THE RELEVANCE OF SOUNDSCAPE RESEARCH TO THE ASSESSMENT OF NOISE ANNOYANCE AT THE COMMUNITY LEVEL

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Introduction After consensus has been reached about harmonized indicators of noise exposure (Miedema & Oudshoorn, 2001; EU-directive on environmental noise, 2002) and a standard annoyance question format (Fields et al 1997, 2001) it seems we have forgotten that the size of variance explanation of the standard dose-response curve is limited (Job 1988) and varies from location to location. We still face several major challenges to overcome (Lercher 2001, 2003):

- Single source assessment – but typically several sound sources are present
- Mono-sensory assessment – but other sensory qualities (visual, air, vibrations) contribute
- Predicting change – but data are only valid for "steady state" conditions-
  Generalisation across context – given substantial differences in context

The challenges must be placed in the context of recent policy developments (WHO 2000, OECD 2000, CEC 2002, Norway White Paper 2002) which need a firm basis for effective and efficient action.
Multi-sectoral environmental health impact assessment, the perspective on sustainable development, environmental zoning (e.g. in Norway), citizen involvement, preservation of quiet areas, consideration of "sensitive areas" and the design of "supportive environments" require new insights in the existing annoyance data new integrative research strategies.
The soundscape approach can contribute to these requirements, because its main aim is the study and the improvement of the relationship between the "aural space" and the living environment - the "soundscape" (Wrightson 2000). The sonic environment is seen here as mediator between humans, their activities and the environment. Depending on the "acoustic colouration" from the larger environment (geography, climate, wind, water, people, buildings, animals etc.) sound sources create "meanings" to the exposed and block or enable human activities, thoughts, feelings. Therefore, soundscape assessment is engaged in assessing acoustical but also other sensory, aesthetic, geographic, social, psychological and cultural modalities in the context of human activity across space, time, and society. Such an approach clearly helps to overcome the sectoral barriers.
The paper provides a short account of the variety of approaches, presents selected examples of current aspects of soundscape research and intents to make the utility of the soundscape approach for the assessment of noise annoyance at the community level more visible.

History and main approaches In the original soundscape approach, Schafer (1977) was worried about the dominance of the "eye culture" and the parallel loss of "sonological competence" in the modern societies. This concern let him develop a series of hearing exercises which aimed at maintaining a high level of sonic awareness. The interaction of people and sound, the way people consciously perceive their environment were therefore central in his approach. He understood the acoustic environment as a musical composition for

which we own responsibility. His first field studies (World Soundscape Project) involved level measurements (isobel maps), soundscape recordings and the description of a wide range of sonic features. The interest was directed to distinguish "hi-fi" from "low-fi" soundscapes by recording and transcribing it into acoustical spectrographic maps. From these analyses he concluded: a "hi-fi" soundscape can be characterised by its lack of masking from noise and other sounds. This lack of masking allows full interaction with the physical and social environment and leads to "acoustic coloration", which provides significant information to the listener and fosters a sense of place for those living in the area. On the opposite site, in "low-fi" soundscapes meaningful sounds are masked to such an extent that an individual's "aural space" is shrunk and the listener is isolated from the environment. While a "hi-fi" soundscape is balanced in terms of level, spectra and rhythm, the "low-fi" soundscape consists of almost constant level – creating a "sound wall" which is also biased towards the low frequency range and blocks interactions with the ambient environment. In such an acoustical environment individuals try either to shut the noise out (closing windows) or to control it with "acoustic perfume" (creating a virtual soundscape with music or other sounds). Sound is used here as defensive barrier ("audioanalgesic") against the soundscape and leads to further increase in local sound levels. He hypothesised that the "sound wall" blocks the inner dialogue, leads to unexpressed thoughts and feelings, decreases psychological health and may also explain inappropriate actions – the worst case scenario - people killed due to disputes over noisy neighbours. Indeed, neighbour noise accounts for a large amount of annoyance complaints, as recent surveys from the UK and the Netherlands indicate (van Dongen 2001, Grimwood 2002).
Schafer's phenomenological approach is intriguing and may be true for the two outer poles (hi- and low-fi) he describes but clearly is an elitist perspective. It seems difficult to escape the inherent good-bad dichotomy in the form of an aesthetic moralism (Wagstaff, 1999) and the majority of people are exposed to sound in the midrange level (45-65 dB,A), where dichotomous criteria may not result in effective action. Nevertheless, the approach brought a systematic to the discussion and a bunch of thoughtful ideas to convert into practice:

- It is not only the level that matters, it's the balance in level and frequencies
- It is the daily rhythm and the amount of meaning left in the soundscape
- Sonological competence must be learned and incorporated into environmental design
- If people perceive their environment consciously they will have a chance to change it

In order to widen and/or strengthen the criteria for good soundscapes many individuals and group of researchers have provided input – often not well recognized from the outside of these small communities.
Within the soundscape community, some argued for an integration of the phenomenological approach with ecological and social theories to make it more valid (Winkler 1995, Wagstaff, 1999). The concepts and results from gestalt-theory, ecological (Gibson, 1982) and cognitive psychology (Neisser, 1982; McAdams 1993) were proposed as complementary pieces.
Other earlier and recent work in Environmental Psychology and Sociology is related to this approach (Kastka and Noack, 1987; Carles et al. 1992; Tamura, 1997; Maffiolo et al., 1999; Suzuki et al., 2000; Berglund and Nilsson, 2001; Schulte-Fortkamp 1999, 2002; Viollon et al., 2002) and a fuller utilisation of these ideas in annoyance research should be fostered.
Today's Acoustic Ecology represents a broad variety of approaches (e.g. ecological, sociological, phenomenological, semiotic).
Acoustic ecologists have developed a variety of descriptive and analytical techniques , such as "participatory sound & listening walks", "Ecoute réactivée ","cognitive maps", "acoustical spectrographic maps", "soundscapegraphy" (Amphoux 1993, 1995, Truax 1998, Augoyard, 1998, Hiramatsu 1999, 2001).

Augoyard (1999) proposed six fundamental dimensions to explore by taking four necessary relations into account at the same time. Ipsen (2000) identified three relevant components for soundscapes analysis: the context, the focus of attention, and personal knowledge/experience.
Architectural groups in France have a strong emphasis on urban planning and design, making heavy use of geographic information systems (GIS). They use additional layers of social, behavioral, and sensory modalities as GIS-input to implement innovative procedures into architecture and sound design (Grosjean and Thibaud, 2001). For practice examples visit their webpages (Cresson, CERMA, Acroe/ICA). In Japan, soundscape activities have focused mainly on interdisciplinary research, the sonic design and conservation of public spaces (Hiramatsu, 1999). An outstanding part of the last activity is a huge conservation program of 100 diverse soundscapes across the country (Torigoe, 1998; Hiramatsu, 1999).
The field of psychoacoustics has contributed a lot to understand the limitations of the A-weighted sound level in dB as criterion metric (Zwicker and Fastl, 1986, 1999). The further development of binaural analysis (Genuit 1999, 2002) and supplementary assessment criteria – like sharpness, roughness, fluctuation strength brought progress into the assessment of complex sound environments and made specifically tailored intervention measures feasible.
Unfortunately, the analytical potential has been almost exclusively utilised for consumer and industrial products or for closed spatial units such as cars, trains, air planes, and workplaces. Applications within in the field of community annoyance remain rare, partly, because a sound propagation model for loudness does not yet exist and the currently required measurement expense is prohibitive for standard application. Therefore, Schomer (2000) and Schomer et al. (2001) have recently proposed an approximate method (loudness-level weighting) that is easier to implement for environmental noise assessment.
The engineering approach of the sound design community has considerable overlap with psychoacoustics. The emphasis is more on auditory system quality (Hempel and Blauert, 1999; Hempel, 2001). The range of contributions goes from product sound quality (Blauert and Jekosch, 1998), virtual simulations of noise exposure, improvement of the human-environment interaction to sound quality assessment (Blauert and Jekosch, 1996; Susini et al., 1999). The sound design of indoor and outdoor spaces can be considered as a specialized branch of these activities (Namba, 1994, Ando, 1998).

Selected annoyance related empirical research The empirical work spans over a wide range of applications and includes experimental, small- and large-scale field work. Some of the major topics and results are shortly described.

Integrated environmental context analyses An earlier review indicated that certain aspects of residential quality work like a noise exposure equivalent and build up interactions (Job 1991). The decibel equivalent of various factors may range up to 25 dB,A. As Norwegian research has shown, the contribution of the components to annoyance can substantially vary in different residential areas (TOI 1992).
Recent studies have shown strong mediator effects of vibrations and air pollution on the annoyance response (Passchier-Vermeer 1998, Zeichart 1998, Lercher et al. 1999, Klaboe et al. 2000, 2003). Klaboe (2000a) consistently speaks of the "omitted variable" problem, when dose-response regression models do not take into account sufficiently other environmental indicators (air pollution, vibrations, safety) which may co-vary with the soundscape.
Botteldooren et al. (2002a) introduced a flexible, fuzzy expert rule based engine to predict noise annoyance. They tested it on various context, life style, coping and health variables and found a more accurate prediction at the individual level.
Using similar fuzzy models with another survey, Verkeyn & Botteldooren (2002b) found an effect of some land use variables on the reported noise annoyance keeping sound level

constant: reported traffic density and degree of urbanization made significant, separate contributions in a Ldn based model. In a classical analysis, people living in an environment with rather uniform land use were found to report less frequently high annoyance by road traffic noise than people living in a mixed environment or at an edge, compared with what is expected based on an Ldn based model.
Schulte-Fortkamp & Nitsch (1999), following Schafer's (1977) and Meyer / Meyer-Dallach's (1992) distinction of macro and micro level analysis, could show the usefulness of this approach in a multi-source environment to predict noise annoyance by triangulation of objective and subjective data. In a further study with a multi-exposure helicopter environment (Schulte-Fortkamp 2002) a context oriented semantic differential was developed and subjected to principal component analysis. It revealed that aside noise and vibrations a number of other environmental characteristics (air pollution, temperature, humidity, air drafts etc.) were related to comfort and well being).
Based on earlier findings, that response to sound depends on the listener's mental, social and geographical relation with the sound source, Hiramatsu et al. (1999) have proposed a method for comparing sonic environments on the basis of physical properties of and experiences and/or memories on sonic environments. As an extension of this approach they developed the Environment Similarity Index (ESI) to judge differences and/or change in the quality of various environments (Hiramatsu et al. 2001).
Lercher et al (1999) provided indirect evidence for the higher demand on residents when noise sources interact with the specific acoustic and environmental makeup (topography, meteorology, land use pattern, and lifestyle): "The higher dissatisfaction expressed with their environment, in spite of overall satisfaction with personal life quality, points to difficulties to control the noise adequately."
Indeed, Hatfield et al. (2002) found perceived control over aircraft noise negatively correlated with some (but not all) effects of noise. The observed effects were also better predicted by perceived control than by noise level. This is in line with Taylor and Repetti's (1997) mentioning of "the ability to predict and/or control aspects of the environment" as one of three main components of a "healthy environment".
In one of the rare annoyance studies with children, the largest moderation of the reported noise-annoyance curve came from satisfaction with the living area (I like to live here) and from opportunities to act out and have fun in the neighborhood (Lercher et al. 2000a).

Audio-visual interactions The effect of visual settings on the perception of noise has been demonstrated in many laboratory and field studies (Carles 1999, Abe et al 1999, Suzuki 2000). In an appealing recent experiment Shan et al. (2002) demonstrated that auditory information can even qualitatively alter the perception of an unambiguous visual stimulus.
Evaluating garden soundscapes, Maffiolo et al (1999) found, that a positive evaluation of the landscape reduces annoyance of the soundscapes whereas a negative evaluation of the landscape increases annoyance. From several smaller field studies in Norway, Fyhri & Klaboe (1999) derived that living in a "pretty" street (mean ratings on nature, buildings, roadside) reduces annoyance by a dB-equivalent of about 6 dB.
Viollon et al. (1999, 2002) observed that some types of sound environments were rated significantly more negative when associated with more urban visual scenes (bird song and traffic noises), but other environments (i.e. environments involving human noises) remained unaffected by co-occurring visual stimuli and independent of the degree of urbanization of these visual stimuli. The degree of matching between visual and auditory information has been forwarded as possible explanation. Another argument is that more orienting sounds (like human voices) draw attention towards the auditory modality and the importance of other modalities will be lessened. In an alpine valley, Lercher et al. (2000b) found higher annoyance

where the incongruence between ambient nature and road was high and lower annoyance where the surroundings fit more with the road structure. These results are compatible with both the matching argument and an attitudinal approach based on expectations. Another study by Carles et al. (1999) also revealed that coherence between sound and image influences preferences and coherent combinations were rated higher (better) than the mean of the component stimuli.

Urban planning, residential design and building structure In order to minimize the traffic noise problems in urban areas it has been proposed to keep the main traffic flows at the widest possible mesh size and to minimize the traffic inside the meshes (Kihlman & Kropp 2001). But inside the meshes the design matters. The traditionally quiet courtyards in old European cities are a good example for a highly effective and cost efficient design to provide a "quiet side" for residents. A Swedish research programme is investigating the potential of this design feature with respect to health and well being (Kihlman et al. 2001; Berglund & Nilsson 2002, Kihlman et al. 2002, Skanberg & Öhrström, 2002). Unfortunatley, a closer inspection revealed that the shielded sides of the buildings are not as quiet as expected. This research has shown that existing traffic noise prediction methods underestimate noise levels even in well shielded courtyards by 10 to 15 dB. This is mainly due to the contribution of traffic noise from the wider area (Kihlman 2002) or due to significant neighbourhood differences in traffic (Klaboe 2000a)
Berglund & Nilsson (2002) concluded from a perceptual analyses of courtyards that psycho-acoustical instead of acoustical criteria are needed to improve the shielding effect.
Another issue not yet fully understood is the reported relationship of house type (apartment versus others) with annoyance (Sato et al., 1999, Lercher et al. 2000a, Sato et al. 2002). While apartment homes were found to have lower annoyance reporting at the same noise level in one study the other study found the opposite. Differences in outdoor area design and/or indoor structure/design of homes may be responsible for these discrepant findings. For instance, indoor density (persons per room) was related to higher annoyance in children and their mothers with road traffic noise but not with rail noise exposure (Lercher et al. 2000a).
A UK-project (RUROS) links the soundscape approach into the intentional design process of urban public spaces (Yang & Kang 2001). First results from a comparison of 3 open spaces revealed human activities and sound from landscape elements as most preferred sounds. On one site, people were more satisfied, when they used the site for recreation, when they stayed longer/often and when group sizes were larger. These findings did not fully fit the other sites.
In another study of Berglund (2001) the participants characterize the residential soundscapes under four dimensions, namely, *adverse, reposing, affective,* and *expressionless*.

Aspects of quiet sites Agnesod et al. (2001) reported a first attempt to monitor acoustical changes in an Italian mountain resort. They used classical indicators (L95, L5, Leq) to locate geographical areas of increases in intrusiveness of the soundscape and linked it to activity pattern of the area.
Appelberg & Runström (2001) conducted several projects to define and localize quiet areas for a nature conservation program. They used a five-step exclusion approach to arrive at candidate areas below 30 dBA,Leq which are now subject of further investigation.

Acoustical issues in soundscape research
Measurement issues Pesonen (2000) summarized the significant seasonal variations in soundscapes observed in cold climates. The reasons include emission pattern, life style and activity pattern and excess attenuation processes (meteorology, ground impedance, vegetation

related). These variations can cumulate (sound channelling above a bigger lake) or cancel each other in small areas and more input variables are required for adequate modeling.
Hohmann (2000, 2001) outlined the potential use of sourroundscapes to demonstrate and communicate harmonic and disharmonic effects of an urban environment in real time.
Genuit (1999, 2000, 2002) reported about various uses of binaural measurement techniques and psychoacoustic indicators to receive a more objective description of the subjectively perceived sound quality. Virtual binaural simulations allow lab-analyses of soundscapes and how these soundscapes are affected by addition or removal of sound sources.
The low frequency issue It is well known that problems exist with the proper annoyance assessment of sound sources containing strong low frequency components such as diesel cars, trucks, ventilation and air-conditioning systems etc. (van den Berg 1998, Persson Waye et al. 2001, Persson Waye et al. 2002). Unfortunately, the quietness of courtyards is often polluted with low frequency sound from air-conditioning systems (Persson Waye et al. 2003)
Mixed noise sources When noises from different sources have to be judged, more difficulties arise. Only recent research has confirmed a variety of possible combinations with considerable moderation of dose-response relationships (Moehler et al 2000, Joncour et al. 2000, Cremezi et al. 2001, Botteldooren & Verkeyn 2002c). Although there are various attempts to solve this problem, there is no definitive model or procedure which covers the diverse requirements. To effectively estimating combined effects there is the need to provide a better map of the relevant psychscape variables, obtain more precise indicators of the sound – and enviroscape factors and to find out how to bind it all together (Job 2000).

Discussion and Conclusions Harmonization of indicators and noise mapping – as required by the new Environmental noise directive delivers basic administrative information for comparisons across European countries. Such activities do, however, not provide any tools nor essential knowledge for more demanding tasks which are required in environmental health impact assessments and in the design and planning of sustainable environments which are supportive to health. At this intersection, soundscape research does aim to fill the gaps. Without knowledge of the determining factors "behind" the dose-response curves the decision process to "action plans" is narrowed down and alternative courses of action to handle the noise problem cannot be sufficiently considered (Wright & Grimwood, 1999; Flindell & Porter, 2000).
Content aspects of research The label "soundscape research" currently runs the risk of inflation. Researchers conducting classical annoyance research have relabelled their activities. Future research with this label should be required to define the contribution to this field more carefully. Some investigations were designed with too narrow research questions and analysed in isolation from the other psych- and enviroscape while other studies missed a clear focus.
We see an urgent need for the use of innovative designs which integrate the different levels of current analyses (qualitative & quantitative, individual & aggregate level). The mediator/moderator concept requires methodologically sophisticated analyses – only a minority of research does comply with this demand. Therefore, existing data are sometimes not fully exploited or samples are too small - which calls for multi-center studies with standardized study and analysis protocols.
Among the many potential research ideas some clearly have higher priorities. The question about the criteria (beyond sound level) of a "good" soundscape or what is a "sensitive" soundscapes or what are the soundscape requirements of a "resort area" or a "quiet area", which should be protected, are central to the origin of the soundscape idea. Other classical acoustics questions such as the role of background noise, audibility, intrusiveness under critical conditions, under condition of mixed sources and time pattern should be asked differently than hitherto to deepen understanding. Both central questions should be persued only in the context

of psych- and enviroscape – preferably studied in different areas with a sufficiently large sample of typical urban and rural layouts, lifestyles and pattern of land use.
Organizational aspects of research The still wide scatter and isolation of research requests further hard work to bundle and integrate activities to serve effectively and efficiently the intended contributions. The personal efforts of the authors of this paper within ICBEN Team 6 through the organization of regular "soundscape sessions" at international noise conferences was a first step in this process. Still, many groups do not yet recognize each others contribution sufficiently – as a close inspection of quoted reference lists undoubtedly uncovers. The next step must involve common research proposals which try to integrate the wide range of activities (experiment, field, assessment, planning). This requires funding plans that are better suited to team up smaller group expertise world-wide and that value higher the integrative aspect of these approaches.

References

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