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Developing a typological matrix of Museum Sound Sources to Enhance Design and Management

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Keywords:

Sound Design, Soundwalking, Sound sketches, Museum, Exhibition design.

ABSTRACT:

Sound offers a promising direction for enhancing the visitor's experience in the context of digital transformation and multisensory engagement. However, what visitors perceive on site is a composite soundscape woven from multiple sound sources. If curators and designers attend only to the sound inside the exhibit while overlooking these other sources, the intended effect of sound design may be diluted or disrupted. This study introduces two sound methods, Soundwalking and Sound Sketch, and engages 24 participants in guided listening activities at two museums in Hangzhou, China. These activities generated a rich body of empirical materials, they provide the basis for developing a typological framework of museum sound sources and for formulating the concept of *Sound Field Thinking*. This framework contributes to a more precise description of the museum's soundscape and provides a more comprehensive perspective for museum professionals to understand sound in museums.

Il suono offre una prospettiva promettente per migliorare l'esperienza del visitatore nel contesto della trasformazione digitale e del coinvolgimento multisensoriale. Tuttavia, ciò che i visitatori percepiscono sul posto è un paesaggio sonoro composto, un intreccio di molteplici sorgenti sonore. Se curatori e progettisti si concentrano soltanto sui suoni interni alla mostra, trascurando queste altre sorgenti, l'effetto previsto del sound design rischia di essere attenuato o compromesso. Questo studio introduce due metodi sonori, il *Soundwalking* e il *Sound Sketch*, coinvolgendo 24 partecipanti in attività di ascolto guidato in due musei di Hangzhou, Cina. Tali attività hanno generato un corpus ricco di materiali empirici, che costituisce la base per sviluppare un quadro tipologico delle sorgenti sonore museali e formulare il concetto di *Sound Field Thinking*, contribuendo a descrivere con maggiore precisione il paesaggio sonoro del museo.

Opening Picture:

Examples of sound sketches, created by CAA students.

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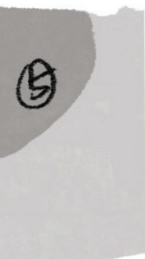
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1. Introduction

In recent decades, a new generation of museums has adopted diverse strategies to expand their audiences and challenge the traditional image of silence, sanctity, and rigidity.¹ In the meantime, the soundscape and sonic texture have undergone profound transformations.² Modern society has become accustomed to the constant roar and noise generated by industrial products, sounds that have inevitably permeated museums and evolved into various forms and functions. Sound serves multiple purposes in the cultural production of various types of museums.³ It functions as a curatorial theme, a medium of communication, an artifact, and a component of multi-sensory experiences.⁴ Through the strategic use of sound, museums can enhance storytelling, facilitate knowledge interpretation, and enrich visitor engagement.⁵

A growing body of literature highlights a shared observation: the positive aspects of sound and its sensory qualities are often largely overlooked in museum environments.⁶ In the digital age, while many museums have come to recognize the role of sound in shaping exhibition experiences, a noteworthy gap remains in understanding the interplay of museum acoustics ecology and the potential of diverse sound sources. Sound is often regarded as a challenging and intrusive element that is often selectively skipped in many museum settings.⁷ Sound has been consistently marginalised by the dominance of visual hierarchies, struggling to achieve equal recognition. Although multilayered, multichannel, and multi-perspective exhibition practices

are increasingly accepted,⁸ the uneven power dynamics between sensory modalities in museums remain difficult to address fully.

Museum soundscapes have become increasingly complex. Digital exhibits, interactive installations, immersive media, and audio guide systems add layers of sound, while ambient noise – from air conditioning, elevators, external traffic, and conversations – continually permeates the exhibition hall. These sounds, often beyond the control of curators or designers, shape how visitors perceive space, exhibits, and narrative. Museum sound design, therefore, requires understanding how multiple sound sources coexist, overlap, and interact, rather than focusing on any single sound in isolation.

Thus, this study addresses two primary research questions:

- What types of sound sources exist in museums, and how do these sound sources affect visitors' experience?
- Given the increasing demand for sound content in the current era of digital transformation, what attitudes should museum professionals adopt toward designing and managing sound?

This study proposes a typological matrix of museum sound sources and intervention strategies, developed through sonic exercises with 24 participants across two distinct museums. The contributions of this study include: (i) introducing *soundwalking* and *sound sketches* into museum design education and on-site observation as a repeatable process for guided listening; (ii) de-

veloping a typological matrix of museum sound sources to describe the relationships among ambient background sound, operating sound, sound from the audience and designed sound; (iii) proposing *Sound Field Thinking* as an initial concept for understanding museum sound environment as a continuous, dynamic, and interrelated environment.

2. The roles of sound in exhibition interpretations

Currently, academic discussions on the classification of sound in museums are shaped by varying definitions and taxonomies. These frameworks are shaped by the role, function and narration of sound within exhibitions.

According to Stocker,⁹ sound was categorized into useful and useless types. Useful sounds were defined as music, narrative, and ambient sounds – mirroring classifications used in film production. Useless sounds were identified as noise. It was noted that both types of sound could be intentionally created and applied for specific purposes.

Bubaris¹⁰ introduced an initial framework for understanding sound in museum narratives inspired by the film sound design theory, transposing concepts previously explored by Chion¹¹ in his description of the cinematic space to the museum field. It includes two categories: diegetic sounds and non-diegetic sounds, layered either in the foreground or background of the exhibition experience to facilitate the communication of sonic information. Diegetic sounds are intentionally designed to align close-

ly with the audience's experience, while non-diegetic sounds, though less directly related to the thematic content, can meaningfully contribute to the narrative. de Jong¹² also explored these concepts and applied them in Polish museums.

Salmouka and Gazi¹³ proposed a framework for classifying sound in exhibitions that identifies three key roles: informative, interpretive, and immersive. The *informative* role means sound as information, similar to text in exhibitions, offering supplementary context. The *interpretive* sound is crucial in shaping the exhibition narrative, fostering audience engagement and connecting different exhibit elements, promoting meaning-making processes. The *immersive* sound focuses on creating a deeply engaging sensory experience to evoke emotions and enhance audience immersion.

Cortez¹⁴ developed a typological framework for sound in museums based on literature and field observations from 59 on-site exhibitions and 10 online exhibitions. It includes five “genres”: sound as lecturing, sound as ambience/soundtrack, sound as artifact, sound as art, sound as crowd curation. She later expanded the framework by adding two further categories: sound as a mental phenomenon, and sound as live performance.¹⁵ This categorization illustrates the diversity of sound practices in museums and highlights its significance in shaping sensory experiences and contributing to audience's meaning-making.

These sound typologies underscore the complexity of sound in exhibitions and its diverse applications through the lenses of curation, design, visitors' experience, and infor-

mation exchange. Yet they mainly address curated or designed sounds, or the role of sound in meaning-making and sensory experience. In actual museum settings, other sources, such as mechanical operations, visitor activity, and external environmental sounds, are often left outside these frameworks. Sometimes, unpredictable sound sources may even interact unexpectedly with those well-crafted by curators or designers, leading to shifts in their intended use and the visitor's experience. This study, therefore, does not seek to replace existing frameworks but to offer a more integrative perspective for identifying overlooked sound sources that may significantly affect everyday museum experience.

3. The Listening Activities for Observing Museums

3.1 Soundwalking

Soundwalking is an active listening activity designed to explore environments, soundscapes and acoustic characteristics. It shifts the emphasis from a visually dominant spatial experience to auditory perception, encouraging awareness of subtle sounds in the surroundings. Soundwalking is widely employed as a research method across disciplines and contexts, including its theoretical reviews,¹⁶ studies of measuring urban and outdoor soundscapes,¹⁷ and research on soundscapes in interior spaces.¹⁸ Soundwalking remains rarely applied in museum spaces, though it has been explored in educational and observational contexts. Soundwalking remains rarely applied in museum spaces, although existing studies have begun to demonstrate

its potential for exhibition practice and curatorial education.¹⁹

In recent years, Soundwalking has been adopted as an official method in empirical soundscape research, with efforts to establish a standardised framework for its implementation. The international standard ISO 12913-2²⁰ outlined detailed procedures and guidelines for using Soundwalking to collect perceptual data and evaluate soundscapes in specific sites or spaces.²¹ Under this framework, the author combine Soundwalking with surveys and interviews to gather insights into the soundscape of a location, informing its planning and design related to sound.

3.2 Sound sketch

The *Sound sketch* can be regarded as the sonic counterpart to traditional sketch by visual representation of the perception and characteristics of sound.²² This method captures the cognitive processes and design thinking involved, thereby reducing the load on working memory.²³ This approach of *auralization* helps designers and creators to document inspiration, articulate thought processes, and preserve fleeting sound experiences. Previous studies have explored sound sketches from various perspectives, including the associations and semantic-auditory channels of sound sketches,²⁴ the iterative refinement of sound sketches in design processes,²⁵ and the use of vocal sketching, gestures, and other multimodal means of representing sounds as a research and design creative tool.²⁶ In the museum context, Kannenberg²⁷ proposed a framework for creating sound sketches by integrating

listening, recording, and drawing to interpret museum soundscapes. This approach incorporates drawing, a fundamental artistic skill, into sound art practice, metaphorically representing specific listening experiences.

Sound sketches, when understood as metaphorical interpretations and representations, serve not only as a means of creating new meanings but also as a way of perceiving ourselves and structuring our language.²⁸ Analyzed primarily through a generative semiotic and narrative lens,²⁹ metaphors and analogies reflect a ‘corporeal reverberation’ that can consciously connect individuals, their cultures, languages, and backgrounds through embodied representations such as diagrams or linear narratives. This is particularly relevant in the fields of design and architecture.³⁰ Similar to how revisiting sketches in visual art can yield fresh discoveries, sound sketches can help participants or designers revisit and refine compelling concepts about sound.³¹ Here, participants did not seek to reproduce the sounds themselves with precision. Instead, they used lines, shapes, colours, and written annotations to record the sound sources, movement, intensity, emotional qualities, and spatial relationships they perceived during the soundwalking. In this study, sound sketches are therefore treated as a supporting tool for soundwalking, helping participants recall and reflect on their listening experience.

4. Methodological phases and implementation

4.1 Research sites

Soundwalking and Sound Sketch practices were conducted as part of the extracurricular activities for the course *Research-based Artistic Practices: Narrating the Post-human in the Multi-Sensory Exhibition*. This course was offered during the PLAY-SHOP summer school³² at the China Academy of Art from June to July 2023, with the author serving as the main tutor.

The Soundwalking and Sound Sketch sessions were conducted at two renowned museums in Hangzhou, China: *The China Museum of Design Bauhaus Collection*³³ (hereinafter referred to as CDM), designed by Álvaro Siza and Carlos Castanheira, and *the China Comic & Animation Museum*³⁴ (hereinafter referred to as CCAM), designed by MVRDV. CDM was selected for its typical characteristics as a white-cube design dedicated to art and design themes. In comparison, CCAM was chosen for its extensive use of audiovisual content and interactive experiences that enhance visitors’ understanding of animation, with sound playing an important role in its narrative.

4.2 Participants and Research Activity Process

The experiment involved 24 second-year students from the major of art, science, and design at the CAA School of Innovation Design. The experimental procedures were explained to all participants, and written informed consent was obtained from each participant prior to the start of the study. All interviews

were audio-recorded with consent.

Before the Soundwalking and Sound Sketch sessions began, a deep listening exercise was organized on campus. As Figure 1 shows, the author embarked on a three-part exercise designed to enhance our auditory perception and attune us to the intricate and textural nuances of the sounds that envelop us.

The first step underscored how routinely we categorize, and name sounds based on their sources. The second step brought students' attention to aspects such as tempo, pitch, and timbre. The third step served as an immersive exploration of the acoustic ecosystem that constantly surrounds us, often unnoticed. The exercise proved transformative, providing us with an enhanced appreciation for the richness of sound and the many ways in which it influences our perception of space

and environment.

Then, students were divided into two groups and asked to explore the soundscapes of each museum from two perspectives: as visitors with traditional soundwalking questionnaires and as artists or designers with sound sketches. Their roles were switched between the museums to provide a balanced exploration. The study drew on a set of listening questions suggested by Voegelin.³⁵ These questions can inspire students to reflect on their sound exploration in museums. Within two days of the activities, the author conducted semi-structured interviews with all students, each lasting approximately thirty minutes. Students were invited to reflect on their soundwalking experiences and discuss their insights into the intersections of sound, art, and design, referencing their questionnaires and sound sketches.

Fig. 1:
A deep listening exercise at CAA campus, photographed by the author.



Key questions included:

- How would you describe your listening experience in the museum? Please refer to your questionnaire and sound sketch.
- How would you evaluate the soundscapes of the two museums?
- What role do you think sound plays in the overall museum experience?
- Which sounds left the most significant impression on you?
- As an artist and designer, what insights did you gain from this experience?

The research used a multisensory dataset to document the characteristics, functions, and potential impacts of sound on visitors. The dataset includes: observational field notes written by the author; photographs and videos documenting museum spaces, exhibits, visitor activity, and the surrounding environment; on-site audio recordings capturing designed sounds, ambient noise, music, and mechanical operations; sound sketches created by participants; soundwalking questionnaires completed by participants; and semi-structured interviews conducted by the author, along with their transcriptions.

This study frames the listening activities as an exploratory investigation based on observation, documentation, discussion, and reflection. Through open coding, it identifies recurring sound sources and perceptual experiences from questionnaires, interviews, and field notes, and cross-references them with sound sketches, photographs, videos, and audio recordings to con-

firm their spatial and contextual relations. These findings are then synthesized into four categories of sound. Drawing on workshop materials, participant feedback, and existing literature, the study clarifies the value of this matrix for museum sound design and management.

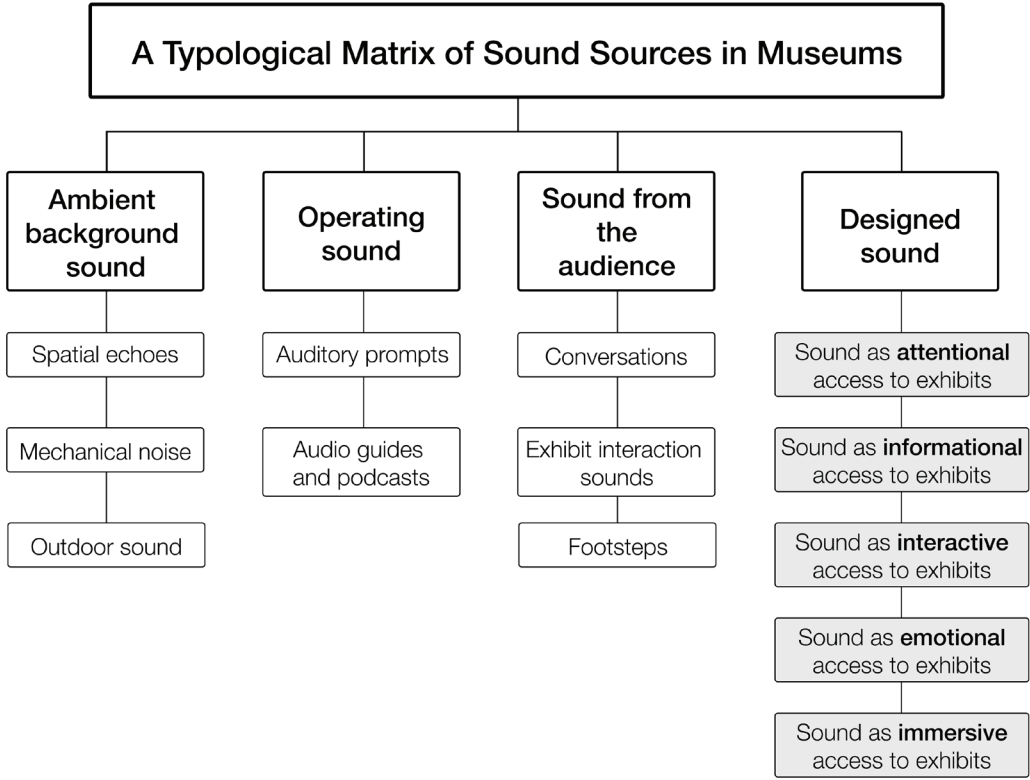
5. A typological matrix for listening to museum

Building on the previous activities, the author proposes a typological matrix that serves as a conceptual framework to address the potential of sound in terms of its source, function, and designability within the exhibition design field (see Figure 2). The aim is to encourage a more holistic and listening-oriented design approach to sound, understood as a critical element in exhibition narratives and spatial design.

Ambient background sound

In this study, ambient background sound refers to the collection of non-specific, continuously present sounds within a museum space under normal operating conditions and without visitors. These sounds typically include spatial echoes, mechanical noise, and environmental sounds from the outdoor surroundings.

Spatial echoes are influenced by the architecture and materials of the space, which influence how sound diffuses and decays. A quarter of students noted that the echoes in CDM created a pronounced sense of openness, to the extent of evoking disorientation. These reverberations enhanced the impression of spaciousness, even though CDM is an enclosed, windowless building.



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When effectively applied, reverberation can create an optimal listening environment and foster a sense of immersion. Among notable examples, Fiebig, Piereth and Karnatz in *Soundscape as Methodology in psychoacoustics and noise management*,³⁶ demonstrated how the integration of staircase design and reverberation at *Cadolzburg Castle Museum* in Germany enhanced historical perception, and Susan Philipsz’s sound art in museums³⁷ used reverberation to blur spatial boundaries. Mechanical noise, on the other hand, originates from facilities such as air conditioning, elevators, and exhibit equipment. About one-third of participants highlighted that air conditioning noise in the corridor connecting two exhibition halls at CCAM detracted from their experience. The intrusive sound discouraged visitors from lingering in the corridor, causing them to overlook the exhibits displayed there.

Ambient sounds are also influenced by the museum location and are often random and dynamic. Whether located in the countryside or the urban landscape, these sounds may include natural elements, such as birdsong, wind, or water, as well as external traffic noise. One student recalled arriving at CCAM on a quiet morning, noting the profound stillness of its suburban setting, which atmosphere was accentuated by the presence of a lake just behind the building.

Operating sound

The daily operation of a museum is a complex and meticulous process requiring the coordination of numerous individuals, systems, and resources. For example, systems for ventilation, temperature control, surveillance, and lighting maintain a safe and comfortable environment for museums to ensure basic

Fig. 2:
A Typological Matrix of Sound Sources in Museums, created by the author.

infrastructure and accessibility.

From this perspective, two subcategories of sound are identified: auditory prompts, audio guides and podcasts.

Auditory prompts

In museums, auditory prompts are categorized into two types: broadcast systems covering the entire venue and localized audio cues for specific areas. Museum-wide broadcasts are used in particular contexts to convey information, such as reminding visitors to follow the rules, assisting in locating individuals, or announcing closing times. Localized audio cues guide navigation, help visitors orient themselves through sound, and provide directional support, especially in dark environments, multi-sensory exhibitions, or customized space where sound enhances the experience. While the design of auditory prompts has been extensively studied in fields like automotive and healthcare,³⁸ design research in museum contexts remains limited and often leads to the generation of unintentionally intrusive and annoying soundscapes.

Audio guides and podcasts

Audio guides are widely used and well-accepted tools for auditory interpretation in museums.³⁹ These guides use storytelling to explain exhibits, helping visitors to learn about their background and details. Audio guides can be either automatically activated via Bluetooth, RF, RFID or IR triggering systems at specific locations or they can be manually selected on devices. In recent years, many museums have made audio guides accessible online so

that visitors can use their smartphones to scan QR codes and access the content. Audio guides function as a compass that helps visitors navigate the overwhelming array of displayed artefacts and offers each individual a personalised guide.⁴⁰

Museum podcasts represent a newer category of sonic media gaining traction. The museum podcasts cover a range of topics, including the history of the museum, detailed knowledge about collections, and behind-the-scenes stories of exhibition production. It contributes to museums extending their cultural influence beyond physical boundaries, offering audiences a flexible way of engagement.

Operating sounds refer to sounds generated by museums to maintain order, convey information, manage circulation, and support visitor services. Here, the following types of sound are grouped together because they all serve the museum's operational and guidance functions at different scales. Museum-wide broadcasts address the entire facility and are typically used for closing reminders, rules, or emergency notifications. Localized audio cues target specific areas, offering directional guidance, interactive reminders, or safety alerts. While audio guides and podcasts primarily support the interpretation of exhibition content. While often considered beyond the conventional responsibilities of exhibition designers, these sounds remain integral to the holistic construction of the visitor's experience.

Sound from the audience

Nearly all students emphasised the

impact of sounds from the audience on their museum experience, including conversations, exhibit interactions, and footsteps.

Visitors' conversations typically involve sharing impressions, exchanging ideas, or seeking information. At CCAM, where children are a primary audience group, their unpredictable behaviour creates particular challenges. In the interactive game areas, children's excitement often leads to loud screams, creating an excessively noisy environment that diminishes the effectiveness of the exhibition content and coerces the audience to escape.

Footsteps are generally considered part of the ambient background noise, yet they may also be understood as sounds produced by visitors' bodily movement. While their influence is subtle, they can become prominent in quieter galleries. Over half of the students mentioned the creaking wooden floors in CDM's Bauhaus design exhibition room. Opinions of students on this sound varied. Some students found it distracting and preferred the quieter terrazzo flooring. One student observed that the creaking sound was tolerable when walking alone but became pretty jarring as large groups were present. Others felt the sound encouraged more careful movements to keep a serene atmosphere. One student associated the sound with the solemn tranquillity of wooden ancestral halls in her hometown, describing it as calming and comforting. As noted by Orhan and Yilmazer⁴¹ some visitors reported that certain sounds in museums can foster a sense of ease, helping them avoid the overly restrained and cautious behaviour often asso-

ciated with library environments.

It shows that visitors are not passive recipients of the sound, but active contributors to the museum soundscape. Their behaviour may reinforce, mask, or interrupt the designed sounds for the exhibition. Thus, exhibition designers and museum managers should consider the sonic effects of visitors' density and interaction.

Designed sound

The integration of this type of sound in exhibitions is often driven by curators' and designers' efforts to enhance interpretative and interactive experiences. Designed sounds can be categorised into five functional subtypes.

Sound as Attentional Access to Exhibits

Sound holds the inherent power to capture, guide, and focus attention, and it is a fundamental perceptual property of auditory stimuli in daily life.⁴² In exhibitions, this type of sound is used to direct visitor focus to specific exhibits or areas in an information-rich context. Examples include brief alert tones, tonal variations, or rhythmically distinct sound compositions.

Sound as Informational Access to Exhibits

Sound serves as a dynamic medium for conveying complex information, encouraging active listening and observation beyond passive reliance on visual elements. Common examples include *ad hoc* and/or archival recordings of scripted narratives, theatrical presentations, readings, interactive dialogues, oral

stories, and interviews. Especially within highly complex sensory contexts, these narrative sounds can enhance or restrict the visitors' interpretation and meaning-making while opening or closing interpretative perspectives on content. For instance, historical recordings or dialogue segments can vividly illustrate past events and stories. For instance, historical recordings or dialogue segments can vividly illustrate past events and stories.

Sound as Interactive Access to Exhibits

Sound can stimulate curiosity and enhance visitor engagement through immediate and dynamic feedback. In museums, interactive and reactive sound takes various forms, such as in hands-on systems, body-on systems, motion-based systems and complex multimedia installations. These sound interactions can occur through changing sound effects, increasing volume, or shifting sound positioning in space to help visitors locate specific exhibits, select, manipulate or uncover hidden content. This use of sound fosters active visitors' participation and transforms the exhibition experience into a more engaging, embodied and enjoyable process.

Sound as Emotional Access to Exhibits

As noted by Kang,⁴³ "Compared to vision, sound perception is usually information-poor but emotion-rich". This emotional depth makes the sound a powerful narrative tool in exhibitions, capable of evoking specific emotional states such as suspense, nostalgia, joy, sorrow, solemnity, or relaxation. Often

presented as music, sound effects, or soundscapes, these sounds have low informational density but are highly emotionally impactful. Yet, these sounds transcend cultural and linguistic barriers to convey emotions that visual elements alone cannot comprehensively express. For instance, a familiar melody or a specific sound effect can evoke emotional resonance without requiring verbal explanation.

Sound as Immersive Access to Exhibits

Spatial sound goes beyond emotional engagement to create a sensory-enhanced environment that draws and immerse visitors deeply into a narrative. Unlike emotional sound, immersive sound is designed to construct a mentally contained environment that captures and sustains attention. This type of sound design is frequently integrated with lighting, visuals, and spatial elements to create comprehensive, multi-sensory experiences, often used to reconstruct or simulate narrative settings. Among sonic forms, the soundscape is particularly significant in defining the overall exhibition atmosphere and shaping immersive experiences. The term immersion frequently appears in discussions of sound experiences.⁴⁴ In museums, immersive experiences often construct self-contained narrative spaces, where spatial enclosures and multisensory stimuli concentrate visitors' awareness, guiding them into a predefined scenario. The role of sound in this process is significant, as listening can enhance the audience's perception of realism of the scene.⁴⁵

6. Inspirational insights: *Sound Field Thinking*

*Only a total appreciation of the acoustic environment can give us the resources for improving the orchestration of the world soundscape.*⁴⁶

Listening actively to an exhibition reveals the diverse array of sound sources within a museum. These include music, audio guides, background and operating sounds, sound effects, visitors' conversations, and other sounds that merge and interact from all directions. The potential of sound to create meaningful museum experiences is increasingly recognized, permeating exhibitions in various forms. The insights gathered in this study are converging into a problem consciousness that remains to be further tested and developed: *Sound Field Thinking*. This concept views the museum as a unified and continuous auditory environment where sound design must take the entire space into account rather than being confined to isolated installations or specific areas. Designers are encouraged to perceive the museum as a dynamic sound field and consider both its inherent sound sources and the unpredictable, visitor-generated sounds that occur during the experience. To create a coherent and harmonious auditory environment, designers must address the narrative of both existing and designed sounds, mediate the relationships between different sound sources, and consider how visitors' behaviour shapes the overall soundscape.

One participant remarked that sound has the power to ruin an ex-

hibition due to its significant disruptive potential. Whether it is a central element or not, sound is inherently intrusive and cannot be ignored.⁴⁷ Unlike visitors who can choose to close their eyes to turn off the visual, they cannot turn off their perception of sound.⁴⁸ Uncontrolled noise or sound design that contradicts the exhibition narrative, whether through excessive volume, disruptive noise, or irrelevant effects, can impede deeper visitor engagement. Its negative impact is more easily amplified in the minds of visitors than visual failure or visual disruptions. For example, visitors themselves are often the largest and least controllable source of noise in museums.⁴⁹ Human-generated noise significantly affects acoustic comfort.⁵⁰ Many visitors describe a museum as a noisy and disordered place, particularly one featuring interactive or multimedia exhibits. The sounds of visitors tapping on interactive displays, the hum of air conditioning, sound bleeding from exhibits, and the chatter or shouts of children combine to form a dynamic and often chaotic soundscape.⁵¹ This issue is exacerbated by two factors: insufficient consideration during the design phase of cumulative visitor sounds and the frequent use of highly reflective surfaces in museum architecture.⁵² It also underscores a broader issue: discussions about sound and acoustic design often focus solely on noise control and mitigating negative impacts.⁵³ This negative image overlooks the potential of sound as a powerful tool for enhancing visitors' experiences.

A student described an exhibition hall at CCAM where two interactive touch walls allowed visitors to trigger thematic content by tapping

the screens. Children screamed and fought intensely for control of the display, their noise blending with the loud scolding from parents and the constantly shifting sound effects from the installation. The cacophony reverberated through the smooth surfaces of the hall, creating what the student described as ‘sounds battling each other’. At this point, the sound volume of the space exceeded its reasonable limit, prompting visitors to hurry past the hall to escape the overwhelming noise. Background noise is an unavoidable aspect of human environments,⁵⁴ and noise cannot be entirely eliminated.⁵⁵

Another student shared her experience at an exhibition room on rural education at CDM. She noted that as the temperature and the number of visitors increase, the museum usually adjust the indoor temperature, but sound levels remain unchanged. In this exhibition, she initially heard the faint sound of running water, which fit the ambience of the space well. However, as more visitors entered, the delicate sound was quickly overpowered by crowd noise. Despite the wealth of research on how visual elements and temperature affect museum experiences, sound, as an essential parameter for improving spatial comfort and visitor engagement, has received comparatively little attention.⁵⁶

These examples illustrate a critical insight: the spatial sound volume is not static but fluctuates with the number of visitors. Moreover, when one set of sounds interacts with another, they may amplify, cancel out, interfere, or resonate in unpredictable ways. Designers often test designed sounds in empty or minimal-

ly occupied rooms without other sound sources, overlooking how visitor presence dynamically alters sound volume and interactions between different sounds.

From a practical perspective, *Sound Field Thinking* offers a form of practical awareness for curators, designers, and museum managers. It begins with identifying sound sources early in the exhibition production process, especially ambient background sounds and their influence on the exhibition. Audio guides, museum-wide podcasts, and localized prompts should be planned as part of a unified sound design strategy, while designers should test designed sound under real visitor conditions rather than only in empty spaces. It is important to recognize that sound is not simply an added layer of content, but a medium that shapes spatial perception, narrative rhythm, and embodied experience. After opening, designers or museum technicians should adjust volume, duration, playback frequency, and spatial placement based on visitor feedback to refine the sound experience during daily operations.

7. Application of sound research methods in museum interior environment

The development of sound design relies on effective methods and tools. In our exploration of listening in museums, the author guided students to adopt the perspectives of audiences, artists or designers. As Figure 3 manifests, they learned to document and articulate their thoughts and impressions during the listening process. Our bodies serve as sensitive and practical instruments for detecting sound.

they offer designers a visual tool for reflecting on how sounds move, interact, and flow within the space.

Variations in sensory sensitivity, commonly referred to as *aural diversity*⁵⁷, mean that participants may have different auditory and perceptual abilities due to varying degrees of hearing loss or listening habits. Besides, the lack of a standardized visualization system means that sound sketches depend on individual expression. As a result, these records remain subjective and situated, and cannot be treated as comparable representations of sound experience. However, these explorations can offer some insights for teaching and practicing sound design in museums. Perhaps, future research could focus on integrating *soundwalking*, sound sketch, and other complementary tools into a comprehensive sound design toolkit. It would provide exhibition designers with a structured process for transitioning from sound perception to expression, advancing the application of sound-driven design in museums and broader design contexts.

8. Conclusions: towards a listening-driven design approach

This paper presented an in-depth investigation into the important role that sound plays in modern museums, addressing two main topics. On the one hand, the author considered the different types of sound existing in museums and how they affect the visitors' experience. On the other, we explored possible ways and methodological tools that museum professionals can adopt to design and manage sound in museums in the era of digital transformation.

Fieldwork conducted in two renowned museums with a group of students demonstrates how *Soundwalking* and *Sound Sketches* methods can be useful for learning to open one's ears and analyse different sound environments, thus enhancing creative conceptual exploration and sensory documentation. In addition, findings on the multifaceted role of sound from literature review and fieldwork have led to the definition of a typological matrix of museum sound sources that reveals the potential of sound for construction, design and narrative transformation within the museum context.

Although it is not possible to analyse every sound source that contributes to the generation of the overall museum soundscape, this research tries to provide a useful analytical framework for building a more systematic and comprehensive understanding of sound. This typological matrix then informed the concept of *Sound Field Thinking*, understood as a method to view the museum as a unified and continuous auditory environment that should be taken into consideration

as whole within the design process. Finally, these methods can support further exploration of sound applications in museum contexts, offering museum professionals a tool to integrate sound within the design process thus supporting the further exploration of sound-driven design and management approaches in the future.

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Endnotes:

- 1 Bruce 2006; Greenberg 2005, p. 226.
- 2 Schafer 1977; Sterne 2012, p. 1.
- 3 Pekarik, Doering, Karns 1999; Salmouka, Gazi 2021.
- 4 Bubaris 2014; Everrett 2019.
- 5 Candela, de Visscher 2023; Salmouka, Gazi 2021.
- 6 Binter 2014; Classen, Howes 2006; Everrett 2019.
- 7 Bubaris 2014; Stocker 1994; 1995.
- 8 Fiebig, Piereth, Karnatz 2017.
- 9 Stocker 1994; 1995.
- 10 Bubaris 2014.
- 11 Chion 1994.
- 12 de Jong 2018.
- 13 Salmouka, Gazi 2021.
- 14 Cortez 2022.
- 15 Cortez 2024.
- 16 Adams, Bruce, Davies et al. 2008; Biserna 2020; Radicchi 2017.
- 17 Aletta, Guattari, Evangelisti et al. 2019; Sun, Qi, Da et al. 2023; Zhang, Kang 2007.
- 18 Xiao, Aletta 2016.
- 19 Voegelin 2014.
- 20 ISO 12913-2 2018.
- 21 Fiebig, Schulte-Fortkamp 2020.
- 22 Engeln, Keck 2022.
- 23 Bilda, Gero, Purcell 2006.
- 24 Engeln, Keck 2022.
- 25 Nykänen, Wingstedt, Sundhage et al. 2015.
- 26 Ekman, Rinott 2010; Delle Monache, Rocchesso 2019; Hug 2020; Selfridge, Delle Monache, Pauletto 2024.
- 27 Kannenberg 2016.
- 28 Lakoff, Johnson 1980, p. 196.
- 29 Greimas, Collins, Perron 1989.
- 30 Wischer 2012; Zellner 2012.
- 31 Goldschmidt, Sever 2011.
- 32 <https://sdi.caa.edu.cn/youngtoyoung/#> (last accessed on 5 July 2026)
- 33 <https://cdm.caa.edu.cn/#/home> (last accessed on 5 July 2026)
- 34 <https://ccam.hzxcw.gov.cn> (last accessed on 5 July 2026)
- 35 Voegelin 2014.
- 36 Fiebig, Piereth, Karnatz 2017.
- 37 Philipsz 2019.
- 38 Delle Monache, Misdariis, Özcan 2022; Hug, Pfaff 2019.

- 39 Abi Khalil, Daou, Mishlawi 2019.
- 40 Pavement 2014.
- 41 Orhan, Yilmazer 2021.
- 42 Hug, Pfaff 2019, pp. 102–130.
- 43 Kang 2006, p. 48.
- 44 Agrawal, Simon, Bech et al 2020; Kaghat, Le Prado, Damala et al. 2009.
- 45 Pursey, Lomas 2018.
- 46 Schafer 1977, p. 205-206.
- 47 Stocker 1994.
- 48 Bull, Back 2020.
- 49 Fry 2002.
- 50 D’Orazio, Montoschi, Garai 2020.
- 51 Fry 2002.
- 52 Fry 2002.
- 53 Bild, Coler, Pfeffer et al. 2016; Truax 1984, p. 94.
- 54 Truax 1998, pp. 8-16.
- 55 Truax, 1984, p. 94.
- 56 D’Orazio, Montoschi, Garai 2020; Stocker 1994.
- 57 Drever, Hugill 2022; Renel 2018.

References

- Abi Khalil, Daou, Mishlawi 2019: Abi Khalil A., Daou A., Mishlawi N., *Sounding the Museum: A Shared Reflection on the Chou Hayda. Intervention at the National Museum of Beirut*, in “Curator: The Museum Journal”, 2019, 62, 3, pp. 367-376. DOI: <https://doi.org/10.1111/cura.12312>.
- Adams, Bruce, Davies et al. 2008: Adams, M., Bruce, N., Davies W.J. et al., *Soundwalking as a methodology for understanding soundscapes*, in the Proceedings of the Institute of Acoustics, Reading, U.K., Institute of Acoustics, 2008, pp. 548-554.
- Agrawal, Simon, Bech et al 2020: Agrawal S., Simon A., Bech S. et al., *Defining Immersion: Literature Review and Implications for Research on Audiovisual Experiences*, in “Journal of the Audio Engineering Society”, 2020, 68, 6, pp. 404–417.
- Aletta, Guattari, Evangelisti et al. 2019: Aletta F., Guattari C., Evangelisti L. et al., *Exploring the compatibility of “Method A” and “Method B” data collection protocols reported in the ISO/TS 12913-2:2018 for urban soundscape via a soundwalk*, in “Applied Acoustics”, 2019, 155, pp. 190-203. DOI: <https://doi.org/10.1016/j.apacoust.2019.05.024>.
- Bild, Coler, Pfeffer et al. 2016: Bild E., Coler M., Pfeffer K. et al., *Considering Sound in Planning and Designing Public Spaces: A Review of Theory and Applications and a Proposed Framework for Integrating Research and Practice*, in “Journal of Planning Literature”, 2016, 31, 4, pp. 419-434. DOI: <https://doi.org/10.1177/0885412216662001>.
- Bilda, Gero, Purcell 2006: Bilda Z., Gero J.S., Purcell T., *To Sketch or Not to Sketch? That Is the Question*, in “Design Studies”, 2006, 27, 5, pp. 587–613. DOI: <https://doi.org/10.1016/j.destud.2006.02.002>.
- Binter 2014: Binter J.T.S., *Unruly Voices in the Museum*, in “The Senses and Society”, 2014, 9, 3, pp. 342-60. DOI: <https://doi.org/10.2752/174589314X14023847039674>.
- Biserna 2020: Biserna E., *Ambulatory Sound-Making: Rewriting, Reappropriating*,

- “Presencing” Auditory Spaces, in Bull M., Cobussen M. (eds.), *The Bloomsbury Handbook of Sonic Methodologies*, New York, Bloomsbury Publishing, 2020, pp. 297–314.
- Bruce 2006: Bruce C., *Spectacle and Democracy: Experience Music Project as a Post-Museum*, in Marstine J. (ed.), *New Museum Theory and Practice*, John Wiley & Sons Ltd., 2006, pp. 129-151. DOI: <https://doi.org/10.1002/9780470776230.ch5>.
- Bubaris 2014: Bubaris N., *Sound in Museums. Museums in Sound*, in “Museum Management and Curatorship”, 2014, 29, 4, pp. 391-402. DOI: <https://doi.org/10.1080/09647775.2014.934049>.
- Bull, Back 2020: Bull M., Back L., *The Auditory Culture Reader*, London – New York, Routledge, 2020.
- Candela, de Visscher 2023: Candela E., de Visscher E., *Learning from “The Sounding Object”: Sound Design in the Critical Reimagining of Museum Object Narratives*, in “Design Issues”, 2023, , 2, pp. 57-71. DOI: https://doi.org/10.1162/desi_a_00717.
- Chion 1994: Chion M., *Audio-Vision. Sound on screen*, Columbia University Press, 1994.
- Classen, Howes 2006: Classen C., Howes D., *The Museum as Sensescape: Western Sensibilities and Indigenous Artifacts*, in Edwards E., Gosden C., Phillips R. (eds.), *Sensible Objects*, London – New York, Routledge, 2006, pp. 199-222.
- Cortez 2022: Cortez A., *Museums as Sites for Displaying Sound Materials: A Five-Use Framework*, in “Sound Studies”, 2022, 8, 1, pp. 43–72. DOI: <https://doi.org/10.1080/20551940.2021.1975442>.
- Cortez 2024: Cortez A., *Communicating Through Sound in Museums: A Genre-Based Framework*, in “Curator: The Museum Journal”, 2024, pp. 513-533. DOI: <https://doi.org/10.1111/cura.12667>.
- D’Orazio, Montoschi, Garai 2020: D’Orazio D., Montoschi F., Garai M., *Acoustic Comfort in Highly Attended Museums: A Dynamical Model*, in “Building and Environment”, 2020, 183:107176, pp. 1-10. DOI: <https://doi.org/10.1016/j.buildenv.2020.107176>
- de Jong 2018: de Jong S., *Sentimental Education. Sound and Silence at History Museums*, in “Museum and Society”, 2018, 16,1, pp. 88-106. DOI: <https://doi.org/10.29311/mas.v16i1.2537>.
- Delle Monache, Misdariis, Özcan 2022: Delle Monache S., Misdariis N., Özcan E., *Editorial: Sound and Design*, in Lockton, D., Lenzi, S., Hekkert, P., Oak, A., Sádaba, J., Lloyd, P. (eds.), DRS2022: Bilbao, 25 June - 3 July, Bilbao, Spain, 2022. DOI: <https://doi.org/10.21606/drs.2022.1055>.
- Delle Monache, Rocchesso 2019: Delle Monache S., Rocchesso D., *Sketching Sonic Interactions, in Foundations in Sound Design for Embedded Media*, London – New York, Routledge, 2019, pp. 79-101. DOI: <https://doi.org/10.4324/9781315106359-4>.
- Drever, Hugill 2022: Drever J.L., Hugill A., *Aural Diversity*, London – New York, Routledge, 2022.
- Ekman, Rinott 2010: Ekman I., Rinott M., *Using Vocal Sketching for Designing Sonic Interactions*, in Bertelsen O.W., Krogh P., Halsov K., Graves Petersen M. (eds.), *DIS’10: Proceedings of the 8th ACM Conference on Designing Interactive Systems*, New York, Association for Computing Machinery, 2010, pp. 123–131. DOI: <https://doi.org/10.1145/1858171.1858195>.
- Engeln, Keck 2022: Engeln L., Keck M., *Exploring Sketch-Based Sound Associations for Sonification*, AVI 2022 Workshop on Audio-Visual Analytics: Workshop on the International Conference on Advanced Visual Interface 2022, Frascati, Rome, Italy, 2022. DOI: <https://doi.org/10.5281/zenodo.6576696>.
- Everrett 2019: Everett T., *A Curatorial Guide to Museum Sound Design*, in “Curator: The Museum Journal”, 2019, 62, 3, pp.313–325. DOI: <https://doi.org/10.1111/cura.12305>.
- Fiebig, Schulte-Fortkamp 2020: Fiebig A., Schulte-Fortkamp B., *Soundscape as Methodology in psychoacoustics and noise management*, in Bull M., Cobussen M. (eds.), *The Bloomsbury*

Handbook of Sonic Methodologies, Bloomsbury Handbooks, London – New York, Bloomsbury Publishing, 2020, pp. 252–268.

Fiebig, Piereth, Karnatz 2017: Fiebig A., Piereth U., Karnatz S., *The Cadolzburg Experience: On the Use of Sound in a Historical Museum*, in “Leonardo Music Journal”, 2017, 27, pp. 67–70. DOI: https://doi.org/10.1162/LMJ_a_01021.

Fry 2002: Fry R., *Delightful Sound and Distracting Noise*, in “Journal of Museum Education”, 2002, 27, 1, pp. 14–17.

Goldschmidt, Sever 2011: Goldschmidt G., Sever A.L., *Inspiring Design Ideas with Texts*, in “Design Studies”, 2011, 32, 2, pp. 139–55. DOI: <https://doi.org/10.1016/j.destud.2010.09.006>.

Greenberg 2005: Greenberg S., *The Vital Museum*, in *Reshaping Museum Space*, London – New York, Routledge, 2005.

Greimas, Collins, Perron 1989: Greimas A.J., Collins F., Perron P., *Figurative Semiotics and the Semiotics of the Plastic Arts*, in “New Literary History”, 1989, 20, pp. 627–649.

Hug 2020: Hug D., *How Do You Sound Design? An Exploratory Investigation of Sound Design Process Visualizations*, in Groß-Vogt K., Höldrich R. (eds.), *AM '20: Proceedings of the 15th International Audio Mostly Conference*, New York, Association for Computing Machinery, 2020, pp. 114–121. DOI: <https://doi.org/10.1145/3411109.3411144>.

Hug, Pfaff 2019: Hug D., Pfaff S., *Bringing Sound to Interaction Design: Challenges, Opportunities, Inspirations*, New York, Routledge, 2019.

ISO 12913-2 2018: *International Organization for Standardization. Acoustics – Soundscape – Part 2: Data collection and reporting requirements (ISO/TS 12913-2:2018)* ISO, 2018.

Kaghat, Le Prado, Damala et al. 2009: Kaghat F.Z., Le Prado C., Damala A. et al., *Experimenting with Sound Immersion in an Arts and Crafts Museum*, in Natkin S., Dupire J. (eds.), *Entertainment Computing – ICEC 2009*, Berlin, Springer, 2009, pp. 173–178. DOI: https://doi.org/10.1007/978-3-642-04052-8_16.

Kang 2006: Kang J., *Urban Sound Environment*, London, CRC Press, 2006.

Kannenbergh 2016: Kannenbergh J., *Listening to Museums: Sound Mapping towards a Sonically Inclusive Museology*, in “Museological Review”, 2016, 20, pp. 6–17.

Lakoff, Johnson 1980: Lakoff G., Johnson M., *Metaphors we live by*, Chicago, University of Chicago Press, 1980.

Nykänen, Wingstedt, Sundhage et al. 2015: Nykänen A., Wingstedt J., Sundhage J. et al., *Sketching Sounds – Kinds of Listening and Their Functions* in “Design Studies”, 2015, 39 (July), pp. 19–47. DOI: <https://doi.org/10.1016/j.destud.2015.04.002>.

Orhan, Yilmazer 2021: Orhan C., Yilmazer S., *Harmony of Context and the Built Environment: Soundscapes in Museum Environments via GT*, in “Applied Acoustics” 2021, 173 (February), pp.1–12. DOI: <https://doi.org/10.1016/j.apacoust.2020.107709>

Pavement 2014: Pavement P., *Gramophones in the Gallery: A Chronology of Museums and Media Technology*, in “Journal of Museum Ethnography”, 2014, 27, pp. 12–26.

Pekarik, Doering, Karns 1999: Pekarik A.J., Doering Z.D., Karns D.A., *Exploring Satisfying Experiences in Museums*, in “Curator: The Museum Journal”, 1999, 42, 2, pp. 152–173. DOI: <https://doi.org/10.1111/j.21516952.1999.tb01137.x>.

Philipsz 2019: Philipsz S., *Beyond Borders*, in “Curator: The Museum Journal”, 2019, 62, 3, pp. 283–290. DOI: <https://doi.org/10.1111/cura.12299>.

Pursey, Lomas 2018: Pursey T., Lomas D., *Tate Sensorium: An Experiment in Multisensory Immersive Design*, in “The Senses and Society”, 2018, 13, 3, pp. 354–366. DOI: <https://doi.org/10.1080/17458927.2018.1516026>.

Radicchi 2017: Radicchi A., *A Pocket Guide to Soundwalking: Some Introductory Notes on Its Origin, Established Methods and Four Experimental Variations*, in Besecke A., Meier J., Pätzold R., Thomaier S. (eds.), *Stadtökonomie – Blickwinkel und Perspektiven: ein*

- Gemischtwarenladen / Perspectives on urban economics: a general merchandise Store*, Berlin, Sonderpublikation des Instituts für Stadt und Regionalplanung der Technischen Universität Berlin, 2017, pp.70-73.
- Renel 2018: Renel W., “Auraldiversity”: *Defining a Hearing-Centred Perspective to Socially Equitable Design of the Built Environment*, in “Built Environment”, 2018, 44, 1, pp. 36–51.
- Salmouka, Gazi 2021: Salmouka F., Gazi, A., *Mapping Sonic Practices in Museum Exhibitions – An Overview*, in Shehade M., Stylianou-Lambert T. (eds), *Emerging Technologies and the Digital Transformation of Museums and Heritage Sites*, Cham, Springer International Publishing, pp. 61–75, 2021. DOI: https://doi.org/10.1007/978-3-030-83647-4_5.
- Schafer 1977: Schafer R.M., *The Soundscape: Our Sonic Environment and the Tuning of the World*, Rochester, Destiny Books, 1977.
- Selfridge, Delle Monache, Pauletto 2024: Selfridge R., Delle Monache S., Pauletto S., *Sound Design Ideation: A Structured and Systematic Analysis*, in Ludovico L.A., Mauro D.A., *AM '24: Proceedings of the 19th International Audio Mostly Conference: Explorations in Sonic Cultures*, New York, Association for Computing Machinery, 2024, pp. 492–501. DOI: <https://doi.org/10.1145/3678299.3678350>.
- Sterne 2012: Sterne J. (ed.), *The Sound Studies Reader. Sport in the Global Society*, New York, Routledge, 2012.
- Stocker 1994: Stocker M., *Exhibit Sound Design for Public Presentation Spaces*, in “Museum Management and Curatorship”, 1994, 13, 2, pp. 177–183. DOI: [https://doi.org/10.1016/0964-7775\(94\)90075-2](https://doi.org/10.1016/0964-7775(94)90075-2).
- Stocker 1995: Stocker M., *Exhibit Sound Design*, in “Museum International”, 1995, 47, 1, pp. 25–28. DOI: <https://doi.org/10.1111/j.1468-0033.1995.tb01219.x>.
- Sun, Qi, Da et al. 2023: Sun C., Qi M., Da Y., Yue Wu, *Soundwalk Path Affecting Soundscape Assessment in Urban Parks*, in “Frontiers in Psychology”, 2023, 13, pp. 1-16. DOI: <https://doi.org/10.3389/fpsyg.2022.1096952>.
- Truax 1984: Truax B., *Acoustic Communication*, Norwood, New Jersey, Ablex Publishing Corporation, 1984.
- Truax 1998: Truax B., *Models and Strategies for Acoustic Design*, 1998. https://www.sfu.ca/sonic-studio-webdav/WSP_Doc/Articles/Truax_Models&Strategies.pdf.
- Voegelin 2014: Voegelin S., *Soundwalking the Museum: A Sonic Journey through the Visual Display*, in Levent N., Pascual-Leone A. (eds.), *The Multisensory Museum: Cross-Disciplinary Perspectives on Touch, Sound, Smell, Memory, and Space*, Lanham, Maryland, Rowman & Littlefield, 2014, pp. 119–130.
- Wischer 2012: Wischer S.A., *Narrative Transformations And The Architectural Artefact*, in Macleod S., Hanks L.H., Hale J. (eds.), *Museum Making. Narratives, Architectures, Exhibitions*, London, Routledge, 2012, pp. 132–143.
- Xiao, Aletta 2016: Xiao J., Aletta F., *A Soundscape Approach to Exploring Design Strategies for Acoustic Comfort in Modern Public Libraries: A Case Study of the Library of Birmingham*, in “Noise Mapping”, 2016, 3, 1, pp. 264-273. DOI: <https://doi.org/10.1515/noise-2016-0018>.
- Zellner 2012: Zellner P., *Narrative Space: The Book of Lies*, in Macleod S., Hanks L.H., Hale J. (eds.), *Museum Making. Narratives, Architectures, Exhibitions*, London, Routledge, 2012, pp. 203-212.
- Zhang, Kang 2007: Zhang M., Kang J., *Towards the Evaluation, Description, and Creation of Soundscapes in Urban Open Spaces*, in “Environment and Planning B: Planning and Design”, 2007, 34, 1, pp. 68–86. DOI: <https://doi.org/10.1068/b31162>.