ReSilence: Retune the Soundscape of future cities through art and science collaboration

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Abstract

Advances in cognitive science, sensing technologies, the arts and creative industries are paving the way for a deeper understanding of the behaviour of individuals regarding the land/soundscape they live in. Through a symbiotic relationship between artists, scientists and technology experts ReSilence explores the borders between sound and silence in a changing world by producing sound awareness in urban spaces (not only reducing the intensity of noise, but also considering it as energy producer and designing positive sounds, sounds we want to preserve and multiply). More specifically ReSilence focuses in musical experience design centred on the active participation of citizens, in the new silence of mobility, in the acoustic perception of outdoor urban soundscapes and in enhancing experiences for people with hearing and vision impairments.

Keywords

Art, Urbanism, Sound, Artificial intelligence, Extended Reality, accessibility, social inclusion, participation.

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Introduction

ReSilence is a project that is part of the S+T+ARTS initiative of the European Commission to foster alliances between science, technology, and the arts, centred on human needs and values. In order to encourage collaboration of research projects and artists, S+T+ARTS funds residencies of artists in technology institutions, as well as activities of scientists and technologists in artists' studios.

Started in 2022, ReSilence is a consortium of institutions, universities and SME's that put together their expertise in terms of scientific, technological, artistic and pedagogical research. Through S+T+ARTS residencies artists will become part of the research team, which aims to 1) explore the borders between sound and silence in a changing world by producing acoustic awareness in urban spaces, not only through reducing the intensity of noise, but also by designing, enhancing and/or multiplying existing sound considering it as an energy factor, 2) create new types of sonic urban experiences that expand possibilities for accessibility, active participation/engagement, sustainability and social inclusion and 3) build trust around AI & XR technologies.

Background

Cities and metropolitan areas are often acting as social condensers, through the dense cohabitation of people, services and cultures. By 2050, cities will host 2.5 billion more urban dwellers, making the world almost 70% urban. Europe's urban areas are home to over two thirds of the EU's population [(1)]. This coexistence brings along a series of issues and urgencies, related to place making, the collaborative process by which we can shape our public realm in order to maximise shared value and make space for diversity. Sound is a fundamental component of our cities, of their cultures, and of the health and well-being of their citizens. In an urban fabric, the soundscape of a city is entangled with social behaviour and impacts citizens' attitudes and behaviour in urban, natural and manmade environments. New ways of mobility, communication, interaction, and sharing are beginning to have profound consequences for the way that cities sound. More inhabitants lead to a necessity for more housing, and thus more construction. Increased surveillance introduces new sounds, such as those made by drones.

The project ReSilence builds on the novel and prima facie paradoxical observation that elements of city life are becoming more silent due to the emerging electrification of public and private transport, allowing us to question which sounds are necessary for safety

and environmental awareness, and which sounds can be made more pleasant. Decades ago, artists already worked on these questions. Composer John Cage famously stated that "everything we do is music," and his seminal work "4:33", composed in 1952, is a work which considers as music the sounds humans make just by simply enacting everyday movements. Before Cage, Futurist artist Luigi Russolo wrote the manifesto "The Art of Noises," in 1913. Russolo concludes "the variety of noise is infinite, and as man creates new machines the number of noises he can differentiate between continues to grow."[1] How then should we tackle this growing number of different sounds in order to improve the quality of life for inhabitants, all while considering the important role of sound and music to each person's life, culture, and identity?

Aims and objectives

As new technologies make their appearance in public spaces and enter our everyday lives, the need to re-imagine and envisage these spaces unfold, either by addressing their visual or non-visual (sound) aspects and values, in architectural and urban settings. How cities might sound in the future is a challenge that will significantly affect the emotional and cognitive state of individuals and will influence the functionality and effectiveness of indoors and outdoors spaces in manners that need to analyse and take into consideration.[2] Our world is shaped through fast modes of communication, distant social interaction and electrification. While physicality and space continue to be important premises when planning our cities, it is time to start thinking about how we can design experiences for people living hybridly (physically and virtually) in the city and how we can orchestrate the sounds our cities produce, sculpting people's existence. To achieve this, it is essential to find new ways to engage citizens and audiences to re-think how cities sound. Therefore, **ReSilence** is developing technologies by proposing a new methodology with the scope to shape in novel and innovative ways urban environments and soundscapes, repositioning the role of silence and that of sound. Recent efforts have focused on the city as the generator of very large datasets used in an effort to become "smarter," greener and safer.

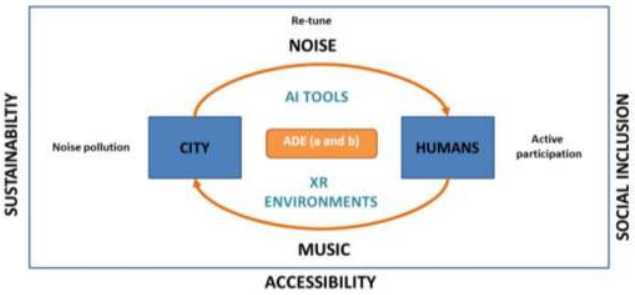

Figure 1. ReSilence overview. ©ReSilence Copyright

Now, **ReSilence** turns the attention to the social and human experiential dimensions of the cities' datasets in order to make citizens more creative and aware of their surroundings, while improving quality of life through the consideration of noise (see Figure 1).

Main objective of the **ReSilence** project is to support the development of art-driven technologies for designing the soundscape of future cities through the collaboration of artists, architects, urban designers, scientists, engineers and researchers. The project achieves this by targeting a) AI and XR tools to primarily address challenges from the Urbanism/Mobility sector while exploring the borders between music and noise, and b) user experience measurements assessing a sound space.

Methodology

The symbiosis between humans and computer-based technologies has a significant impact on Art. Frameworks like STARTS allow technology to contribute to both the creative process and artistic practice, when in addition; it works dynamically with humans in the realisation of designs, sounds, etc.

ReSilence supports Art-Driven Experiments (ADE) through Open Calls to artists and artist-SME teams. Artists, through **ReSilence,** have access to AI and XR technologies and also help in ensuring that the development process and system behaviour of the technologies explicitly acknowledges human values and needs. The following figure (Figure 2.) represents the above-mentioned, based on the research, technology and art objectives set. Art and artists have a leading role in the development and evolution of the project and ADE play a critical role to support it. ADE, does not only bring together artists/sound designers, scientists and technology providers, who explore and work with existing technologies to enhance their usability and uptake or design art-driven products and services to tackle Urbanism/Mobility challenges described. While AI

and MR technologies take cities to the next step of utilising the data collected and knowledge to support decision-making, they often solve city problems following top-down solutions. Instead, **ReSilence** actually tries to harness such technologies through ADE to engage some of the most fundamental issues of citizens, focusing on a bottom-up approach and leverage their creativity.

To begin with, we ensure that the development of services and products follows a human-centred design philosophy so that **ReSilence** is properly deployed in the project implementation scenarios. A set of use-case scenarios is defined at first by the artists that include information on their current workflows and objectives, the challenges they face and the areas where new solutions would be supportive. In this step, ReSilence in fact builds bridges between artists, science and technology experts. Once the artists define the challenges and the implementation scenarios, we develop AI-based methods to increase the active experience of citizens and integrate individual and collective experience of music and sound. Artists and their creations in the context of Re-Silence, through interactive visualisations and user participation, also foster trust in the deployed technologies. More specifically the above-mentioned is approached using multimodal movement analysis and sonification, by developing and integrating in the system platform tools capable to measure the non-verbal, full body expressive and emotional behaviour, at both individual and group (e.g., synchronisation, entertainment, leadership) levels. Novel tools for qualitative urban soundscape-analysis are also developed, guided by the goals set by the artists, based on immersive visual and acoustic stimuli. With the help of those, the consistency of a soundscape can be investigated to identify needs and means for redesign of outside or inside spaces. The "AI for real-time interaction" objective is also supported by the generation of sound related to images, the synthesis of scenes based on sounds and the further study of the relation between auditory and visual stimuli by means of explainable AI.

Figure 2. Objective-based ReSilence methodology (AO-**A**rt **O**bjectives, RO-**R**esearch **O**bjectives, TO-**T**echnology **O**bjectives) ©ReSilence Copyright.

The above led to the art-driven toolkit, which deals with the integration of the modules based on which artists, creatives and technologists co-create artworks, products and services. Artists will be using the collected audio-visual and spatial data to assist and empower specific user groups by means of multisensory technology. More specifically, this stage is related to the development of multisensory experiences in XR environments and allows artists to create different solutions to reshape our urban environments and soundscapes, rebalancing the role of silence and that of sound. The development and integration of AI tools are also part of this phase and defines the underlying architecture for a robust communication system between the components and how the components are integrated in each required system. Artists and architects are also supported by an object-based interactive audio engine, allowing the algorithmic composition of soundscapes based on visual data. This engine facilitates the virtual design of urban soundscapes by means of 3D-modelling techniques. Moreover, the art-driven experiments are evaluated in the "Soundscape Experience Assessment" phase, which achieves a novel understanding of the human perception in relation to sound and his environment. At this point, we deal with emotional sensing and analysis, sentiment analysis from crawled social media data and reviews, multimodal analysis of sound related behaviour and self-report generation. To support the above, we develop novel physiological signal processing algorithms and signal integration frameworks to detect, extract and classify markers of emotional responses to aesthetic and/or artistic stimuli. Through this analysis, ReSilence essentially understands individual and collective perceptions and preferences, leading to a more transparent decision-making process. Part of this work is also a novel algorithmic approach to investigate the correspondences between artists' music composition and listeners' perception. Another part of this phase of our methodology is devoted to the linguistic analysis of social media posts and human verbal comments acquired within ReSilence that discuss topics related to the music sector in order to give an overview of larger societal preferences and sentiment. Furthermore, for the multimodal analysis, we combine the outcomes of different components, in order to acquire a more integrated result for understanding the role of active audience participation. The combined components vary among the different scenarios. The project's methodology ends with the fabrication of creative solutions to reach the public, resulting from the collaboration with the artists. The challenges that led the artists in the definition of the implementation scenarios, along with the opportunities sound and related media offer to the urban future eventually result in artworks that stimulate public dialogue through exhibitions, communication initiatives and/or industry

collaborations. The first phase of these S+T+Arts residencies is the research phase during which the artists will spend time discussing with the ReSilence partners and learning about research and technology initiatives. In return, consortium members learn about the artist's practice, working methods and perceptions of the questions being explored. The second phase is the technical/scientific realisation of the project and the third is the phase for preparing the results for exhibition and communication.

In a nutshell, **ReSilence** achieves its goals by establishing a symbiotic relationship between artists and scientists in a co-creation ground to address urban and societal challenges aiming for an enhanced urban-sonic experience. Hence, it supports two kinds of art-driven experimentations: (a) artists exploring and working with **ReSilence**'s technologies to improve their usability and uptake and (b) artists and end-users/providers of novel technologies collaborating in art-driven experiments addressing specific challenges through a variety of scenarios. These scenarios address either 1) the active participation of citizens, or 2) the *new silenc*e of mobility, or 3) the acoustic perception of outdoor urban soundscapes, or 4) the enhanced experiences for people with hearing and vision impairments, with all of them aiming to affect the urban/mobility sector.

Implementation Scenarios Musical Experience Design

Cities are not only places where people live and work; they also offer spaces for leisure, entertainment and art participation. Van der Hoevenan has done long research on how music becomes part of the urban landscape. [3] Concert halls, opera houses, theatres and other performance spaces are architectural landmarks in many cities.[4] They offer spaces where urban communities can meet and share meaningful experiences. The increasing number of mediated performances (broadcasts, recordings, on demand and live streams) that can be consumed individually and at homes, is a chance and threat at the same time: They offer people with restricted mobility, small budgets, or that live far away from cultural urban centres the chance for participation. They also question the future and continuing value of such public spaces and the number and diversity of performing ensembles.

In this use-case scenario, we focus on live performances of music and dance and explore the value of shared aesthetic experiences. Live performances are defined by the temporal and spatial co-presence of the performers and their audience and the creation of the performed work in the here and now – features that can be broken down into further characteristics and that are relevant for the attractiveness of live performances and the intense and meaningful experiences they can afford.[5] Artists will develop and use technologies to liquify the boundaries between in-person and mediatized performances. E.g., through the use of XR technologies we seek, on the one hand, to bring a social and interactive dimension to individual streams, and, on the other, to enhance and individualise live experiences. Therefore, in this use case artists in collaboration with technologists, scientists, architects and designers will explore new ways of designing musical and dance performances as well as interactive, performative spaces and environments, both physical and XR-enhanced.

In general, artists can adopt a quantitative or a quality approach in relation to audience experiences. In the qualitative approach, the aim is to use novel technologies to increase accessibility, participation and audience engagement. Here, new ways of enabling participation—on site and remotely—should be explored. Specifically, groups of people who are typically less well represented in certain types of concerts should be addressed, such as people with disabilities, people that do not belong to the socio-demographic group(s) that are related to the concrete type of concert and musical repertoire, and people who cannot attend live performances due to living far away, being immobile or not able to pay for a ticket. In the qualitative approach, the focus is on broadening and deepening the audience experience. Here, technology-assisted ways of making the music and concert experience more engaging and meaningful should be explored. One of them would be to allow audience members to actively participate in the performance. Further, it can be studied to what degree mixed reality events can provide experiences similar to live concerts, but also whether virtual or augmented concerts could be a performance format in its own right, with unique features and affordances for its participants, with a strong impact on the music and on the creative industry sector in general. Our research will extend on methodologies of studying live performances but also concert streams, for instance in the context of research projects such as *Experimental Concert Research*, *Digital Concert Experience,* the EU Projects H2020 ICT DANCE (dance.dibris.unige.it) and H2020 FET PROACTIVE EnTimeMent (entimement.dibris.unige.it), providing research results in automated analysis of expressive qualities of full-body individual as well as joint movement (e.g., of musicians in small ensembles, or audience members) and of interactive sonification: An

example from the DANCE project is the performances in collaboration with the choreographer Virgilio Sieni involving audience members as active participants in museum and other public spaces, such as *Atlante del Gesto* in Genoa, and the *Europa* events in occasion of the celebration of the Treaty of Rome.[6, 12]

Such novel technology-driven experiences are a major departure from the conventional situation of the listener located in a definite space for the time of a concert. They are also a challenge for composers, musicians, audiences and the classical concert hall.

In this direction, **ReSilence** investigates how artists can explore and propose novel formats of concerts and performances characterised by *audience engagement* to create novel artworks and change perceptions of how technology can be used and how we experience it.

Besides the virtual platforms, Thessaloniki Music Hall (for performances over 50 participants), Casa Paganini and the ArtLab of the MPIEA (for smaller groups) will be used for live and for hybrid events and be test beds for audience co-creation.

The New Silence (Sound and mobility)

The sound fabric of the city has evolved and will keep mutating within the next decades. If the dominant sound of the city was the one of mechanics in action, from the combustion engine to the factories in action once investigated by artists such as the Futurist Luigi Russolo glorifying industrial noise in his Manifesto “The Art of Noises” (1913), we are getting in a society of services that wants to reduce the impact of the old mechanical model. [1] Combustion creates two forms of pollution: chemical and noise. Electric vehicles start changing the sound paradigm. The evolution of this new kind of mobility objects can be compared with the introduction of a new species in an ecosystem. These 'species' need to find its right place by means of external signs embodying its reality concerning others.[13]

The electric vehicle as a potential predator for the pedestrian, does not warn the potential unfortunate preys of its coming. Citizens navigate in the city wearing headphones creating a parallel world that emotionally disconnect them from the reality of their environment. The accident is the collision of parallel realities that nobody perceives as coexisting. Suddenly the management of the most immersive component of our reality could become an unsurmountable challenge. The alternative now is to choose between fighting against the sound of the city or taming it, accepting the noise or designing the sound. We could also consider that this evolution resulting from technologies creates interesting opportunities to reconsider our urban sound environment. Often quoted without explicit references, Goethe was clearly anticipating in the 18th century the subtle relation between sound and architecture, music and the city: “Architecture is frozen music; Music is liquid architecture.”

This “liquid architecture” that fills the interstices of the city is a territory to reconquer. If the specific ambiance of each city is a signature, it is something to be culturally redefined, redesigned. While it is not only about reintroducing local music, but also accepting sound and noises as mediums to be worked out and contextualised. Car’s sound used to result from the specific mechanics that make the engine work. Now it can be designed as the expression of a brand, of a culture, of a driver’s personality, of a composer’s expression. Space can be acoustically improved to reduce some part of the sound spectrum in terms of frequencies or to modulate the global sound intensity. Draining asphalt for example can reduce significantly the sound reverberation of the streets. Reflecting surfaces like glass, concrete or polished marble increase the reverberation of the sound. Understanding and controlling these parameters allows the city to master its voice, to refine its expression. The feeling of belonging to a specific place may come from the light, the architecture, the climate, the language, the smell of food, and it may also come from the sound that reveals the city spirit and feelings. Can the car be the concert hall of the 21st century? Now that we no longer undergo the sound induced by noisy mechanics, we may consider designing the interior car sound—with or without music—as a combination of an ambiance a global receptor for environmental and circumstantial events. The car becomes an audio interface to perceive the outside in a way to prevent collisions, and to warn the surrounding people of the vehicle presence and intentions. This can be done in collaboration with companies working on the sound quality in situation of mobility.

Headphones that are sometimes isolating the pedestrian or the cyclist, may integrate subtle variation that help to perceive potential issues in the immediate environment. Detection of presence and proximity may be translated into a change of texture or reverberation of the music we listen to. This would be interpreted as a warning signal. Indoor acoustic design: Audio reflectivity of surfaces need special attention for the selection of construction materials. After acoustic music instrument makers, architects working on theatre and concert hall

design have explored this field. It is time to apply this knowledge to places receiving public like restaurant, subway, and train stations. These places should be considered an acoustic standpoint and the quality of structural absorption and reflectivity will determine their impact on people and the quality of their experience. In McLuhanian vision of technology as being an extension of the human body, the car is the perfect prosthetics in our relation to the city.[14] Bicycles, motorcycles, and cars allow us to accelerate our motion, amplify our spatial reach, and partially control our space-time relation to the urban environment.

Beyond being an engine of mobility, the car is providing a second skin, at the same time protecting us from potential aggression coming from unexpected obstacles and dotted by design with extended sensory-motor capacities to perceive our environment and the complex relation we, as human, may build with contextual aspects that could have been overlooked while moving at a higher speed than the familiar human walk. This sentient skin may play a new role in our relation to the environment, not only at the survival level, but also as an emotional translator allowing us to perceive and to interpret differently the surroundings.

The car may become a very versatile sentient instrument, simultaneously receiver, interpreter, environmental reader, and full musical dashboard. It can communicate with the passenger and with the surroundings. Like the shape of the organ pipes impact the harmonics, the timber and the quality of sound, the inertial relation the car build with its dynamic environment tunes the resulting auditory experience into a complex dialogue that the driver can understand, and the composer can interpret.

The parameters the composer//interpreter can play with are, but not limited to:

– Speed, acceleration, wind speed and direction, spatial localisation of external events: Proximitiy, relativity, potential danger, obstacle collision,

– Light, temperature, ambient noise

– Negative/positive noise treatment. (Amplification vs reduction)

– Additional components, rhythmic, harmonic, melodic

Building a relation between users and the environment mediated by the car skin. Users make one with the car navigating in the city/country side. The most recent technologies convert the vehicle into an autonomous artefact able to perceive, analyze, recognize, and react, thanks to sensors and more and more of artificial cognitive functionalities like AI, extending human perception with infrared and ultra violet light, ultrasounds. We imagine how new narrative may go beyond augmented perception allowing new narrative. The traveling experience may become a live geolocalise documentary, a romantic journey or a science fiction experience. From ambient relaxation, and entertainment, vs stimulation awareness, the scenario will have to find a middle way between fiction and the actual reality with potential dangers. As the most obvious evolution of technologies, musical AI models may apply through sets of references open to specific creation related to the user or to the car make.

Sound of Urban Spaces

The problem of noise pollution is a serious challenge in urban areas. Soundscape design has been an issue in city-planning over the last years; there are still tools and methods needed to shape the sound of spaces to ensure public well- being, and for the time being we do not look enough towards the potential solutions provided by artists.[15, 16] While the sound of spaces often is already considered during their urban planning and architectural design state, the problem mostly affects existing spaces, which demand sound analysis and redesign of restorative soundscapes. We aim towards building tools and techniques that will allow architects and urban designers to address the issue of noise pollution in various scales, led by innovative thinking by sound artists. This will require simulations and fabricated prototypes in small sections of the urban environment, where few individuals are involved, and gradually expand to larger areas of cities and communities of citizens. This scenario aims to create tools that help city planners and researchers to speed-up the analysis of the sound of cities and give urban designers and architects new possibilities to create urban spaces in an inclusive way so that people can feel comfortable. Furthermore, it opens new space for creativity not limited to urban design but also for all artists working with sound. Some artists are already working on soundscapes of cities, such as Justin Bennett who investigated acoustic territories of the city of Brussels and created devices for active listening such as a microphone inside a trumpet or a wooden stethoscope, for example.[17]

Another interesting artwork related to urban space and sound is“Signals and Hums” by Banu içek Tülü. It refers to a soundscape work that asks listeners to concentrate on perception. The artwork exhorts viewers to hone their hearing and listening skills. Sounds are connected

to past experiences and assist us navigate the city on a daily basis. Sound is also a crucial component in understanding our surroundings.Acoustic environment is not just background noise, a particular soundscape, or noise pollution brought on by traffic or everyday activities. Instead, the project focuses on appreciating auditory experiences and exploring sound landscapes in urban environments through listening and hearing.[18, 19] Soundscapes are defined from an ecological perspective as the physical, biological, and anthropogenic sound that makes up a landscape, it is presented as a "footprint of an ecosystem," reflecting the dynamics of a community structure and function.[20] With the help of machine learning, mixed reality and intelligent interactive systems, artists work with existing and future architectural and urban spaces, considering their visibility and auditory functions. This gives the opportunity to architects and planners to work on the composition of urban soundscapes, working in parallel in areas with “silent parts” intermixed with more “noisy parts” and design individual acoustic interventions for specific zones on a city scale. While at the same time working on small neighbourhood scales using innovative design and material properties such soundproof or sound reflecting materials in VR environments.

Using 3D-audio-capturing systems, 3D-laser scanners as well as 3D-modelling technologies, we design and create immersive / navigable audio-visual computational models of existing spaces at various scales of the city. The AIM (Audio-visual Immersive Maps) platform offers an immersive, virtual experience of cities and places around the world.[19] Its functions range from sound integration in Google Streetview to high-resolution 3D scans of buildings, districts or cities. AIM makes real places virtually tangible also through hearing—in the browser, on the smartphone, in 3D glasses or in the VR room. Using geotagging, AIM enables people to experience fully immersive virtual travel with 3D Sound. AIM will be further developed to help urban planners to better assess and design soundscapes of cities and thus improve the sonic environment and well-being in the city.

ReSilence also provides artists and designers with tools and simulations to analyse and test improvements on the soundscape design. Such simulations could allow measuring behaviour (and possibly brain imaging) on people inhabiting different versions of such spaces. Body and movement analysis[21] including expressive qualities of full-body movement,[9] as well as non-verbal social signals in small groups (e.g., real-time measures of entrainment, of leader-follower relations)[10] can give further indications about how citizens react to pre-existing conditions of polluted urban sounds (e.g., trajectories of pedestrians to avoid noisy points; indications of confusion and hesitation in correspondence with noisy zones). Evaluation and validation can be realised through measuring the change of group behaviour of people in urban spaces, with respect to changes in urban sounds and environment. The same technologies can measure effects of design interventions, through the use of prototypes (time spent in silent points, slowdowns in pleasant sonic zones, etc.). Real-time sonification of traffic (trajectories, volumes, speed) and environmental conditions are used as a tool to generate interactive sound, meant to counterbalance noisy emissions with background sounds of stability and fluidity. Such sounds characterised by fluidity might be also related with real-time measures of the fluidity (Vs. hesitation, rigidity) in movements of citizens: cross-sensory correspondence of movement and sound qualities is a very interesting and challenging direction in this and in other ReSilence scenarios. Examples of scientific results and technologies in this direction of movement analysis and interactive sonification, available also for future experiments in ReSilence, can be found from the previously mentioned EU Projects DANCE and EnTimeMent.[6, 9, 11]

Sound and social inclusion

Through vibration and tactile sensation, we can achieve a “new way of hearing” and through sound we can find “new ways of seeing”. This use case will focus a) on the importance of a full-body approach to experiencing music and sound as opposed to engaging solely the ears and b) on the translation of physical objects into soundscapes and vibrations, inspired by artists such as Christine Sun Kim. By focusing on individuals who are hearing impaired or visually impaired, ReSilence will work towards creating richer experiences for people with disabilities. There are 34.4 million adults with a disabling hearing loss in EU.[22] Hearing impairment can mean a loss of hearing, but it can also mean sensitivity to loud noise, or certain frequencies.

In addition, there are estimated to be over 30 million fully or partially blind citizens in geographical Europe. Most XR technologies are incapable of providing enhanced information for visually and audibly impaired people.[23] Traditionally we expect sound to be experienced through our ears. However, nowadays we have the ability to create multimodal tools and wearables that can support a full-body approach in experiencing music and sound.[24]

Concerning visual impairments, the H2020 ICT DANCE project (dance.dibris.unige.it) focused on the automated analysis and interactive sonification of the expressive qualities of full-body movement. Scientific results and technologies developed by Casa Paganini and Maastricht University were experimented in artistic projects: (i) *Emobodies* (Maastricht Jazz Festival— performance of the blind pianist Bert van der Brink with the dancer Sagi Gross, in which the pianist could “hear the dance” and perform in a duo); *Atlante del Gesto* (performance in four different public sites in Genoa by the choreographer Virgilio Sieni involving active participation of about 150 citizens: in one of these sites the blind dancer Giuseppe Comuniello performed as leader of the active audience with the support of interactive sonification of movement qualities). More details and video excerpts are available in [12] and in [6, 9, 11]. Casa Paganini developed recently the *DanzArTe - Emotional Wellbeing Project* (youtube.com/Infomuslab), an interactive system supporting embodied experiences of visual arts (classical religious paintings, image manipulation and 3D modelling) based on the real-time analysis and interactive sonification of expressive movement. Expressive movements of visitors in museums or cultural institutions are measured in real-time (e.g., fluidity, entrainment in a dyad moving together) while imitating the affective gesture in a painting. This is also successfully adopted to support aesthetically resonant physical exercises and rehabilitation in frail older people and in general for cultural wellness and inclusion. This example of cultural welfare interactive technology is a possible challenging direction for ReSilence.

Exploring innovative technologies to bypass impaired sensory organs (like eyes and ears) can enhance our spatial awareness, allowing us to perceive sound and visuals through other parts of the body. This novel approach offers a more comprehensive sensory experience, including the ability to "hear" through the body.

Enhancing our bodies with technology can empower individuals with disabilities, enabling them to experience the world, communicate, and foster a stronger sense of community, thereby improving city planning and a sense of belonging.

Conclusion

This paper presents **ReSilence**, a transdisciplinary project that emphasizes silence and the space between sounds. **ReSilence** facilitates the uptake of digital technologies in the Mobility/Urbansim sector through the integration of technologies such as XR environments, data analysis and artificial intelligence in an ecosystem of tools designed to support citizens’ needs, motivations and experiences of the city. Through art-driven experiments with these technologies, **ReSilence** explores the multiple ways in which cities are constructed, perceived by incorporating soundscape information into urban spatial arrangement. The real-world scenarios of **ReSilence** demonstrate the expected impact of the proposed solution by focusing on specific societal problems related to cities soundscapes (indoor and outdoor).

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(1)

https://ec.europa.eu/regional_policy/en/policy/themes/urban-development

References

1 Russolo, Luigi, *The Art of Noises,* Pendragon Press, 1986.

2 Vaessen, Maarten, Kiki Van der Heijden, and Beatrice de Gelder, "Decoding of Emotion Expression in the Face, Body and Voice Reveals Sensory Modality Specific Representations," *BioRxiv*, 2019, 869578.

3 Hoeven, Arno van der, Erik Hitters, "The Spatial Value of Live Music: Performing,(Re) Developing and Narrating Urban Spaces," *Geoforum* 117, 2020, 154–64.

4 Smith, Neil Thomas, "Constructing the Public Concert Hall," *Journal of the Royal Musical Association* 146, no. 2, 2021, 255–81.

5 Wald-Fuhrmann, Melanie, Hauke Egermann, Anna Czepiel, Katherine O’Neill, Christian Weining, Deborah Meier, Wolfgang Tschacher, Folkert Uhde, Jutta Toelle, Martin Tröndle, "Music Listening in Classical Concerts: Theory, Literature Review, and Research Program," *Frontiers in Psychology* 12, 2021, 638783.

6 Camurri, Antonio, Gualtiero Volpe, "The Intersection of Art and Technology," *IEEE MultiMedia* 23, no. 1, 2016, 10– 17.

7 Czepiel, Anna, Lauren K. Fink, Lea T. Fink, Melanie Wald-Fuhrmann, Martin Tröndle, Julia Merrill, "Synchrony in the Periphery: Inter-Subject Correlation of Physiological Responses during Live Music Concerts," *Scientific Reports* 11, no. 1, 2021, 1–16.

8 Tschacher, Wolfgang, Steven Greenwood, Hauke Egermann, Melanie Wald-Fuhrmann, Anna Czepiel, Martin Tröndle, Deborah Meier, 'Physiological Synchrony in Audiences of Live Concerts'. *Psychology of Aesthetics, Creativity, and the Arts*, 2021.

9 Antonio Camurri, Gualtiero Volpe, Stefano Piana, Maurizio Mancini, Radoslaw Niewiadomski, Nicola Ferrari, Corrado Canepa, "The Dancer in the Eye: Towards a Multi-Layered Computational Framework of Qualities in Movement," In *Proceedings of the 3rd International Symposium on Movement and Computing*, 2016, 1–7.

10 Giovanna Varni, Maurizio Mancini, Luciano Fadiga, Antonio Camurri, Gualtiero Volpe, "The Change Matters! Measuring the Effect of Changing the Leader in Joint Music Performances," *IEEE Transactions on Affective Computing*, 2019.

11 Niewiadomski, Radoslaw, Maurizio Mancini, Andrea Cera, Stefano Piana, Corrado Canepa, Antonio Camurri, "Does Embodied Training Improve the Recognition of Mid-Level Expressive Movement Qualities Sonification?", *Journal on Multimodal User Interfaces* 13, no. 3, 2019, 191–203.

12 Esodi, Public performance at Museo di Palazzo Reale, Genoa - March 25th 2017, accessed December 9, 2022 http://dance.dibris.unige.it/index.php/dance-media#a_vid_artistic

13 Nicolas Misdariis, and Louis-Ferdinand Pardo, "The Sound of Silence of Electric Vehicles--Issues and Answers," In *InterNoise*, 2017.

14 Marshall McLuhan, "Media Hot and Cold," *Understanding Media: The Extensions of Man*, 1964, 22–32.

15 Reeman Mohammed Rehan, "The Phonic Identity of the City Urban Soundscape for Sustainable Spaces," *HBRC Journal* 12, no. 3, 2016, 337–49.

16 Yildirim, Yalcin, Merve Dilman, Volkan Muftuoglu, and Sara Demir, "Soundscape Assessment of Green and Blue Infra-structures," *Urban Science* 6, no. 1, 2022, 22.

17 J. Bennett, "justinbennett.nl," accessed January 01, 2022 http://www.justinbennett.nl

18 Sounds of our cities, accessed December 9, 2022 https://www.idensitat.net/en/current-projects/sounds-of-our-cities-3/1456-sounds-of-our-cities-open-call

19 "Audiovisual Immersive Maps," *AIM / Audiovisual Immersive Maps,* Accessed January 01, 2022. https://weaim.de/en/

20 Barry, Truax, Gary W. Barrett, "Soundscape in a Context of Acoustic and Landscape Ecology", *Landscape Ecology* 26, no. 9, 2011, 1201–7.

21 Gelder, Beatrice de, Marta Poyo Solanas, "A Computational Neuroethology Perspective on Body and Expression Perception," *Trends in Cognitive Sciences* 25, no. 9, 2021, 744–56.

22 "Europe- Hearing-loss | hear-it.org," accessed December 9, 2022 https://www.hear-it.org/hearing-loss-in-europe

23 Joshue O Connor, Shadi Abou-Zahra, Mario Covarrubias Rodriguez, Beatrice Aruanno, "XR Accessibility--Learn- ing from the Past and Addressing Real User Needs for Inclusive Immersive Environments," In *International Conference on Computers Helping People with Special Needs*, Springer, 2020, 117–22.

24 Alice Haynes, Jonathan Lawry, Christopher Kent, Jonathan Rossiter, "FeelMusic: Enriching Our Emotive Experience of Music through Audio-Tactile Mappings," *Multimodal Technologies and Interaction* 5, no. 6, 2021, 29.

Bibliography

Antonio Camurri, Gualtiero Volpe, "The Intersection of Art and Technology," *IEEE MultiMedia* 23, no. 1, 2016, 10–17.

Antonio Camurri, Gualtiero Volpe, Stefano Piana, Maurizio Mancini, Radoslaw Niewiadomski, Nicola Ferrari, Corrado Canepa, "The Dancer in the Eye: Towards a Multi-Layered Computational Framework of Qualities in Movement," In *Proceedings of the 3rd International Symposium on Movement and Computing*, 2016, 1–7.

Anna Czepiel, Lauren K. Fink, Lea T. Fink, Melanie Wald-Fuhrmann, Martin Tröndle, Julia Merrill, 'Synchrony in the Periphery: Inter-Subject Correlation of Physiological Responses during Live Music Concerts'. *Scientific Reports* 11, no. 1, 2021, 1–16.

Beatrice de Gelder, Marta Poyo Solanas, "A Computational Neuroethology Perspective on Body and Expression Perception," *Trends in Cognitive Sciences* 25, no. 9, 2021, 744–56.

Alice Haynes, Jonathan Lawry, Christopher Kent, Jonathan Rossiter, "FeelMusic: Enriching Our Emotive Experience of Music through Audio-Tactile Mappings," *Multimodal Technologies and Interaction* 5, no. 6, 2021, 29.

Hoeven, Erik Hitters, "The Spatial Value of Live Music: Performing,(Re) Developing and Narrating Urban Spaces," *Geoforum* 117, 2020, 154–64.

Marshall McLuhan, "Media Hot and Cold," *Understanding Media: The Extensions of Man*, 1964, 22–32.

Nicolas Misdariis, Louis-Ferdinand Pardo, "The Sound of Silence of Electric Vehicles--Issues and Answers," In *InterNoise*, 2017.

Radoslaw Niewiadomski, Maurizio Mancini, Andrea Cera, Stefano Piana, Corrado Canepa, Antonio Camurri, "Does Embodied Training Improve the Recognition of Mid-Level Expressive Movement Qualities Sonification?", *Journal on Multimodal User Interfaces* 13, no. 3, 2019, 191–203.

Joshue O Connor, Shadi Abou-Zahra, Mario Covarrubias Rodriguez, and Beatrice Aruanno, "XR Accessibility--Learning from the Past and Addressing Real User Needs for Inclusive Immersive Environments," In *International Conference on Computers Helping People with Special Needs*, Springer, 2020, 117–22.

Reeman Mohammed Rehan, "The Phonic Identity of the City Urban Soundscape for Sustainable Spaces," *HBRC Journal* 12, no. 3, 2016, 337–49.

Russolo Luigi, *The Art of Noises,* Pendragon Press, 1986.

Smith Neil Thomas, "Constructing the Public Concert Hall," *Journal of the Royal Musical Association* 146, no. 2, 2021, 255–81.

Barry Truax, Gary W. Barrett, "Soundscape in a Context of Acoustic and Landscape Ecology," *Landscape Ecology* 26, no. 9, 2011, 1201–7.

Tschacher Folkert Uhde, Jutta Toelle, Martin Tröndle, "Music Listening in Classical Concerts: Theory, Literature Review, and Research Program," *Frontiers in Psychology* 12, 2021, 638783.

Tschacher Wolfgang, Steven Greenwood, Hauke Egermann, Melanie Wald-Fuhrmann, Anna Czepiel, Martin Tröndle, Deborah Meier, "Physiological Synchrony in Audiences of Live Concerts," *Psychology of Aesthetics, Creativity, and the Arts*, 2021.

Vaessen Maarten, Kiki Van der Heijden, Beatrice de Gelder, "Decoding of Emotion Expression in the Face, Body and Voice Reveals Sensory Modality Specific Representations," *Bio-Rxiv*, 2019, 869578.

Melanie Wald-Fuhrmann, Hauke Egermann, Anna Czepiel, Katherine O'Neill, Christian Weining, Deborah Meier, Wolfgang Tschacher, Folkert Uhde, Jutta Toelle, Martin Tröndle, "Music Listening in Classical Concerts: Theory, Literature Review, and Research Program," *Frontiers in Psychology* 12, 2021, 638783.

Yalcin Yildirim, Merve Dilman, Volkan Muftuoglu, Sara Demir, "Soundscape Assessment of Green and Blue Infrastructures," *Urban Science* 6, no. 1, 2022, 22.