musicians, and pianists represent the largest group. 14% of the participants are singers, while the number of actors is less relevant (4% of the total).

Not surprisingly, the expert group is composed of persons who are likely to participate to cultural events and are theater-goers; 73% of the participants attend a cultural event more than 6 times a year.

3.3.1 | *Round tables*

No participants to round tables belonging to the experts' group had used audio-video immersive tools before for work-related activities.

Experts agreed that the possibility to listen to the music piece from different points of the theatre and to appreciate acoustic differences is particularly useful to evaluate the spatial response of a music performance and to identify the best points on stage for actors' voice output. This was considered particularly helpful to test and evaluate the acoustic response of the theatre or other spaces before the performance, especially as regards recently built theatres whose acoustic is not well known by artists. According to the majority of experts, immersive experiences are useful for didactic purposes. Several potentialities as marketing tool were also identified; e.g., the integration of auralisation in virtual reality can give theater audience the possibility to hear online what the acoustic response might be from a specific seat to be booked. Also, a participant suggested the following: "an instrument of this kind instead of being used to enjoy a "traditional" theatre experience can open up new avenues for completely new performances in a virtual environment, specifically designed to make the most of the innovative technological application".

Notably, many participants identified the need to enhance the AURA 3D models in terms of acoustic performance with technical improvements (e.g., as regards signal amplitude and reverberation at different positions) to provide a better reproduction of the sound environment of a real space.

4 | Discussion on results and ongoing project activities

Thanks to the organized sessions, 155 participants enjoyed the AURA immersive experiences designed and conducted by Vie en.ro.se Ingegneria project partner. Results demonstrate that virtual immersive theatre experiences provide a great tool for audience to enjoy performances from the comfort of their own homes. Indeed, the great majority of the general public sample, mainly composed of young people and non-theatre goers, defined the AURA immersive experience as "evocative" and "enjoyable" and expressed their desire to have a similar experience at home. Specifically, enjoying the possibility to listen to the piece of music from points of the theatre which are usually difficult to access was generally considered an added value compared to the real experience.

The sample also identified the possibility of attending a performance when it is not possible to go to theatres (e.g., during COVID-19 pandemic restrictions or for patients in hospital), or the theatre is far from home, as useful applications of the auralisation tool. Data also show that the immersive experiences have the potential to attract new theatre audience, especially young people.

Round table discussions have shed light on the diversity of potential applications for auralised 3D models encompassing the integration of auralisations in architect workflows, application as marketing tools for theatres, teaching instruments, and their use for new performance practices.

Some limitations were also pointed out in particular by musicians. Specifically, they explained that a gap still exists between the real experience and the immersive 3D simulated environment which still makes them prefer the real experience to the virtual one to become aware of the architecture and acoustics of a theatre before a performance. A possible future development for the effective use of the tool by the specific musicians target group could be in this sense to carry out an auralisation process as accurate as possible [3]. Building on the results of the immersive experience sessions and in order to widely disseminate findings, three different video tutorials are being designed by Vie en.ro.se Ingegneria, targeting three stakeholder groups: interested adults (belonging to general public), children (belonging to general public) and the technicians. It was considered appropriate not to match the three target groups with those chosen for the enjoyment of the auralisation experience, deciding to focus on those who, according to the project partners, can most benefit from these tools. Examples are illustrated in Figures 11 and 12.

Target	**General Public**	–
Pills	**1. A Brief Overview on Acoustics**	***Contents*** Basics of acoustics, room acoustics ***Running time*** 5 minutes ***Language*** Italian - Familiar
	2. Auralization and the Potentiality of the Tool	***Contents*** Auralization: explanation of the term "Auralization", in analogy with "Visualization", and opportunities of the tool. ***Running time*** 5 minutes ***Language*** Italian - Familiar
	3. The AURA Project	***Contents*** Presentation of the AURA Project, the experience set at the DIDA Lab and the involved public. ***Running time*** 5 minutes ***Language*** Italian - Familiar

Fig. 11 – Structure of the video tutorial for General Public
Struttura del video tutorial per il Pubblico

Fig. 12 – Extracts from the video tutorial for children
Estratti dal video tutorial per i bambini

5 | Conclusions

The assessment of end-users experiences of the auralised 3d models for theatres has pointed out that auralisation can offer valuable immersive experience providing an exciting alternative to live performances and promoting the enjoyment of cultural heritage. Our study also suggests that music communities and technicians are very interested in adopting auralisation tools for a variety of purposes. To this end, taking on board the highlighted current limitations is crucial to enhance the AURA tools and make auralisation of cultural places accessible to future developments and uses.

Conclusioni

La valutazione delle esperienze degli utenti dei modelli 3D auralizzati, applicati ai teatri, ha evidenziato che l'auralizzazione offre la possibilità di una esperienza immersiva virtuale che è in grado di fornire una alternativa alle performance dal vivo e di promuovere la fruizione del patrimonio culturale. Il nostro studio suggerisce che la comunità musicale e i tecnici sono molto interessati ad adottare strumenti di auralizzazione per una varietà di scopi. È dunque importante prendere in considerazione i limiti che sono emersi, per potenziare gli strumenti sviluppati dal progetto e rendere l'auralizzazione dei luoghi culturali accessibile a futuri sviluppi e applicazioni.

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