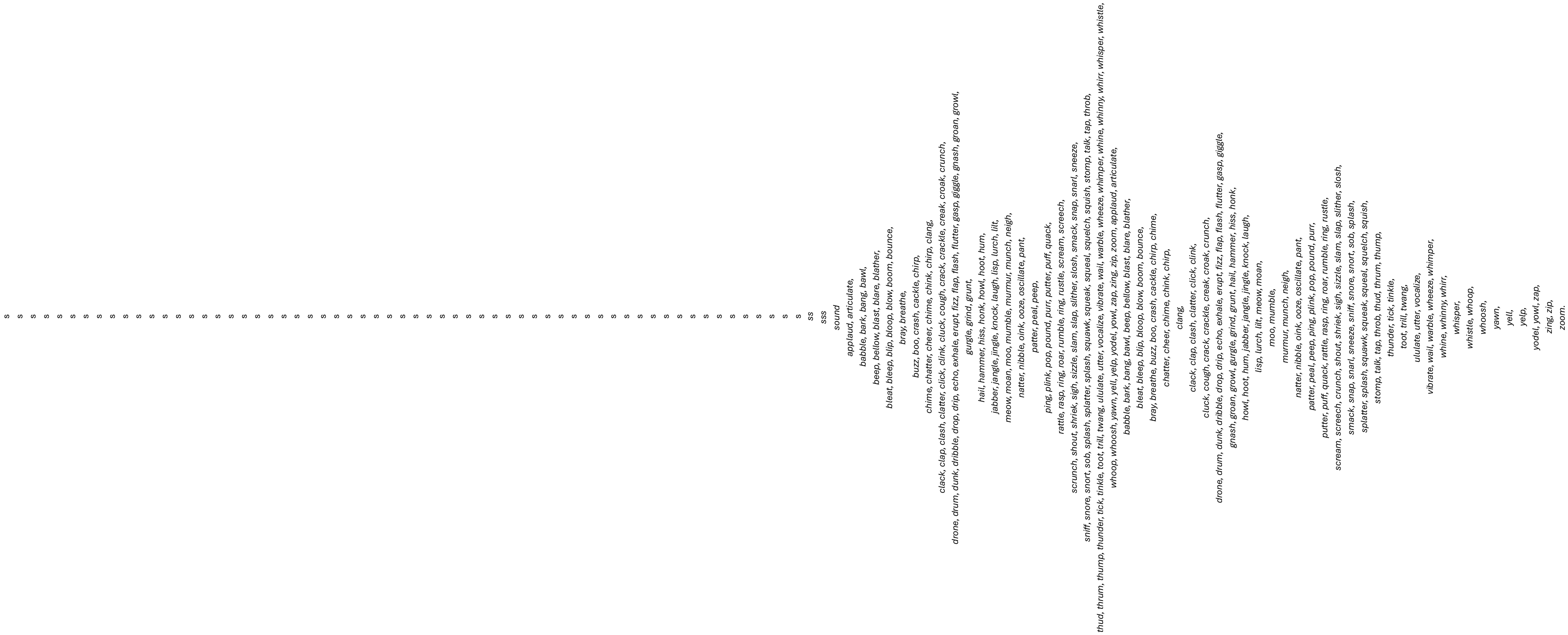
Architecture speaks. Are you Listening?

The Influence of Sound on the Experience of Space



Graduation Thesis

By Emily Wermeier

Architecture speaks. Are you Listening?

The Influence of Sound on the Experience of Space

Thesis Referent: Marion Zwarts

Master Interior Architecture 2024-2025

Zuyd University of Applied Sciences

Maastricht Academy of Architecture

I would like to thank my mentor Marion for her unwavering support, guidance, and encouragement throughout this journey. Your insightful feedback has helped me in shaping my work and helped me grow as a researcher. I am truly grateful for the time and effort invested in this thesis.

Furthermore, I would also like to sincerely thank my parents for providing me with the opportunity to hear, to listen and acknowledge this problematic topic. Without their courage, I would not have come this far.

A door slams,

An old floor creaks,

A conversation fades into reverb,

And the hum of a machine fills the room.

But no one hears it.

Not really.

Sounds surround us.

They shape us. The space.

With or without permission.

This thesis asks what happens,

when we begin to notice.

Where most buildings end,

This work begins.

With the sound that remains

after the drawing is done.

Contents

Preface

In order to explain the motivation behind this thesis,
I would like to tell you a little about myself.

Figure 1: Photograph of me and my cochlear implant device

I was born deaf. But I was fitted with cochlear implants, from when I was seven months old, so that my hearing with hearing aids today is at a level that would be considered ‘normal’, for about 90 percent of the time. It is the remaining 10 percent that inspired me to this topic. In those I usually have a hard time understanding speech, often due to background noises, which I cannot suppress easily, to unclear acoustics, or to reverberations that muffle the clarity of words. These moments can overwhelm or isolate me, as they cut me off from necessary information, and the mental fight against these noises drains my energy and concentration. Especially if the space is indifferent to sound, since often the built spaces which enclose the sound enhance these effects and mostly not for the better. On the other hand, I have the possibility to choose deaf silence by switching off my hearing devices. This duality gives me a unique perspective on sound and its relation to space, given that I can experience spaces without any sound. However, not hearing is not always a choice, since in many situations, such as in social engagements or when auditory cues are necessary, I am sound-reliant. My awareness of sound, shaped not by its tones, but by its effects, has given sound a strange position in my life. Distant yet inescapable. Invisible, yet profoundly vital. Born deaf, I have never experienced sound as others do, but my position between sound and silence allows me to deeply explore and compare the sensory and emotional qualities of both silent and sound-filled environments, offering insights that others may not have.

As an architectural student, on the other hand, I noticed, in architecture, sound is often neglected or treated as a technical afterthought. Here, I seek to approach it differently. As something that shapes how we move, orient, and feel within space. Through this work, I hope to bring greater awareness to the role of sound in architecture. Not simply as an element to be controlled, but as a medium through which space is lived.

Introduction

Figure 2: Illustration of the influence of sound on a person while working in a space

With architecture, we are not only creating spaces to live, work and dwell. We are creating experiences. With every decision an architect takes, they create guidelines, invitations, limitations, and a sensory influence, however big it may be. The experience of a space is shaped by many things: knowledge of functions, cultural associations, memory, and imagination. But, next to visual perception, the *way* we experience a space is largely defined by our auditory perception. Sounds play a crucial, often underestimated role in understanding a place, that we need to be aware of. While architectural practice has long prioritized the visual sense, this thesis explores how everyday sounds influence our experience of space.

While further looking into the topic, I realized I was not alone. Sounds in architecture have an underestimated impact on all people, whether they have a hearing impairment or not. Some may be bigger than others, but we are all shaped by it. I also realized that the built spaces of our surroundings interact with those sounds. Nevertheless, it is rarely part of the design. As designers of space, I believe architects and interior architects have the tools and responsibility to shape the experience. So, with this research, I chose to look further into the relevance of aural design in architecture.

Therefore, this thesis focuses on the relationship between sound and architectural design, by exploring how sound, as an auditory phenomenon, influences the interior experience of space and atmosphere. Sound, in this context, will be limited to environmental sound, usually defined as 'noise', which describes the omnipresent sounds created by either human activities, machines, or nature. Disregarding the natural component, this thesis concentrates on the interior and urban life. However, the term 'noise', often negatively connotated, characterizes sounds with an unwanted and disruptive nature. Whereas I see noise as a complex element that shapes the emotional and sensory perception of interiors, with a positive effect as well as negative. This attitude of mine stems from my German background, where 'noise' would be translated to '*Geräusch*', which in German has a neutral connotation, that simply describes the unintended sound created due to human or natural action. In order to convey the idea of its dual nature, I will refrain from using the term 'noise' and instead call that sort of sound '*Geräusch*', or '*Geräusche'* in plural. This frames an attempt to redefine the perception of sound.

Understanding architectural space not merely as visual but as lived and sounded experience leads to the question: How significant is the influence of everyday sounds on the phenomenological experience of space, and would the integration of sound management into architectural design enrich spatial atmosphere, perception, and personal well-being?

By exploring the phenomenology of *Geräusche*, how it is experienced, interpreted, and felt, physiologically and psychologically, I intend to verify its two sides as both a source of disruption and a potential enhancer of spatial ambiance. Within that, the research emphasizes the subjective perception of *Geräusche* and its dependence on various factors, such as sensitivity towards noise, context, and the interaction of sound with the built space. Additionally, a look at the interplay of sound and built architecture might reveal the scope of responsibility it holds. The general objective is to raise awareness of the need for integrating thoughtful sound design into architectural design, to create meaningful experiences of space.

As this topic is more relevant than most anticipate. This can be seen in its often neglect in architectural practices, where visual aesthetics seem to dominate the aural, which ultimately impacts the way individuals experience and interact with spaces. Especially in an increasingly urbanized and noisy world, understanding how *Geräusche* influence the interior experience is significant for creating environments that support well-being, productivity, and comfort. This study looks beyond purely technical solutions and challenges traditional approaches to sound management by focusing on the phenomenology of *Geräusche* and exploring its emotional and sensory dimensions. As well as, looking at the interplay of *Geräusche* and Architecture, and the role of the architect. Additionally, the insight of questioning how *Geräusche* affect the perception of space and atmosphere will be valuable to architects, interior architects, and urban planners intending to create environments that will hopefully balance functional needs with the subtleties of human experience. Ultimately, this study might contribute to a more holistic understanding of sound as a fundamental component of spatial design, emphasizing its potential to enhance or detract from the quality of daily life for everyone. I am to expand the conversation about spatial perception and challenge the field to listen more closely to what has often gone unheard.

So, to come to a thorough response to the main question, it is essential to ask three subsidiary, more specific questions: What effects do *Geräusche* have on the human being? Do they influence the perception of space and atmosphere and the experience within? And do architects have the responsibility to integrate sound management into architectural design?

Hearing Geräusche

“Hearing is a way of touching at a distance and the intimacy of the first sense is fused with sociability whenever people gather together to hear something special.”

- R. Murray Schafer

Understanding Sound

To understand the subject of this thesis a little better ‘sound’ must be defined first. There are many ways to define sound. One of the first known definitions comes from the Roman architect, Vitruvius, who lived in the first century BC. In *The Ten Books of Architecture* (translated by M.H. Morgan, 1960) he describes the nature of sound produced by the voice as follows:

Figure 3: Photograph of a waterdrop causing a circular wave on a water surface

“Voice is a flowing breath of air, perceptible to the hearing by contact. It moves in an endless number of circular rounds, like the innumerably increasing circular waves which appear when a stone is thrown into smooth water… but while in the case of water the circles move horizontally on the plane surface, the voice not only proceeds horizontally, but also vertically in regular stages.” (Orlowski, Raf. 2021. pos.88)

He gives an illustrative example of how we could imagine sound to look like, referring to a stone’s impact on water, but corrects himself, that on water we only see one layer of the sound wave, whereas sound expands not only in one direction but expands in spherical shapes from its source to all directions.

A more modern definition, that is used often in physics, defines sound as “a disturbance that propagates in an elastic medium, such as air, at a speed that is characteristic of that medium.” (Orlowski, Raf. 2021. pos.98) It mentions the need for an oscillating body (solid, liquid, or gas) for the sound to be transmitted with, often air, as well as that the medium determines the speed of sound. This disturbance could also be described as a vibration and the pressure of these vibrations within a given frequency range then stimulates sensation in the ears and enables hearing. (Mehta, R.; Zhu, R.; Cheema, A. 2012. p.2) According to that definition, sound can therefore also be a sensation, that is perceptible to the human and animal hearing systems.

The sound theorist Brandon LaBelle (2009) gives another imaginative description of sound in his article ‘Other Acoustics’ (p.16), saying: “*Many spiritual traditions understand sound as the voice of objects, of nature, of animals, etcetera, and the world as an audible chorus whose multiple voices are continually speaking.*” Interesting here is the acknowledgment of the omnipresent character of sound. Sound appears as a vast, enveloping medium from the listener's point of view. A hearing person simultaneously hears an acoustic expanse without physical boundaries coming from all directions (Avidar, P.; Ganchrow, R.; Kursell, J. 2009. p.4). That is, because hearing is always active and since there are no "earlids" or a conscious point of focus, listeners are unintentionally linked to the audible sonic events (Blesser, B.; Salter, L.R. 2009. p.54). It is only intentional if the sound is created or wished for, like producing music or listening to it consciously. Nevertheless, it is not possible to ‘listen away’. At least for people with naturally developed hearing, whereas ironically in my specific case, I have the possibility to sort of turn off my hearing, since I never had one that works naturally.

While going into the behavior and characteristics, it can be said that sound is inherently unruly. It originates from a source and travels towards a distance, meanwhile, it frequently bends around corners and circumnavigates obstructions, leaving behind the original object or body and imposing itself on the listener. Sound is pervasive, diffused, and obtrusive, regardless of whether it is muffled, channeled, reflected, or even timbrally altered (Avidar, P.; Ganchrow, R.; Kursell, J. 2009. p.4). But human beings are also reliant on sound and its intrusive behavior. It always comes from a source and when hearing it, we automatically try to identify where it is coming from and what it is. It signals its presence and lends direction and orientation through proximity, volume, movement, reflection, and refraction. A space's size, shape, and material can be detected by auditory cues, for instance, a tiny room with carpet absorbs sound and feels more intimate than an open cathedral, which has a long reverberation time. Echoes and reflections help us judge distances and directions. Auditory cues like alarms or changes in background noise levels, guide people toward exits, in emergencies. With sound, we can even navigate in the dark. Its navigational characteristics are crucial to human orientation in daily life.

Another characteristic stated by Rudolf Markgraf in 1911, is that "*sound has no existence, shape or form, it must be made new all the time, it slumbers until it is awaken[ed], and after it ceases its place of being is unknown.*" (Thompson, Emily. 2002. p.12). He highlights sound's invisibility and temporal existence, where it radically announces its presence or suggests movement happening and then fades into nowhere. However, while it lasts, it carries a collection of information related to the conditions of the original object or body, and the related environment. Therefore, it functions as a communicational medium as well. It indicates that life is happening, even if it can only be communicated by already disappearing (LaBelle, Brandon. 2009. p.16).

By considering sound in terms of "messages," the acoustic landscape is projected into a symbolic exchange space (Avidar, P.; Ganchrow, R.; Kursell, J. 2009. p.8), which makes sound a social material, that connects us to others in a sense of sharing and by bringing human events to our notice. Speech is the most important communicational sound, that allows us to interact with each other, but even background noises, that announce movement of other individuals, connect us with the knowledge of sharing the same space. Consequently, it potentializes relationships with emotional and psychological impact and creates communities. (LaBelle, Brandon. 2009. p.16)

Lastly, it is important to mention that while sound always exists in space, it is highly influenced by its spatial context. In its journey from the source to air molecule to air molecule to the human ear, it is determined both by the characteristics of the sound and by the shape, size, objects, and material of the space it moves in (Curtis, Charles. 2009. p.108). Therefore, a sound in one space will never completely sound the same in another. This impact of the context on the sound is why architecture plays a crucial role in the way we hear in a space. Further discussions about this topic will be provided at a later point.

From these conclusions it can be established, that sound is a disturbance in the air, caused by an oscillating object, which is transmitted to the ear, with a pervasive, vanishing and unruly behavior, and navigational, communicational, and social characteristics, influenced by its spatial context.

Noise (n.)

(...) mid-13c., "loud speech, outcry, clamor, shouting;" c. 1300, "a sound of any kind from any source," especially a loud and disagreeable sound, from Old French noise "din, disturbance, uproar, brawl" (...).

According to some, it is from Latin nausea "disgust, annoyance, discomfort," (...). According to others, it is from Latin noxia "hurting, injury, damage." OED considers that "the sense of the word is against both suggestions," but nausea could have developed a sense in Vulgar Latin of "unpleasant situation, noise, quarrel" (...). Confusion with annoy, noisome, and other similar words seems to have occurred.

Figure 4: Etymology of Noise

Geräusch (n.)

(translated) Sn "Schall" std. (13th century), mhd. "geriusche" root word. Initially a verbal abstract of the verb mentioned under "rauschen" (rustling). Then generalization of meaning to describe any auditory impression. German s. "rauschen" (rustling)

Definition: "something that is perceived acoustically to a greater or lesser extent (and which is created without conscious intention by something in motion or set in motion)"

Figure 5: Etymology and Definition of Geräusch

From Sound to *Geräusch*

In general, sound can be categorized into three main types: music, speech, and what is usually termed "noise." Music is composed of tone and pitch, intentionally produced by humans to create harmony and rhythm. Speech is a mixture of noises and tonal elements, vowels are formed through tonal vibrations of the vocal cords, while consonants are shaped by the interaction of the tongue, lips, and airflow, producing non-tonal sounds (Levarie, Siegmund. 1977. p.22). Noise is more ambiguous. Sound events can be both intentional and unintentional. Either they are directly connected to the reason that brought the individual to that space, or they may be incidental and perceived as ambient sound or if perceived unpleasant, as noise (Blesser, B.; Salter, L.R. 2009. p.50).

In the English language, the term "noise" has a primarily negative connotation, implying an unwanted sound, annoyance, or disturbance. However, from my perspective, influenced by my German background, the translated term *Geräusch* offers a more neutral approach. Unlike "noise," which suggests disorder, *Geräusch* simply refers to sound without underlying positive or negative judgment. It describes a sound produced by natural or human-made activities in context, such as the rustling of leaves, the rain dropping, traffic, or the impact of footsteps, and they are consequences of interactions between physical elements, atmospheric conditions, and human or animal activity. With this neutral term, I intend to combine ambient sound and noise into one, since I believe them to be the same and only differentiated by the way the sound is perceived individually. Only by redefining the concept beyond its negative connotation, can we appreciate sound in all its richness, regardless of its perception. Therefore, this research focuses on *Geräusche* and to a limited extent speech, with a particular focus on human-generated *Geräusche*, while disregarding naturally created *Geräusche*.

So how does one decide whether a *Geräusch* is a noise or an ambient sound?

Subjectivity

It is dependent on various factors that relate to the individual, since the perception of *Geräusche* is a very subjective manner. Factors, such as 'personal sensitivity' towards sound, can vary from person to person and influence the judgement on the perceived *Geräusch*. Some people can withstand certain frequencies, volumes, or patterns better, whereas others get annoyed or disrupted by them more easily. This can occur, if there is hearing loss, or when the ability to blend out sounds is not developed well, and when there is already another underlying burden. For instance, stress, fatigue, or the need to focus on a task, can heighten annoyance, and therefore 'the state of mind' is another factor, that plays into the perception of *Geräusche*. It can also happen due to some diseases. Long Covid, for instance, a side effect from the recent Covid-19 pandemic shows symptoms of cognitive impairment and hearing loss. Significant also is the 'personal background' of a person, which entails their culture and how they grew up. A person who lived in a city, for example, might be used to the constant sound of traffic, and a person from the countryside might get easier disturbed by that unusual soundscape. Traffic also is often associated with congestion and delays, stress, or frustration, and therefore negatively connotated. Perhaps though for some people, the business of the street evokes positive memories and therefore is seen more as an ambient sound. Also, a child's loud laughter might be joyful for parents, but distracting to a stranger. This is why the subjective 'emotional association' plays a crucial role in the judgement of a *Geräusch*. Lastly, the 'relevance' of whether someone needs to hear that sound is subject to whether they are willing to withstand its annoyance factor. This entails active listening to a sound source, where effort and concentration are put into receiving information.

Nevertheless, it is apparent that people, with any sort of hearing loss or who are hard of hearing, struggle with perceiving sound due to their individual impairment. Like me, they probably have difficulties with background noise or diffused sounds, like reverberated speech, and need to put more effort into processing the perceived sound. Though this is not always visible for others to see. In my case, I encounter a lot of people, who only notice my hearing situation after a while, or when I mention it. Therefore, a lot of people are not aware of my occasional struggle.

If we are looking at statistics of the World Health Organization (WHO), we see that in 2021 over 1.5 billion people experienced some degree of hearing loss, and it was estimated that it would only grow to 2.5 billion in 2050 (WHO. 2021. p.1). This shows that currently, almost 2 in every 10 people have some sort of hearing loss and therefore have the potential to struggle with certain soundscapes. 'Hearing capability' is consequently another factor, which influences the subjective perception of *Geräusche*.

Designing sensory experiences then requires an acceptance of cultural relativism. We must ascertain by whom, under what circumstances, for what purposes, and with what meanings acoustic attributes are perceived. The way a *Geräusch* is perceived is very subjective to every individual and thus cannot be generalized. Which makes it harder to design a soundscape. However, there are certain sounds in certain situations where the majority of people have a clear judgement on whether the *Geräusch* is wished for or not. And by analyzing the impact *Geräusche* can have, it is easier to estimate what soundscape fits best in the context.

Soundscapes

In this thesis, one will come across the term ‘soundscape’ quite often. Along with *Geräusche*, soundscape is the second most important subject of this study and to give the reader a better understanding of its meaning and background, it is necessary to explain a little further.

The term ‘soundscape’ refers to the acoustic environment, perceived by humans, including all surrounding sounds, natural and artificial. Described as an auditory landscape, it is a sonic composition of all sounding elements, such as wind, water, voices, and machines, that are heard in one place. Influenced by geography, culture and human activity, it shapes the way humans experience and interpret space.

Emily Thompson goes a little further and says that soundscape is *“a physical environment and a way of perceiving that environment; it is both a world and a culture constructed to make sense of that world. The physical aspects of a soundscape consist of not only the sound themselves, the waves of acoustic energy permeating the atmosphere in which people live, but also the material objects that create, and sometimes destroy those sounds.”* (Thompson, Emily. 2002. p.1) She portrays a soundscape as a more materialistic subject of a world on its own, even if it is not visible, and highlights the influence of the context, that is carried in a soundscape, part of it, as well as its energy.

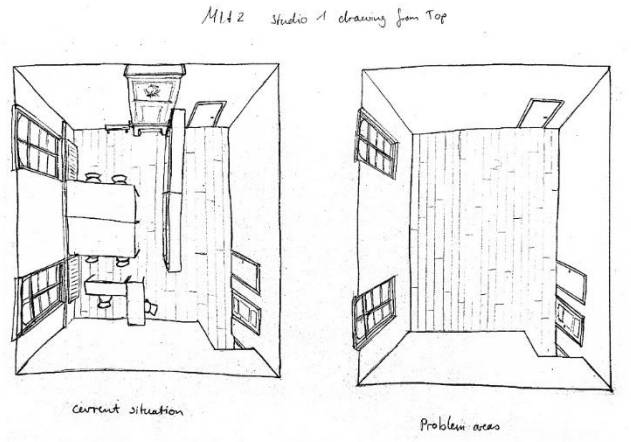


Figure 6: Sketch of what architectural elements support the MIA soundscape

Example ‘De Stuers’ House

Throughout the thesis, I will be naming some examples to illustrate the written content of the thesis. These will be taken out of the project that I am working on alongside writing the thesis. This project takes place in a house, called ‘De Stuers’, which is part of the Academy of Arts and Architecture in Maastricht and houses the two years of Master of Interior Architecture (MIA), part of Master of Architecture (MAC) and the two years of Master of Scientific Illustration (MSI). The house itself, a former residential building, is from the 18th Century and displays historical features and construction, which take part in its acoustic environment.

The soundscape of the De Stuers house expresses the busy activities that happen inside the house, and the history hiding in its construction and materials, at the same time. A working atmosphere is carried by the clicking of laptop keyboards, and computer mice, rustling of paper, sliding of cutting material, and occasional shifting of chairs. Voices from meetings in neighboring rooms are heard, reverberation carrying them through the old doors, into other rooms. A slowly increasing rumbling sound, with lower frequency, is frequently moving through the thin old windows into the building, letting the students know when a car drives past. Doors that slam into their frame, when people pass from one room to the other, announcing the presence of movement. But the most significant one comes from the floor, as the hollow steps of people walking by, passing to get from A to B, are amplified and emphasize each step growing louder as it nears the listener and fades as it goes in distance. Adding to that, occasionally the creaking of the old wooden flooring sounds when someone steps onto a weak spot. Here, the historic construction allows the wood to move and speak. A symphony of quiet moments, with moderate volume in an atmosphere of creativity, and voices that are carried through the rooms, and interruptions of busier, more hectic sounds with higher volume, that announce the presence of the amount of people in the house.

Figure 7: Picture of one MIA2 Atelier

Although the concept was originally coined by Michael Southworth for urban planning, it was R. Murray Schafer's use of the term that resulted in its widespread adoption and popularity. In his book, 'The Soundscape: Our Sonic Environment and the Tuning of the World' (1977) the Canadian composer and environmentalist sets a foundational text in the field of acoustic ecology, that examines the relationship between living beings and their sonic environments. He claims that the noise level in contemporary culture has increased, impairing aural awareness and creating an imbalance in sensory perceptions. Schafer's investigation of soundscapes encourages readers to actively influence our acoustic surroundings and listen to the world with greater attention. In his work, he connects disciplines of music, environmental studies, and cultural theory, and thereby positions sound as a powerful force that influences social interactions and consciousness, rather than just as a sensory input.

One of his contributions in his book are two terms, a distinction between the so-called 'hi-fi' and 'lo-fi' soundscapes. A hi-fi system describes environments with low ambient volume levels, where individual sounds can be heard clearly. He uses the example of a calm landscape, where "*sounds overlap less frequently*" (p.69) and the "*soundscape allows the listener to hear farther into the distance*" (p.69), carrying a sense of spatial depth. Whereas lo-fi soundscapes obscure individual acoustic signals in an over-dense population of sounds and are often related to cityscapes with high volume levels (Schafer, R. Murray. 1993. p.69).

According to him, a soundscape has three categories of sound that define its character. The 'Features of the Soundscape', how he describes it, are *Keynote sounds*, *Signals*, and *Soundmarks*. "Keynote sounds" are background sounds that are usually heard unconsciously and form the ambient backdrop of a place. He states that although they often become omnipresent listening habits, they have the potential to deeply influence an individual's mood and behavior. "Signals" are foreground sounds, that are listened to consciously and intended to be heard, such as alarms. These communicate certain messages, guiding human behavior and interactions within a space. Lastly, "soundmarks" describe unique sounds that hold cultural or personal significance and are strongly associated with a certain place. (Schafer, R. Murray. 1993. pp.19-21)

As mentioned above, the need for increased auditory awareness is one of The Soundscape's main themes. Schafer contends that the aural dimension has been neglected as a result of modern society's predominance of visual orientation (p.22). To improve listening abilities and promote deeper interaction with the auditory environment, he suggests 'ear cleaning' exercises. Some of these exercises, for instance, teach a respect for silence, by challenging people not to speak for a day and learn to listen to the soundscape. He contends that this increased consciousness not only improves personal sensory experiences but also cultivates a stronger bond with location and society. (Schafer, R. Murray. 1993. p.312)

After all, Schafer argues that we can intentionally create and enhance our soundscapes, a process he refers to as 'the tuning of the world', in the same way, a musician tunes an instrument. In order to create spaces that are both aesthetically pleasing and sound harmonic, he highlights the importance of acoustic design in architecture and urban planning. Schafer urges society to pay more attention to the acoustic characteristics of space and promotes noise reduction and the preservation of significant soundmarks. By looking at how sound impacts both the environment and human well-being, he highlights a harmonious and lasting connection between people and their acoustic environments.

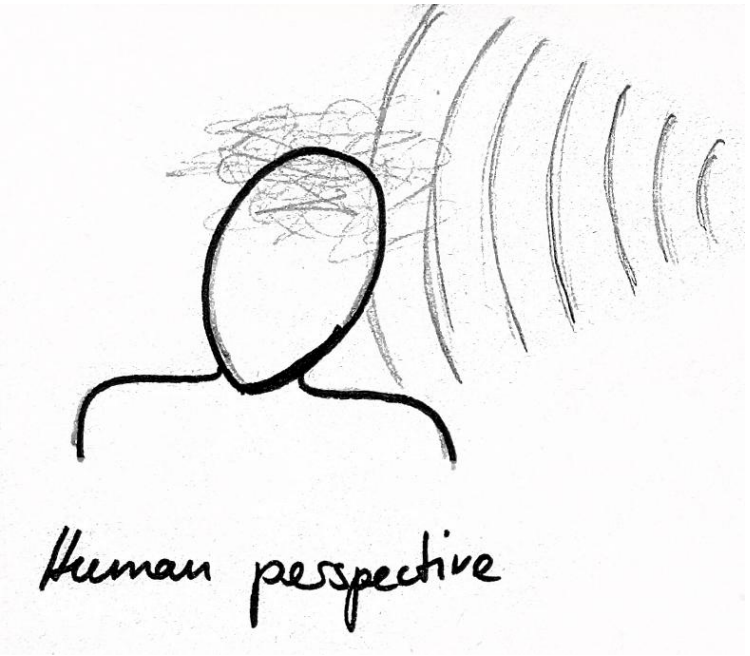
These statements, that were an urgently discussed topic, date back almost 50 years ago. Yet, most of Schafer's arguments resonate with the ones stated in this thesis today. For instance, the argument that by recognizing the influence of sound on human perception and spatial experience, designers can create environments that engage all senses and create meaningful interior experiences. To validate the argument sufficiently, it is first necessary to look at the phenomenology of *Geräusche* and evaluate its impacts on human physiology as well as psychology.

The Phenomenology of Geräusche

„Sound provides the most forceful stimulus that human beings experience, and the most evanescent."

- Bruce R. Smith

Geräusch is an omnipresent but often unconscious element of spatial perception. While architecture is largely impacted by visual and tactile dimensions, auditory perception plays a key role in both human physiological and psychological well-being and experience of space. *Geräusche*, whether incidental, controlled, or as an aural backdrop, influences comfort, orientation, and even behavior. They quietly shape how a person interacts with their environment by influencing a sensation of presence, materiality, and spatial depth. This chapter seeks to reveal the frequently disregarded contribution of auditory perception to spatial experience and well-being, by investigating the physiological and psychological aspects of sound in architecture.



Physiology of Hearing

Hearing is one of the most significant senses when it comes to navigating through life, and due to hearing anatomy, our bodies are able to process and perceive *Geräusche*. As mentioned earlier, in this text we already know how a *Geräusch* travels to our ears, but how the ear conveys the sound wave into something we can actually hear, still needs to be discussed.

It starts with the outer ear, also called pinna, that captures the *Geräusch* and channels it into the ear canal. There it is amplified and transferred to the drum head, also known as the eardrum or tympanic membrane, which is located at the end of the canal. The drum head separates the ear canal from the middle ear and is the first part of the sound-transducing mechanism. Once the amplified soundwaves reach the skin of the drum the *Geräusch* is transmitted from the middle ear to the inner ear, by three little bones. The malleus, incus and stapes. The inner ear, which is also called the cochlea, is transducing vibrations of the soundwaves, which cause the fluid inside the cochlear to sway. Then “the cilia of the inner hair cells are bent in relation to the body of the cell, ion passages are opened or closed in the body of the stimulated.” (Alberti, Peter W. 2001. p. 58) So, they move over the basilar membrane and activate the organ of Corti's hair cells. In the cochlea, each frequency component travels through until it reaches its place of resonance and stops there. For higher frequencies, this is at the beginning of the cochlea and for lower frequencies at its end, for which they have to travel farther. In the cochlear nerve's fibers, the hair cells transform sound waves into nerve impulses. These impulses are then sent to the brainstem, where they undergo a thorough processing process before being sent to the cerebral cortex's primary auditory area, the brain's final hearing center. Only then are we aware of the *Geräusche*. Only then can we hear (Hawkins, Joseph E. 2024).

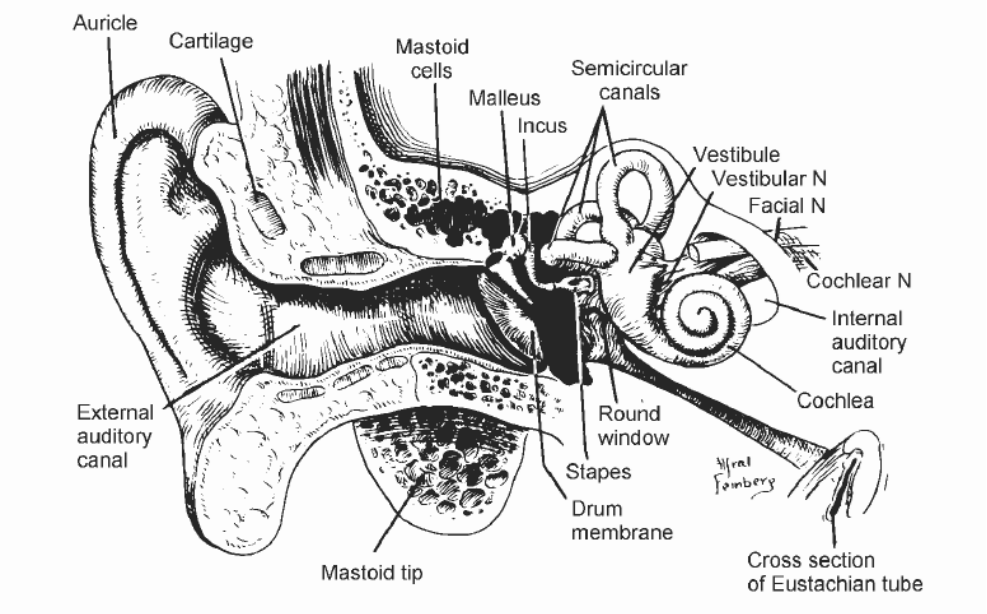


Figure 8: Scientific illustration of hearing anatomy.

In the end, all of us hear with our brains. As a reader of a thesis with a deaf author, you may be curious to learn how I can perceive sound, and the reason behind my deaf hearing. My inability to hear naturally was detected when I was not responding to any auditory signals or messages after I was born. Following tests with an audiologist showed that either I never developed hair cells in the cochlear, or that they do not function. Therefore, my body is not able to convert the sound waves into impulses, which are led to the brain. So, all that technology has to do is replace the hair cells, which is done by electrodes implanted in the cochlear via surgery. However, to convert sound into electrical impulses, the reception of sound changes. For that, I wear a sound processor, that sorts the sounds received by a microphone and then sends signals to a transmitter, attached to the scalp with a magnet. The transmitter converts the signals into electric impulses, that are sent to the electrodes in my cochlear and transmitted to the brainstem. From this point, I hear like a natural hearing person.

Continuing from the explanation before, the physiological procedure of processing *Geräusche* enables humans also to have some wonderful abilities, such as:

Spatial hearing and sound localization

As established earlier, hearing *Geräusche* provides us with navigational skills and allows us to locate where a *Geräusch* comes from. However it is not understood yet, how that is made possible.

First of all, one would need to have the ability to hear with both ears. The head serves as a barrier between these two and therefore a sound source coming from one side will stimulate the ear nearest to it more intensely than the other. Incidentally, the sound will arrive there sooner in comparison to the other and provides a speculation of a direction, by analyzing the intensity and time of arrival. It is more difficult to locate a sound with hearing loss since high frequencies are more necessary than low frequencies. Most of the older people, for example, are struggling to locate sound, due to the decreasing range of maximum sensitivity and audibility with age. Higher frequencies are also important in the localization of sound from the front or back. The pinna's angle allows to catch more sounds from the front than behind and blocks some high-frequency sounds from behind (Alberti, Peter W. 2001. p. 59). Another aspect that might hinder the ability to navigate by sound is when the general density of a soundscape in a place dominates the clarity of single sounds. Therefore, louder environments often lead to auditory disorientation.

The ability to block out unwanted Geräusche

Also known as the 'cocktail party effect', this ability occurs when a young person with normal hearing can be in a crowded noisy room and tune in and out background noises at will. What happens is that the brain automatically modifies the time of arrival and intensity differences of sound from various signal sources. Feedback loops then suppress any signals that do not fit these requirements. Again, this requires two ears, another central mechanism, and good high-frequency peripheral hearing. Elderly people lose a portion of the central mechanism and usually have trouble hearing in crowded environments, even if they have good bilateral peripheral hearing (Alberti, Peter W. 2001. p. 61).

On and Off *Geräusche*

Often *Geräusche* appear suddenly and then disappear or it becomes steady and blends into the background. For instance, when an air conditioner turns on to cool the room, one notices, and as the sound lingers, the brain adjusts to it, but once it turns off, one notices again, and that absence of it will also blend into the background (See fig. 9 for example). The change is acknowledged by specific brain cells, some that respond only to the start of a sound and some to the disappearance of a sound. They allow the ear to respond to acoustic change, that is immediately noticeable, and to interpret its meaning. But they also distract the listener from every task they are focusing on (Alberti, Peter W. 2001. p. 62).

From my experience, I can say that I have not developed the ability to block out unwanted sounds, my localization skills leave much to be desired and the on and off *Geräusche* are very concise to me. This might be the consequence of two things: First, the quality of the processed sounds received and converted by the cochlear implant is artificial and not comparable to natural hearing, and second, I missed the first few months of hearing in my development, which means that my brain learned to deal with the auditory perception later than people with natural hearing. Therefore, one can say that most people with any sort of hearing damage struggle more with certain acoustic situations and everyone should be aware of that.

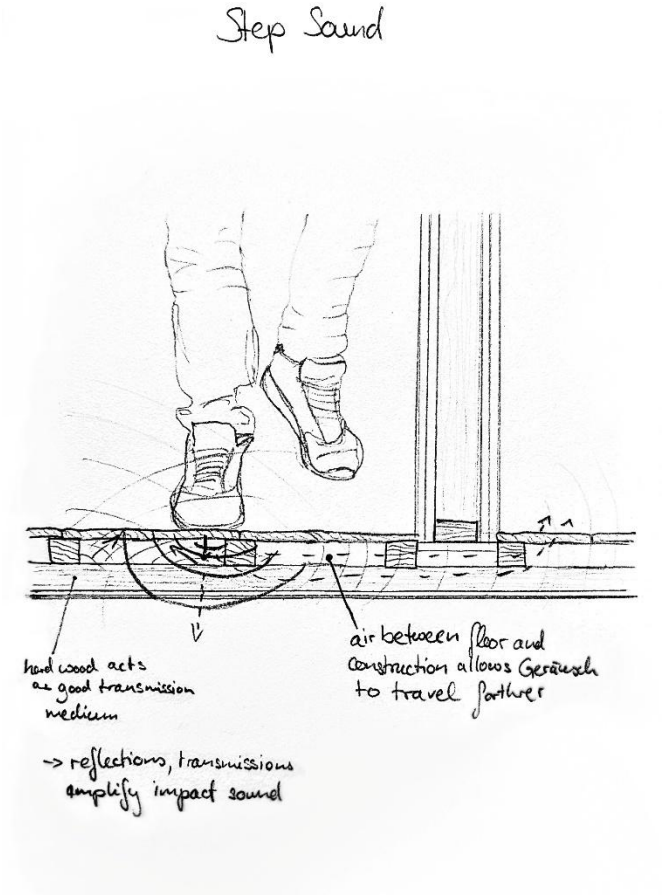


Figure 9: Sketch of how the step sound arises and reaches a high volume.

A disturbing "on and off *Geräusch*" that can be found in the De Stuers House, is the constantly appearing and disappearing step sounds of people walking by the MIA 2 workspaces.

As they are amplified by the old floor construction, they are very loud in the otherwise supposedly quiet workspace, and then often disturb the working students who try to concentrate on their workflow. Being exposed to a busy hallway and having no control over the noise often leads to frustration and anger as well.

Impact

Having established how the auditory perception functions scientifically, it is important to discuss the influence *Geräusche* can have on a hearing person, to illustrate the significance of aural design.

A significant global health concern is noise-induced hearing loss (NIHL). According to a 2019 report, approximately 1,57 billion people worldwide (20,3% of the world population) experience some form of hearing loss, with noise exposure being a leading cause (Natarajan, N.; Batts, S.; Stankovic, K.M. 2023. p.2). NIHL occurs when excessive sound intensity damages the structures within the inner ear, particularly the hair cells in the cochlea, and can affect one ear or both. Damage is created in different manners, for instance, the volume of *Geräusche* can cause mechanical harm and lead to cell death, as well as oxidative stress, which is overstimulation, that increases the production of reactive oxygen species. Intense *Geräusch* exposure can also decrease blood flow to the inner ear, resulting in hypoxia. Lastly, damage extends to synaptic connections between hair cells and auditory fibers, which leads to neural degeneration. Once the damage is done and hair cells are destroyed, they cannot be regenerated, which means that NIHL is irreversible and may have a negative impact on an individual's quality of life (Natarajan, N.; Batts, S.; Stankovic, K.M. 2023. pp.2-9). However, it is preventable when appropriate precautions are implemented, and I believe integrating thoughtful aural design into architecture is one of them.

Another health concern that can be prevented is that chronic noise exposure can stimulate the hypothalamic-pituitary-adrenal (HPA) axis and the sympathetic nervous system, which results in the production of stress hormones such as cortisol, adrenaline, and noradrenaline. This hormonal surge is related to elevated heart rate, high blood pressure, and prolonged activation of these stress responses may be linked to cardiovascular disease and metabolic problems (Arregi, A., Vegas, O., Lertxundi, A., et al. 2024. pp.2-11).

Additionally, it has been demonstrated that nocturnal noise disrupts sleep, which causes a redistribution of time spent in the various important sleep phases and more in shallow stages. Light sleep reduces restorative elements and may result in next-day impairments in cognitive performance, mood, and overall well-being. Chronic sleep disturbances are also linked to long-term adverse health outcomes, including cardiovascular and metabolic diseases (Halperin, Demian. 2014. p.210).

However, considering momentarily reactions towards *Geräusche* immediate responses from the body can be observed, such as muscle tension, increase in the heart rhythm, and blood pressure. This fight-or-flight response is often caused by sudden, unexpected noises or alarming signals, inducing stress, but there is a rapid adaptation (Veljković, M.; ivković, S.; Milenović, M. 2016. pp.38-39). Furthermore, some *Geräusche* may induce relaxation and release the tension of the muscles or lower the heart rhythm. This depends largely on the individual perception of the given *Geräusch* and the emotions that are evoked.

Hearing damage examples in decibels

Breathing	**10 dB**	**Safe sound level**
Ticking watch	**20 dB**	
Average room noise	**30-50 dB**	
Normal conversation/ backgroud music	**60 dB**	
Average office noise	**70 dB**	
Landscaping equipment (inside house)	**75 dB**	**Repeated or prolonged exposure could lead to NIHL over time**
Vacuum / inside an airplane	**80 dB**	
City traffic (inside a car) / noisy restaurant	**85 dB**	
Subway, shouted conversation	**90-95 dB**	
Pro sports events/ car horn at 16 ft	**95-100 dB**	
Motorcycle, stereo	**100 dB**	
Chainsaw, leafblower, snowmobile	**106-115 dB**	
Music concert, ambulance siren	**120 dB**	**Can result in immediate and permanent hearing loss after a single close-range exposure**
Jet engine taking off	**140 dB**	
Gun shot	**140-60 dB**	

Figure 10: Examples for hearing damage due to volume.

Besides physiological impacts, *Geräusche* also have a crucial influence on the individual's psychology. This influence mostly happens unconsciously and affects different aspects, such as emotions, cognitive abilities, behavior, social connections, and memories. In the following, I will discuss three of those dimensions.

Emotional impact

The *Geräusche,* that surround us, shape our emotional responses to space, often without consciously realizing it. From subtle background noises to disruptive auditory stimuli, *Geräusche* influence stress, comfort, and overall emotional well-being in profound ways.

One of them is the tension and anxiety that is created through sudden and unpredictable *Geräusche*, such as sirens or alarms. Along with the physiological fight-and-flight response, emotions like fear and insecurity are evoked and produce stress hormones.

Steady and continuous *Geräusche*, like the humming of a machine, on the other hand, provides a sense of consistency and normalcy. Similarly, well-defined and directional *Geräusche*, create security and certainty, whereas unclear and diffused *Geräusche* evoke tension or curiosity (Västfjäll, Daniel. 2013. p.1056). These uncontrollable and unpredictable *Geräusche* may also evoke frustration and anger as there is a helpless exposure to its behavior, possibly interrupting an individual's thoughts or other cognitive processes leading to a resignation of an unchangeable situation (Hahad, O.; Kuntic, M.; Al-Kindi, S. et al. 2024. p.2). For instance, if a neighbor is moving furniture causing loud rumbling on and off, while the affected person below has to study and wishes to do so in silence. However, there is also beauty in hearing the presence of other people, even if they are not visible. Through sharing the *Geräusch* these two individuals are connected to each other, whether it was wished for or not, and the feeling of loneliness decreases.

The perception depends on various aspects, nevertheless, subtle *Geräusche* of movement, always indicate that one is not alone and connects them to their surroundings (LaBelle, Brandon. 2009. p.16).

However, when the *Geräusche* fill a space more densely, like a busy café with overlapping voices and loud coffee machines in the background, the soundscape may induce stress while a sparse, quiet environment might evoke calmness. The shift from a dense place to a quiet one often also evokes relief from overstimulation, while unexpected silence in a normally active place can feel eerie. Therefore, how *Geräusche* affect perceived privacy, and exposure, plays a role in the emotional state as well. It has been established that high volume levels can make people feel exposed or overwhelmed, while a lack of ambient noise can make conversations feel too intrusive. The right balance of soundscaping therefore helps to create a sense of security and comfort, and the interaction between materials, shape, and texture of the architecture, with *Geräusche,* may impact the emotional state. A highly reverberant space, for instance, can feel grand yet impersonal, while an acoustically dampened one can feel intimate and comforting (Algaroosh, A. 2021. p.45).

As indicated before, in some cases *Geräusche* lead to feelings, that are correlated with stress, and longer exposure to emotional distress increases mental exhaustion, and affect cognitive abilities (Hahad, O.; Kuntic, M.; Al-Kindi, S. et al. 2024. p.2). Therefore, it might be necessary to examine the cognitive impacts caused by *Geräusche*.

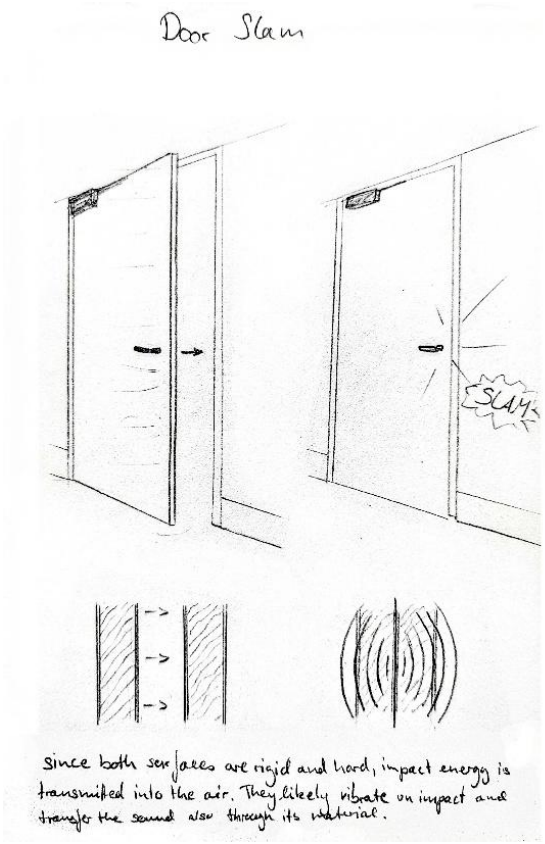


Figure 11: Sketch of how the door slam sound arises and reaches a high volume.

A sudden *Geräusch*, found in the De Stuers House, is the slamming sound of the main door in the MIA 2 workspaces, that connects the De Stuers House to the other facilities of the Academy.

It is a frequently opened door, with a hydraulic doorstopper that slowly closes the door but releases the door right before it falls into its frame and therefore creates a sudden loud 'bang' sound. The sound is sudden and unexpected, because of a delay after slowly and quietly closing. This stresses the students who are working nearby and startles them, causing a short fight-and-flight response.

Cognitive impact

Cognitive skills are vital to day-to-day functioning because they influence how we perceive, comprehend, and engage with the world through the senses. Hearing *Geräusche* is essential to this process because it can either improve comprehension and concentration or cause cognitive overload, which impairs memory, learning, and mental performance in general.

Cognitive load is when the brain has to put more effort into processing than usual, which can be achieved by distracting noise that overwhelms attention. For instance, if a listener tries to follow a conversation in a busy environment, such as a restaurant, but the sound of strangers' voices overlaps the voice of the conversation partner. Then more focus needs to be put on blocking unwelcome sounds and more focus on the sounds that are wished to be heard. Prolonged, the overstimulation of *Geräusche* can lead to mental exhaustion, which makes it difficult to process information. However, there is a difference to be found in the volume of the soundscape. If the background noises reach a volume of 85dB, it reduces the extent of information processing or may cause a great deal of distraction, but a moderate volume of 70dB is established, to have the potential to increase mental abilities. In an experiment by Ravi Mehta, Rui Zhu, and Amar Cheema, in 2012, it was found that a moderate volume in contrast to low volume increased processing difficulty, raised the construal level and encouraged abstract thinking, which in turn boosts creativity. Although it is mentioned that it only applies to people with higher creativity (pp.795-796). This phenomenon is also known as the 'coffee shop effect'. However, if a soundscape makes it difficult to hear the desired sound, such as speech in the example of a restaurant conversation, noisy environments impair intelligibility and therefore the retention of information. Additionally, it was found that background noise adversely affects the ability to recall information and comprehend reading material, thereby hindering learning and memory retention (Mama, Y.; Fostick; L.; Icht, M. 2018. p.236).

Along with cognitive fatigue and emotional responses to the *Geräusche* of the soundscape, the behavior of an individual and their interaction with the space changes. Therefore, this also is a matter which needs to be evaluated.

Behavioral impact

As a constant presence in the human environment, *Geräusche* subtly shape how an individual acts, moves, and interacts with others, without consciously being aware of it.

In situations like those mentioned above, where loud environments lead to cognitive overload, humans are more likely to make impulsive decisions. Overstimulation and stress give the perception that there is no time to weigh decisions, when there really is no mental capacity, whereas in quieter spaces, people tend to think more carefully and analytically before they decide. People also tend to move faster, and more hectic. In loud and chaotic situations, such as subways, the energy of the soundscape influences the individual's energy and patience. Seeming, as if they desire to leave sooner. Calm and quiet spaces, like libraries, on the other hand, encourage slower movements and lingering. The slower energy of the soundscape, then makes it easier to dwell and slow down. From that insight, it can be noticed that soundscapes influence people's preference for places they visit. If people desire to experience high-energy, loud, stimulating environments, bars and clubs are preferred in contrast to cafés or lounges, which encourage relaxation and lingering in a more comforting atmosphere.

It can also be observed that people's speech patterns adjust to the volume of the soundscape. The so-called 'Lombard effect' is when people tend to raise the amplitude and frequency of their voices increasingly louder to overpower the background noises (Zollinger, Sue A.; Brumm, Henrik. 2011. p.2). For example, in busy cafés with poor acoustics, the more people enter, the more voices overlap and to overpower those of others, people raise their voices, which only increases the overall volume. This often leads to loud and intense conversations, that can be exhausting after a while. Whereas in quiet environments, like libraries people naturally lower their voices and move more carefully, since every *Geräusch* that is created is heard more significantly.

Noisy settings, where intelligibility is difficult, often also lead to miscommunication or having to repeat sentences, which might evoke frustration, impatience, or even avoidance of conversations. Places like clubs for example, which are usually not meant to be for conversations, people are more likely not to speak for long or express in different ways. Nevertheless, due to evoked emotions, people's behavior and decision-making tend to be more emotion-related as well. Impatience could turn to anger and aggression or in more balanced surroundings tolerance might encourage relaxation and social connection. Another significant aspect, where *Geräusche* influence human behavior, which is already mentioned in other contexts above, is the navigational skills that one obtains. Due to heard *Geräusche* we move through space in certain ways and react to them, which is why it counts as a behavioral impact as well.

Lastly, I would like to discuss an experiment that studies the impact of the sound environment on study areas and compares students' satisfaction with the sound environment, perceived loudness, and overall satisfaction, performed by Volkan Acun and Semiha Yilmazer, in 2018. In this experiment, four open study areas for students, that have social functions included, promoting an environment that is open to conversation and cooperative work, were evaluated. Whereas usually students tend to search for quiet and closed-off environments, like libraries, these study areas allow social interaction and creative flow in their informal nature. However, since they often have access to busy facilities, like cafés or hallways, they are prone to issues with the sound environment. Nevertheless, other than studying in a silent zone, where *Geräusche* often lead to frustration and annoyance, it was observed that students can adapt to the sound level even if it is high. Open study areas are even preferred due to their ability to combine learning and social identity, in an informal but also an academic environment. Interesting for this thesis is the insights on coping mechanisms with potentially disturbing noises by the students, that were observed in the experiment. When asked how they deal with an unsatisfactory auditory environment, the students came up with four coping mechanisms. These included leaving the study area, going to a quieter location, putting on headphones (to listen to music, etc.),

and interfering with the sound source. However, not all of them are practical or actual coping methods, since leaving the sound environment means abandoning the study area and relocating to a quieter area is often not an option. For the option of interfering with a sound source, there are two methods. The first is to verbally intervene a human-generated sound, such as laughter, speech, or other *Geräusche* that often occur in a study group. This way students may decide to communicate their dissatisfaction to others if they are irritated or distracted by them. The second method is physically stopping a non-human sound source, although this isn't always achievable, due to social or practical factors. Questionnaires of the experiment showed that interfering with the disturbance was the least favored option anyway. Only two coping mechanisms remain then: earphone use, and acceptance and habituation. The use of earphones may have shown itself to be the most favorable coping mechanism but seems to evoke issues as well. By isolating themselves from the sound environment, the concentration of an individual seems to be higher, and less disturbance may occur due to the inability to hear them, which is why it is favored during individual study. However, by doing so social interaction is less likely to happen and a disconnection from the immediate surrounding develops. This phenomenon is also known as 'The Walkman effect' which will be discussed more in detail later. Another interesting finding in the experiment was that intelligible and incomprehensible speaking, laughter, and walking were the human actions that produced the most upsetting and common noises. The participants' self-rated level of focus was also moderately impacted by these activities. Yet, laughter seemed to be seen less as disturbing, due to its positive and compassionate nature, which determines the context of the sound highly influences the perception (Acun, V.; Yilmazer, S. 2018. pp.66-75). After all, coping mechanisms with dissatisfying soundscapes, are ways of behaving in response to the *Geräusche* of the surrounding and are interesting to observe since everybody reacts differently to it.

In conclusion, *Geräusche* actively shape human behavior, from communication and movement to stress levels, decision-making, and even social interactions. When uncontrolled, a soundscape can lead to avoidance, aggression, or cognitive overload, while well-designed sound environments encourage focus, relaxation, and social connection.

The study areas of the experiment seem to be similar to the MIA 2 workspaces, since they are open to the main hallway and therefore also have a busy soundscape, even though they are private workspaces for the MIA 2 only. Nevertheless, due to the exposure of people from various studies constantly walking by it is open to different sound levels, where some people work in focused silence, some chatter loudly, some walk by with loud steps, and some try to have an undisturbed conversation.

Due to this situation, I observed some coping mechanisms here as well. It seems that the sound of the frequently slamming door is trying to be prevented by keeping the door open with a chair or other objects, that hold it in its place. This way the door cannot produce any noise, but allows other sounds from neighboring rooms in. Other coping mechanisms were observed and confirmed in a survey that I created. There people say that they sometimes cope with the noise by abandoning it and change location either to other rooms or even to work from home. Which as stated in the thesis, is not an actual coping mechanism. Other than that, 69% percent of the survey participants stated that they often choose to wear headphones to cope with the noises, which evokes its own problems of isolation and sometimes is not functional or even effective when the volume reaches through its barrier.

Figure 12: Two photos of the loud door being kept open by a wooden plank (top) and a chair (bottom)

The Imaginary Space

The American architect Louis I. Kahn once said, "*To hear a sound is to see a space*", which describes beautifully how hearing is inherently connected to imagination. When we hear a sound, we instinctively look for its source. We think "a sound of what? Where does it come from and what produced it?" If we cannot readily see or allocate the source of the sound, our mind tries to imagine it, seeking verification of what we are hearing (McCombe, Christine. 2001. p.2). It uses the whole spectrum of sound as its material and constructs an image in our heads. Like that, an imaginary space is evoked (Kursell, J.; Schäfer, A. 2009. p.102). Juhani Pallasmaa gives an illustrative example in his book *The Eyes of the Skin,* as follows:

"Anyone who has become entranced by the sound of dripping water in the darkness of a ruin can attest to the extraordinary capacity of the ear to carve a volume into the void of darkness. The space traced by the ear in the darkness becomes a cavity sculpted directly in the interior of the mind." (Pallasmaa, Juhani. 1996. p.41)

Unless we are listening through headphones, all sound is heard and experienced in a space. It is a physical experience since sound needs a medium that is oscillated by an oscillating body that transmits the sound to the ear (Kursell, J.; Schäfer, A. 2009. p.96), and the physical context in which a sound is heard and travels, is a crucial influence on that sound. Yet, our perception of sound is not always a direct experience of its source. Our ears can recognize pitch and make judgments based on the rules of sound, but they might make mistakes. We often do not actually hear the sound source directly, instead, we learn to guess what it is, based on the sound we hear. Even when the position of the sound source seems to be separate from the sound itself.

Recording technology has allowed us to isolate the sound from its source and spatial context, enabling it to exist independently. For instance, if we are listening to the sound of the market in Maastricht at 12 am on a Friday, *where* we are hearing and *what* we are hearing in some ways amounts to the same thing. We are listening to the place. If we listen to a recording of the market in Maastricht played through headphones in our living room, we imagine that place. The relationship between sound and source has completely been reinvented because of recording technology. Technology enables us to move and recontextualize sound and thus manipulate its profound associative potential, as demonstrated by the fact that we can hear the market of Maastricht in our living room (McCombe, Christine. 2001. p.2).

Even the relationship between time and place changes this way. Recordings allow us to mobilize sound and save it. As Sean Cubitt highlights, *"... every recording is a piece of the past restorable to the present, but the act of recording is also an attempt to secure that piece for the future when the recording will be played."* (McCombe, Christine. 2001. p.6). Therefore, hearing a recording of, for example, splashing water and the laughter of children in a past situation, will immediately take the listener back to the place where and when it was recorded, if he knows it. The sound artists Janet Cardiff and George Bures Miller provide an interesting experience with their sound walks, where one listens to a recording through headphones and watches a video that shows the exact surrounding the person is in. Both guide the individual on a specific path, while on the video people appear, such as dancers, and the sound tricks the mind into thinking they are actually beside that person. Proving a recording of the past to be brought to the present, disconnected from its source, which is then imagined to be there, even if it is not.

Figure 13: Janet Cardiff and George Bures Miller - Night Walk for Edinburgh 2019

"*Every sound heard is a construction, and the result of a complicated psycho-physical calculation.*", as how Julia Kursell and Armin Schäfer state in their article *Spaces Beyond Tonality I* (p.100). Because hearing is not just about receiving sound, it is a process of interpreting information, like a radio does not solely transmit and play recordings, it influences how we experience space through hearing. This is done by creating an image of the source, including its nature, situation, and context, due to the given information. Nevertheless, when hearing a recording in a different context, it always sounds like a loudspeaker transmitting the sound of an absent space.

Another interesting phenomenon caused by technological development, already in 1984, is the 'Walkman-Effect', which is a term named by Shuhei Hosokawa, that refers to the way listening devices, like the newly invented Sony Walkman back then, caused people to isolate from their immediate surroundings and changed their perception of space. Nowadays, with smartphones, wireless earbuds, and noise-cancelling, that effect still exists, if it is not even worse. Portable music allows the listener to create a private, mobile auditory world, while still being physically present in reality. On one hand, this development basically provides the listener with his own personal soundtrack to their life, which makes the experience more pleasurable. But while muting the noises of their surroundings, it creates a bubble around the listeners, disconnecting them from the surroundings, recontextualizing the space they are in and changing social interaction, or rather, taking it away (Hosokawa, Shuhei. 1984. pp.165-171).

Figure 14: Illustration of Walkman-effect. Foto by plastique fantastique

Often, we are not aware of the significance of hearing in spatial experience and how it helps us understand the space and feel connected with it. Unless we take the sound away like in silent films. When the soundtrack of modern movies is removed from a film, you can nearly imagine how it is to be deaf. The scene loses its plasticity and sense of continuity and life. Silent films definitely had to compensate for the lack of sound with a demonstrative manner of overacting (Pallasmaa, Juhani. 1996. p.41). Hearing creates a sense of connection and solidarity, which for instance is often felt in a crowd that bursts into applause. Before the applause, we are an individual on our own, but joining the applause unites us with the crowd. Many sounds, or I would say *Geräusche*, connect us with the space of our surroundings, putting us in direct interaction by announcing its presence to us and reminding us of its nature.

From my perspective, as someone who experiences both hearing and not hearing on a daily basis, I can attest to that statement. Once I turn off my hearing devices, I notice that I am more isolated and detached from the happenings of my surroundings. My consciousness and attention are focused solely on the other senses, often solely on my vision or sometimes feeling. On the other hand, when I turn my hearing devices on and start using my auditory perception, I instantly notice more happenings around me, as sound sources from farther and outside of my narrowed vision reach me. By getting more information through the actions of my surroundings I do feel more connected to it.

To conclude, one could say that due to recording technology, sounds can manipulate our auditory perception and allow us to create an imaginary space. This space is created as well, when sound sources are heard, but not seen and therefore imagined. Additionally, in navigation, hearing is not only about localization but also a process of imagination. It is a crucial factor that helps connect to the spaces we are moving in and has the potential of disconnecting as well. So, sound is not just an experience, it is an act of imagination that continuously constructs and reconstructs the spaces we inhabit.

By examining the phenomenology of hearing *Geräusche* from a physiological and psychological perspective, as well as regarding the evoked imaginary space, the perspective of the perceiver is now established and the question of *"What effects do Geräusche have on the human being?"* has been answered regarding the physiological and psychological experience of the individual. As a next step, it is necessary to shift the focus to the perception of the creator of space and *Geräusche*, to examine the influence of Architecture on the auditory experience of space and the creator's responsibility in shaping that experience.

Architecture and Geräusche

“Sound is the invisible architecture that we move through every day.”

– Christopher Janney

Architecture Speaks

I would like to invite you, the reader, to close your eyes for a moment and to just listen.

Listen to the soundscape around you. Take in all the sounds. The close and dominant ones. The subtle ones from far away that you can barely hear. Where do they come from? Who or what creates them? What do you hear? What does it do to you? And why do you hear them? Most probably you are in an environment surrounded by architecture while reading this. Have you ever wondered how architecture influences what you hear? How it speaks?

This sort of hearing is called ‘attentive listening’. As opposed to ‘passive hearing, you are intensively focusing on the sounds of life in the immediate environment. It creates an intimate connection to the dynamic activities of life, human and natural, and therefore listening is an important human activity. An entire soundscape, complete with memories and emotions, is brought to life through sound alone. Soundscapes are constantly alive. As long as there are animated activities that produce sonic events, they always surround us. Other than visually. For instance, when a light source is turned off, the room suddenly goes dark, but if you turn off a source of sound, the room will still talk (Blesser, B.; Salter, L.R. 2007. p.17).

It proves that we are able to "hear" space. For a hypothetical "space-tasting" exercise, consider the following familiar spaces: a bathroom, a vintage telephone booth, a sports arena, a sophisticated living room, a school auditorium, a Gothic cathedral, an empty house, an airport lounge, a narrow hallway, an atrium, and a fast-food restaurant. The fact that most of us can easily imagine these spaces' aural experiences, indicates that we are aware of their unique aural personalities (Blesser, B.; Salter, L.R. 2007. p.20). This way we can hear the auditory character of a place. Though not all objects of a place sound on their own, we can hear even those through their materials, shape, and setting.

Let's take a look at a flat wall at a distance, to see how we can hear something that doesn't make any sound. The reflection of a handclap sound wave bouncing off that wall is audible to us as a distinct echo. The delay in the echo's arrival is determined by the distance to the wall, its area determines its intensity, and the frequency content is determined by the material of the wall's surface. The echo is how we hear the wall and its characteristics, including its size, location, and surface composition. When our ability to decode spatial attributes is sufficiently developed using a wide range of acoustic cues, we can easily visualize objects and spatial geometry: we can "see" with our ears, as we are associating the information gathered from the handclap with objects that we know, and form a picture in our imaginary space. This means that even though the wall is not the original source of sound energy, it has an audible manifestation (Blesser, B.; Salter, L.R. 2007. p.2). Thus, we indeed hear an architectural element ‘speaking’.

“Each material has its own sound, and architecture is a symphony of those materials.” – Jean Nouvel

The Role of Architecture in shaping the Acoustic Environment

After discussing the relationship between *Geräusche* and the listener, and exploring the phenomenological dimensions and its impact on the individual, it is now necessary to take a look at the relationship between architecture and *Geräusche,* as well as how it influences the experience of the individual within. In that manner it is intended to answer the question, *do architects have the responsibility to integrate sound management into architectural design?*

Every space we inhabit resonates with sound. Whether it is intended, like the reverberation of a cathedral, or accidental, such as the sound of footsteps in a residential building. The physical attributes of the built environment take a crucial role in shaping the resulting soundscape. Yet, despite its severe influence on experience and well-being, the soundscape remains an afterthought in architectural practice, overshadowed by the dominance of the visual.

One point that clearly establishes the connection between *Geräusche* and space, is that there is no sound that is spaceless. All sound moves through a space (Blesser, B.; Salter, L.R. 2009. p.50). Therefore, architecture can be seen as a framework in which every constructed space proposes an auditory concept. Within the space then also moves its user, as Bernard Tschumi states: *"Architecture, then, is only an organism engaged in constant intercourse with users, whose bodies rush against the carefully established rules of architectural thought."* (Tschumi, Bernard. 1996. p.123) His emphasis on the interaction of the individual with the space could be interpreted as a play of the architectural environment like an instrument, with the user as its player and the architect as its composer. In the interactivity with the physical environment, the user automatically creates *Geräusche,* as they are often a consequence of actions. Whether they are as small as putting a book on a shelf or as big as the closing of a door. The surroundings react as though they were a conversation partner. When you snap your fingers, the space reacts. When you sing a song, certain pitches are emphasized by the space. Keep quiet, and the room stays quiet. There rarely is a specific location for the aural response, which immerses the listener in the space.

Aural architecture responds to human presence, making it enveloping, dynamic, and reactive (Blesser, B.; Salter, L.R. 2007. p.16). Therefore, every built space also resonates with the human activity that occurs within it. This leads to the second point. Architectural environments are meant for living beings to make use of them. All human beings, that can hear, are inherently influenced by their senses and hearing *Geräusche* is one of them. Space is a sensory experience from the perspective of the user. We experience sensory architecture when we combine information from our eyes, ears, nose, and skin to create an overall awareness of a location. We can identify the location and determine what is happening by using our senses. In addition, we develop an assessment of our experience in that space and, consequently, of the space itself (Blesser, B.; Salter, L.R. 2009. p.50). Hearing, as well as the other senses, is therefore a significant perception, that shapes the experience of the listener within a space. So, sensory architecture could be defined as a medium to create experiences. The study of aural architecture examines how our sense of hearing interacts with the built and natural environments. It focuses on the experience of sounds in spaces that have been altered by their physical characteristics, which, in combination with the other senses, determines the experience of the architectural space (Blesser, B.; Salter, L.R. 2009. p.50).

However, when it comes to aural architecture it is often associated with buildings, like musical institutions or cathedrals, that have an intentioned focus on sound design due to its specific sonic or spiritual use. Whereas sound occurs everywhere and all the time. Rather than limiting architecture's resounding to specialized cases, it should also be recognized in everyday experiences, no matter how small and insignificant they seem, since even in ordinary civic environments, existing architectural forms seem to influence auditory perception (Avidar, P.; Ganchrow, R.; Kursell, J. 2009. p.6). Nevertheless, one consequence of the remedial foundation of architectural acoustics is, that sound continues to be regarded predominantly as a technical issue, rather than an experiential aesthetic consideration. It is regarded as an inevitable consequence of the construction process that must be reduced, or at the very least, contained (Avidar, P.; Ganchrow, R.; Kursell, J. 2009. p.8). Therefore, it is necessary to state the distinction between physical acoustics and aural architecture. Although they are interconnected, they possess distinctly different focal points. The first employs scientific terminology to explain how spatial acoustics alter sound wave characteristics, whereas the latter examines the experiences and behaviors of occupants within a space. One focuses on discrete measurement and modeling, whereas the other investigates a complicated interaction process (Blesser, B.; Salter, L.R. 2009. p.54).

Aural vs Visual - The Dominance of the Eye

Another visible problem that led to the lack of aural design in a lot of architectural contexts is the dominance of the visual sense in architectural practices. It has characterized Western culture since the Renaissance, which then influenced the evolution of its architecture. This dominance in theory and historiography favors the visual representation of buildings over the multi-sensory experience that is occurring (Sheridan, T.; Van Lengen, K. 2003. p.37). This can be shown from the example of an office transformation known as the 133 Wai Yip Street in Hong Kong, designed by the Dutch firm MVRDV. In the project, the architects stripped down an old industrial building to its foundation and built up the interior areas using only glass and stainless-steel infill. The floor, walls, tables, shelves, speakers, computers, everything is made of glass. This decision had three reasons. One was to represent the office as one with ultimate transparency within the workspace. Another was to give a reminder of the industrial history of the neighborhood since the original structure is visible through the glass. Obviously, this decision is designed in a purely visual manner as it is mainly aesthetically pleasing. The last reason was to aim for an office that "*offered maximum attractiveness and perceived spaciousness in order to provide a as pleasant working environment as possible.*" (MVRDV. 2016) Whether that pleasant working environment was achieved or not, is not clarified, but in regard to the reflective acoustic property of glass, the created soundscape should not fit the standards of a workspace. A usual workspace needs controlled acoustics for speech intelligibility, concentration, and overall comfort, whereas in a space dominated by hard smooth surfaces, soundwaves continuously bounce, amplifying background noise and making communication hard. Conversations become muddled, and typing sounds and footsteps are exaggerated. This way the space becomes aurally chaotic, or rather, aurally exhausting. The architects focused on spatial symbolism and visual coherence, yet ignored how sound behaves in such an environment. This shows the risks of a visually driven approach that disregards auditory perception. The 133 Wai Yip Street project serves as a cautionary example of why sound design should be an integral part of architectural practice, not an afterthought. Spaces should be designed not just to be seen but to be heard and experienced holistically.

Figure 15: Glass office 133 Wai Yip Street

There is more to architecture than meets the eye. This should be recognized now more than ever, as Thompson emphasizes in her book *'The Soundscape of Modernity'* (p.10), that with modernization and the development of technology, more and more sounds arise, and a new kind of listening culture evolved. Yet, it lacks well-established tools for creating and assessing buildings as sounding forms, in comparison to those for visual design. If taken a look at the characteristics of both vision and hearing, they seem to contradict each other. Seeing is practiced from a distance and hearing occurs at the ear, therefore vision separates, and sound incorporates, as paraphrased from Pallasmaa. He continues, *"vision is directional, whereas sound is omni-directional. The sense of sight implies exteriority, but sound creates an experience of interiority. I regard an object, but sound approaches me; the eye reaches, but the ear receives."* (Pallasmaa, Juhani. 1996. p.34). When it comes to expressing the nature of space, we must keep in mind that each type of sensory architecture is neither "better" nor "worse" than the others. The senses offer complementary aspects of space, and neglecting one sense in favor

of another impairs our capacity to recognize and create spaces that are both useful and enjoyable. The navigational ability through aural perception, for instance, serves as an important supplement to vision. The temporal continuum that visual impressions are embedded in is frequently provided by sound. Meaning, sound serves as a framework that connects and orders our visual impressions over time (Pallasmaa, Juhani. 1996. p.41). For instance, as a person walks down a long corridor, they see walls, doorways, and windows passing by in sequence, creating a series of shifting visual impressions. These moments might feel disconnected without a sense of temporal flow. *Geräusche*, such as the echo of footsteps, the murmur of distant voices, or the changing acoustics from one space to another, provides this continuity. It links visual impressions into a cohesive spatial experience, reinforcing movement and transition. In this way, sound structures the perception of space, turning fragmented visuals into a continuous architectural journey. Therefore, there is no reason why the visual and auditory elements of architectural design cannot coexist. In fact, they do anyway, since there is no definitive silence, if there is functional hearing. Only when sound is no longer measured against the eye will it start to play a meaningful role in architecture, or in general in cultural consciousness. There is no such thing as a simply mono-sensory space from the perspective of an experienced subject. Each perception of "place" already incorporates an account derived from the senses as a whole, providing short-lived, yet significant "spatial ambiances" shape and personality. It's not just a technical difficulty to invest in an architecture that addresses acoustic concerns (Avidar, P.; Ganchrow, R.; Kursell, J. 2009. p.10). Any built structure or place has a distinct sound that conveys intimacy or enormousness, acceptance or rejection, welcoming and unwelcoming. Although the auditory percept is typically an unconscious background sensation, a space's echo can be comprehended and appreciated just as much as its visual shape (Pallasmaa, Juhani. 1996. p.34).

If recognized, that the built environment exists aurally as well as visually, the aural perception of space, could contribute to the experiential identity of an environment. As Pallasmaa expresses, *"Sound gives to architecture a sense of lived time, a register and medium for the movements of temporal exchanges, sharing and experience."* (Pallasmaa, Juhani. 1996. p.41). On the other hand, aural architecture can change the personality of a sonic event, such as whether a violin solo is heard in a concert hall or a football stadium, impacts the emotional effect (Blesser, B.; Salter, L.R. 2009. p.54). However, due to architectural globalization, a tendency to produce uniform sterile spaces with a lack of meaning and experience evolved. The desire for clear, controlled, signal-like sound became pervasive (Thompson, Emily. 2002. p.3), and often the science of acoustics overlaps with architecture of 'silencing', which means, that as a consequence of perceiving *Geräusche* negatively, acoustic tools are used to eliminate them completely. Instead of designing *with* them, which would result in a more meaningful atmosphere. By incorporating so-called 'earcons' (derived from 'icons'), that create unique and memorable aural experiences, a differentiation could be achieved. Earcons can be described as unusual sonic events or particular spatial acoustics, that are related to a specific context. With repeated exposure, any type of memorable acoustics combined with specific events might come to represent the significance of a given location. For example, the embracing reverberation of a grand cathedral. It starts to become associated with the sounds of the religious rituals performed in that space (Blesser, B.; Salter, L.R. 2009. pp.58-59). Consequently, these auditory interpretations provide architectural experience on deeper levels of meaning.

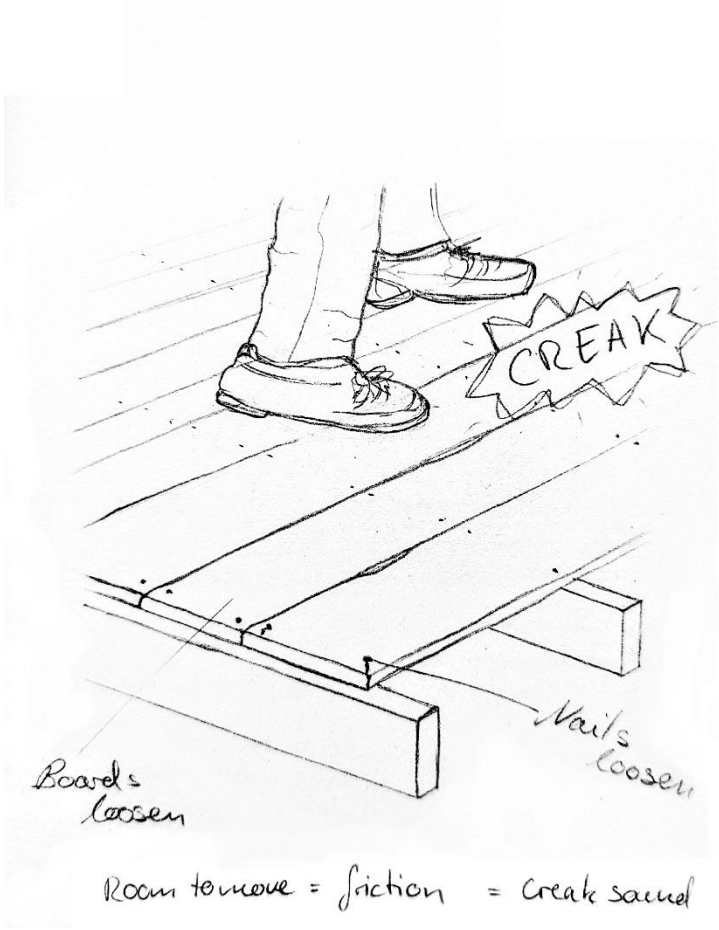


Figure 16: Sketch of how the creaking sounds arises

An earcon that I have found and personally relate to the De Stuers house, is the creaking sound of the old wooden floorboards in the entire building. I find it very dominant and memorable, as it reminds me of the history and age of the house.

Reverberation is a sonic phenomenon that works as an element to contribute to meaningful soundscapes created through the properties of built space. Its persistence in space after the original sound has ceased gives each little *Geräusch* an emphasis. There is beauty in highlighting every little interaction between elements or people with space. Although, if multiple sources sound, they overlap and create a complex pattern of echoes, fading over time but leading to a diffused unclear soundscape. That is why it became just another type of noise, which was impractical and better eliminated. Modern soundscapes aimed for clear, direct, and non-reverberant architecture, even if it meant muting its unique voice. Considering that the lingering over time of residual sound is created through the size of a room and its materials, means that reverberation reflects the character of the architecture (Thompson, Emily. 2002. p.3). The architect is its creator, which makes it their responsibility to create a balance and match the soundscape to the function.

But in order to design with *Geräusche*, its interaction with the built space needs to be understood first, so how does reverberation occur? And what role does the decision of material and spatial layout play?

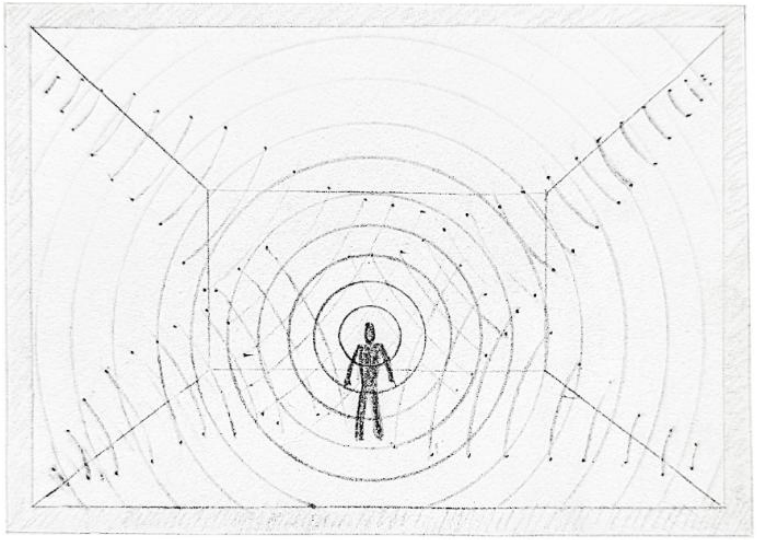


Figure 17: Reverberation Illustrated

In everyday listening, *Geräusche* reach the human perception directly from a source as well as indirectly through reflections, known as reverberation. As a *Geräusch* is produced it expands in the air in a spherical shape and meets the human ear, as well as all objects and surfaces of the surrounding. As it collides with a surface a part of the wave energy gets absorbed by the barrier and the remaining portion gets reflected and begins to travel in the opposite direction. Depending on the properties of these objects, the sound wave reflects stronger or weaker. Due to the reflection a *Geräusch* lingers longer in space and fades slower, while the direct sound source has stopped. That effect lets *Geräusche* travel farther and enables multiple sound waves to become dense so that they overlap in time and distort the sound from a source (Traer, J.; McDermott, J.H. 2016. p.1-2). The term reverberation time describes the duration required for a sound to fade and was coined by acoustic engineering pioneer Wallace Clement Sabine, who published a formula to predict the reverberation of a room even before its construction (Thompson, Emily. 2002. p.41).

Sabine's reverberation formula:

$$RT60 = 0{,}161 * (V/A)$$

RT60 - Reverberation Time V - Total volume of the room, in m^3

A - Effective absorbing area of the room, in m^2

This equation establishes the relation between the reverberation time and the absorptive properties of the room in regard to the volume. Therefore, it could provide an effective tool for architects to calculate the resulting reverberation time of a room, whether it exists or is yet to be built, and then tune it until a pleasant time is reached. Ideal reverberation times depend on the function and size of the room. However according to the DIN 18041 of the German Baunormenlexikon, speech-oriented spaces, like classrooms, lecture halls or offices, where clarity is crucial for speech intelligibility, a reverberation time from 0.4 to 1.2 seconds would be ideal. For music-oriented spaces, like concert halls, the architect should aim for a longer reverberation time of 1.2 to 2.2 seconds. Cathedrals can go up to 6.0 seconds. However, in everyday environments, a reverberation time from 0.4 to 1.2 seconds seems to be the most comfortable.

There are surfaces and things that reflect sound in most settings, especially indoors, and these reflections can also raise the overall sound level that is heard. Reducing sound reflections is desirable for several other reasons too: reflections may distort music, render speech incomprehensible, and make it difficult to identify the source of sounds. However, a careful balance must be struck, otherwise a room may feel excessively dry, silent, or lifeless if there aren't enough reflections. To lower or alter the sound wave reflections then, is often reached through the choice of material, the spatial layout, or the shape of the architecture. When sound waves collide

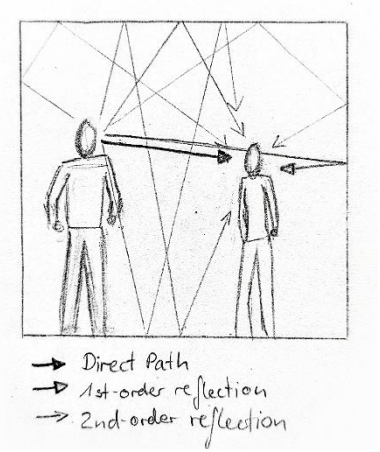


Figure 18: Reflections of reverberation illustrated

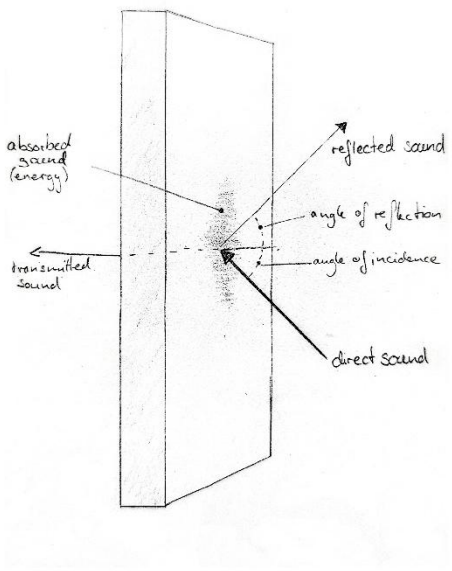


Figure 19: Illustration of sound interaction with objects

with the surrounding surfaces, they interact with and respond to the material and formal condition of that surface. Even if these interactions are slight, they are communicated to the listener as sound travels through the confines of our surroundings and reaches our ears. When a *Geräusch* meets a material, three basic interactions occur: some energy is absorbed by the material, some energy is reflected back, and some energy may pass through the substance to the opposite side. Each material transmits, reflects, and absorbs sound differently and is usually assigned a sound absorption coefficient, represented as alpha (α), which is the fraction or percentage of sound absorbed on a scale between 0.0 (reflective) and 1.0 (totally absorptive). Similar to how an environment's material combination creates its visual identity, it can also create its aural identity. They tell us not only about the source, but also the environment or context within which the source and receiver are placed. When it comes to aural aesthetics, materials that absorb sound can be utilized to determine how we perceive environments and to create or highlight spatial contrast, such as vibrant to deadened, public to private, or cool to warm. However, they are mostly used to influence the sonic environment, such as reducing noise, enhancing speech intelligibility, improving the listening quality of music, or controlling reverberation. Their effect is often unnoticed as people are used to these environments. People only become aware of their auditory experience when there are no materials to absorb sound, the environment becomes noisy, and then speech is incomprehensible. The extraordinarily dynamic nature of sound-absorbing materials allows them to function differently depending on how they are mounted or positioned. This adaptability creates numerous opportunities for the same material to be applied in various settings to address a range of issues. For the designer, sound-absorbing materials also offer a multitude of aesthetic options. They can be placed as a striking, eye-catching visual design element or they can be made to blend in perfectly with the environment. The act of perforation, for instance, may turn a wide variety of materials, including metals, stones, polymers, and woods, into sound absorbers, since the colliding sound waves are divided by the holes and then reflect less. Nowadays, with digital modeling capabilities, there are infinite design possibilities for absorbing materials. Additionally, they can be placed and tested in virtual environments that may be auralized, to be able to alter the soundscape even before constructing a space. Sound-absorbing materials can then be designed and engineered to suit the needs of various applications and environments. Together with material, the form of a surface also affects sound. A sound may reflect more diffusely at the surface scale due to the complexity of the texture, whereas a flat, homogenous surface will reflect particularly. The wavelength of the sound with respect to the surface pattering's dimensions also affects this interaction. By dispersing the sound in multiple directions, a diffuse reflection prevents recurrent reflections across parallel surfaces and produces a more uniform sound field. Smooth surfaces with inverted parabolic shapes can concentrate sound into beams, enhancing and extending its range. This is frequently heard in "whisper-galleries," where a whisper seems to cling to a wall's edge before resurfacing in another

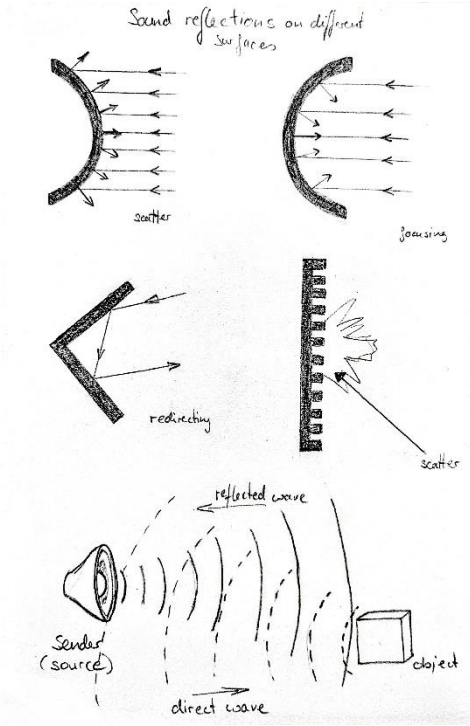


Figure 20: Sound reflection behavior with different surfaces

location. Sound reflections will be dispersed or diffused by smooth convex shapes. The decision of the size, or rather volume of a room, also has its impact on the acoustic environment. This is because sound waves and reflections travel farther in a large volume and take longer to decay, whereas one can hear the volume of a small space by its sharp frequency resonances. Spatial layouts and objects in spaces might influence the *Geräusche* as well, as they pose additional boundaries, obstacles, and surfaces, where sound waves collide. Depending on their materials, they allow additional absorption, reflection, transmission or even blocking. Another phenomenon that is interesting to achieve is 'resonance', which supports, amplifies, and filters sound when surfaces come together to create an enclosure. Resonance is the ability of a space's volume, shape, and material properties to highlight particular frequencies. An empty glass bottle's resonance frequency is excited, for example, when blown across its top. Therefore, it is obvious that there are various options to manage an acoustic environment, whether to quieten *Geräusche* or to enhance them, and to achieve functionality or a unique soundscape. (Adams, Tyler. 2016. pp.4-13)

Impact on Perception of Space

Knowledge of the interaction between materials, size, shape, and spatial layout helps to understand the soundscape of a place and how to design it. It is, additionally, significant to do so to comprehend, or even generate, its impact on space and the experience within. Earlier, this thesis discussed the influences of *Geräusche* on human beings and their physiological and psychological well-being, whereas it yet needs to be explained in what ways it influences the perception of architectural space.

As reverberation was discussed before, it is interesting to mention that it can have an impact on the enclosure or openness of an interior. A cathedral's long reverberation time for instance makes it feel vast and awe-inspiring, whereas a small non-reverberant room feels intimate and enclosed. It also affects the perception of privacy, as a high-reverberant room exposes each *Geräusch* that arises, whilst a sound-absorbing room feels more private, since it limits sound transmission, creating more isolated experiences. On the other hand, the presence of background noise can mask conversations, fostering anonymity in public spaces, while silent rooms can feel more exposed. This gives sound management the opportunity to create boundaries or to open them up to enhance social connections. It also shows that differences in volume can be used to shape the perception. A louder environment with fast rhythms, such as a subway, seems more energetic and chaotic, whereas silent interiors with steady sounds or slower rhythms provide a calm atmosphere. Materiality and texture may also influence the perception of space, as different surfaces reflect or absorb sound in varying ways. Hard surfaces like concrete or glass produce sharp, clear reflections, creating a bright, sometimes harsh, and cold auditory environment. In contrast, soft materials like fabric or wood absorb sound, making a space feel warmer and more muted. A peaceful, diffused soundscape can make a space feel light or delicate, while a low, resonant hum from traffic or industry can give it weight (Blesser, B.; Salter, L.R. 2007. p.2-3). And lastly, a felt presence can be achieved through 'auditory mass', which, as defined by Barry Blesser and Linda-Ruth Salter (2009. p.56), is the way sound itself becomes substantial in space.

Sonic Atmospheres

This ‘felt presence’ that the text mentioned above can also be defined as an atmosphere of a space. At this point, it is clear that *Geräusche* contribute to the sensory identity of a place and influence perception, emotion, and spatial awareness. As an example, the overlapping noises of an urban setting frequently help to create a vibrant atmosphere by demonstrating its various layers and the presence of human activity. The way sound interacts with surfaces, materials, and volumes creates unique acoustic qualities that define an environment. Or rather, an atmosphere.

Atmosphere, in this context, is defined as the overall sensory and emotional experience a space evokes. It is an immersive environment, which influences how people feel and interact within a space. Since this thesis focuses exclusively on the auditory perception it needs to be clarified, that a single, specific sensory impression can never capture the holistic character of an atmosphere. Rather, it emerges before such impressions are singled out. The felt-body collects sensory impressions in the reality of situations rather than by assembling disparate sensory impressions, and therefore atmospheres as holistic formations are diffused and all-encompassing. Atmospheres cannot be centered on listening only, however, *Geräusche* still fundamentally contribute to the shaping of atmospheres in a holistic interplay with the other senses. For instance, there is a close connection between the sonic and the motion suggestions that are so important to the phenomenology of atmospheres. The sonic as traveling vibratory and energetic phenomena not only transcends the audible but also offers a general frame for the stirrings and movement suggestions that evoke atmospheres (Eisenlohr, Patrick. 2023. p.40). Then, Ulrik Schmidt introduces the term ‘sonic environmentality’ to describe the ways sound can act and affect individuals as an environment. He also defines ‘environment’ in this context as *“a meaningful relationship between an individual and its immediate surroundings.”* (p.518) and states, that *“sound - like light and smell - may basically be of a surrounding character; it propagates, resonates, and reverberates throughout space.”* (p.519) Therefore *Geräusche* create a part of an atmosphere, as they are surrounding and enveloping the experiencing person. Schmidt argues that the sense of atmosphere as an environmental presence is produced by two correlated factors. One, that the medium communicates something about the specific qualities of a place and relates to the production of presence as site-specific. Which for the sonic dimension would mean, for instance, the site-specific materiality that is heard in a *Geräusch*, like the soft sound of wood. The second factor is, that it conveys the ‘state of a place or situation’ and makes an individual notice *“how a particular environment is and is coming along.”* (p.525) As it carries a certain mood, such as soft echoes that create a calming atmosphere. He derives this conclusion from Böhme, who notes that atmospheres evoke a vague sense of something or someone's environmental "being-here", as a feeling of indeterminate and spatially dispersed moods, and they seem to fill the space with a certain tone of feeling like a haze (Schmidt, Ulrik. 2019. p.525). Therefore, he highlights its characteristics of having a felt ‘sense of presence’ and carrying emotions, which the sonic environmentality provides as it announces movements or the presence of living beings and evokes emotions. Whether through reverberation, ambient noise, or silence, the acoustic character of a place plays a vital role in its atmosphere, making it feel serene, vibrant, intimate, or monumental, to name a few.

The term "atmospheric dimension" describes the immersive nature of architecture, and its capacity to evoke emotions and stimulate the senses, creating an idyllic setting for our everyday existence. *Geräusche* contribute to this by defining spatial depth, reinforcing moods, and shaping the way people perceive and navigate their surroundings. However, when they are not aligning with the other senses that produce a certain atmosphere, sound can disturb an existing atmosphere, as well as it can contribute to it. Whether on purpose or not, architects shape the air inside structures, establish boundaries, and start undetectable behaviors that give a place its distinct atmosphere and are felt by living things. Even before we consciously understand the building, our bodies are aware of and respond to the fleeting effects of light, sound, heat, and smell that are carried on or in the air (Karabašević, Anđela. 2016. p.180). Unquestionably, atmosphere is an important and unavoidable byproduct of the architectural design process, and as such, it needs to be taken into account and debated alongside other more well-acknowledged aspects of built architecture.

Role of the architect

After discussing the interaction between the built environment by the architect and the *Geräusche* within, the outcome of it, and its impact on the perception of space, the interdependence of both is apparent and the responsibility of the architect in shaping the acoustic environment is larger than realized.

The role of the architect is then to acknowledge the soundscape of a place and tune it, until it is desirable and or fitting to the purpose of the designed space. This is mostly done by considering the auditory impact of each design choice they make and by adding specific acoustic elements if needed. As discussed at the beginning of the thesis, the source, the path, and the receiver are the three components that make up the auditory environment. The source is the object making the sound (e.g. person, bird, speaker, machine), the path is the medium through which the sound travels (e.g. air, building structure), and the receiver might be a microphone or a listener who perceives. If a sound source is regarded as unwanted, the design goal is to make it harder for a *Geräusch* to reach the receiver. This can be achieved by putting a distance between the source and the receiver or adjusting the path or surroundings to block or dampen the sound. If a sound source, like music or speech, is desirable, the design goal is to preserve or improve it until it is clearly perceived and not distorted or deteriorated by the surroundings (Adams, Tyler. 2016. p.8). To become an 'aural architect', the architect also has the responsibility to recognize the unique features of a place and to enhance them, rather than diminishing them, so that the aural environment can be perceived as positive and beautiful, instead of as noise and disturbance, that is wished away. Bringing back the lovely and desired perception of sound. Therefore, a 'aural architect' is a person who chooses particular aural features of a space based on what is desirable, serving as both an artist and a social engineer. A skilled and knowledgeable aural architect can design a setting that evokes emotions in its occupants, such as heightened arousal, contemplative tranquility, excitement, or a harmonious and mystical link to the world. An auditory architect has the ability to design a setting that either promotes or inhibits social cohesiveness among its occupants, as well as create auditory comfort or discomfort to the individual experiencing the space. An "acoustic architect," on the other hand, is a physical scientist, engineer, or builder who uses the aural qualities that an aural architect has already chosen. Due to their divergent viewpoints, auditory architects concentrate on how listeners experience a space, while acoustic architects concentrate on how the space alters the physical characteristics of sound waves (Blesser, B.; Salter, L.R. 2007. p.5). Architects make their artistic messages visible, audible, and tactile through the selection and blending of materials, colors, and shapes. In order to convey the artistic, social, emotional, and historical context of space, however, architects typically focus on a structure's visual elements. They hardly ever think about the acoustic characteristics. It is rarely acknowledged that humans have a natural gift to sense a space through hearing (p.1). This might be due to the dominance of the visual and the subtleness of the aural or caused by the lack of education in designing with all senses. Aural aesthetics, sensory sociology, and physical acoustics are subjects that are rarely or never taught in professional schools. As Barry Blesser and Linda-Ruth Salter argue in their book (2007), *"Because aural architecture is not a recognized discipline, its concepts are not a significant part of our cultural and intellectual mainstream."* (pp.6-7) Even I can attest to this statement, since the topic of the senses has never been concisely addressed in my education as an interior architect. But perhaps, it should be recognized as a significant discipline. Professional architects are reflecting a tradition that devalues listening when they only concentrate on a space's aesthetic and functional qualities. Additionally, listeners also undervalue the aural experience when they tolerate a setting whose acoustics harm their social interactions, their ears, or both.

However, it is not that there is no one taking that responsibility. It is when there is freedom to choose and tackle the aural features of a spatial experience that audio engineers, composers, acoustic scientists, and spatial designers function as aural architects. Artists and architects, such as the Finnish architect Juhani Pallasmaa (1996), who viewed sensory architecture as a broad concept that specifically encompassed aural architecture, or R. Murray Schafer (1977), who created the concept of the soundscape, or more contemporary Peter Zumthor, an architect who calls himself a phenomenologist, who deeply values the senses in his works, are representative examples who especially focused on aural architecture. A positive example, where the impact of the acoustic

environment was recognized and dealt with, is the planning of the New York Life Insurance Company for their new building, back in 1928. The architect Cass Gilbert realized the increase of noise and its impact on the health and productivity of the workers, so he began to consider how to isolate and insulate his buildings and to design healthful working conditions for the company's 3,500 employees. The acoustic intervention was used in all spaces where excessive noise may occur or where it is beneficial that silence should prevail. With over 450,000 square feet of acoustic material, this was the biggest installation at the time. Sound-absorbing materials, high-speed passenger elevators, and the biggest pneumatic mail-delivery system in the world all worked together to make the new building an exemplary representation of the efficiency of modern business in addition to increasing worker productivity and reducing fatigue (Thompson, Emily. 2002. pp.200-207).

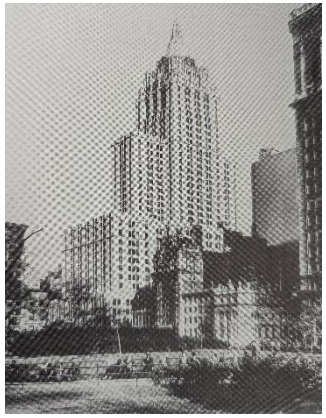


Figure 21: The New York Life Insurance Company Building

Figure 22: The acoustic treatment in a women working space: Absorbent felt on the ceiling and pneumatic tube also acoustically treated

Nevertheless, often the freedom to deal with the sonic environment is limited by the construction budget, time shortage, lack of tools or favoring of other senses so that the auditory perception is often swept under the carpet. Since architecture is experienced with more than one sense, not all can be shaped to their best at the same time and architects must make a decision on which to put more weight. Any object or geometric shape contains both visual and aural qualities and sets an example of how aural and visual architecture align but also contradict each other. For example, panels suspended from the ceiling may produce welcome amplification through early sonic reflections but may also produce an unwelcome visual sense of confinement. Where diffusion of *Geräusche* is wished for, the used acoustic object might be too visually unappealing to include in a design (p.65). Therefore, some challenges must be overcome by the architect who wants to take the acoustic environment into account while designing a space.

However, I agree with Ted Sheridan and Karen van Lengen who argued in their book 'Hearing Architecture' (2003), that aural consideration needs to be intentionally integrated into architectural education programs *"to achieve a richer, more satisfying built environment: one that responds to the ear as well as the eye."* (p.37) *Geräusche* should be treated as vital players in the history of buildings, in the present experience of space and listening must be part of design analysis and criticism. It might be difficult to convince every architect to become an aural architect, who actively focuses on shaping the soundscape, but it is crucial to be aware of the auditory influence of their design choices on the resulting soundscape and its impact on the space and the individuals within. That is the responsibility of every architect.

Figure 23: Peter Zumthor's Swiss Sound Box - Hanover Expo2000

“Sound is not just a phenomenon in space, but a creator of space”

– Bernhard Leitner

Conclusion

This research aimed to explore the complex relationship between *Geräusche* and the spatial experience of individuals within architectural environments, revealing how auditory elements can shape, enhance, diminish, and redefine human perception of space and atmosphere, as well as human behavior and well-being, both physical and psychological. These impacts were then proven to potentially be shaped by architectural design.

Motivated by my personal hearing experience and the frequent disregard of sound in architectural practices, this thesis was rooted in the belief that sounds, particularly everyday *Geräusche*, are too often dismissed as mere noise, and then accepted without considering its influence on the listener. Additionally, that architecture influences the sound waves that collide with it and could therefore potentially be used as a tool to shape a place's soundscape, for better or worse, depending on the attention given to sound design.

Geräusch is not the enemy. As proved in the research, people perceive *Geräusche* negatively, often due to the lack of sound awareness. Rather than resigning to it, or silencing it, this research appeals for an active engagement with sound, so that we may appreciate its full richness and reveal its potential to be beautiful as well. For that, we start by redefining the perception of *Geräusche* and dismantling its negative connotation.

Together with these beliefs, three central questions guided this research:

What effects do Geräusche have on the human being? They evoke emotions, strain or enhance cognitive processes, guide behavior, affect physical and mental health, lead to hearing damage, provide comfort, discomfort or orientation, confusion, establish or limit social connections, convey messages, trigger memories, create an imaginary space...

Do they influence the perception of space and atmosphere and the experience within? Yes. It makes spaces feel a spectrum from vast large to embracing small, exposing to intimate, dynamic to calm, cold to warm, distant to welcoming, light to heavy, and thereby constructs atmospheres... all of which contribute to its spatial experience.

Do architects have the responsibility to integrate sound management into architectural design? Yes. A soundscape of a place that is designed by an architect should always be considered in the choice of material, layout, and size, to use it as a tool and create a place that is best working towards their goal and to hinder negative impacts of disturbing *Geräusche*...

At the heart of this investigation lies a deeper recognition: *Geräusche* are not just an additive layer to a space, but a fundamental medium of spatial experience that is shaped by architecture and overall contributes to the lived experience of architectural spaces.

By reflecting on the findings, various core insights become visible, each contributing to a deeper awareness of either how *Geräusche* indeed influence the individual experience of space or how architects are responsible for shaping the soundscape within a space.

Firstly, sound is an unruly, pervasive, and invisible force that omni presently reaches human ears and constantly influences every hearing individual without being aware of it. The subjective nature of that aural experience depends on various factors: culturally, socially, and emotionally, shaped by the listener's context, purpose, and sensitivity. Nevertheless, it is proven that people with hearing impairments struggle more in acoustically challenging situations and architects need to be aware that, as we know out of research, at least every fifth person might benefit from acoustic supporting architecture, with clear inclusive soundscapes. Hence, consider sound management, particularly for those whose sensory processing demands greater care.

Then the physiological investigation revealed: Human bodies hear and hurt. The processing of sound is not abstract, it is embodied. It leads to abilities from spatial navigation, the tuning out of background noises, and the recognition of on and off *Geräusche* to protection from noise-induced harm to human hearing and health. The physiological responses to Geräusche emphasize the urgent demand for attention, as the harm is preventable with a cautious architectural design.

Moreover, *Geräusche* affect the human psyche. The research into psychological effects demonstrates that they influence psychological states in subtle but powerful ways, as they evoke emotions, shape moods, create stress or comfort, disrupt or enhance cognitive processes, like concentration and memory, and influence behavior, encouraging or discouraging interaction. Therefore, sound management could also prevent negative effects, like avoidance or anxiety, and promote a well-working environment supporting the goals of a space. As part of the psychological investigation, this thesis explored the concept of imaginary space and discovered that sound is not just an experience, but also an act of imagination. We can imagine space through sound. Sound extends beyond what is visible and tangible and creates imagined volumes, evokes memory, and bridges past and present through its brief presence conveyed in a mental image. This occurs in spatial navigation or if non-visible sources are to be imagined, but especially through recording technology as it manipulates auditory perception and separates auditory content from time and place.

All these findings lead back to architecture, as this research aimed to explore the responsibility of the architect in this matter. That said, there is no architecture without sound. Every built space emits and responds to sound. Especially in the response to human interactivity within, it hums with the life it houses. Decisions on materials, form, and layout all contribute to a space's soundscape, making it the architect's responsibility to choose these wisely and tune the sonic environment. Rather than suppress it, which leads to sterile, aurally unconsidered environments, where the experience of space is flattened. It is apparent that architecture is primarily designed for the eye. This leaves other senses, such as hearing, underappreciated or neglected and possibly leads to consequences, as shown in the example of the 133 Wai Yip Street project. Architecture is not only seen but sensed and experienced. The resonance of sound and little *Geräusche* announcing presence, give life and depth to spatial experience. Therefore, architects must recognize their role in shaping the sonic identity of a space and the influence it might have on its users. Whether through absorption, amplification, or redirection, materials, these tools should be used not only to serve function but to create atmospheres and soundscapes that are emotionally engaging and give a sense of meaning. Though long neglected, the research reveals the sonic dimension of architecture is not a new concern. From Schafer to contemporary theorists, this thesis builds upon statements of various artists questioning visual dominance in design over other senses such as hearing, and pleads for environments that engage all senses to create meaningful experiences. Then again, the acoustic environment continues to be overlooked.

Therefore, this thesis calls for a shift in architectural education and practice. It needs to be taught, and awareness needs to be spread. Architects should be equipped to design with the ear as well as the eye, not necessarily to become aural specialists, but to be at least critically aware of the auditory consequences of their design choices. However, more 'aural architects' are also needed. Designers not only of sound but atmosphere, emotion, social connection, and spatial experience. This study also provides a newly considered phenomenological perspective on sound in architecture, which highlights how sound is lived and experienced and demonstrates that sounds in space have a larger impact than anticipated, and calls for a rethinking of its significance in spatial design. Thereby, through this research a dialogue on the overlooked role of sound in architectural design has been opened, and looking forward, it invites architects and designers of space to listen more deeply and to design with the ear as much as with the eye. By reclaiming *Geräusche* as essential components of space, this research offers a richer architectural language, one that acknowledges sound not as a disturbance or as an afterthought, but as part of spatial experience. It contributes to a broader understanding of architecture as a multisensory discipline and offers a critical rethinking of how we engage with space through sound. This is crucial to overcome the current dominance of the eye and ignorance of sonic consequences in the field of architecture.

Architecture speaks.

It is time to listen.

Bibliography

A Acun, Volkan; Yilmazer, Semiha. 2018. *Understanding the indoor soundscape of study areas in terms of users' satisfaction, coping methods and perceptual dimensions.* Institute of Noise Control Engineering. INCE/USA.

Adams, Tyler. 2016. *Sound materials: a compendium of sound absorbing materials for architecture and design*. Frame Publishers.

Alberti, Peter W. 2001. *The anatomy and physiology of the ear and hearing*. Occupational exposure to noise: Evaluation, prevention, and control. pp.53-62.

Algaroosh, Alaa. 2021. *Aural Architecture as Affect: Understanding the Impact of Acoustic Environments on Human Experience.* The University of Michigan. https://dx.doi.org/10.7302/1414.

Arregi, A., Vegas, O., Lertxundi, A. et al. 2024. *Road traffic noise exposure and its impact on health: evidence from animal and human studies - chronic stress, inflammation, and oxidative stress as key components of the complex downstream pathway underlying noise-induced non-auditory health effects*. Environ Sci Pollut Res 31, 46820–46839. https://doi.org/10.1007/s11356-024-33973-9.

Avidar, Pnina; Ganchrow, Raviv; Kursell, Julia (eds). 2009. *Editorial. OASE #75 Immersed – Sound and Architecture*. OASE Journal for Architecture. NAi Publishers.

B Blesser, Barry; Salter, Linda-Ruth. 2007. *Spaces Speak, are you listening?: experiencing aural architecture*. Cambridge, Mass: MIT Press.

Blesser, Barry; Salter, Linda-Ruth. 2009. *Aural Architecture: The Invisible Experience of Space. OASE #75 Immersed – Sound and Architecture*. OASE Journal for Architecture. NAi Publishers.

C Cubitt, Sean. 1998. *Digital Aesthetics.* p.100. Sage Publications, London.

Curtis, Charles. 2009. *Incomprehensible Space. OASE #75 Immersed – Sound and Architecture*. OASE Journal for Architecture. NAi Publishers.

D Di Croce, Nicola. 2023. *Sonic Coexistence: Toward an Inclusive and Uncomfortable Atmosphere.* In HEAR. University of Westminster Press. https://www.jstor.org/stable/jj.608325.10.

DIN 18041 | Ausgabe 2016-03. *Hörsamkeit in Räumen – Anforderungen, Empfehlungen und Hinweise für die Planung.* Baunormenlexikon. https://www.baunormenlexikon.de/norm/din-18041/8047ccbe-c76f-4ce0-b94b-e92a51495ed5#f2294bc4-4711-abcd-ffac395124c1 (Accessed 04 March 2025).

E Eisenlohr, Patrick. 2023. *Atmospheres: The multisensoriality of spatially extended emotions*. Ethos. Wiley Periodicals LLC.

H Hahad, Omar; Kuntic, Marin; Al-Kindi, Sardeer et al. 2024. *Noise and mental health: evidence, mechanisms, and consequences*. J Expo Sci Environ Epidemiol. https://doi.org/10.1038/s41370-024-00642-5.

Halperin, Demian. 2014. *Environmental noise and sleep disturbances: A threat to health?* Sleep science, 7(4), pp.209–212. https://doi.org/10.1016/j.slsci.2014.11.003.

Hawkins, Joseph E. 21.11.2024. *human ear*. Encyclopedia Britannica. https://www.britannica.com/science/ear. Accessed 30 January 2025.

Hosokawa, Shuhei. 1984. *The Walkman Effect.* Popular Music, Vol. 4, Performers and Audiences, pp.165-180. Cambridge University Press.

K Karabašević, Anđela. 2016. *Atmospheric Dimensions of Architecture.* University of Belgrade - Faculty of Architecture.

Kursell, Julia; Schäfer, Armin. 2009. *Spaces Beyond Tonality II – John Cage, Imaginary Landscape I. OASE #75 Immersed – Sound and Architecture*. OASE Journal for Architecture. NAi Publishers.

L LaBelle, Brandon. 2009. *Other Acoustics. OASE #75 Immersed – Sound and Architecture*. OASE Journal for Architecture. NAi Publishers.

Levarie, Siegmund. 1977. *Noise*. Critical Inquiry, Autumn, 1977, Vol. 4, No. 1 (Autumn, 1977), pp.21-31. The University of Chicago Press.

M Mama, Yaniv; Fostick; Leah; Icht, Michal. 2018. *The impact of different background noises on the Production Effect.* Acta Psychologica, Volume 185, pp.235-242, ISSN 0001-6918, https://doi.org/10.1016/j.actpsy.2018.03.002.

Manohare, Manish; Rajasekar, E; Oberman, Tin; Aletta, Francesco; Kang, Jian; Parida, Manoranjan. 2022. *Analysing the Changes in Physiological Response to Different Soundscape Scenarios*. Inter.noise 2022.

McCombe, Christine. 2001. *Imagining Space through Sound.* UK and Ireland Soundscape Community.

Mehta, Ravi; Zhu, Rui; Cheema, Amar. 2012. *Is Noise Always Bad? Exploring the Effects of Ambient Noise on Creative Cognition.* Journal of Consumer Research, Vol. 39, No. 4 (December 2012), pp. 784-799. Oxford University Press.

MRDVD. 2016. https://www.mvrdv.com/projects/245/133-wai-yip-street. Accessed 23 February 2025.

N Natarajan, Nirvikalpa; Batts, Shelley; Stankovic, Konstantina M. 2023. *Noise-Induced Hearing Loss*. Journal of clinical medicine, 12(6), 2347. https://doi.org/10.3390/jcm12062347.

O Orlowski, Raf. 2021. *Acoustics in Architectural Design.* The Crowood Press Ltd.

P Pallasmaa, Juhani. 1996 (2012). *The Eyes of the Skin: Architecture and the Senses.* John Wiley & Sons.

Park SH; Lee PJ; Jeong JH. 2018. *Emotions evoked by exposure to footstep noise in residential buildings.* PLoS ONE 13(8): e0202058. https://doi.org/10.1371/journal.pone.0202058

S Schafer, R. Murray. 01.10.1993. *The Soundscape: Our Sonic Environment and the Tuning of the World*. Simon and Schuster.

Schmidt, Ulrik. 2019. *Sound as Environmental Presence. Toward an Aesthetics of Sonic Atmospheres.* in Mark Grimshaw-Aagaard, Mads Walther-Hansen, and Martin Knakkergaard (eds), The Oxford Handbook of Sound and Imagination, Volume 2, Oxford Handbooks. https://doi.org/10.1093/oxfordhb/9780190460242.013.18.

Sheridan, Ted; Van Lengen, Karen. 2003. *Hearing Architecture: Exploring and Designing the Aural Environment.* Journal of Architectural Education (1984), Nov., 2003, Vol. 57, No. 2 (Nov., 2003), pp. 37-44. Taylor & Francis.

T Thompson, Emily. 2002. *The Soundscape of Modernity: Architectural Acoustics and the Culture of Listening in America.* Massachusetts Institute of Technology. The MIT Press.

Thomsen, Christian W.; Krewani, Angela; Winkler, Hartrnut. 1990. *Der Walkmann-Effekt. Neue Konzepte fiir mobile Räume und Klangarchitekturen*. In: DAIDALOS Architektur Kunst Kultur, S. 52-6 1.

Traer, James; McDermott, Josh H. 2016. *Statistics of natural reverberation enable perceptual separation of sound and space.* Proceedings of the National Academy of Sciences of the United States of America vol. 113,48: E7856-E7865. doi:10.1073/pnas.1612524113.

Tschumi, Bernard. 1996. *Architecture and Disjunction.* Cambridge, Mass: The MIT Press.

V Västfjäll, Daniel. 2013. *Emotional Reactions to Tonal and Noise Components of Environmental Sounds.* Psychology, 4, 1051-1058. doi: 10.4236/psych.2013.412153.

Veljković, Milan; Živković, Snežana; Milenović, Miodrag. 2016. *Psychophysiological impact of noise as a stressor.* Vol 6, No1. pp.37-46. DOI: 10.7562/SE2016.6.01.06.

W World Health Organization. 2021. *World Report On Hearing*. https://www.who.int/publications/i/item/9789240020481.

Z Zollinger, Sue Anne; Brumm, Henrik. 2011. *The Lombard Effect*. Current Biology, Volume 21, Issue 16, R614 - R615. Elsevier Ltd. DOI: 10.1016/j.cub.2011.06.003.

List of figures

This thesis was written in deaf silence.