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Sound Quality Aspects for Environmental Noise

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Abstract

The environmental noise has an important contribution to the total life quality of human being. The annoyance of noise depends not only on the A-weighted sound pressure level. The human signal processing is more complex. The transformation of a sound event into a hearing event is influenced by different aspects: first the physical aspect, the sound will be changed in dependence on frequency and direction of incidence, second the psychoacoustical aspect, the inner ear perceives sound dependent on the time structure and frequency distribution, and third the psychological aspect, the context, the kind of information, the individual expectation and attitude to the sound are influencing the classification of the sound event. With respect to product sound quality the acoustical engineers take care of all these parameters. At which time we will start to consider sound quality aspects for environmental noise?

1. Introduction

Acoustic environments are evaluated by our own human hearing, the sound perception mechanisms of which can be described in terms of psychoacoustic parameters, such as loudness, sharpness, roughness, and fluctuation strength. Other parameters necessary in fully capturing an acoustic environment in engineering terms are the number of signal sources (and their spatial distribution), and also the direction and speed of any movement of these sources [1]. Nevertheless, questions as to the annoyance of environmental noise cannot be satisfactorily answered by reference to these parameters alone. Both the nature of the information in the acoustic environment and the personal attitude of those hearing it greatly impact the subjective impression. Available for some years now, Artificial Head technology has proven an eminently useful tool as an objective recording system, able to weight sound in relation to the direction of sound incidence and thus be analogous to human hearing [2]. Furthermore, Artificial Head recordings, backed up by listening tests, are also able to provide aurally-accurate reproduction of acoustic environments with the aim of achieving auditory events which are directly comparable.

2. Aurally-equivalent Sound Analysis

The characteristic of the outer ear enables human hearing to perceive the difference in loudness between sound events arriving at the ear from different angles of incidence. Psychoacoustic calculation methods [3], as a function of time structure and spectral distribution, produce results which yield information of greater differentiation than is possible with A-weighted sound pressure measurement. Human hearing may perceive a narrowband sound source as less loud than a broadband sound source of the same A-weighted SPL. Sound sources in which SPL is greater in the higher frequency spectral ranges result in a sharpness which normally increases the annoyance of the sound. Time structures, in particular those arising through modulation, give rise to fluctuation and roughness, which in turn may cause a sound to be perceived as more apparent and also more unpleasant. Properties of this kind also partly persist when the broadband level of the sound source is reduced. Above all, human hearing can be thought of as a process of pattern recognition, able to detect certain spectral patterns and time structures irrespective of absolute SPL [4]. This means that human hearing adapts itself to a basic noise level and essentially only captures the relevant pattern in the time and frequency domains. A sound event perceived as annoying because of quite definite features arising from certain time and spectral structures will be equally unpleasant if the dB value is reduced, for example, by 3 dB.

3. From the Sound Event to a Hearing Event

Fig. 1 is a schematic diagram of the process involved in sound perception, directly applicable to environmental noise. Several parameters are involved from the sound source to the perceived noise quality. It becomes obviously that this complex relationship between sound emission on the one hand and classification by listener on the other hand cannot be described properly by only the A-weighted sound pressure level.

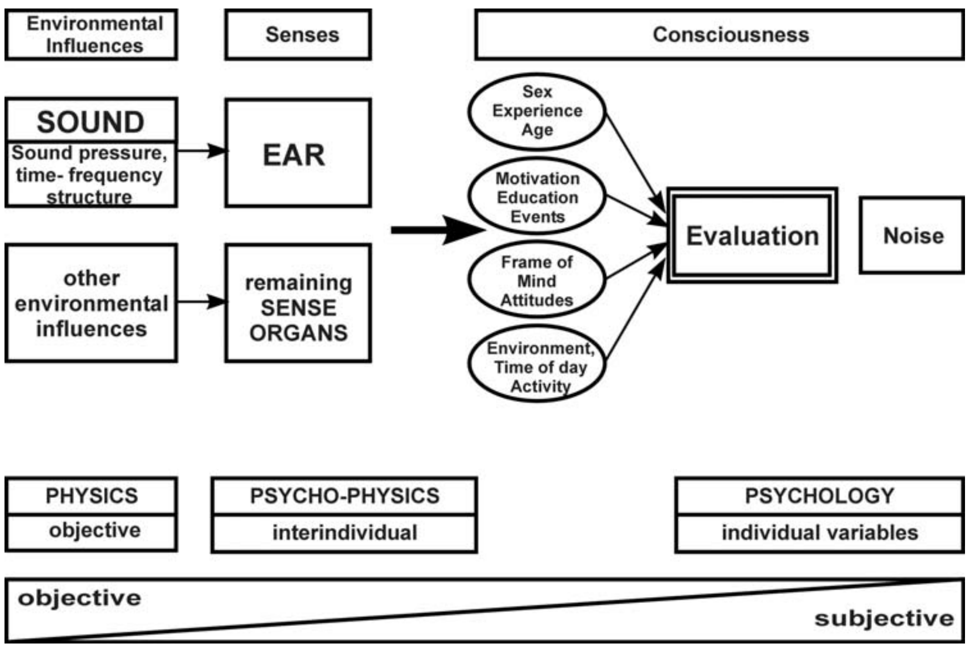

Figure 1: The process of sound perception [5]

4. Sound Engineering of Environmental Noise

Sound engineering [6] generally requires

- a general definition of the term „sound quality“
- applicability testing of existing measurement and analysis techniques
- taking account of the requirements of affected individuals, and, in consequence, the special characteristics of the human hearing
- the development of calculation techniques and describing variables, leading to objectification of subjective noise rating in terms of reproducible testability.

The enterprise of linking the various dimensions of sound event capture will eventually result in a definition of the term „sound quality“. However, practice has shown that a definition of terms of this kind is no straightforward matter. This is because sound quality is determined by a large number of different parameters (see fig. 3). Alongside the more familiar actuating variables, such as SPL, duration of exposure, spectral composition and time structure, also included are spatial distribution of sound sources and information content, plus the hearer's subjectivity.

Artificial Head measuring [2] technology allows true-to-original recording and reproduction of instances of noise pollution. This creates the basis for an extensive database containing a wide range of sound environments, thus providing a pool of expert knowledge enabling specialists to become aware of and trained in identifying a range of different sources of noise pollution, with a view to successfully developing appropriate countermeasures. A-weighted sound pressure levels in excess of 85 dB(A) are a basic risk to human hearing, but can be measured without the necessity of extensive binaural measurement technology and psychoacoustic analysis techniques. However, in the threshold ranges around (and also greatly below) 85 dB(A), Artificial Head measurement technology, as an aurally-accurate sound recorder using aurally-equivalent analysis techniques, can deliver clear and meaningful results for the classification of noise annoyance and its accompanying physiological effects (see Fig. 2).

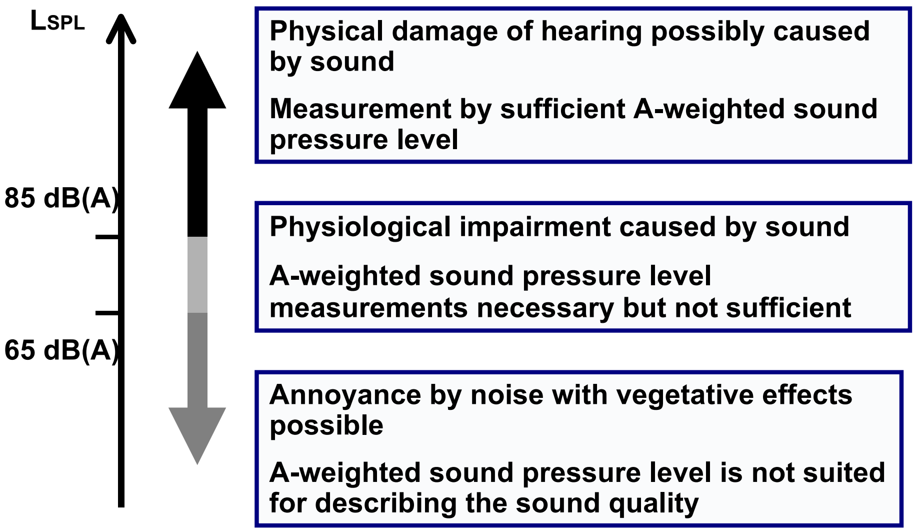

Figure 2: Significance of A-weighted sound pressure level

Environmental acoustic design can be regarded as a multidimensional task comprising a number of different aspects:

a) Physical aspect: previously the only aspect to be taken into account. This aspect ensures prevention of physical damage to the inner ear.

b) Psychoacoustic aspect: sound recording with the aid of the Artificial Head Measuring System and analysis, comparable to how the human auditory apparatus functions. Incoming sound waves are weighted by the filter effect of the outer ear and analyzed in relation to spectral and time structure.

c) Cognitive aspect: the information content of the sound event, movement of the sound source and also the way in which individual subjects relate to the sound event have an effect on physiological response, and thus the extent to which individuals exposed are affected.

5. Sound Quality Parameters

All previous attempts at standardizing the term „sound quality“ have failed. In what follows, the term „sound quality“ is to be understood as the degree to which the sum of all the individual demands made on an auditory event are satisfied [7]. Generally, we can say that sound quality is negative when sound events lead to auditory events perceived to be unpleasant, annoying, or disturbing, or produce negative associations or sounds uncharacteristic of the product. Similarly, sound quality is positive if auditory events are not perceived as such, produce no disturbance, result in a pleasant auditory impression or create positive associations in relation to the product.

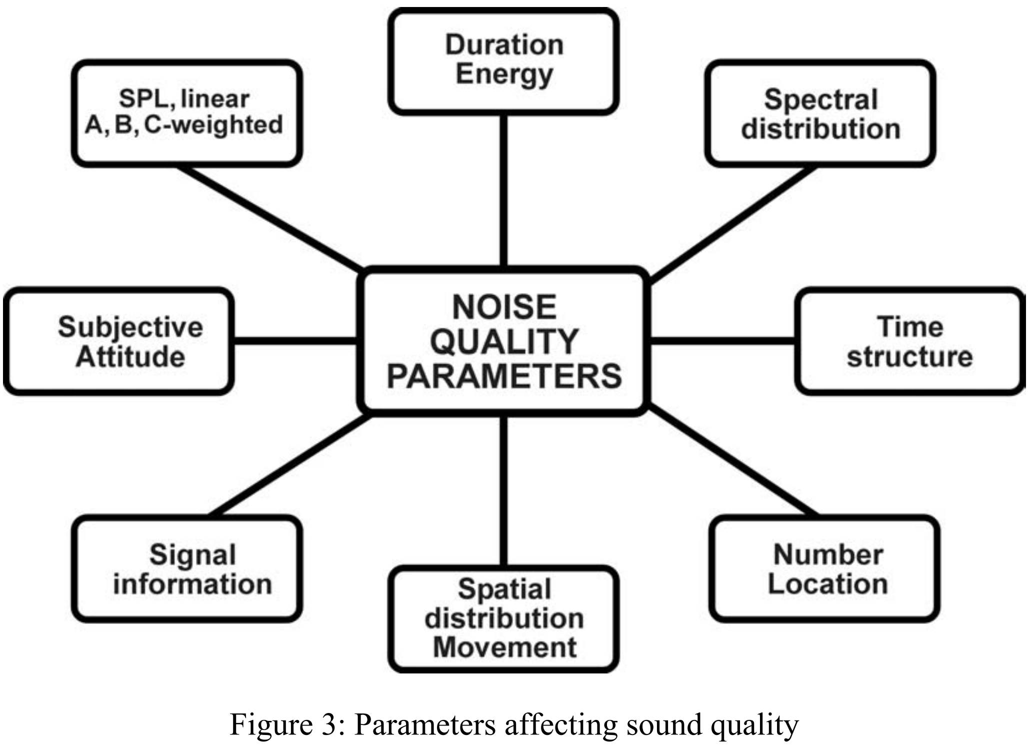

Figure 3: Parameters affecting sound quality

The first step towards engineering environmental sounds is by adequately processing acoustic signals using aurally-equivalent measurement and analysis techniques. This is currently being achieved in large sectors of the automobile industry through the application of Artificial Head technology. Alongside aurally-accurate recording, this technology provides the following advantages in aural monitoring of sound [8]:

- sound uniquely defined
- repeatable as often as required
- direct A/B comparison
- unlimited archiving
- no environmental distraction
- spatial impression

Also required to arrive at a global evaluation of sound quality is a fundamental knowledge about the psychoacoustic properties of human hearing, combined with the cognitive aspects and source-related weighting (see fig. 4).

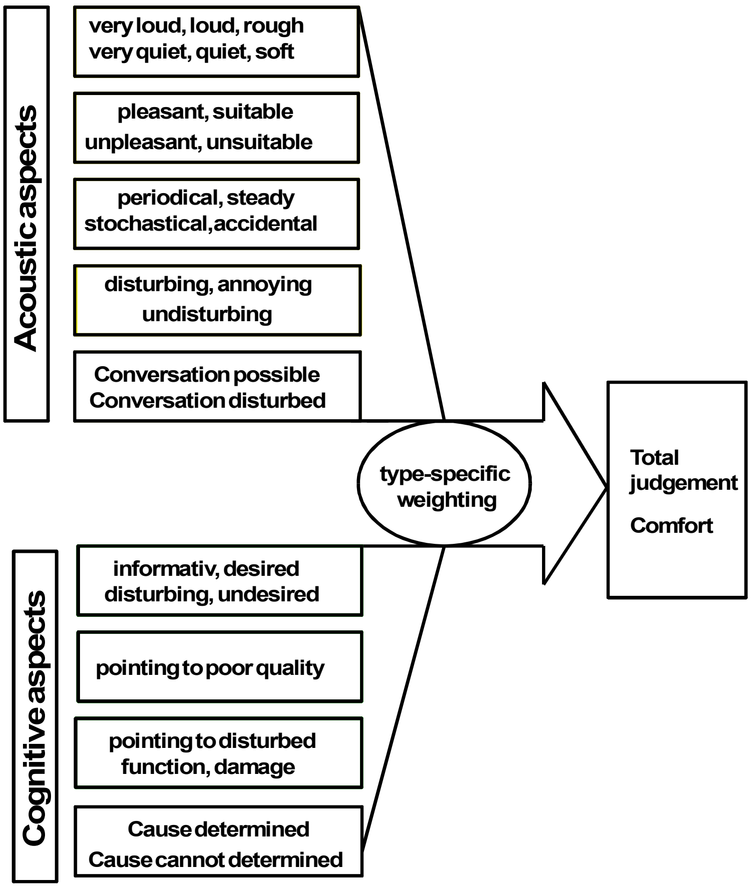

Figure 4: Variables applying for subjective rating of noise comfort level

Only an approach which takes account of the all aspects described here can result in adequately engineered environmental noise, achieving auditory events perceived at least as non-disturbing, if not actually pleasant.

6. Conclusion

“Sound quality is most definitely in the mode... except for one important area. Environmental noise, where A-weighted equivalent level (L_{Aeq}) continues its convenient dominance.

This is the great contradiction in our approaches to noise. When we want to sell something we make it sound good. But when we want an environmental criterion we suppress all the sound quality by averaging over long periods and take no account of what it actually sounds like. We rate intermittent noise in the same way as we rate continuous noise. We suppress low frequencies. We suppress the information carried by fluctuations. We throw out the recognized subjective contributors to sound quality, whilst assuming that those exposed to the noise have brains like buckets of water. Our legislators and decision makers must relinquish the comfort given them by L_{Aeq} criteria, behind which they hide at the first mention of noise. It is time to send them a clear message: **Put some quality into environmental criteria.** [9]”

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