The Other Half of the Soundscape: Aural Architecture

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Abstract

Ever since the concept of a soundscape entered our culture in the mid 20th century, various disciplines have examined its properties from the perspective of sound sources distributed throughout the environment. Yet, soundscapes are far more than experiencing nature, enjoying music, and understanding speech. To fully appreciate the meaning of soundscapes, we need to examine interactions among sound, place, culture, cognition, and evolution. Soundscapes help to answer the questions: where are we, how will we behave, and how do we feel? A soundscape is a complex system that provides the means by which people connect to dynamic activities: it is the life of a space experienced by listening.

1. Introduction to Self in Space

When listening to a soundscape[1], we are building an internal sense of a space. The soundscape embeds the listener in those activities that have an audible manifestation. When listening to a soundscape, location is described by the activities occurring there; for example, I am in the midst of playing children, shouting street vendors, and speeding automobiles. But when viewing a landscape, location is the physical description of a static world; for example, I am located 20 meters north-east of the Eifel tower in the center of a school yard. Without activities, there are no soundscapes. When activities change, the soundscape changes. Viewing, listening, touching and smelling are each relatively independent ways of positioning your body in an internal representation of the external world. Each sensory system makes its own unique contribution to our awareness of place and location.

[1] The concept of a soundscape, first formulated by Schafer (1977) and then extended by Truax (2001) and others, has been generalized to mean a sound field within which we are immersed.

The very sense of self depends on its sensory relationship to the external world (Howard and Templeton, 1966). Everyone exists someplace. Conversely, sensory deprivation disconnects our internal reference frame from the physical and social environment, and rapidly produces hallucinations (Cohen et al., 1965). The experience of spacelessness does not exist as a normal state; it produces disorientation. A half century ago, Roth (1955) reported that undiagnosed hearing loss was the primary cause of mental illness in the elderly, and more recently, Zimbardo et al. (1981) demonstrated that simulated deafness in normal individuals produced symptoms of paranoia. Modern culture often undervalues the importance of the soundscape as a means of sensory connection.

Biology partially determines how we use our senses; cultural attitudes and individual personality also play a dominant role. The Hausa people, for example, recognize only two senses: seeing and experiencing; the former is for avoiding physical obstacles, while the latter encompasses intuition, emotion, smell, touch, taste, and hearing (Ritchie, 1991). There is a great variety of cognitive strategies used to establish a sense of place.

2. Soundscapes: Being Immersed in Life

Sound is ethereal. Burnett (1991) commented that the "dominant impression that one gets from reading the medieval philosopher's account of sound is their fascination with the illusiveness of the entity." Sound was too abstract to be readily understood, and was often experienced as the *voice* of god, people, and objects. Imagine a pre-literate hunter who came upon an opening to a vast cavern. Background sound entering the cavern was changed sufficiently such that, when it re-radiated outward from the opening, it was perceived as originating from within: he heard the cavern speak to him. The reverberating sound of the cavern then became the voice of the *cave spirit* from deep inside the cavity.

Ong (1982), a scholar of anthropologic psychiatry, asserted that ancient man would have been aware of sound as revealing the interior state of objects and animals. In contrast, vision only reveals the surface. Tapping on a closed box produces the sound of a hollow interior. By listening, the interior properties of the box "magically" appear inside the listener's head, a phenomenon called aural consciousness. Sound acquires its power by the lack of experiential separateness between source and listener. Voice and music are particularly powerful because they connect the interior of one person to the interior of another.

Sound is unique in that it always originates from a dynamic event that transforms mechanical energy into a propagating sound wave, which then broadcasts the existence of the event over a wide area. Sound is the transport mechanism by which we are able to sense remote events. Periodic vibrations and sudden impacts produce sound, but we experience the event, not the sound as being separate from the event. A shoe hitting a hard floor signals the approach of someone; whistling a cheerful tune broadcasts emotional comfort; a heated dialog radiates interpersonal conflict; and the sound of a wailing siren warns of danger. In fact, from a psychological perspective, one might say that we do not hear sound so much as we perceive events. Try describing the sound of an automobile rapidly turning the corner without referencing its tires skidding on the pavement. It is virtually impossible.

In tribal societies where survival was a continuous struggle against invisible and dangerous events, soundscapes were frequently more relevant (Feld, 1996) than landscapes. From an evolutionary perspective, hearing events made a critically important contribution to survival. Whereas landscapes can be comparatively static, sometimes almost lifeless, soundscapes require activities to produce sonic events. Because events might signal danger, soundscapes were an early warning system. Even in modern society, we still depend on sound to warn of possible danger, as for example, the anxious cry of a baby, the loud sirens of a fire truck, or impact of a large tree in a storm.

The sonic broadcast of a dynamic event flows around obstacles and through crevices, entering a space without permission. Because hearing is always active, without "earlids" or a voluntary point of spatial focus, listeners are involuntarily connected to those events that are audible regardless of their location. An unexpected thump from the roof immediately catches our attention because sound is an early warning system. When either biologically or functionally[2] deaf, we have more difficulty experiencing significant events because vision is not particularly good for recognizing them. Vision requires us to first voluntarily focus on the target; vision is easily obscured by intervening objects; vision requires a light source; and vision is weak for sensing fast movement or rapid change.

[2] Functional deafness is the inability of a normal hearing person to detect sonic events, which is the case when wearing headphones or when very loud ambient noise masks event broadcasts. For example, in a large urban city at rush hour, one cannot hear the event of your shoes hitting the pavement when walking.

For any given subculture, the quality and comfort of a particular soundscape is based on the value judgment about which events are desirable and which are unpleasant. In some subcultures, listeners want to be completely isolated from public events, thereby having complete control over what events can access their consciousness. In other subcultures, being isolated from public events creates a sense of irrelevance and isolation. Similarly, attitudes towards natural and man-made events arise from personal preference. A natural forest soundscape is not intrinsically better or worse than a dense urban soundscape.

3. Sharing and Competing for Soundscapes

Space and sound are shared resources used by human beings and other species for broadcasting events to other inhabitants over an acoustic arena[3]. Broadcasting vocal signals by animals in a complex environment, such as a forest, is one of the most effective means of communicating because the acoustic horizon[4] can be far larger than the visual or olfactory horizon. Many species therefore evolved specialized auditory biology and social systems, adapting to their specific acoustic environment: nature's aural architecture[5]. Hauser (1997), in his analysis of animal communications among numerous species, described the complexity and importance of vocal signaling among competing species in a shared acoustic environment. Each species is forced to adapt, finding acoustic niches that are not otherwise occupied by competing species.

Historically, human beings also used sonic broadcasts as an integral part of their social system. The invention of the mechanical clock is one of the best examples of a soundmark[6] that enlarged and identified the community. Boorstin (1983) described how sundials and hourglasses were superseded by the sound of a synchronized hammer striking a bell, thereby replacing a small visual arena with a much larger acoustic arena. Time no longer flowed; it was now broadcast to the community at punctuated intervals. In his extensive study of bells in the 19th

[3] An acoustic arena is that area of the space where a particular sonic event can be heard. Arenas grow and shrink depending on other competing sonic broadcasts. Moreover, the physical acoustics of the environment strongly influences the area over which a broadcast will propagate.
[4] An acoustic horizon, centered at the listener, represents the area over which sonic events can be heard. It is the analog to a visual horizon. An arena references the sound source, a horizon references the listener.
[5] For more information about aural architecture, consult our book (Blesser and Salter, 2006) and visit its companion web site www.SpacesSpeak.com.
[6] Analogous to a landmark, a soundmark is a readily recognized sound that acquires unique meaning to the community.

century French countryside, Corbin (1998) explained that self-esteem, emotional well-being, civic pride, and territorial identity all depended on hearing the town bells. When citizens heard the chiming of the bells, they felt rooted within a cultural geography that could easily be walked. Clock towers built to announce the beginning of religious services acquired additional civic responsibility as broadcasters of public announcements. Bells warned of imminent danger from nature, signaled the beginning of public ceremonies, and celebrated victory in battle. Soundmarks provided local cohesion. Competition among towns and communes occasionally resulted in stealing one another's bells, and legal confrontation over the right to ring the bells resulted in riots.

Because the arena for a soundmark determined the scope of the town, those geological formations that would support sound propagation determined which regions could be absorbed into the township. Sound propagates farthest in valleys, which act like acoustic wave-guides, and least over mountains, which cast acoustic shadows. As aural architecture on a grand scale, sonic geography controlled the social fabric of early rural communities.

On a smaller scale, individuals experience community from a local soundscape. Schafer (1978) quotes a resident of a small town who remembers from the early 20th century the importance of a large acoustic horizon, and the value of identifying horses by the sound of their steps. "The iceman had a couple of very heavy cobs,…the coalman had a pair of substantial Percherons that always walked, …the dry-goods store had lightweight horses,…and the Chinese vegetable men had very lazy horses." With acoustically porous living spaces, individuals could hear the fishing boats returning to harbor, the children walking home from school, the rattling of leaves in the wind, and the dog fighting with the cat. You would know that it was time to visit your neighbors when you heard their wagon returning from shopping excusion.

Hogarth's Enraged Musician. Courtesy of Graphic Arts Collection, Princeton University

The advent of industrialization produced intense conflicts about who could "own" the soundscape in urban environments. These conflicts were seldom resolved by legal regulations (Thompson, 2002). In the picture above, Hogarth depicts such a conflict between a middle-class musician in the parlor of his private home and lower-class peasants whose home was the street. From a visual perspective, there are two distinct spaces: street and parlor; but from an aural perspective, the open window creates a single acoustic arena as a shared resource. The creator of the loudest sounds becomes the owner.

This Darwinian contest continues in the 21st century where advertisers use televisions in the public areas of airports to insert monetized messages into the heads of those waiting for their flights. Similarly, owners of cinema theaters are paid for excessively loud commercial messages to their captive audiences. Everyone wants to control the soundscape, either for their own private use or for capturing the consciousness of helpless individuals. This is similar to the early 20th century with the fight over frequency and power in radio broadcasting. The soundscape is a resource medium where combat over broadcasting takes place. Those who loose the battle then

react by adopting a defensive strategy. For example, portable sound devices using headphones allow listeners to suppress the external soundscape and substitute their own, which displaces the listener to the soundscape created in a recording studio. Headphones are an aural space transporter[7].

In summary, we can understand soundscapes by viewing them as a resource that allows inhabitants to connect to dynamic events, both man-made and natural. Soundscapes are an arena for a power struggle among those that share the space. Because sound is valuable as a means for making connections among people and events, and because soundscapes are a limited resource, soundscapes are intrinsically political[8]. Those who control the soundscape control the world.

4. Sound Sources Influenced by Aural Architecture

Although we have made a direct association between sound sources and the dynamic events that produced them, listeners never experience sound as it emanates from its source at a remote location. As the sound wave propagates to the listener, it undergoes changes produced by the acoustics of the environment. Spatial acoustics produces reflections, resonances, reverberation, dead zones, focused intensity, sonic channels, dispersion, and so on, all of which have an audible manifestation. When listeners engage in *auditory spatial awareness*[9], they can detect and interpret the audible attributes of spatial acoustics. Audible cues can produce emotional responses, such as an elevated sense of intimacy; cues can change behavior, such as a pair of lovers choosing a closer distance for aural privacy; cues can make the sound source appear larger and dominant without any change in loudness.

In order to avoid the scientific language of physical acoustics for exploring the ways in which listeners engage in auditory spatial awareness, we use the word *spatiality*[10] for the aural experience of space. At this time, we have identified at least six types of spatiality: navigational,

[7] Recently, several pedestrians were killed in New York City when they crossed the street wearing headphones. They were in the space of a concert hall rather than the space of truck traffic.
[8] Using a neutral definition of political, we define it as the social process for allocating limited resources among those who want a share of them.
[9] Depending on culture and personality, listeners may become very skilled at incorporating an audible cue into their cognitive strategy for connecting to the world. Conversely, listeners may also be oblivious to the most dramatic manifestation of spatial acoustics.
[10] Because of the sparseness of a vocabulary for sound, we have either created new words or borrowed words from the visual domain.

social, timbre, musical, aesthetic, and symbolic[11]. Spaces typically manifest more than one type of spatiality. Together, the different manifestations of spatiality create the *aural architecture* of a space, which refers to the human experience of those spatial attributes that have an audible manifestation even though they themselves do not produce sound (Blesser and Salter, 2006). For example, although walls have a physical influence on sound because they produce reflections, dispersion, and changes in spectral content, they can also be described as having navigational and social spatiality. The aural experience of walls varies depending on the functional context, thus manifesting one or more types of spatiality.

Imagine a friend clapping his hands, and consider how a variety of aural architectures influences the experience of that event. The sound has different emotional impact when in a marble bathroom, a well-upholstered plush living room, a majestic 17th century cathedral, a beach on a quiet Sunday morning, or an isolated underground cave. Similarly, the experience of listening to a religious oration in a cathedral is a combination of the minister's passionate articulation and the spatial reverberation. A performance of a violin concerto combines the sounds of musical instruments with the acoustics of the concert hall. If played in an open field, the concerto would have a very different emotional impact. When listening to a concert, musical spatiality dominates.

Alternatively, we can consider how objects and geometries of a space can be experienced directly. An echo from a distant wall reveals its location, size, and surface materials. We experience the vast volume of a cathedral by its long reverberation, and we hear an open doorway by the absence of reflections from the opening. Just as one cannot see an object without a source of light, listeners cannot hear objects without a source of sonic illumination[12]. In the traditional view of a soundscape, sounds are important in themselves, as for example, birds singing or people talking. But those same sounds also serve as a source of illumination of objects and geometry. When a listener perceives objects and geometries, navigational spatiality dominates.

The personality of a soundscape results from the inseparable combination of sounds from dynamic events and the aural architecture of the space. Consider a visual analogy. A chandelier is both an aesthetic light source that can be experienced directly, and a source of illumination for

[11] For more details about the various types of spatiality, see our more recent papers at www.SpacesSpeak.com
[12] The word illuminate is used to mean sonic excitation of passive objects and geometries.

objects in the room. Similarly, birds produce song, which also illuminates forest acoustics. The soundscape of a forest combines the singing of birds with the acoustical properties of hills, dales, flora, and turbulent air[13], which is nature's aural architecture. As is the case with many environments, the unique personality of a forest soundscape arises from a distinctive aural architecture and distinctive sound sources.

To use a food analogy, sonic events are like raw ingredients, aural architecture is like a cooking style, and as an inseparable blend of both, the soundscape is the resulting meal. We now have a rich and expanded definition of soundscape: the simultaneous experience of both the sound sources modified by the aural architecture and the aural architecture illuminated by sound sources.

5. Cultural and Individual Variability in Spatial Awareness

Normal hearing people, with similar measured responses to test signals in the laboratory, vary in their ability to hear and respond to components of the soundscape. This variability arises from *cultural acoustics*[14]: cognitive strategies and sensory training that determine how listeners experience sound. The ability to appreciate aural architecture, soundscapes, and various types of auditory awareness are not intrinsic. Although evolution provided bats and dolphins with specialized biology for using echolocation[15] to navigate space, a more latent form of auditory spatial awareness[16] exists in hamsters (Etienne at al., 1982), oilbirds (Griffin, 1986), rats (Riley and Rosenzweig, 1957), and human beings. We have a latent ability to become proficient at using hearing for detecting objects, geometries, and other spatial attributes, but actualizing this ability varies dramatically.

At one extreme, some people are oblivious to even the most dramatic aspects of aural architecture. At the other extreme, some are actually able to *visualize*[17] objects and geometries of

[13] Forests have their own unique form of reverberation, which is different from that of enclosed spaces (Richards and Wiley, 1980), and musicians have taken advantage of its uniqueness for concert venues (Rother, 2005).
[14] Cultural acoustics is that part of listening that arises from personality, attitudes, cognitive strategies, life style, perceptual biases, and personal preferences. While everyone is unique, groups of similar individuals form a sensory subculture. Soundscapes include cultural acoustics.
[15] Echolocation has had the meaning that the species produces a synchronized sound, whose reflection from the environment is used to form a model of objects.
[16] Auditory spatial awareness assumes only that the animal can decode the way in which the environment changes background sound sources without necessarily generating them.
[17] *Visualize* is used to mean that the listener can create an internal picture of the environment from the sound entering the auditory system.

a space even though they are not a source of sound. For example, Ved Mehta (1957), blind from childhood, described his experience of navigational space. Wanting to live a normal life in Calcutta, he learned to jump from banister to banister, from roof to roof, and rode his bicycle through unfamiliar places. Ray Charles, the world famous jazz musician, eloquently describes a similar approach to living as a blind child, never using a cane or seeing-eye dog to navigate a space (Charles and Ritz, 1978). In addition to sensing large objects, such as doors and walls, a few people can aurally identify small objects, such as the hexagonal shape of a stop sign (Rice, 1967).

Even without special training, most of us can hear the emptiness of an uninhabited house, the depth of a cave, the nearness of a low-hanging ceiling, softness of a room with thick carpets, and the cavernous avenues of an urban city. When blindfolded, most everyone can approach a wall without touching it, just by attending to the way the wall changes the frequency balance of the background noise.

Appreciating the nuances in a soundscape is neither a uniform nor objective ability that arises solely from biology. Our perceptual skills are learned. Buonomano and Merzenich (1998) commented that "the cortex can preferentially [re]allocate cortical areas to represent selected peripheral inputs. The increased cortical neuronal population and plasticity-induced changes [are] … thought to be critical for certain forms of perceptual learning." When individuals engage extensively in particular types of sensory experience, their brains adapt (Münte et al., 2001). We are how we live.

6. Soundscapes as a Complex Feedback System

Analyzing the dynamics of sound in a restaurant illustrates the concepts of soundscapes that we have been discussing. Most everyone has had the experience of dining in a restaurant with corrosive and unpleasant ambient sound. It is actually the result of a complex soundscape system that involves both physical and cultural acoustics interacting with each other within an aural architecture. When the restaurant's aural architecture does not support the appropriate acoustic arenas for everyone, the spaces becomes very noisy.

From the perspective of an acoustic architect with training in physical acoustics, noise is caused by insufficient sound absorption, which results from a lack of acoustic tiles, thick rugs, dense curtains, or upholstered seating. From the perspective of a social scientist, the noise results

from too many diners engaging in loud conversation. Both perspectives are true, but they both ignore the fact that a restaurant soundscape is actually a positive feedback system involving both physical and cultural acoustics. A simple analysis illustrates the complexity.

Assume that each table has a pair of diners preferring to converse at a speaking level that makes their conversation intelligible to each other. With no ambient noise, they would choose a comfortable speaking voice at a physical distance consistent with their relationship[18] (Hall, 1966). If the background noise were to become louder, they would now converse with more intensity in order to overcome noise, thus preserving intelligibility. Reducing the distance between them is often socially uncomfortable. This dynamic plays out at each table. However, the background noise is itself the composite of the reverberated sound energy from conversations at all the tables. The noise is the reverberated conversations. As the background noise increases, diners converse with louder voices; this further increases the background noise, which forces still louder voices. Eventually, everyone is shouting. A relatively quiet restaurant can suddenly become noisy with the addition of only a few more diners. Additional conversations incrementally increase background noise such that the feedback gain becomes greater than 1, and the feedback system suddenly becomes unstable. In summary, the soundscape in a restaurant is a system whose properties are that of a basic feedback system.

The speaking strategy among diners is a major component of the feedback gain. Romantic couples who just want to gaze into the eyes of their partners are unlikely to speak loudly. Groups of young adults, possibly celebrating a sports victory, are likely to express their enthusiasm with a high speaking volume. Each of these groups has a speaking and listening strategy, which are both components of cultural acoustics. Unwittingly, each table is in sonic combat with other tables over who has control of the local soundscape.

When the ambient noise becomes too loud, many diners will stop conversing because overcoming noise is too much effort. As a result, conversation stops at some tables and the ambient noise now decreases; somewhat later, sensing the reduced background noise, diners again begin to converse. This explains why restaurant noise may have a cyclical property, periods of relative quiet followed by deafening noise. In the language of system theory, these are limit cycle oscillations, which are typical of non-linear time-varying positive feedback systems.

[18] Using physical distance as an expression of social relationships, the social anthropologist Edward Hall conceptualized social distance in the field of *proxemics*.

Modifying either physical or cultural acoustics can reduce the background noise. Changes to physical acoustics might include adding sound absorption or using small square or round tables that decrease the distance among diners. When closer to each other, diners are likely to unconsciously converse in a softer voice without sacrificing intelligibility. In contrast, long rectangular tables increase the average distance between diners, thus producing louder voices. Changes to cultural acoustics might include diners who voluntarily remain silent some of the time or change the way that they speak. Intelligibility remains unchanged even with a decrease in speaking intensity if accompanied by an increase in semantic redundancy and careful pronunciation. Without social conventions to ration a scarce resource, that resource will be destroyed for everyone.

This same type of system dynamic also takes place in natural soundscapes where groups of people and animals are also in a positive feedback system. In various natural soundscapes, species have adopted a collaborative strategy for sharing, vocalizing only at certain times of day or using particular regions of the frequency spectrum. To truly understand the soundscape, we need a system view.

7. Summary and Conclusion

Soundscapes result when inhabitants of a space engage in broadcasting vocalization and creating dynamic events that produce sound, both of which consume a shared resource. Be it natural, designed, or accidental, aural architecture contributes to distributing that resource among individuals. But when the soundscape resource is insufficient for everyone who wishes to consume it, individuals may engage in a struggle to take a larger percentage of a sparse resource. Allocating soundscape resources is an adaptation to ecological niches using collaborative or aggressive strategies. Soundscapes can best be understood as systems that include aural architecture interacting with the behavioral strategies of those people and animals that occupy the space.

Because soundscapes are the result of vocalization and dynamic events in an aural architecture, an individual can create a clear sense of what is happing by listening to the activities of the inhabitants. Soundscapes are alive with the life that is creating it. We have now expanded the traditional definition of a soundscape to be more than a collection of passive sound

sources distributed throughout the environment. A soundscape is a living organism[19] with a personality that arises from the composite behavior of the inhabitants.

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[19] See Johnson (2001) for an extended discussion of how many small elements in a system can create a living organism with its own personality and life cycle. A city and an ant hill are obvious examples.

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9. Biographical Sketch of Authors

Dr. Barry Blesser has spent the last 40 years exploring the influence of cognitive and perceptual psychology on the design and implementation of technology. After 9 years as an Associate Professor of Electrical Engineering at M.I.T, he founded Blesser Associates as a technical and management consulting firm. In the 1970s, he was one of the pioneers of digital audio technology, and invented the first commercial digital reverberation system. Recently, he and Dr. Salter co-authored the book, *Spaces Speak, Are You Listening? Experiencing Aural Architecture*, which was published by MIT Press in 2006.

Dr. Linda-Ruth Salter was a pioneer in crossing discipline boundaries when she obtained a Ph.D. degree in Interdisciplinary Studies from Boston University in 1984. Her doctoral dissertation examined the nature of sacred space in secular societies. Dr. Salter has consulted in the area of research and planning for a successful built environment in public housing, educational and business spaces. Presently she is an Associate Professor of Humanities and Social Sciences at New England Institute of Technology, where she creates and teaches courses that integrate technology with the social sciences.

Drs. Blesser and Salter, a husband and wife team of 35 years, fused their collective knowledge and experience of the physical and social sciences to create the concepts of cultural acoustics, auditory spatial awareness, and their relationship to aural architecture. *Spaces Speak* embodies their shared philosophic bias: technology changes the social and artistic aspects of culture, while at the same time, culture influences the properties of technology, invention, and innovation.