From soundscape to meaningscape

Frederik Laigaard Nielbo
Center for Semiotics, Aarhus University, Denmark.

Summary

Throughout evolution the auditory system has been shaped to detect, localize and identify significant events in the environment. Sounds carry information about events relevant for the perceiving organism, enabling it to navigate in the environment, detect prey, avoid potential dangers, etc. The sounds can, in other words, be considered sign vehicles or meaning carriers and the sense of hearing, thus, is a tool for gathering information about events in the surroundings in order to initiate appropriate behavior (chasing, fleeing, etc.). Insights from biosemiotics, cybernetics and ecological psychology suggest that perception is intimately linked to action, but this linkage has been largely ignored in traditional research on human auditory perception. I argue that interaction potentials play an important role in soundscape perception. It is well established that individual sounds can carry meaning for the perceiver, and studies indicate that listeners' perception of soundscapes is structured by semantic categories related to events and activities taking place in the heard environment. From the rudimentary hearing system of simpler organisms to the complex human auditory system, perception of such events is functional and instrumental; it guides the perceiver's behavior by utilizing information about potential interactions with the environment. With this paper I wish to discuss the notion of a semiotic dimension of soundscape perception, where soundscapes are considered as "meaningscapes", complexes of functional auditory signs to be perceived and acted upon, and by which the perceiver makes sense of the environment.

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1. Introduction

The study of soundscapes has, since the emergence of the concept in the 1960s, involved a multitude of different academic disciplines, such as aesthetics [1,2], psychoacoustics [3] and ecology [4]. A central topic spanning across these disciplines is the informational aspect of the soundscape [5,6]. The fact that the soundscape is informative is uncontroversial. But what characterizes these informational dynamics? In what sense can a soundscape be said to be meaningful to the perceiver?

A defining functional property of the sense of hearing is that it permits the perceiving organism to establish "magnitude, direction, and significance" [7] of events in the environment by means of vibratory energy, that is, to pick-up information about the direction and nature of an event [8]. Perception, thus, is always relative to the needs of the perceiving organism[2], as well as the environmental resources and restraints for satisfying those needs. From the rudimentary hearing system of simpler organisms to the complex human auditory system, the perception of auditory events is instrumental in supporting behavioral interactions with the environment.

The discussion of soundscape perception, therefore, cannot be limited to passive reception of auditory stimuli, but requires an integrative approach in considering the ways in which our embodied cognitive system is coupled with the environment through sound. This relation is inherently semiotic; it is due to this functional coupling that fundamental auditory sense-making may take place.

It is necessary to revisit the concepts of *information* and *meaning* in this context, as they

[2] These needs are meant to include not only primary biological needs, but also social and cultural ones. Though subject to different dynamics, it has been argued that a continuum exists between natural and cultural affordances [8].

deviate somewhat from the standard uses of the terms. While an exhaustive definition is beyond the scope of this paper, an operational approach is proposed which unites perception, cognition and action. The capability of the auditory system to utilize the information in the environment is discussed with the aim of grounding auditory meaning-making in the interaction between organism and environment.

In this perspective, a soundscape can be considered a *meaningscape*, a semiotic resource comprised of functional auditory signs to be perceived and acted upon, and by which the perceiver makes sense of the environment.

2. Sensorimotor meaning-making

A widespread understanding of the concept of information relies on Claude Shannon's definition of it as a reduction of statistical uncertainty in a system, or negative entropy [9]. The negentropic account, however, treats information as a probabilistic function and explicitly neglects the *meaning* of information. An alternative approach, which is better suited for studying information in biological and ecological systems, should include not only the information proper, but also the use of the information of an organism. It must, in other words, be grounded in the sensorimotor system and its interaction with its environment.

2.1 Ecological symmetry

Based on the Gibson's theory of direct information pick-up, Shaw et al. provide a symmetry postulate stating that "An organism possesses the highest degree of adaptation to its environment when the greatest degree of symmetry exists between its states (both biological and psychological) and the states of its environment," [10]. Ecological information, in turn, is defined as a perturbation of this symmetry relation which affects the organism's health and well-being [Shaw et al.: 281]. In other words, changes in the environment which may support or hinder the organism's sustenance create changes in the organism by stimulation of its perceptual system and, in order to restore the symmetry, the organism must act in an adaptive fashion.

This notion of ecological information alludes to Gregory Bateson's famous definition of the minimal unit of information as "a difference which makes a difference" [11]. Differences in the environment that lead to some form of potential behavioral change in the organism can then be considered informative.[3] Obvious examples of such environmental dynamics in the auditory realm are the Lombard effect, the adjustment of vocal audibility to compensate for loud background noise [13] found in humans as well as several other species, or the human avoidance behavior by the sound of an approaching car. In both cases a change in the environment, expressed in sound, calls for a behavioral response to restore symmetry.

2.2 A semiotic dimension to perception

For information to be meaningful for an organism, it must somehow be utilized by the organism. According to Jesper Hoffmeyer, meaning-making is a general property of the life world [14]. As sensorimotor systems, all biological organisms operate within a world of meaning, the so-called "semiosphere", which is understood as the total sum of potentially meaningful signs [15, 16]. And just as a species, from a biophysical point of view, occupies an ecological niche in the global biosphere, it must also occupy a *semiotic* niche, that is, a subset of the signs of the semiosphere relevant for the survival of the species. Thus, the organism must be able to utilize a set of relevant signs available in its niche.

What counts as relevant, as mentioned above, is relative to the perceiver. Each species' perceptual abilities specialize through adaptation to the ecologically relevant signs in the environment. Humans, for example, cannot perceive ultrasonic frequencies because events producing such sounds are rarely relevant at a human level. For the moth, however, the detection of ultrasound is crucial for survival, as it is used in the feeding strategy of the predatory bat [17].

The signs of the semiotic niche, expressed in sound, are 'interpreted' (in the broadest possible sense of the word) by the perceiving organism as a carrier of meaning, and an appropriate action can be initiated (c.f. below).

2.3 Environmental shaping of the ear

[3] VanDerveer has made a similar suggestion specifically regarding the sense of hearing, namely that it is not the presence of acoustical energy as such that is significant, but the deviation from the normal acoustical pattern [12].

Because sounds are causally related to the source event and the environment in which they travel, they have the property of carrying meaning about the event and environment [18]. The sound is determined by the physics of the source event, for instance the type of interaction and size, shape and material of objects involved. Additionally, the sound gets shaped by being reflected and absorbed by objects in the environment. The information is, so to speak, imprinted on the sound, and it can therefore serve as a sign carrying meaning about source event and environment.

In this sense, the morphophysiology of the organism's perceptual system reflects the ecological and semiotic niche that the species has adapted to [15]. Similar to the way in which discontinuities in the structure and function of the eye correspond to discontinuities in the visual environment, as pointed out in [19], the ear has been shaped by the environmental restraints.

Although the anatomy of the ear may vary, the function of the auditory system is strikingly similar across species as a result of convergent evolution [20, 21]. It has been suggested that this is because all hearing organisms essentially are faced with the same problems, namely sound source segregation and determination, and furthermore, that this has been the most important evolutionary factor in shaping the sense of hearing due to its fundamental adaptive value [20, 22].

In humans, an intricate combination of mobile location detection (body, head and pinnae), pressure sensitivity (tympanic membrane), and frequency and temporal filtering (tonotopic organization of the cochlea and the pre-cortical auditory system), the auditory system has specialized in detecting, localizing and determining the nature of the source event.[4] Or, in other words, it has adapted to a world of acoustically specified information about events in the organism's semiotic niche.

Far from being a passive receptor system, the perceptual system is actively engaged in scanning the environment, 'picking up' available information [23]. This process is supported by the properties of the auditory system which guide our auditory attention to salient changes in the soundscape [24, 25], a property not unlike the so-called "grabbiness" of the visual system which directs the attention to sudden changes in the environment and thereby functions as an alerting system that is constantly active [19].

The auditory system, in this sense, has been attuned to the relevant signs of the environment realized in sound. By means of the sense of hearing, then, we utilize auditory meaning-carriers through which we get access to significant events in the world.

2.4 Loops and affordances

The environmental information cannot be understood in isolation, but must be considered in respect to the perceiving organism and its interactive relation to its environment.

One of the early models of organism-environment interaction was proposed by the biosemiotician Jakob von Uexküll, who aimed at constructing a subjectivist biology based on "lawfulness of meaning relations" [26]. In his model of 'the functional circle', the organism is coupled to its environment through its perceptual and operational organs, which correspond to sets of perceptual and operational cues, or signs, to be perceived and acted upon. Every behavior, according to Uexküll, begins with a perceptual cue and ends with an operational cue, thereby forming a tight bond between organism and environment in the form of a perception-action loop [26].

The perceptual and operational abilities together define the organism's *Umwelt*, the phenomenal world of the organism [26], and it is by entering the Umwelt that stimuli are transformed into properties.

An example of this is the auditory system of the moth which, as mentioned above, is specialized in detecting the call of the bat. When the bat enters the Umwelt of the moth, the auditory cue will function as a sign of danger, and the moth can then initiate avoidance by means of its operational organs, the wings. The Umwelt, therefore, depends on potential sensorimotor interactions with the environment, and perception and action form a "teleological circuit" [27] where each becomes the presupposition of the other. As a result of this loop, objects entering the phenomenal world of the organism carry a "functional tone" [28], a quality

[4] In addition to these low-level perceptual processes, higher-order processes such as emotions or memory play an important role. The aim for this paper, however, is not to present a complete account of auditory perception, but rather to discuss the fundamental ecological dynamics in auditory meaning-making.

indicating how it may be interacted with by the organism.
A similar idea can be found in the Gibsonian framework in the form of *affordances* [29]. Ecological information is determined by the event it specifies, and thereby conveying the ways in which the perceiver may interact with the event: "The affordances of events are those invariant properties which imply directly the meaningful dimensions of interaction an organism might have with its world," [10].
Opposing the traditional distinction between object and subject, a meaningful affordance is neither simply a quality belonging to the object or a mental construct in the mind of the perceiver, but should instead be understood as an emergent property of the potential for interaction between an organism and its environment [23]. A chair, for instance, affords sitability, an affordance determined both by the structural make-up of the chair and the way in which it corresponds to the perceiver's bodily structure and the act of sitting. From the perspective of affordance theory, perception is intimately tied to action in a reciprocal relationship where one is informing the other [30]. A perception-action loop is thereby formed, which is assumed to be foundational for our interaction with and experience of the world.

3. Action in perception of soundscapes

While Gibson's main focus was visual perception, perception-action loops – in the form of functional tones or affordances – are thought to be a general property of perceptual systems and their interaction with the environment. Although theoretical principles of ecological psychology have been applied to human auditory perception [18, 12], only few empirical studies have directly assessed the affordance character of sounds. Nevertheless, there are experimental findings indicating that auditory perception is affected, at least, by potentials for interaction.

3.1 Experimental indications

In a study of auditory reachability, Rosenblum et al. [31] designed an experiment to test listeners' judgment of the "reachability" afforded by a sound source. If perception is relative to the bodily dimensions of the perceiving organism, it should be expected that the listeners' judgment of distance to the sound source is scaled according to those dimensions. Rosenblum et al. found that participants did indeed perceive the distance of the sound source relative to intrinsic bodily dimensions, such as arm length. This is an indication that the judgment of distance is a function of the interaction potential of reachability.
Most often, however, we don't encounter isolated sound sources, but rather rich soundscapes comprised of multiple sounds simultaneously. Studies of auditory comfort have shown that evaluation of a soundscape is relative to specific activities of the listener. Sounds in trains and airplanes, for example, are evaluated in relation to the activities of sleeping or having a discussion [32, 33], suggesting that the meaning of a soundscape varies according to how well it affords different activities, i.e. the potential for interaction.
Furthermore, studies of categorization of sounds in outdoor urban environments found that most listeners group soundscapes according to the activities carried out in the environment, the type of environment and specific sound sources [34, 35, 36]. This indicates that the information necessary for interaction is present in the soundscape for the perceiver to pick up.
In a study designed specifically to investigate possible affordances of urban soundscapes, Nielbo et al. presented participants with eight urban soundscape recordings with varying sound sources [37]. The participants were asked to indicate how appropriate they found each soundscape for four typical urban activities ("Studying for an exam", "Meeting up with a friend", "Riding your bike" and "Relaxing after school/work"). Those formulations were chosen to be sufficiently specific for outlining four distinct activity types, while still being general enough for participants to find them familiar. The results showed that listeners' evaluation of the soundscapes, as indicated by appropriateness rating, was influenced by its potential for interaction.
Furthermore, participants were invited to provide free-format comments to accompany their ratings. The distribution of comments suggested that spatial properties of the soundscape and events taking place in the environment are more relevant for riding a bike (being a spatial task), while acoustical features and the effect of the sound on the listener was more relevant for the activity of studying (being a cognitive task). This lends further support to the hypothesis that the perception of soundscapes is relative to the potential for interaction.

4. Conclusions

An important discussion regarding soundscape theory is the capacity of the soundscape to carry information or meaning to the perceiver. How this takes place, however, has only received little attention. It is suggested that, instead of considering auditory perception as a passive reception of stimuli, a broader approach to information and meaning-making is taken.

In this paper, some of the general properties of information in organism-environment relations have been considered. From the perspective of ecological psychology, a perturbation in the symmetry between organism and environment is informative, and the organism must restore the symmetry by behavioral adaption. Similarly, a biosemiotic approach holds that all species have adapted to a subset of the semiosphere, and that a perceptual apparatus specialized in handling relevant signs allow the organism to utilize these signs by means of perception and action.

The coupling between organism and environment was discussed in relation to the way in which the auditory system reflects the environment. Since sounds are causally related to the source events, the human auditory system has been shaped to treat the sounds that are relevant at a human level. Furthermore, the perception-action theories discussed here suggest that the information of the environment comes in the form of functional tones or affordances, properties in the event specifying potential interactions.

Lastly, empirical studies were considered. While there are indeed indications that action is an integral part of perception, further research is necessary to determine the precise dynamics of the phenomenon.

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