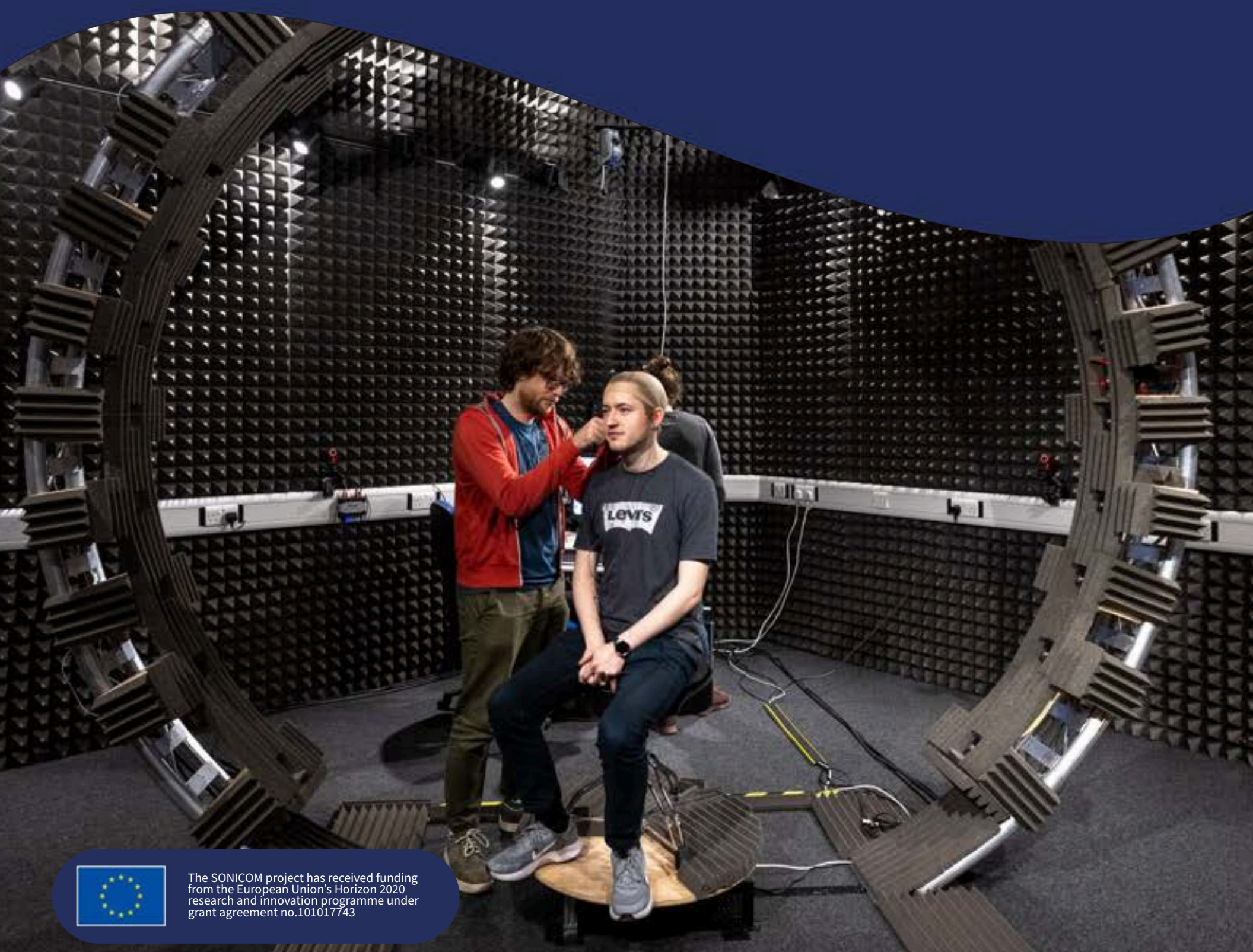
# SONICOM

## A Project Summary

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# FOREWORD

As SONICOM comes to an end, I find myself reflecting not only on what we have achieved, but also on the remarkable journey that brought us here. Coordinating this project has been one of the greatest privileges of my academic career, and without doubt one of the most rewarding research collaborations I have ever experienced.

Over the past five years, our consortium has addressed ambitious scientific and technological challenges in personalised immersive audio. In many areas we have exceeded even our own expectations, developing new theories, datasets, tools and technologies that we could scarcely have imagined when the project began. In other areas we have not yet reached the destination we originally envisaged. Research rarely follows a straight line, and some of the most challenging questions remain open. Yet SONICOM has laid the scientific foundations upon which future work can confidently build.

Perhaps our most important achievement is not any individual publication, algorithm or dataset, but the lasting ecosystem we have created. Through openly released data, software, standards and community resources, we have sought to make our research reproducible, accessible and useful far beyond the lifetime of the project. The SONICOM Ecosystem is intended not as the conclusion of our work, but as the beginning of the next chapter for researchers, developers and innovators working in immersive audio.

Above all, however, what I will remember most are the people. Watching PhD students, postdoctoral researchers and early career academics grow into confident, independent scientists has been the greatest reward of all. Their enthusiasm, creativity and willingness to challenge established thinking have continually reminded me why research matters. At a time when pursuing a career in research has perhaps never been more demanding, their passion gives me enormous confidence for the future.

SONICOM may officially be ending, but I am convinced that its ideas, its people and its impact are only just beginning.

Prof Lorenzo Picinali
SONICOM Lead Investigator
Imperial College London

# RESEARCH OVERVIEW

## Research theme: Immersion

### Improving the immersion of spatial audio rendering in Augmented/Virtual Reality (AR/VR)

Theme lead: Brian FG Katz, Sorbonne University

In AR and VR, sound is as important as visuals for building experiences that feel truly immersive. Our work focused on making virtual audio feel natural by understanding how people perceive sound, then turning that understanding into practical tools, models, and datasets that others can build on.

Since everyone's ears are unique, we developed BézierPPM, a method for building highly accurate personalised 3D ear models from simple scans, so audio can be tailored to each listener without expensive equipment.

Building on this, we explored how AI can predict how sound reaches an individual's ears directly from scans or photos, moving personalised audio closer to everyday accessibility. To support the wider research community, we released the SONICOM HRTF Dataset, a free, openly available resource with ear scans and audio measurements from hundreds of people, which is now used by researchers and developers worldwide.

To make virtual spaces sound authentic, we combined simulated and real-world reflections into hybrid reverberation models supporting real-time, six degrees of freedom navigation, so listeners can move naturally through a space while sound adapts around them. We also built a gradient-descent algorithm that automatically calibrates virtual room acoustics, tested successfully in complex, reverberant spaces such as an abbey church, and used deep learning to estimate a room's acoustics directly from speech recordings, enabling quick, low-effort reverberation time predictions.

Alongside this engineering work, we studied the underlying perception: predictive models of how people localise sound and how headphones affect that ability, how the directivity of a voice or instrument shapes realism, and how personalised audio improves speech understanding in noisy environments. Notably, we showed that personalised HRTFs meaningfully enhance a listener's ability to pick out speech from competing sources, a benefit particularly relevant for non-native speakers.

Together, these results, spanning personalised listener models, perceptually grounded acoustic environments, and openly shared datasets and tools, laid scientific foundations now feeding into gaming, social platforms, and accessibility applications, bringing virtual worlds a step closer to feeling as real as the physical one.

# RESEARCH OVERVIEW

## Research theme: Interaction

Understanding the interactions between the physical, psychological and behavioural

Theme lead: Alessandro Vinciarelli, University of Glasgow

The activities carried out in WP2 addressed several challenges related t o the perception of spatialised audio. One major area of investigation concerned the inference of psychophysical perceptual phenomena in AAR users from measurable properties of acoustic stimuli. Research in this area examined the role of reverberation in speech perception and co-immersion, the impact of interpolation methods on source stability, and the application of Bayesian approaches to sound localisation. Collectively, these studies addressed a broad range of issues concerning the relationship between the physical characteristics of acoustic stimuli and listeners' psychophysical responses.

A second research strand focused on the influence of users' physiological characteristics on auditory perception. The corresponding studies primarily investigated the relationship between sound localisation and key factors such as listener movement and the use of individualised HRTFs. Here again, the central objective was to establish links between the physical properties of acoustic stimuli—including their spatial attributes—and listeners' physiological characteristics, mainly represented through their individual HRTFs.

While the studies described above concentrated largely on the physiological and psychoacoustic dimensions of perception, other WP2 activities explored the observable behavioural effects resulting from exposure to different acoustic stimuli in immersive environments. These studies examined, among other aspects, the relationship between variations in acoustic stimuli, head movements associated with source localisation, and gaming behaviour. This latter line of research differs from the others in that it shifts the focus from low-level responses, primarily linked to physiological and psychoacoustic mechanisms, to higher-level cognitive and behavioural processes involved in the use of immersive environments. This is particularly significant because it establishes a point of convergence between the core SONICOM research community and the field of Human–Computer Interaction.

A further step in this direction involved analysing the relationship between the spatialisation of speech stimuli and the attribution of personality traits to speakers. In other words, this work explored the use of audio-based immersive environments as interfaces to human cognition and psychology. The results revealed, for the first time, a relationship between perceived distance and personality trait attribution, demonstrating that listeners tend to assign different personality characteristics to the same speaker depending on how distant that speaker is perceived to be.

Finally, WP2 contributed to the ecological validation of AR/VR systems through extensive user studies involving large numbers of participants. These studies evaluated two innovative technologies: one that exploits characteristics of the physical acoustic environment to influence musical performance, and another that introduces the concept of a sonic link, whereby a real environmental sound acts as a trigger for a virtual audio stimulus. Both technologies were assessed in real-world settings, including streets and parks, thereby ensuring a high degree of ecological validity.

# RESEARCH OVERVIEW

## Research theme: Integration

### Integrating SONICOM's various research tools and outputs into an accessible framework

Theme lead: Arcadio Reyes-Lecuona, University of Malaga

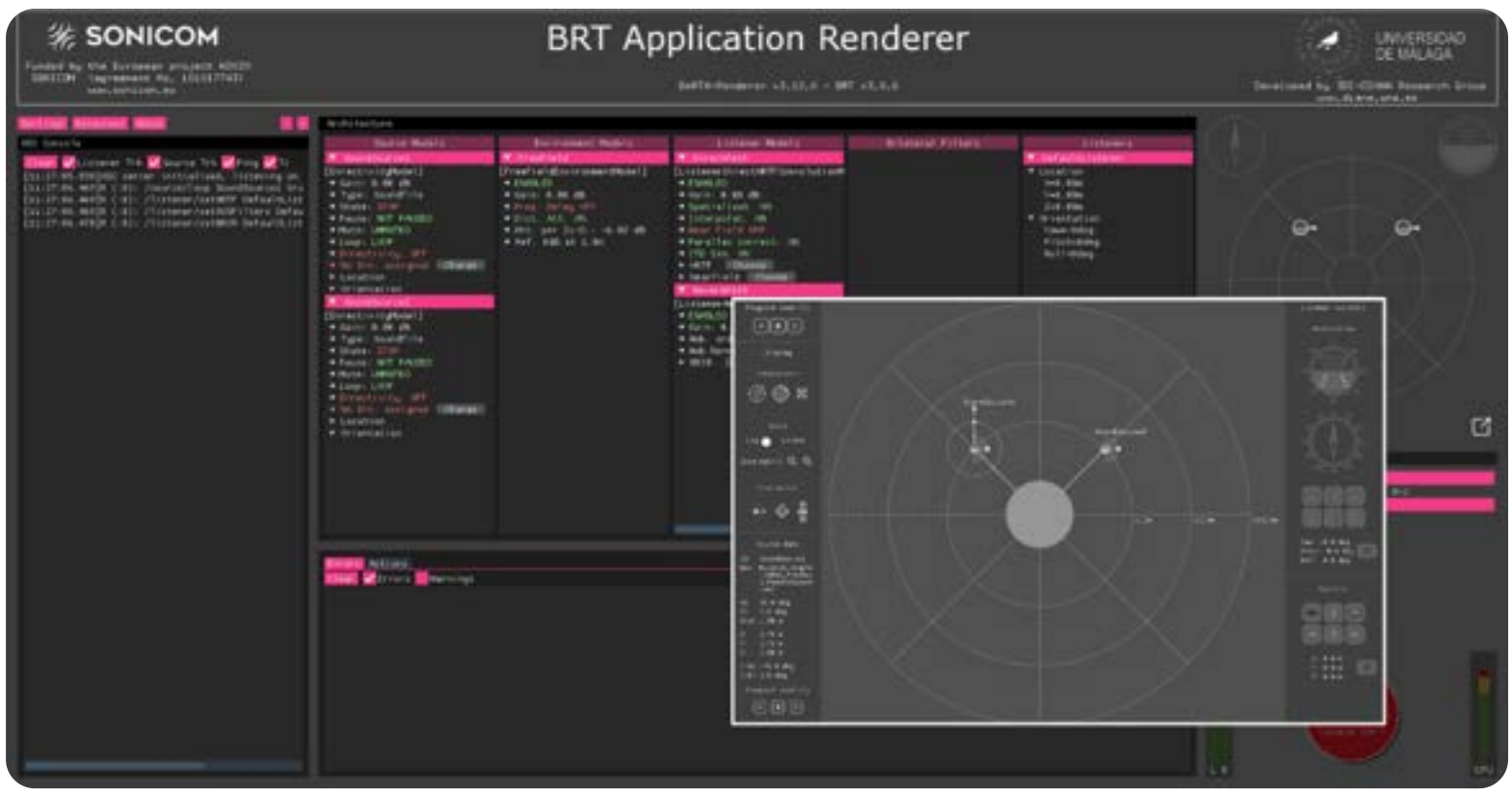
In 2026, SONICOM's Integration work delivered the final releases and results of tools, hardware, and applications.

The Binaural Rendering Toolbox v3.0 was released by UMA, finally including directional source models supporting the new proposed Source Directivity IR SOFA convention, geometric-acoustics environments (SDN and ISM), and hybrid reverberation workflows. Binaural rendering supporting configurable real-time HRTF interpolation, dynamic HRTF switching, Ambisonic encoding, and BRIR-based room simulation.

Bilateral post-binaural filters, enabling the simulation of hearing protection or headphone compensation, and multi-listener rendering with output-level calibration, which provides great experimental flexibility. In addition, a standalone application with an interactive user interface providing access to all the available features has been released, which makes easier the use of BRT in experimental setups controlled by other platforms like Matlab, Python or Unity. The BRT has been presented in a series of workshops together with a complete online documentation and is available as open source.

The Selfone hardware (a multi-speaker/multi-microphone headphone prototype), developed by USound was installed in the laboratory of the Acoustics Research Institute (ÖAW). There, it has been used to create a large dataset. Impulse responses of all pairs of the 20 speakers and the 24 microphones were measured in a set of 100 participants repeating the whole measurements 7 times. In addition, their HRTF was measured with the standard procedure at ÖAW premises as well as the impulse responses from all 20 speakers to the in-ear microphone. This large amount of data (350.000 Selfone impulse responses and 100 HRTFs) is publicly available in the SONICOM Ecosystem and can be used to explore the feasibility of machine learning approaches to get an estimation of the HRTF from the Selfone measurements.

Finally, a set of applications powered by BRT have been developed to support evaluation studies, providing a realistic testbed for SONICOM's integrated technologies. These include a spatialised teleconferencing application, developed by UMIL; an audio augmented reality (AR) system designed to support visually impaired and blind individuals in indoor navigation tasks, developed by Dreamwaves; and a physical installation to showcase outputs of the SONICOM project developed by Reactify with the support of Imperial.




The Binaural Audio Toolbox (BRT)

# RESEARCH OVERVIEW

## Research theme: Experience

Evaluating our results in an ecologically valid manner

Theme lead: Areti Andreopoulou,  The National and Kapodistrian University of Athens (NKUA)

2026 marked the successful completion of WP4-Experience, bringing together the evaluation of SONICOM technologies across a wide range of ecologically valid  applications. Throughout the project, the consortium studied how personalised spatial audio can improve immersive experiences in virtual and augmented reality. The technologies were tested in realistic scenarios, including teleconferencing, remote music education and practice, cultural heritage, and assistive technologies for blind and visually impaired users. All user studies highlighted the benefits of using immersive sound in XR applications, while also providing practical guidance for future applications.

Spatial audio was shown to make virtual experiences more natural, engaging, and effective.  In immersive teleconferencing, for example, participants reported feeling more engaged and more connected to the other people in the virtual meeting. Music-related applications demonstrated how realistic room acoustics and immersive sound rendering can improve remote teaching, rehearsal, and performance preparation. Studies also showed the potential of spatial audio in supporting accessible indoor navigation for blind and visually impaired users, with real-world evaluations demonstrating improved route completion and increased navigation confidence.

Beyond the validation of SONICOM-related research, WP4 developed a comprehensive framework for evaluating immersive audio experiences. By combining objective performance measures with user feedback and qualitative observations, the project established methods that can be used to assess future immersive audio systems in realistic settings. The end of SONICOM opens new opportunities for the future, with the work carried out in WP4 providing a strong basis for the next generation of immersive audio technologies and applications.

# RESEARCH OVERVIEW

## Research theme: Beyond

### Ensuring that SONICOM's outputs remain available beyond the project

Theme lead: Piotr Majdak, Austrian Academy of Sciences

The WP5 Beyond experienced an accelerated start. Originally scheduled for later in the project, immediate in-kind resources allowed the team to fast-track critical spatial-audio components right from month one. The initial strategy blended community outreach with core engineering. By partnering with the journal Acta Acustica, the team established a special issue that brought together spatial hearing experts, resulting in nearly twenty manuscript submissions. Parallel to this community building, software development accelerated dramatically.

The Auditory Modelling Toolbox (AMT) received a substantial framework overhaul to allow researchers to easily replicate experiments and cache complex calculations. This momentum culminated in major releases in 2021, expanding the freely available repository to over 60 models and 40 gigabytes of auditory data. Simultaneously, the team integrated Mesh2HRTF for numerical acoustic calculations and pushed forward with SOFA 2.0, which introduced a standardised way to represent continuous spatial audio data using spherical harmonics.

By 2023, intensive tool development shifted toward stabilisation, bringing the core software suite to near-completion. The mid-year period was characterised by a synchronised wave of major updates across the portfolio. The SOFA Toolbox version 2.2 was deployed to facilitate the sharing of complex acoustic data, while Mesh2HRTF version 1.1.1 rolled out to give researchers and commercial companies the precise tools needed to calculate personalised HRTFs. Spurred by these updates, the AMT reached version 1.5.0, significantly improving how researchers evaluate the success of binaural system personalisation. With the stand-alone software tools functioning reliably, the consortium shifted its strategic focus toward the future, mapping out preliminary structural designs for a centralised online repository and planning an open research challenge.

The momentum of 2023 translated into widespread international engagement through the launch of the Listener Acoustic Personalisation (LAP) challenge. Sponsored by the IEEE Signal Processing Society, this competition targeted difficult engineering hurdles surrounding HRTFs in immersive audio. The initiative drew attention from research groups worldwide, culminating in a formal award ceremony at the European Signal Processing Conference in Lyon, France, where teams were recognised for pioneering neural network solutions to HRTF normalisation and upsampling. Alongside this public success, vital infrastructure milestones were achieved behind the scenes. The team launched the ÖAW Datathek, which serves as the permanent digital backbone of the entire Ecosystem. By archiving research data in a certified manner and assigning permanent Digital Object Identifiers (DOIs), this repository established a secure foundation, paving the way for the development of the Ecosystem's public web interface.

2025 was entirely dedicated to executing the vision of a unified, web-based data repository for spatial-hearing research. The goal was to build an open-access platform combining auditory data, simulation models, and rendering tools into a searchable, highly interactive frontend. To achieve this, the team spent the first half of the year programming software, installing new server hardware, and finalising data-sharing agreements with the repository backbone. The hard work paid off in July 2025, when the first official version of the SONICOM Ecosystem went live. Designed for open science, the platform allowed anonymous visitors to freely browse and download datasets, while offering ORCID-verified researchers the ability to contribute original content and interact via an integrated commenting system. Powered by the initial research outputs of the SONICOM network, the platform grew exponentially, expanding to host more than 20 distinct databases and tools within its first few months.

The SONICOM Ecosystem has transitioned from a specialised project repository into a mature, widely respected hub for the global spatial-hearing community. The platform has been showcased at various international conferences, receiving high acclaim from auditory experts and confirming its utility as an indispensable research asset. The platform’s growth shows no signs of slowing down, currently hosting an expansive library of 64 distinct databases and 15 analytical tools. Although minor technical details continue to be polished, the long-term future of the platform is secured by the commitment of the ÖAW researchers. Strong maintenance plans are established to ensure that the ecosystem will continue to grow, evolve, and support reproducible spatial audio research long beyond the official SONICOM project’s end.

# RESEARCH TOOLS OF SONICOM

Over the course of five years, SONICOM has developed, advanced and openly released a suite of research tools designed to support the wider spatial audio community. From datasets and file format standards to rendering toolboxes and auditory models, these resources are freely available and built to last well beyond the lifetime of the project.

## The SONICOM HRTF Dataset

Created within SONICOM, this dataset includes HRTFs acoustically measured from more than 400 individuals, including HpTFs, RGB+depth pictures and high-resolution 3D models. for 200 subjects we also have a synthetic HRTF.


## Auditory Modelling Toolbox (AMT)

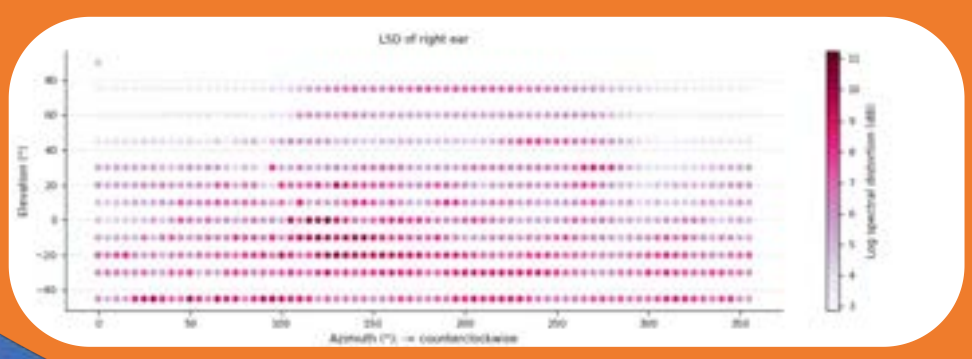
A MATLAB/Octave toolbox for the development and application of computational auditory models, with a particular focus on binaural hearing. The AMT predates SONICOM, but has been actively developed and expanded throughout the project's five-year duration, growing to include over 60 models and 40 gigabytes of auditory data.

## Binaural Rendering Toolbox (BRT)

The BRT library includes the algorithms developed in the 3D Tune-In Toolkit in a new open, extensible architecture. The BRT consists of a library with C++ implementations of listener models, source models, and environment models.

## Spatially Oriented Format for Acoustics (SOFA)

A file format for storing spatially oriented acoustic data like head-related transfer functions (HRTFs) and binaural or spatial room impulse responses (BRIRs, SRIRs), standardised by the Audio Engineering Society. Originally developed prior to SONICOM, the format has been significantly advanced and supported by the project over the past five years.



## Spatial Audio Metrics (SAM)

Created within SONICOM, this dataset includes different types of data measured from 200 subjects, including HRTFs, HpTFs, depth pictures and 3D models of subjects' ears, heads and torsos.

# RESEARCH TOOLS OF SONICOM

A major output of the SONICOM project

*This work was led by Prof Piotr Majdak, Austrian Academy of Sciences*

**One platform** housing 64 databases and 15 tools

**Visualise data** directly in browser before downloading

# THE SONICOM ECOSYSTEM

**Persistent DOIs** for every dataset and tool — fully citable

**Open source and maintained** beyond the project by the Austrian Academy of Sciences

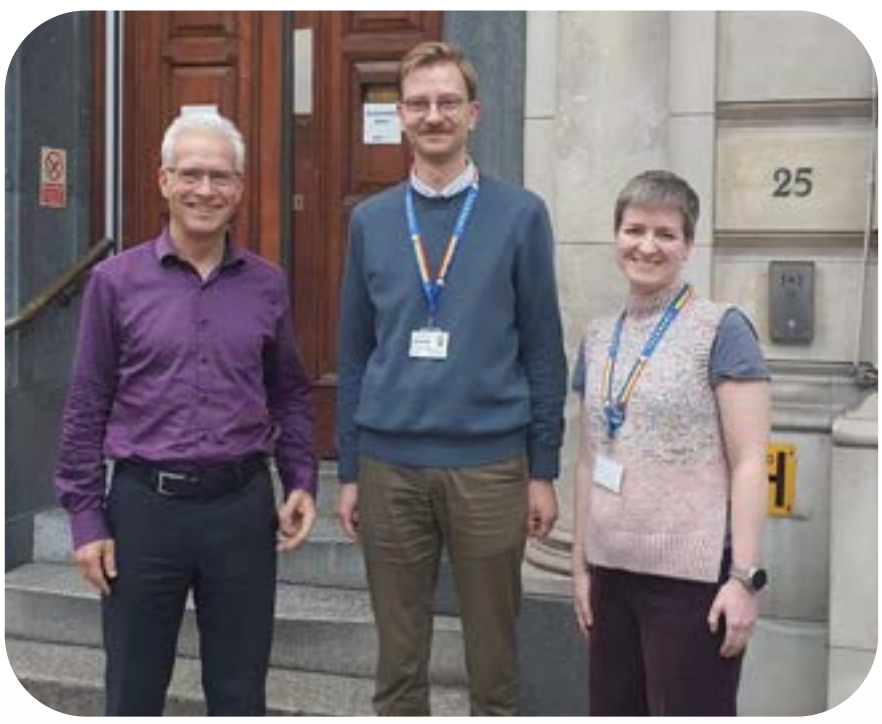
# SUPPORTING THE NEXT GENERATION

One of SONICOM's greatest successes has been supporting the development of early career researchers. Throughout the project, many PhD students have completed their doctoral studies while contributing to advances in personalised immersive audio.

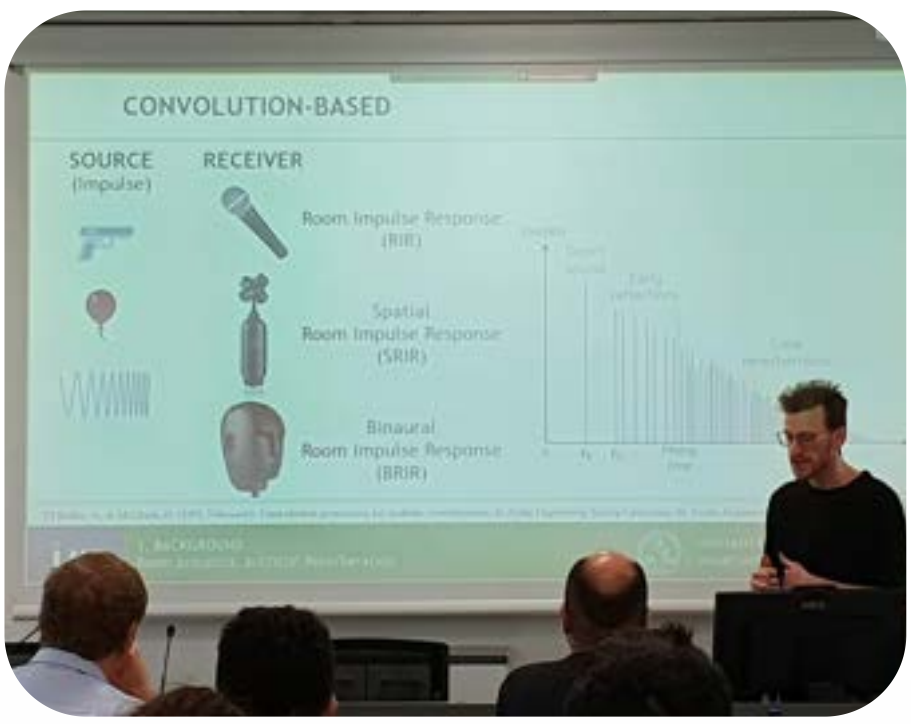
Their achievements are a testament to their hard work, the collaborative environment fostered by the consortium, and the lasting impact the project will have on the next generation of researchers. Congratulations to all on this well-deserved achievement.

Jake Bhattacharyya defended in May 2026
University of Glasgow

Katharina Pollack defended in March 2026
Austrian Academy




Rapolas Daugnitis defended in December 2025
Imperial College London




Davide Fantini defended in December 2024
University of Milan

# WOMEN OF SONICOM

**Jessica Luo** joined the SONICOM team as a Research Engineer at Sorbonne Université in France, where she performs research investigations focusing on AR/VR, architectural acoustics and and sound perception in Space. Hailing from America, Jessica holds her Master of Music in Music Technology from NYU and a Bachelor of Science in Audio and Music Engineering from the University of Rochester.

**Areti Andreopoulou** is an Assistant Professor in the Music Technology Laboratory of Music Acoustics and Technology (LabMAT) at the National and Kapodistrian University of Athens (NKUA) in Greece. She is interested in spatial audio, immersive auditory perception, and audio in xR (encompasses augmented reality (AR), virtual reality (VR), and mixed reality (MR)).

**Eva Fringi** is a Research Associate at the University of Glasgow in the School of Computing Science. Her PhD thesis focused on the effects of child language development on the performance of automatic speech recognition. Eva's area of expertise spans various disciplines such as: signal processing, automatic speech recognition, children's speech development, machine learning for developmental speech errors detection, and neuropsychological assessment.

**Katarina (Kat) Poole** is a Research Associate at the Dyson School of Design Engineering at Imperial College London, UK. She is interested in how the brain interprets complex sensory information. My research uses spatial hearing as a framework to study predictive brain mechanisms, combining psychophysics, electrophysiology, and perceptual modelling.

**María Cuevas-Rodríguez** is an Assistant Professor at the University of Malaga and part of the DIANA research group. She is also a Telecommunication Engineer (BSc+MSc). Since 2010, she has been involved in national and EU-funded projects in the fields of Robotics, Virtual Reality and 3D audio. During her PhD, she accomplished two internships, one at Imperial College London (UK) for 3 months and another at the audio team of Facebook Reality Lab (Seattle, EEUU) for 6 months.

**Siobhan Markus** is the Project Manager for the SONICOM project. She is currently the Head of Impact Management within the Research Impact Management Office at Imperial College London. She has lived in the UK for several years since moving from her home in Sydney, Australia, where she studied a Bachelor of Media and Communications at the University of Wollongong.

**Alexandra (Ally) Rayner** is the Communications Manager for the SONICOM project. Hailing from Australia, Ally has lived in the UK for four years and worked at Imperial College London for the past two. She holds a Bachelor of Arts with a major in Public Relations and Marketing from Macquarie University in Sydney, Australia.

# COMMUNICATIONS CHAMPIONS PROGRAMME

The Communication Champions Programme was established in 2025 as a way to build capacity amongst the consortium.  11  members of the SONICOM consortium from 7 institutions made up the cohort and had the opportunity to attend 4  sessions: 1. Science Writing, 2. Public Engagement, 3. Social Media - Building your profile, and 4. Journalism and Media.

There was a significant increase in confidence and understanding of communicating research effectively when rated before and after.











## Participant Feedback

**107%**
increase in confidence in speaking to journalists

**3 in 4**
participants now feel very confident to communicate their research

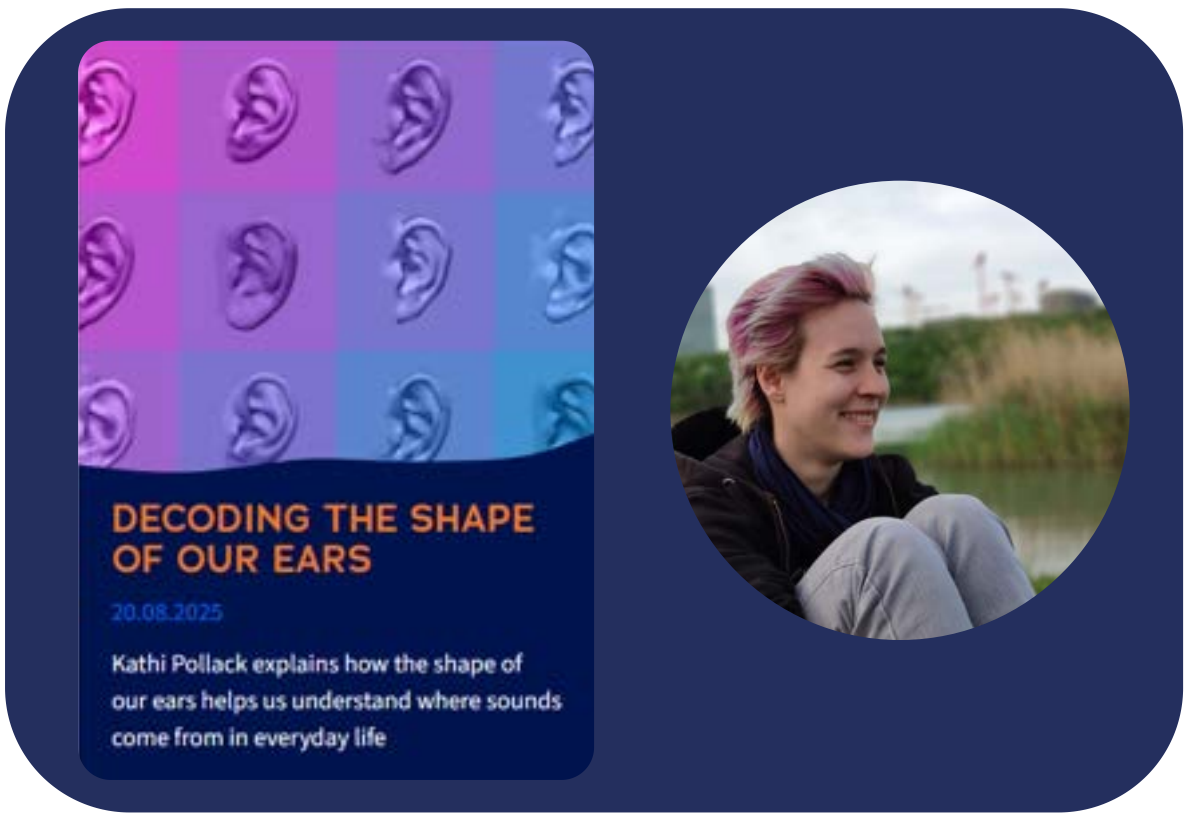
**75%**
participants rated the Public Engagement workshop 5 out of 5

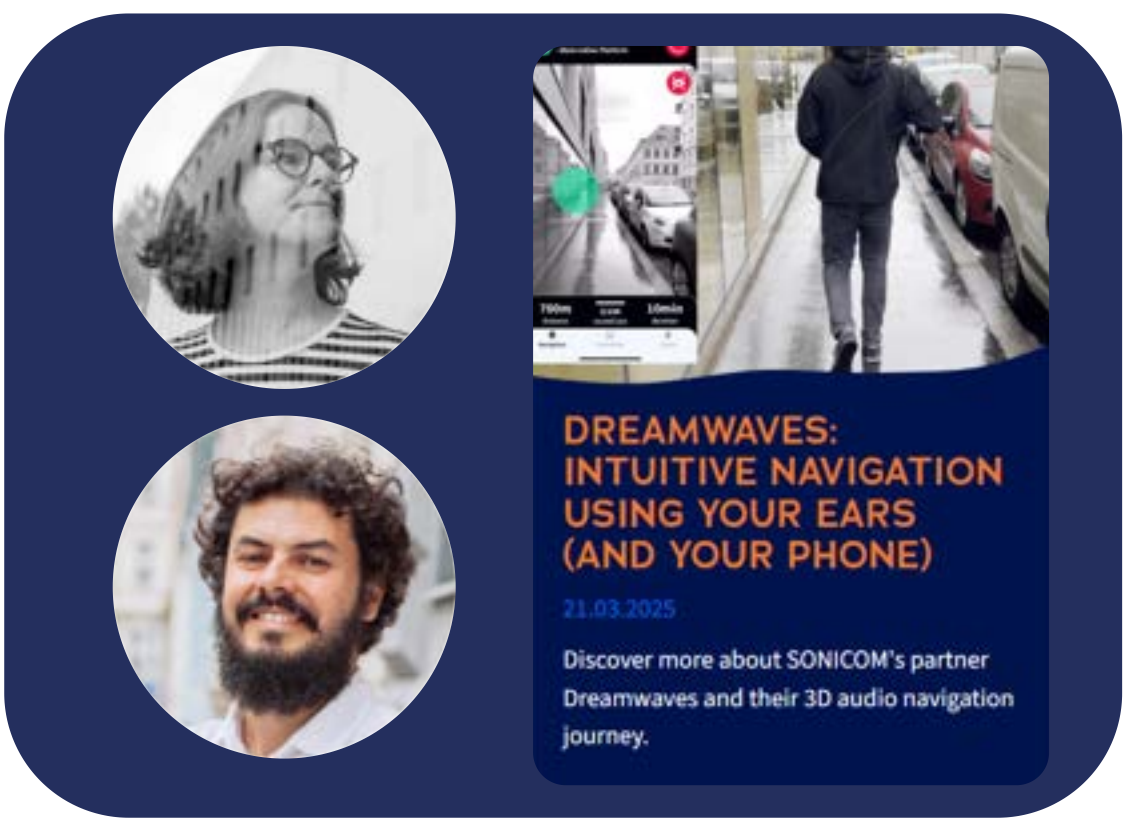
*"With the help of the programme, I realised that there are different levels of communication and that there is a myriad of ways to explain a "simple" scientific fact."*

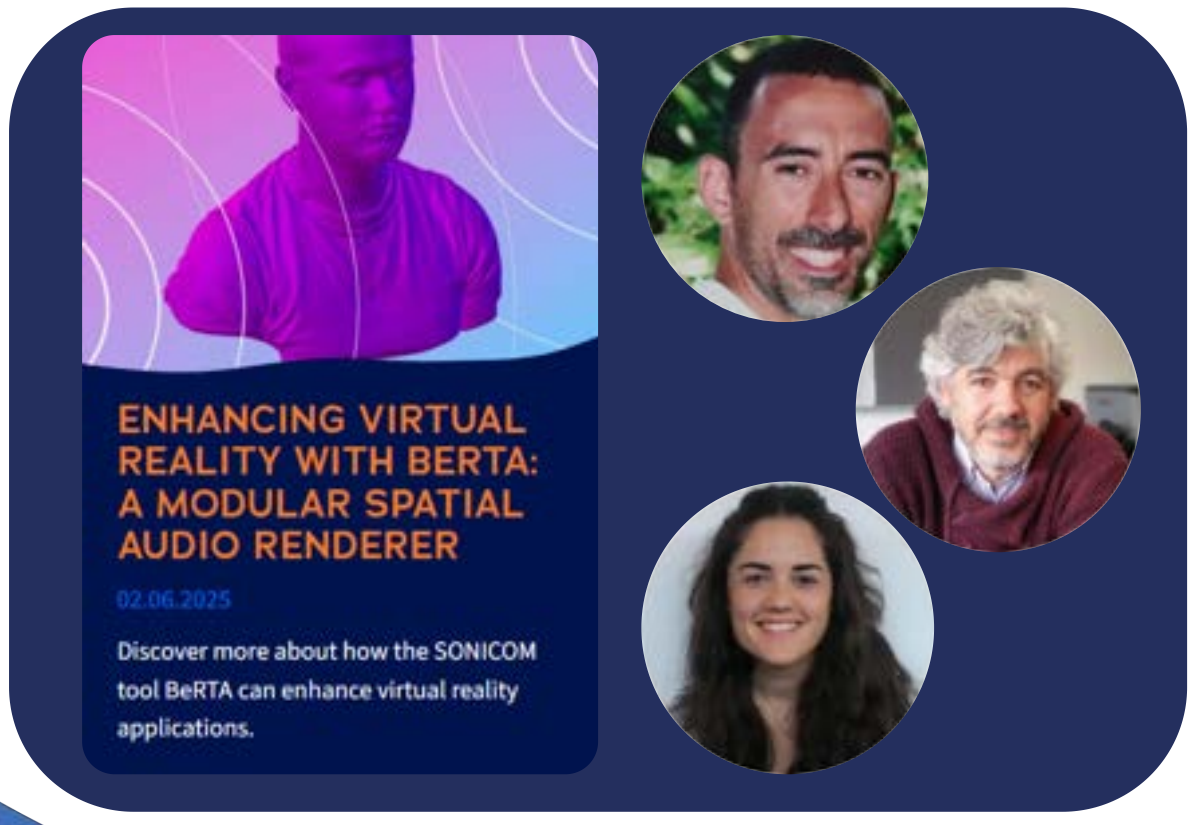
*"The programme encouraged me to adopt a more open and confident approach to communicating my work."*

*"The programme helped me see science communication through a clearer framework, highlighting how messages need to be adapted depending on the audience and the channel used."*

# COMMUNICATION CHAMPIONS OUTPUTS



# PUBLIC ENGAGEMENT IN SONICOM

**SONICOM at the Royal Society's Summer Science Exhibition**

From 4-9 July 2023, SONICOM exhibited at the Royal Society's Summer Science Exhibition, one of the largest science engagement festivals in the UK.

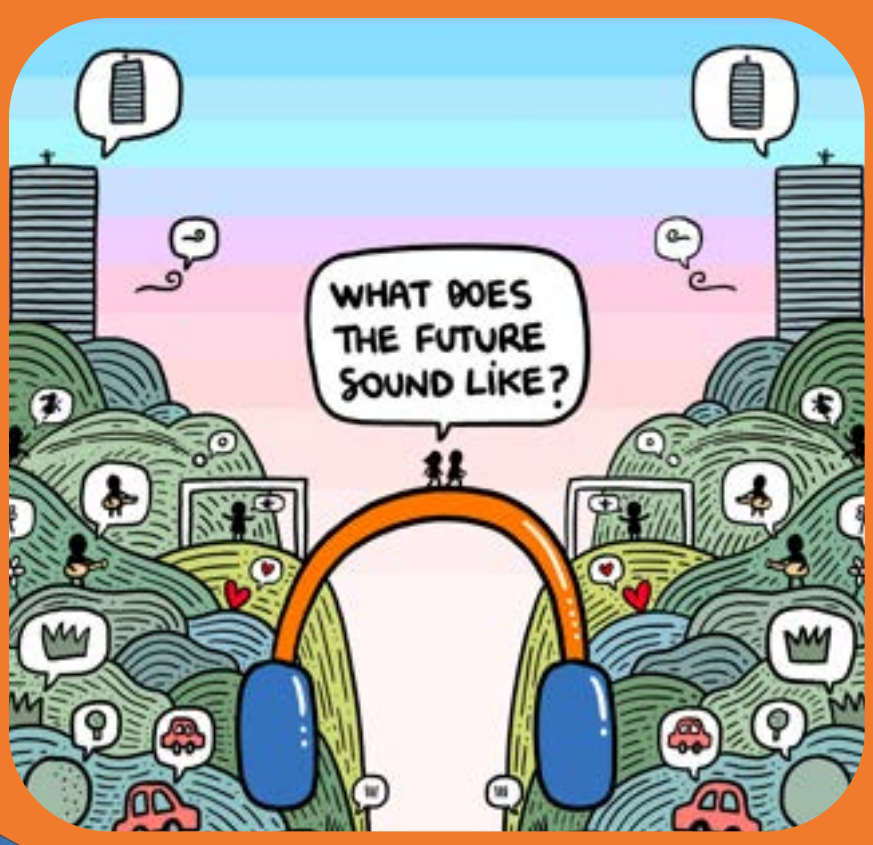
As the Royal Society's flagship event, the Summer Science Exhibition attracts thousands of visitors every year, from families with 4-year-olds to school groups to eminent Fellows of the Royal Society.

The 'Virtual Audio: Illusion or Reality?' exhibit led by Lorenzo Picinali, a member of the Audio Engineering Society, featured research projects from Picinali's Audio Experience Design team at Imperial College London, including SONICOM and the NIHR-funded BEARS project.

**SONICOM at Imperial Lates: AI**

On March 14th 2024, SONICOM exhibited at the Imperial AI Lates. The Lates are an opportunity for the public to interact with the latest scientific developments at Imperial College London, with the theme of this Late focused on Artificial Intelligence (AI).

Across the three-hour evening, over 1000 attendees came through to check out the several exhibits and workshops on display, with 93% describing the night as a fun way to spend an evening.


**'Bridge Between Worlds'**

As part of Imperial College London's Making Research Glow initiative, SONICOM worked with illustrator 72Kilos (Óscar Alonso) to interpret the project's research into personalised immersive audio in a way that was engaging and accessible to non-specialist audiences.

This piece is about our continued exploration of real and virtual soundscapes. This duality is frequently being blended with much of our everyday lives progressively involving AR/VR to the extent where the bridge between what is real, and what is not, is gradually becoming harder to ascertain.


**The Winners of the SONICOM LAP Challenge**

The winners of the SONICOM Listener Acoustic Personalisation (LAP) Challenge were announced at the 32nd European Signal Processing Conference (EUSIPCO 2024) in Lyon, France. Sponsored by the IEEE Signal Processing Society, the challenge brought together researchers from across the auditory community to develop innovative solutions for personalised spatial audio.

Task 1 was won by Jiale Zhao, Dingding Yao, Zelin Qiu, Chengzhong Wang, and Junfeng Li for their solution, Normalization of Head-Related Transfer Functions Based on Neural Networks.

Task 2 was won by Yoshiki Masuyama, Gordon Wichern, Francois G. Germain, Christopher Ick, and Jonathan Le Roux for their solution, Retrieval-Augmented Neural Field for HRTF Upsampling and Personalisation.

**Trust Your Ears? SONICOM’s Immersive Sound Lab puts visitors to the test at London Festival**

SONICOM returned to the Great Exhibition Road Festival 2025, where over 50,000 visitors celebrated science and the arts across South Kensington. Together with the Dyson School of Design Engineering and Reactify, the team unveiled The Immersive Sound Lab, an interactive augmented reality experience challenging visitors to determine whether sounds came from real objects or virtual sources.

As well as putting their listening skills to the test, participants contributed valuable data to SONICOM's research, helping shape the future of personalised spatial audio and immersive experiences.

# THE LAST HURRAH!

Throughout the SONICOM project, the consortium met in person each year (with the exception of one meeting during the COVID-19 pandemic), strengthening collaborations and sharing progress face to face. The final consortium meeting was hosted by Sorbonne University in Paris, bringing partners together one last time before the project's official conclusion.

The meeting provided an opportunity to reflect on achievements, celebrate the consortium's successes, and prepare for the project's final review meeting later this year. To mark the occasion, partners enjoyed a memorable evening at Dans le Noir, the renowned Paris restaurant where guests dine in complete darkness, guided by visually impaired waitstaff. The unique experience encouraged participants to rely on their senses beyond sight, an especially fitting way to celebrate a project dedicated to advancing immersive audio and human perception.

The meeting concluded on the penultimate day of the project, with SONICOM's final day coinciding with the opening of AVARIG 2026. Building on the long-running AVAR conference series, AVARIG introduced a new focus on immersive gaming, bringing together experts in XR audio and game audio under the AES Technical Committee on Immersive Media and Gaming. Hosted in Europe for the first time, the conference provided an ideal setting to showcase SONICOM's legacy.

As a sponsor of the conference's opening day, SONICOM presented eight interactive demonstrations, highlighting research and technologies developed across the consortium. The demonstrations gave attendees the opportunity to experience first-hand the project's innovations in personalised spatial audio and immersive media, providing a fitting finale to almost five years of collaborative research.

**11**
SONICOM
Presentations

**8**
SONICOM
Demonstrations

2026 6th International Conference
**Audio for Virtual & Augmented Reality and Immersive Games**
AVAR IG 2026
Audio Engineering Society
**30 June - 3 July, 2026 | Paris, France**
**Sorbonne University/d'Alembert & IRCAM/STMS**

## Our partners

IMPERIAL

SCIENCES SORBONNE UNIVERSITÉ

Institut Jean le Rond d'Alembert

ÖAW AUSTRIAN ACADEMY OF SCIENCES

UNIVERSITÀ DEGLI STUDI DI MILANO
DIPARTIMENTO DI INFORMATICA

Laboratorio di Informatica Musicale

HELLENIC REPUBLIC
National and Kapodistrian University of Athens

LabMAT

UNIVERSIDAD DE MÁLAGA

University of Glasgow

Dreamwaves

U SOUND

Reachfy ADDING NEW DIMENSIONS TO MUSIC

SONICOM Consortium at the Final Meeting in Paris, France in June 2026