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Towards more inclusive approaches in soundscape research: The soundscape of blind people

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Inclusive design is increasingly receiving attention from researchers and educators in architecture and urban planning. Often, however, it is associated with improvement of living environments for people with reduced mobility. The rapidly growing number of older persons who suffer from reduced visual abilities, together with people who are visually impaired represent a considerable percentage of the population. This group raises new questions not only for the medical sector, but also for architectural design and acoustics, where the currently used normative values are optimized for people with "normal" visual abilities. This article discusses questions related to perception of sound and soundscape by people with a visual impairment by combining (1) findings about their superior ability in auditory perception from objective listening test experiments, magnetic resonance imaging and positron emission tomography with (2) insights gained through in-depth interviews with and testimonies written by them. In this way we hope to make acousticians and soundscape researchers more aware of the actual diversity in people's sensory abilities.

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1 INTRODUCTION

Although the meaning of sound in our life is incalculable, acoustical aspects in architectural design and urban planning have often received little attention. Consequently, acoustical discomfort in buildings is often experienced shortly after they are opened to users. The reasons for this limited attention might lay in the rather "invisible" character of sound, and/or in the fact that the mathematical theory of sound and waves may be rather difficult to explain to designers or stake holders.

Thanks to soundscape approaches, which have brought a more human and less technical/mathematical view on the environments created by sound, together with a more common and understandable language for communication between acousticians and architects, acoustical comfort became a topic of interest and discussions.[1] During the last decade, soundscape topics have attracted also considerable attention from other research fields, such as sociology, psychology, linguistics or anthropology. Along with this very positive evolution we can observe that the approaches in soundscape research evolve very often, like soundscapes themselves, in a very "spontaneous" way. In comparison with acoustics, which is a well established scientific field that uses objective physical and mathematical methods based on knowledge about sound(wave) propagation and other phenomena, the soundscape approaches are of many different kinds, starting from signal processing of sound recordings, ending with grounded theory. So far, no generally accepted method for soundscape description or assessment exists. Work on definitions and harmonization of approaches can be seen in the framework of several national and international projects and networking actions, such as EU COST action TD0804 Soundscape of European Cities and Landscapes.

Soundscape studies (for overview, see e.g. 1) offer a huge amount of interesting information, but it is highly regrettable that they hardly pay attention to the diversity in sensory abilities among the inhabitants of buildings and cities. Many places become acoustically inaccessible for people with a hearing or visual impairment due to too much noise or reverberation.

Acknowledging the diversity in people's abilities lays at the heart of inclusive design. Inclusive design denotes "*a general approach to designing in which designers ensure that their products and services address the needs of the widest possible audience, irrespective of age or ability*"[3] Or, in other words, "*design of mainstream products and/or services that are accessible to, and usable by, people with the widest range of abilities within the widest range of situations without the need for special adaptation or design*".[4] Depending on the continent or region, this design approach is also called *universal design* (US and Japan), or *design for all* (continental Europe). If we look at studies on inclusive design in relation to architecture, however, we can observe that the acoustical aspects are rarely addressed.[2,3]

Apparently there is little communication between inclusive design researchers and acousticians. In acoustics, most of the research meant as an input for standards and legislation presumes healthy people with good hearing and in the research on inclusive design, accessibility and usability is often interpreted in terms of 'physical' accessibility (being able to enter) with little attention for sensory (including auditory) accessibility.[2]

Exceptions to this rule include studies on the acoustical qualities in dwellings for hearing and visually impaired inhabitants,[6] on the auditory experience of spaces and multisensory aspects of the built environment,[3] on acoustical comfort for hearing impaired, visually impaired and older people in auditoria,[2] or the development of a suite of bar furniture and disposable earpieces that allows groups of people with unimpaired and impaired hearing to converse easily despite background noise , e.g. in a restaurant or bar (IDEO's TableTalk system).[7]

In our research we try to build a bridge between acoustics and inclusive design by using "soundscape language" for communication between acousticians and architects. To start with, we focus on the hearing abilities, needs and preferences of people with a visual impairment, as sound plays a crucial role in the way they understand and navigate the built environment.

In this paper, we bring together knowledge from both acoustics and inclusive design research, and summarize insights gained about blind people's perception of sound and soundscapes by conducting (1) a literature review of studies using magnetic resonance imaging (MRI), positron emission tomography (PET) and perceptual laboratory tests, and (2) in-depth interviews with 22 blind adults about their experience of the built environment. The interviews were conducted as part of the second author's Ph.D. research and already have been reported elsewhere.[3, 8]

2 SUPERIOR ABILITY IN AUDITORY PERCEPTION OF BLIND PEOPLE

2.1 Auditory perception by early- and late-onset blind people

It is well known that people with a visual impairment do not receive more acoustical information than sighted people, as their "hardware", i.e. hearing system, consisting of outer, middle and inner ear, is the same as that of a sighted person. However, a blind person is able to compensate the lack of vision by processing the acoustical information better than a sighted one.[9]

Blind people are not only more attentive to auditory cues, but they also dispose of extra abilities, developed thanks to plasticity of the brain.[10] People with visual impairments are able to extract more information from the audio signals mainly concerning perceptual tasks such as spatial orientation, pitch change determination, verbal memory and speech discrimination.[9,10,11]

A striking accuracy in localization of sound has been reported by several authors.[9,10] Many factors play a role in the exploration of the potential of sound, but probably the strongest factor is the age at which an individual looses his/her sight. Several studies pointed out that there is a difference between the sound perception of early- and late-onset blind individuals.[10,11] It has been found that early-onset blind people are e.g. able to localize sounds also monaurally, whereas sighted people always need binaural information[9] and that people with residual peripheral vision localize sounds less precisely than people without such residual vision.[12] A possible explanation for this ability can lay in the reorganization of the neuronal population or alternatively in the usage of the visual centres of the brain for auditory processing.[9] Whether late-onset blind people may develop similar abilities by cerebral plasticity (plasticity of the brain involving the occipital cortex) is a matter of ongoing research.[13]

Several research teams tried to find an age limit for plasticity of the occipital cortex and their results (based on MRI techniques) have indicated an age limit of 14-15 years.[14,15] Techniques such as PET imagining have also shown changes in the brain at later ages[16,17] and differences between subjects have been found as well.

The discussion about differences in perception between late- and early-onset blind people is important in relation to demographic changes, when designing places for people who were born blind and older people who have lost their (partial) vision at later age. It is important to know whether the same auditory abilities apply for older persons (with a visual impairment acquired at older age) as for people who were born blind.

2.2 Echolocation

In relation to orientation of people with visual impairments a phenomenon called "echolocation" (biosonar) is often mentioned. In general, echolocation is described as an ability of a human or an animal to use self emitted sounds to locate and identify the objects around.[19,20] Interestingly, some authors link this ability rather to the sense of touch than to the sense of hearing (cfr. facial vision).[18] Various animals use this phenomenon for navigation and object recognition; the best known are probably bats. For a person (or animal) to be able to use echolocation the essential "hardware" are two healthy ears and the essential "software" is a special sensitivity of the brain to process sound information.

The *distance perception* is based on time and sound intensity differences. The *detection of direction* is based on the interaural level and time differences. It seems that echolocation by animals uses a cross-correlation (e.g. comparison of the outgoing signal with the sound reflection in real time), but in an incoherent form, such as filter bank receiver (e.g. decomposition of the signal to array band-pass filters in which the input signal is separated into single frequency components). It is most likely that humans use similar processes.

2.3 Voice and music perception

Several studies have been conducted in relation to perceptual tasks such as localization, but it is not completely clear whether the superior ability in auditory perception of blind people is also present in the process of listening to music or voices.[13] Measurements of cerebral responses to voice and non-voice stimuli in blind and sighted people using MRI methods reported in literature show different patterns of brain activation between both groups (sighted and blind) if all, and thus not only voice-based stimuli were compared. Blind people have shown stronger activation of the occipital area and weaker activation of temporal areas. However, in case only voice perception stimuli were played to subjects, an overreliance on voice selective regions of the superior temporal sulcus regions has been seen in blind people. This finding indicates that an intra-modal plasticity might be very helpful in enhancement of highly specialized auditory functions such as perception of voice.[18]

3 PERCEPTION OF SOUND AND SOUNDSCAPE BY BLIND PEOPLE

3.1 Perception of outdoor sounds and soundscape

Perception of the soundscape in urban spaces by blind people is partly determined by classical sounds, such as traffic or singing birds but a very important role in acoustical comfort is played by the weather, in particular the wind, rain or thunderstorm.

In urban soundscapes wind acts in a similar way as human breath in playing wind instruments. A mild breeze brings things, such as leaves on the trees, into movement, resulting in production of different sounds. John Hull, an Australian emeritus professor who lost his sight at the age of 45 describes thunder as a very positive element of nature, something that gives unsighted persons a sense of space and distance between objects. "*Thunder puts a roof over my head, a very high, vaulted ceiling of rumbling sound. I realize that I am in a big place, whereas before there was nothing there at all.*"[21] "*I love thunder because it prevents me from wandering in infinity, which is frightening and disorientating.*"[22]

Rain turns the "fragmented" world of a blind person into a continuous acoustical experience when steadily falling rain "highlights" the outdoor environment or landscape. Sound reflections coming from closer surroundings are logically perceived in more detail than objects at a larger distances. "*The rain presents the fullness of entire situation all at once, not merely remembered, not in anticipation, but actually and now. The rain gives a sense of perspective and of the actual relationship of one part of the world to another*".[21]

3.2 Usage of echolocation in real life scenarios

Based on literature and the in-depth interviews with visually impaired people, we can conclude that many, if not all blind people involved are successfully using echolocation, although some of them do not know how this phenomenon is called. For persons who were not born blind, development of this ability can take some time. The period necessary to become aware of it has been reported to be half a year. Echolocation is typically used for the detection of bigger objects, such as buildings, walls, ceilings and large obstacles. For example blind skiers can "hear" if there is a house near by the skiing track, how big the object is and from which material its façade is made.

Small or thin objects such as lampposts or chairs cannot be detected based on this kind of sound information. Blind people also report that object detection is a matter of attention and consequently if walking "on somebody's elbow", less information from the soundscape is consciously perceived. In reality, orientation in space is a very complex ability, based on a combination of different kinds of information. Blind people report that e.g. the end of the building block can be relatively easily found. In reality many different factors might play a role, and more robust cues might be used in this case, such as differences in the air movement (around the edges of a building) or differences in the frequency spectrum and intensity of the perceived sound with a sound source behind the corner. Thus how much information can be extracted from pure echolocation can be tested only in laboratory conditions. In real life, people with a visual impairment perceive space in a multisensory way, like other people do.[23,24]

3.3 Perception of sounds in building interior

There is a huge difference in how blind people orientate themselves in a known versus an unknown building interior. During the interviews, some people have mentioned that at their homes they almost never use haptic cues and that they start to touch things, only once their orientation is for some reason lost.[8] When showing the researcher around in their home, however, it turned out that they do rely on touch frequently.[25] Still they prefer to have some sounds always present in the room, such as a radio, and even a noise from a fridge can make the place for them more "readable".

In relation to an unknown building interior, information on its shape and size can be extracted from the soundscape. Often a white cane is used for getting this information in silent interiors.

Written accounts by blind people suggest that they are able to localize also moving objects, such as people and cars passing by, purely based on the acoustical information.[21] However under certain conditions (such as too noisy environments) this becomes almost completely impossible.

Finally, an interesting description of the auditory perception of a room's interior is given by John Hull, who writes: "*If only rain could fall inside a room, it would help me to understand where things are in that room, to give a sense of being in the room, instead of just sitting on a chair.*"[21]

3.4 Conversations and human voice perception

For visually impaired persons, voice perception is without any doubt as important as localization of sound or egocentric localization. The colour of the voice offers essential information to recognize the speaking person. Furthermore, a blind listener cannot see the facial expression of a speaker and thus must extract almost all information including the emotions accompanying the speech, from the intonation of the speaker.

This is a rather difficult task because the "spoken words" are often too abstract and "touch" is often too concrete[20] and the non-verbal conversation is essential in understanding the real meaning of words.

4 CONCLUSIONS

Differences among people who are blind are as large as differences among sighted people. Any generalization of their perception of soundscapes is therefore very difficult. Furthermore, people with visual impairments, like sighted people, perceive reality in a multisensory way. The brain analyses a combination of different kinds of stimuli simultaneously.

However, people who are visually impaired are in their daily life forced to completely rely on non-visual cues and they are thus more attentive to auditory information. When designing buildings and public spaces, architects and acousticians should understand and learn how blind people use auditory (and other) cues for their orientation in building interiors and outdoors, and how they perceive the overall acoustical comfort.

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