Psychoacoustics and Sound Quality

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1. Introduction

One goal of sound quality research is to end up with a product sound, preferred by most customers. Hence, sound quality is a magnitude which can be tackled by psychophysical methods. Sound quality and psychoacoustics have many aspects in common, since the goal of psychoacoustics is to quantitatively describe the relation between stimuli, defined in the physical domain, and the related perceptual magnitudes.
In this paper, methods useful for both psychoacoustics and sound quality are addressed. Since psychoacoustic magnitudes have been extensively described in the literature, they are only briefly touched. Differences in the evaluation of the same sounds by subjects from different cultures are described, and a procedure to neutralize the meaning of sounds is illustrated. Finally, the influence of other modalities on sound quality evaluation is mentioned.

2. Methods

For sound quality evaluation, psychophysical methods are used which have proven successful in psychoacoustics:
Ranking methods indicate, whether a product sounds better than the product of a competitor. The method of Semantic Differential gives hints, why a specific sound is suitable to convey an intended message, e.g. as a warning signal. Finally, category scaling and magnitude estimation can give an indication, how much the sound quality of products differs. This is of particular relevance for cost / benefit evaluations. While traditional category scaling is confined to five step or seven step scales, magnitude estimation in principle has an infinite resolution. However, in practice effects of the frame of reference as well as influences of the choice of the anchor sound have to be taken into account.

Figure 1 shows an example for a ranking procedure which frequently is called “Random Access”. When clicking on the icons, the respective product sound, e.g. of an electric razor, is heard. The task of the subject is to order the razor sounds by click and drag in a sequence of decreasing sound quality. The subjects can listen as often as they like to the sounds, and correct the sequence until a final status is reached. This large freedom of the subject, who has “random access” to the sounds to be scaled, is one of the reasons that this procedure is nowadays preferred for ranking of sound quality.

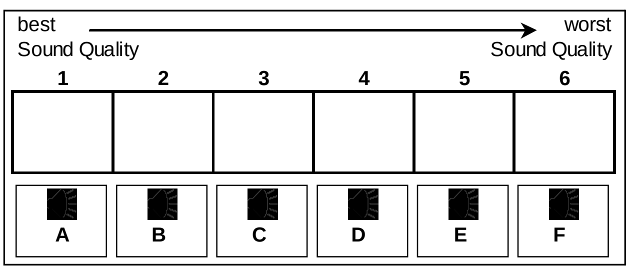

Figure 1: *Example for ranking of sound quality by “Random Access”.*

The method of Semantic Differential is used to test, whether a sound is suitable for an intended purpose. In figure 2 an example is given of adjective scales used in an international study on the suitability of signals as warning signals (Kuwano et al. 2000). Signals which are suitable as warning signals should have high loadings on adjectives like dangerous, frightening, unpleasant, etc.

adjective scales	
loud	soft
deep	shrill
frightening	not frightening
pleasant	unpleasant
dangerous	safe
hard	soft
calm	exciting
bright	dark
weak	powerful
busy	tranquil
conspicuous	inconspicuous
slow	fast
distinct	vague
weak	strong
tense	relaxed
pleasing	unpleasing

Figure 2: *Semantic Differential used in an international study on warning signals (Kuwano et al .2000).*

Category scaling frequently is used for the assessment of the loudness of products. Five step scales as well as seven step scales are usually employed (e.g. Fastl et al. 1996). A variant frequently used in audiology is the subdivision of a five point scale in ten subcategories each, leading to a fifty point scale (Hellbrück 1993).

The procedure of magnitude estimation has proven successful for the assessment of several features of sounds. By magnitude estimates, a direct relation is obtained which is of advantage for cost / benefit analysis. However, sometimes the use of the reference or anchor sound can influence magnitude estimation significantly. Therefore, it is suggested, to use at least two anchor sounds, one with large values of the psychophysical magnitude in question, and the other with small values.

3. Psychoacoustic models

Since psychoacoustic models have been described in detail in the literature (Zwicker, Fastl 1999), here only a new loudness model should be briefly mentioned, which has the advantage that it can account for the loudness perception of normal hearing as well as hearing impaired subjects (Chalupper, Fastl, 2002). In figure 3, the block diagram of the related Dynamic Loudness Model (DLM) is sketched. The model has many features of the classic loudness model by Zwicker. However, the important new feature is that just modifying the transformation from level into specific loudness accounts for

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the differences of normal hearing versus hearing impaired subjects. This single modification accounts for the differences in spectral and temporal resolution between both groups of subjects!

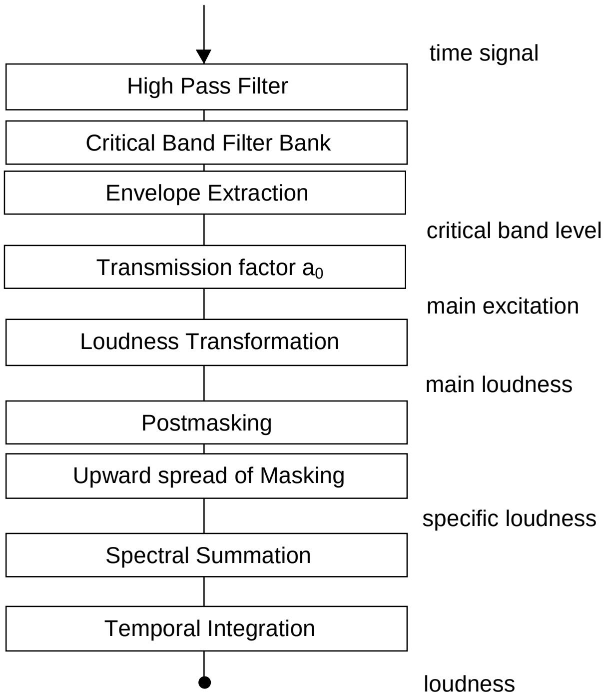

Figure 3: *Block diagram of the Dynamic Loudness Model (DLM) proposed by Chalupper and Fastl 2002.*

4. Meaning of sound

When evaluating sound quality, the cultural background of a subject may play an important part. Cross cultural studies with subjects in Japan and Germany (Kuwano et al. 1997) showed that sometimes one and the same sound can be rated differently. For example, the sound of a bell was interpreted by German subjects as sound of a church bell leading to connotations of ”pleasant" or “safe”. On the contrary, Japanese subjects were reminded by the bell sounds to sounds of a fire engine or a railroad crossing leading to feelings of “dangerous” or “unpleasant”.

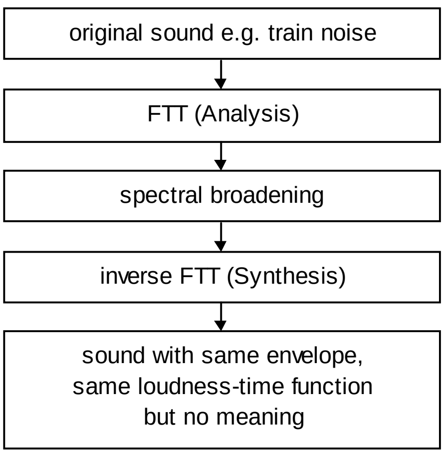

Figure 4: *Block diagram illustrating the procedure to neutralize the meaning of sound.*

In order to largely remove its meaning from a sound, a procedure to “neutralize” the meaning of sounds was proposed (Fastl 2001). In essence, the sound signal is analyzed by FTT and - after spectral broadening - resynthesized by IFTT. The steps of the processing are illustrated in figure 4.
With the procedure mentioned, many signals can be deprived of their meaning. However, some signals like for example speech still can be categorized with respect to the original sound source.

5. Additional modalities

Sound quality ratings can depend on the presence of additional inputs like e.g. visual input. Suzuki et al. (2000), presented evidence that the sound of white noise, when combined with the visual image of a waterfall, significantly increases its pleasantness. On the other hand, when the sound of a product is accompanied by a corresponding visual image, the loudness rating frequently decreases.
Patsouras et al. (2002) showed that the color of a product - despite identical acoustical stimulus - can influence the loudness and hence the sound quality rating. Similar effects hold true for the interaction of acoustic and tactile input (Quehl et al., 2000).

6. Outlook

Psychoacoustics forms a firm basis for the rating of the sound quality of products. Successful sound engineering can profit from the wealth of knowledge in psychoacoustics on the relations between physical features of sounds and their psychoacoustic meaning. However, in an international market with an aging population, also effects of hearing impairment and/or cross cultural differences may play an important part. Finally, the modification of sound quality ratings by other modalities like visual or tactile senses has to be taken into account.

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