MODELS AND STRATEGIES FOR ACOUSTIC DESIGN

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ABSTRACT

The paper presents and discusses three models for acoustic design, namely the traditional, objective energy-based model of the acoustic environment, the subjective listener-centred model of soundscape studies, and the information-based communicational model of the "acoustic community" which attempts to incorporate the other two. For each model, the author presents its basic conceptual framework, its methodological approach, its concept of the role of noise, and its characteristic design criteria and strategies. Parallels between these models of the acoustic environment and those of musical composition are also made. Based on this overview, the limitations and range of applicability of each model to problems of acoustic design in the environment are discussed. The author draws on the 25-year experience of the World Soundscape Project as well as the recommendations of the Urban Noise Task Force of the City of Vancouver (1997) to illustrate various practical implementations of these theoretical models.

Introduction

Acoustic design is an interdiscipline in the throes of being defined, both practically and theoretically. While its daily implementation is of the utmost importance and concern, the heuristic techniques of its practitioners are seldom informed by theory or explicitly related to the conceptual models which they may be understood to embody. And because such models may appear contradictory, their implementation strategies may collide and produce confusion.

I hope to clarify the present situation by sketching the conceptual basis of the two models which seem to stand in the greatest opposition, namely the traditional energy and signal transfer model that derives from acoustical and audio engineering, and the listener-centred soundscape model that has emerged from soundscape studies. In addition, I wish to offer my own acoustic communicational model which attempts to integrate the other two. For each model, I will present its basic conceptual framework, its methodological approach, its concept of the role of noise, and its characteristic design criteria and strategies. I will also attempt to draw parallels between these models of the acoustic environment and those of musical composition. Based on this overview, I will discuss the limitations and range of applicability of each model to problems of acoustic design in the environment.

The Acoustic Environment Model

The traditional model of acoustical processes, whether situated in the theories of acoustics or the applied areas of acoustical engineering, treats sound as a series of energy transfers from source to receiver (White, 1975). This model treats sound, and hence the acoustic environment, as a physical entity that can be studied, and most importantly, measured, independent of the listener. The rather passive role of the listener is as a "receiver" of acoustical energy - a hearer not a listener - whose subsequent reactions to sound become the domain of psychoacoustics. The classical psychophysical approach measures the response of the hearing system statistically and typically formulates a "power law" relating stimulus intensity to the magnitude of subjective response (Roederer, 1975).

source --> transmission path --> receiver --> effects

It is not surprising to find that a similar approach to subjective reactions characterizes noise assessment. Noise is understood as the source of various levels of negative effects on the person, ranging from damage to one's hearing ability, through physiological stress and sleep disturbance, to interference with speech comprehension and task performance (Suter, 1992). However, the most common expression of the subjective reaction to noise has been termed "annoyance", as measured by the traditional social survey methodology. The results are typically plotted on the vertical axis of a graph against stimulus level in the classical psychophysical manner. Some critics have charged that this simplified, averaged response masks a wide range of individual reaction and susceptibility, and that closer examination of those responses might identify a bi-polar distribution, namely individuals who are highly sensitive to noise no matter what the level, as well as those with high tolerance thresholds (Bryan & Tempest, 1973).

The model of linear energy transfer from source, via a medium, to a receiver is expanded in the "message transmission" model of communication by including the coding and decoding of messages as significant stages of what is generally called signal transfer (Leiss, 1991). The audio signal, transduced from its acoustic form into an electrical representation via the microphone, and re-transduced back into an acoustic wave via the loudspeaker, is a prime example of signal transfer where the key concept has traditionally been the "fidelity" or faithfulness of the reproduced signal to the original. The content of the signal is regarded as separate from its quality as measured by a variety of audio criteria, and a great deal of effort has been expended by the audio industry to educate listeners, now consumers, to be knowledgeable about "sound quality" in an effort to valorize their products in the never-ending stream of technical advances in fidelity. However, some industry critics have suggested that consumers are educated only in those criteria which the industry can easily incorporate into their products, not necessarily in those which have the most influence on perceived sound quality (Greenspun, 1986).

The role of noise in the audio context is significant in that in an analog system, background noise is in principle inevitable (whereas in human environments it has merely been the constant accompaniment to every urban environment since the Sumerian cities of the 5th millennium B.C.). Paradoxically, the "noiseless" digital audio domain can only be accessed through the analog gates of analog to digital conversion, and its reverse; hence noise and phase distortion is inevitable. Similarly, computers as machines have introduced whirring disk drives and cooling fans as a constant ambience to all those working with this supposedly "silent" information technology. However, it is the consumer's belief that the reduction of noise and distortion is a consumable value that has been the most recurrent theme of the first "audio century", now drawing to a close.

The design criteria that emerge from the energy transfer and psychoacoustic response model are those which seek to control noise in order to minimize negative effects in those exposed. In certain situations, listener "acceptability" of the noise source is also a criterion, such as what constitutes acceptable background noise levels in offices and other work environments (Beranek, 1971). The linear model from source to receiver translates into a prioritized list of traditional strategies, starting with reduction at the source, proceeding to attenuation via the transmission path, and ending with isolation of the receiver. In other words, the imperative is to change the sound and its environment, not the listener, and such changes must be implemented by experts. This model seems to respond best to "toxic" situations where direct effects can be readily observed, whereas effects that occur over longer periods, involve habituation, or those crossing to other levels, such as psycho-social problems, seem less well served.

The administrative use of this model has evolved to include the determination of appropriate risk criteria for negative effects such as hearing loss. While the exact nature of these criteria is frequently the subject of debate, communication theorists increasingly regard the *communication* of risk as the most important component of the public policy debate surrounding risk. Noise can occur at each stage of the message transfer from the source (experts) to the message itself, transmission via the mass media to a public that is sceptical, apathetic, or wary

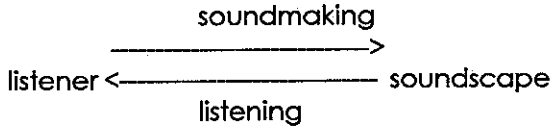
(Leiss, 1991). In industry, the management of the risks of noise has increasingly focussed on the *hearing conservation* paradigm which critics argue appears to be pro-active, but in reality serves to limit industrial liability and expenditure while ignoring the broader range of workers' needs (Hétu, 1994).

Electroacoustic design, as formulated by the audio industry, is based theoretically on the fidelity or quality of the signal, but more precisely, it depends on the production of the consumer (Théberge, 1997) who can discriminate and value degrees of perceived quality, whether the mass produced product or the elite "high end" version (O'Connell, 1992). In situations of inadequate acoustic functionality, the design model offers the surrogate environment of Muzak (a designed stimulus with predictable response) or amplification and equalization of the signal, what is now termed "sound reinforcement". However, these corrective techniques quickly lead to sound "enhancement" and the creation of increasingly artificial sonic images in the service of commerce. What begins as the illusion of fidelity to the real world has become the creation of a virtual synthetic world of greater seductive power than anything in the increasingly meaningless soundscape.

Finally, theorizing about the communicative powers of music frequently imitates the message transfer model (Roederer, 1975). The composer encodes the musical message into a score which can be decoded by the performer and re-coded into the acoustic form which passes to the listener. Although this model may serve to describe the 18th and 19th century European situation, events of the 20th century have fractured the musical code which ensured communication, commoditized and stockpiled the recorded performance (Attali, 1977), and broken down or re-combined the arbitrary divisions of composer, instrument builder, performer and audience in exciting new ways. Acoustic design has much to learn from the new roles in which these traditional "designers" find themselves.

The Soundscape Model

Where the energy transfer model treats the acoustic environment objectively, the soundscape model deliberately places the listener at its centre and hence it may be termed a subjective model. Instead of the one-way linear transfer from source to receiver, the soundscape model most typically describes a balanced, two-way relationship between the listener and the environment. Hildegard Westerkamp (1988) describes this process as the balance between listening and soundmaking, impression and expression. Being listener centred, the soundscape model also places itself in contrast to the energy transfer model which depends on the intervention of experts. In fact, much of the success and effectiveness of the soundscape model over the past 30 years may be attributed to its empowerment of the individual.



Compared to the objective measurements of the energy transfer model, the methodology of the soundscape approach is largely qualitative and depends on perceptual distinctions (Schafer, 1977, 1993). The foreground and background categories of signal and keynote as proposed by the World Soundscape Project (1978a), for instance, are impossible to determine objectively, as they depend on listeners' perceptions which may be constantly shifting. Although acoustical engineers are not averse to identifying sound sources via listening, they are generally loath to venture into the less stable area of qualitative sound evaluation, and even less, the quagmire of listener attitudes. One notable exception to this trend is found in the subjective evaluation of auditorium acoustics where a great deal of funded research has determined that listeners' preferences for clarity balanced against spaciousness, for instance, may be statistically

determined and, most importantly, correlated with objective measures (Rasch and Plomp, 1982; Bradley, 1990).

However, soundscape studies has gone further by attempting to identify listeners' preferences for sounds in general, as well as their phobias. Schafer (1977) has also identified more widespread cultural attitudes expressed as sound romances - a nostalgia for sounds of an earlier time which may have disappeared, or are recreated as tourist attractions - or sound taboos, whose psychological power must be controlled by various social conventions. He also describes a class of loud, potentially invasive sounds that are socially sanctioned and hence immune from public criticism as "sacred noise". Here he touches on a phenomenon known to any acoustical engineer charged with investigating public complaints - social attitudes are often more a determinant of reported annoyance than any objective aspect of the offending sound.

The impact of electroacoustic technology in the soundscape model is frequently characterized as negative (Schafer, 1977, ch. 6). Its "schizophonic" ability to detach sounds from their source and impose them onto another environment, to amplify and to mask, to create endless repetition, and generally to clutter the soundscape, leads to this negative evaluation. Westerkamp (1990) points out that reproduced music shifts the balance of listening and soundmaking in a direction that silences the individual. This use of "music-as-environment" can be regarded as the surrogate solution to the problems of noise, an attempt, even if self-manipulative, to impose order in the face of meaninglessness. However, soundscape recording has been extensively used in this approach both to document and analyze acoustic environments, and as an educational tool to enhance listening abilities. A communicational model is required to reconcile these conflicting attitudes towards electroacoustic technology.

The role of noise in the soundscape model is that it creates an unfavorable listening situation, what Schafer calls a "lo-fi" environment, borrowing the audio engineer's signal-to-noise ratio concept. Although accepting the traditional subjective definition of noise as unwanted sound, the soundscape approach goes further to associate noise with anything which creates negative listening habits, that is, non-listening behaviour. In fact, one of the most cogent soundscape hypotheses argues that rising noise levels will correlate with decreased listening sensitivity which in turn will result in a vicious circle of increased tolerance to further noise. Various psychological attitudes also accompany this desensitization process, such as denial of the intrusiveness of noise, its rationalization as somehow inevitable or a necessary byproduct of social activity, or the internalization of its effects as personal susceptibility.

The criteria for soundscape design are embodied in the ideal of Schafer's "hi-fi", balanced soundscape which promotes active listening and even sonic delight which he describes as the "soniferous garden." The predominant strategy is to maximize pleasing, informative sounds and to minimize unwanted or uninformative (e.g. flatline or broadband) sounds. And since the listener must be central to this process, the educational strategy of "earcleaning" is intended to bring the listener to a state of clairaudience. "Earcleaning in schools to eliminate audiometry in factories," declares Schafer in *The Tuning of the World.*

It is a bold concept that overturns the conventional regulatory approach of the noise consultant and by-law officer. It appears to empower the individual who is otherwise faced with the choice of public protest or fatalistic resignation. It allows the individual to be "for" something of public value, not merely a member of yet another "special interest" lobby group fighting an intractable enemy. The model is strongest when it motivates the individual and weakest when faced with the problems of social consensus and political compromise which are inevitable within the democratic system. It relies on the long-term effects of education and attempts to be the aural conscience of a society which has ceased to be mainly comprised of "ear-minded" people.

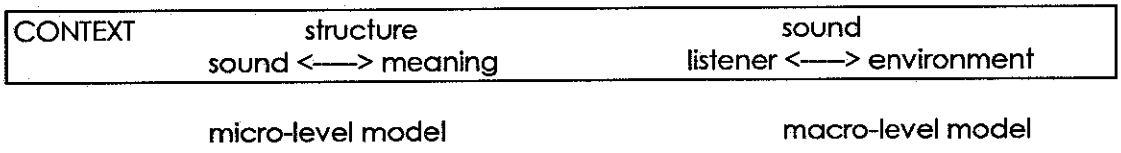
The impact of the soundscape model on musical composition is striking. Along with John Cage and Edgard Varese who opened up the musical universe to *all* sounds, even noise, Schafer (1973) suggested an even more radical concept that the soundscape was a macro-level composition composed by everyone. The intent of this largely rhetorical device is to return the responsibility for compositional design to the listener. Perhaps the simplest and most popular form this may take is the *soundwalk*. Although it is generally considered to be a listening exercise, the soundwalk may also be understood as composition in that the listener chooses which sounds are foreground and background, how much time to spend in any one part of a soundscape, and whether to interact with the environment by producing sounds of one's own. All of the essential elements of composition are involved in an interplay between the listener and the soundscape.

The educational uses of soundscape recording, as referred to above, naturally lead to compositional forms, beginning with the "found" composition where an unedited recording is listened to in the same manner as conventional music. The original World Soundscape Project group, and later various individual composers, also experimented with time-compressed recordings (transparently edited) such as the 24-hour condensations, simulated environments, and the more extensively manipulated form known as the *soundscape composition* (Truax, 1996). In a subtle transformation of the conventional model of the composer transmitting musical messages to attentive listeners, the soundscape composition relies on listeners not only recognizing environmental sounds but also supplying associations and metaphorical meanings, not as incidental to the musical message but integral to it. As composers increasingly use "sampled" sounds as material in electroacoustic music practice, the soundscape composition serves as a useful model to focus issues of source recognition and narrative form (Norman, 1996).

The Acoustic Community Model

It is possible, and I would argue necessary, to move beyond the polarized approaches which I have already described, namely the top-down expert-activated objective model of the acoustic environment versus the grass-roots, listener-centred subjective model of the soundscape. Each model has its strengths and weaknesses which are largely complementary, and therefore their integration (not merely their combination) is desirable. The approach which does this best, I find, is a communicational model (Truax, 1984), which understands acoustic communication as a system within which information is created and exchanged. In order to emphasize the human aspect of such systems, I will refer to them as examples of an *acoustic community* which I define as any bounded system which involves shared acoustic experience among its participants.

The concept of the acoustic community needs to be modelled at two different levels, namely by the micro-level structural model, and the macro-level mediation model.



The micro-level model shows how the listening process extracts meaning in two ways, first by recognizing pattern or structure at various levels (ranging from the micro-level temporal and spectral signature, through the event/gesture level, to longer term forms), and secondly, by the listener's knowledge of context. In other words, what a sound means depends both on the sound itself and its surrounding context. The listener not only recognizes patterns (i.e. ordered information) but also knows how to interpret those patterns based on a wider knowledge of the world. The process of listening, then, is a matter of information exchange. The methodology of this model studies how the acoustic environment creates interpretable differences, hence information (and how the electroacoustic environment often reduces difference through exact repetition).

and how the listener's cognitive processes assign meaning to these patterns through such processes as causality, association, decoding, metaphorical similarity, and symbolism.

The macro-level model describes how sound mediates the relationship between the listener and the environment, where "environment" can refer to the self, others, the immediate soundscape, or any part of society at large. Although this model recognizes the aspect of information exchange, it focuses on a higher level where that information creates, sustains, or in some cases weakens a relationship between the individual and the environment. The methodology of this model studies how such relationships function, such as whether they are positive, stable and binding, or negative, unstable and alienating. Note how the deaf typically suffer from isolation and it will become clear how important the role of sound is in creating social relationships. Electroacoustic mediation frequently takes the form of establishing a surrogate relationship (e.g. the stimulating companion of rush-hour radio) that substitutes for the real one which is lacking. Although messages are transmitted via this technology, its use is largely functional and the listening process itself becomes a consumer activity.

One particular value of this model, compared to the others, is that it makes it possible to trace effects, in the form of patterns of behaviour, across levels. Consider, for instance, the typical impact of noise as a stressor on the body. This effect, and the others associated with it, creates a negative relationship between the person and the noisy environment which in turn may transfer to other social relationships, such as friends and family from whom the affected person seems distant. Such alienation may lead to a loss of satisfaction with those relationships and a feeling of detachment or meaninglessness with society in general. Into this void enter all manner of media surrogates, complete with sociable though "virtual" companions, apparently useful information, soothing or stimulating entertainment, a dependable accompaniment ambience, and if nothing else, a masking agent that distracts one from the real world and one's problems. In the case of broadcast media, the reality is that the listener as a member of the consumer audience is the "product" which is being sold to advertisers (Smythe, 1981).

The role of noise in these models is, first, that it obscures the auditory image and thereby reduces its information, and secondly, that it creates the kind of negative relationships just described. Just as with hearing loss, clarity and definition are lost, and the listener's ability to discern individual sounds among competing sources is impaired. One's perceived acoustic space is reduced and even one's own sounds, whose feedback to our ears we depend on for orientation, become blurred. The sounds produced by technology also tend to reduce difference through their uniformity, constancy and broadband character, thus limiting variety among the "species" comprising the acoustic ecology of any soundscape.

The design imperatives that flow from the two models of the acoustic community are to create a balance between variety and coherence at the level of information exchange, and to create a functional equilibrium at the level of relationships within the community. To implement the former one may need to re-structure the sound in order to make it more informative and patterned, as well as to consider how the sound may be re-integrated into its context so that it may be judged as appropriate and meaningful. Implementing the second criterion of achieving functional equilibrium is clearly more complex because of the various levels that may be involved, but here the model provides some insight into strategies which may succeed. The principle is to modify relationships within the system, particularly those which have degenerated, but the fact that it is a system where essentially everything affects everything else means that one can begin with any element in the system and thereby set off a chain of reactions which may help the system evolve towards a new equilibrium. Unlike the energy transfer model, one can even begin with the listener in the hope that by reactivating people's listening awareness, they will become motivated to makes their own changes to the soundscape, as well as their behavioural and consumption patterns.

The electroacoustic possibilities within this model are enormous as this technology provides unprecedented abilities to create both new sounds and new ways of organizing them. Emmerson (1986) has summarizes this potential as providing a continuum between mimetic and abstract approaches to both the sound material and its syntactical organization. I have argued that electroacoustic technology is significant for the way in which it allows new ways of thinking about sound to emerge, hence new design processes (Truax, 1992). However, one inherent weakness in electroacoustic design is in the way it deals with (or ignores) context. There are no natural examples to follow since every aspect of the communicative process needs to be artificially designed, and schizophonic contradiction is at the heart of the electroacoustic phenomenon. Moreover, composers often subscribe to the aesthetic mandate of the primacy of abstraction in the work of art, in essence stripping the work of any contextual references. However, I have argued that an alternate aesthetic position is possible, even necessary, to integrate art in general, and electroacoustic art in particular, into the social environment, namely one in which the inner complexity of the work is inextricably tied to its external context, as in the soundscape composition (Truax, 1994).

Compared to the negative evaluation of electroacoustic technology found within the soundscape literature, the communicational model tends to view its effects as creating a continuum between the surrogate phenomenon and the creative extensions of electroacoustic communication.

surrogate environment <—> zero-sum <—> creative extension

In the middle lies what might be called the "zero-sum" model in which various pros and cons cancel each other out. Such products carry the illusion of novelty and from a certain perspective, usually the advertisers', offer some advantages. However, they do not entirely replace the older form (e.g. does teleconferencing replace face-to-face meetings?) where the expediency of using the newer form masks the features of the older one which have been lost.

Determining what might constitute a "net" gain instead of a zero-sum process is usually difficult, particularly when the complete impact of a new technology is yet to be felt. In my own experience, the criterion that has been most convincing in observing many technologies come and go is the extent to which a new use of the technology changes our way of understanding the world and other people (Truax, 1984, ch. 14). The key ingredient is not the technology itself - its implications are usually paradoxical - but rather the new ideas which it engenders. New ideas often lead to new technology, but the more important question to answer is under what circumstances new technology leads to new ideas. The answer usually involves a change in the communicational process, not merely the messages being sent. The same technology that allows exact repetition and the surrogate environment, producing what I call distracted listening, also promotes the kind of heightened, analytical listening involved in electroacoustic design. The predictable and unvarying radio format may be controlled by the same computer that permits the composer to assemble startling new combinations of sound. And the mass market commodity produced by a transnational corporation and promoted by a multi-media ad campaign may contrast with the niche market self-productions of the cottage industry with its personal website.

Strategic Models

In *Acoustic Communication* (Truax, 1984, ch. 6) I suggested three types of strategies which might complement the conventional anti-noise approaches of regulation, abatement and control. These were (1) listening and critical evaluation; (2) preservation and protection; and (3) design of alternatives. All of these strategies were intended to create a greater individual and public awareness of the value of sound as a benefit to all, not merely the minority of the aurally sensitive.

A recent opportunity presented itself to pursue some of these goals within the public sphere when the City of Vancouver appointed an Urban Noise Task Force, of which I was a member. The final report of the Task Force, entitled *City Noise* (after the original 1929 New York City report), began with 12 recommendations concerning public education (City of Vancouver, 1997), which may be summarized as follows:

(1) City to include acoustic aspects of future environmental planning;
(2) City to fund an ongoing educational program (called the *Earcare Program*);
(3) Public awareness and feedback on noise issues via a "noise hotline" and city website; mediation offered for situations falling outside the city by-law;
(4) A noise "thermometer" to be installed at a prominent location as a reminder of current and past levels;
(5) Warnings and earplugs at establishments with high sound levels; survey of restaurants with favorable sound environments;
(6) City soundmarks given heritage status and existing heritage buildings with positive acoustic qualities designated as "sound sanctuaries";
(7) Quiet parks increased and made more effective and better known;
(8) Tourism information supplemented by maps and guides to soundwalks, soundmarks and events of sonic interest;
(9) Seasonally timed information sheets to be sent out with municipal mailings, press releases, etc.
(10) School visits by city employees to include soundscape and noise information; encourage use of curricular materials;
(11) Communication between the city and public organizations, particularly those involving the hard of hearing, regarding noise issues;
(12) Communication with neighbourhood organizations, plus public input via the city's website, regarding noise issues.

All of these recommendations were designed to bring acoustic issues into greater public awareness, not just when the individual feels harassed by a specific problem. Acoustic issues must constantly appear to be on the public agenda, and not merely the responsibility of experts - everyone can play a part. Following the soundscape approach, proposals must include both *noise* issues, that is, the elimination of negative effects, and *soundscape* issues, promoting and preserving the positive aspects of the acoustic environment. However, the larger strategy is to suggest in every possible way that acoustic issues are "quality of life" concerns that should be part of the public agenda. Acoustic ecology, to my mind, provides a remarkable model for ecological thinking in general, yet soundscape issues are seldom included when environmental issues are discussed. There seems to be an increasing public support for action on such issues, including personal involvement. It is up to the "ear-minded" community to suggest intelligent design strategies that will put acoustic issues on the public environmental agenda.

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