TOOLS FOR PRODUCT OPTIMISATION

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Abstract:
This paper discusses the importance of the sound from a product for the perception of the overall quality of the product. Test methods based on subjective assessments are essential for the evaluation of the product sound quality and some preliminary considerations about these methods will be presented. A definition of Product Sound and Product Sound Quality is given, and a general process of product optimisation is described by using a model called "The Product Sound Wheel". Some practical applications will be discussed for product optimisation within the automotive and consumer goods markets. The key issue is that the product sound has been improved and hence the acceptability to the users. Finally, the application for quality control in the product is suggested.

Keywords: Acoustics, Human Perception, Listening Test, Product Sound Quality

1 Introduction

In modern society people are almost constantly surrounded by products, whether they are at home, at work, on vacation, or on their way. We suggest that one essential determinant of "quality of life" is the noise or the sound produced by these ubiquitous sound sources. A product that rattles, rumbles, or screeches unpleasantly has a very different effect than one that puts out the various signals and sounds that the user expects. Quality of life is based on a range of values, which are expressed as basic needs that must be fulfilled for a person to experience a high quality of life.

As we see it, the increased interest in product sound is not only due to the psychometrics of product sound perception or the mechanical design, but also to the fact that it is only during the last few years we have begun to realize the importance of product sound to the user assessment and satisfaction and hence also to the market acceptance of the products. There is a rubbing-off effect from marketing of one type of product to marketing of a completely different type. As product sound has more and more become a sales factor as far as cars are concerned, this has been transferred to a large number of other products, first and foremost on the consumer market and especially regarding every conceivable "electrical product", as e.g. vacuum cleaners, dishwashers, hair dryers, small fans, audio products, etc., etc.

Thus, manufacturers wanting to keep their market position have on most markets gradually been forced to be sensitive as to how their customers feel and are affected by the sounds from the products. Or put in other words:

"We buy with our ears, too."

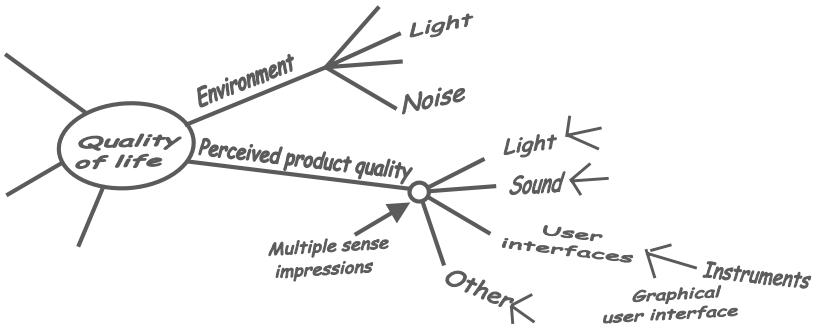

Figure 1: Perceived product quality – one element of quality of life

How the quality of a product is perceived by users and other observers in the vicinity of the product depends of course on a number of product attributes such as appearance, response to user activities, function, noise/sound, weight, smell, taste/flavour, and tactile characteristics. We may even talk about the sound quality, the visual quality, the tactile quality, the quality of user interfaces, etc., See Figure 1.

Product sound optimisation is a method for making "optimal product development" in a broad sense. It contains disciplines within perception psychology, psychoacoustics, and acoustics especially in relation to mechanical design.

The overall objective in the product development is to utilise future consumers' attitudes, expectations, and preferences so that the sound from a product becomes a positive attribute to the user instead of an annoying problem. As all hearing persons can perceive acoustic quality and thus can be said to be experts, there is a need for good acoustic design and development. Totally, this represents a special opportunity to make sure that the product has the desired success with the users.

2 Measurements Involving Human Subjects

Until now two mainstreams have directed acoustic measurements involving human subjects: *Psychoacoustics* on one hand where any kind of bias from the subjects' expectations, mood, preferences, etc., is avoided or minimized, and *consumer surveys* on the other hand where mainly preferences are sought. In the field of product sound quality a basic understanding of the underlying psychoacoustics phenomena – also for rather complex signals – is essential. But in contrast to the pure psychoacoustics research the influence of stimuli from other senses and influence from the listening panel's preferences are not regarded as unwanted bias.

Figure 2 gives a simple illustration of the concepts. With our technical measuring devices we are measuring at the input to "Filter 1" (point 1). With the instruments we can measure the finest details, but we do not know if they are relevant for the perception and preferences. The input to "Filter 2" may be measured by psychoacoustic methods and is an *objective* measurement. By carefully planning and performing the tests, we can obtain reproducible results. From this kind of measurements we will know which details

can be heard. The measurements at point 3 are purely *subjective*. The measurements will tell us what a certain group of people will hear and what they will prefer. The result will depend on the selected group.

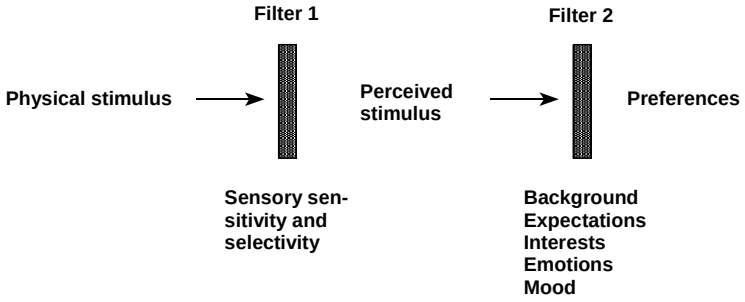

Figure 2: From stimuli to preferences

In designing and developing new methods involving human subjects a clarification of these phenomena is essential for assessing the product sound quality. The same goes for evaluating the annoyance of noise.

At DELTA Acoustics & Vibration we are working for the time being with a project addressing the below four phenomena of human perception of sound:

1. Perception directly related to the physics of the sound
   - How to establish a simple correlation – for instance a loudness value – between the physics and the perception (measurement point 2) which can be measured with sound analysis equipment
2. Perception of complicated phenomena of the sound, common to humans
   - Needs measurements based on human subjects and cannot be measured with instruments
3. Multimodal perception
   - Other senses as moderators of the sound perception or combined stimuli (part of filter one)
4. Perception influenced by mental processing
   - This is the output of the preferences at measurement point 3

One aim is to establish general principles for the coupling between the acoustic perception and the product design.

3 Definitions

Product sound can be thought of as a kind of symbolic language that varies with culture, context, and a variety of other factors. Furthermore, it has a tendency to change over time, partly because of technical advancements, but also because of changing tastes and fashions. This means that the task of optimising product sound is a highly iterative process.

We define *Product Sound* as the perceived sound from a product.

The term *Product Sound Quality* refers to the adequacy of the sound from a product. This is evaluated on the basis of the totality of the sound's auditory characteristics, with reference to the set of desirable product features that are apparent in the user's cognitive and emotional situation.

Product Sound, *Product Sound Quality*, and *Sound Quality* are often used indiscriminately to refer to a variety of related qualities. We choose to use the term *Product Sound* as defined above to emphasize that we are concerned with a characteristic of the product. This is different from "sound quality" or other terms that refer to the performance of speakers, telephones, amplifiers, and other products that are specifically built to reproduce sound.

We have also defined the following categories of *Product Sound*:

Passive Sounds are the sounds that are produced when the product is touched (knocked, pressed, etc.).

In contrast, *Active Sounds* are put out by the product itself. These active sounds can be further categorised as *Running*/*Operating* Sounds, *Action Sounds*, and *Signal Sounds*. These terms are best illustrated by an example using a washing machine:

The machine generates a *Running*/*Operating Sound* when it is in a given part of its cycle (wash, spin, rinse, etc.). The sounds may vary with the different stages of the cycle, and they may be continuous, stationary, or irregular.

When switching from the wash stage to the spin stage, the machine generates an *Action Sound* that has to do with its inner workings and is not intended as a direct signal of anything. This kind of sound can be continuous or impulsive, but is not generally stationary over long periods of time.

A washing machine puts out a humming sound at the end of the cycle. The primary purpose of this sound is to indicate that the machine is finished, and therefore the humming is a *Signal Sound*.

4 Sound in Design: The Product Sound Wheel

We have created a model for product sound optimisation, see Figure 3.

The outer path in the *Product Sound Wheel* describes the fundamental process of optimising the Product Sound Quality. First, alternative sounds from a product, simulated sounds, or sounds from similar products are presented to a test panel. The panel gives their response either in answering forms prepared for statistical computations or directly, e.g. by setting sliders or pressing buttons. The same sounds are measured by analysers, software, etc., and a number of metrics for each sound is the result. The metrics may be any relevant traditional noise measure or may be more psychoacoustically related as loudness, sharpness, fluctuation, strength, roughness, etc., or any combination of these.

By graphical or statistical methods the connections and correlations between the two kinds of measurements are sought, and usually it is possible to describe the preferred sound by objective metrics. By analysis of the physical characteristics of the sound-generating mechanisms, the necessary design changes to obtain the defined values of

the metrics may be implemented. Tools for "sound tailoring", sound editing, and simulation exist, and the lower inner path is often an attractive shortcut to test different versions of possible sounds for further analysis or subjective tests.

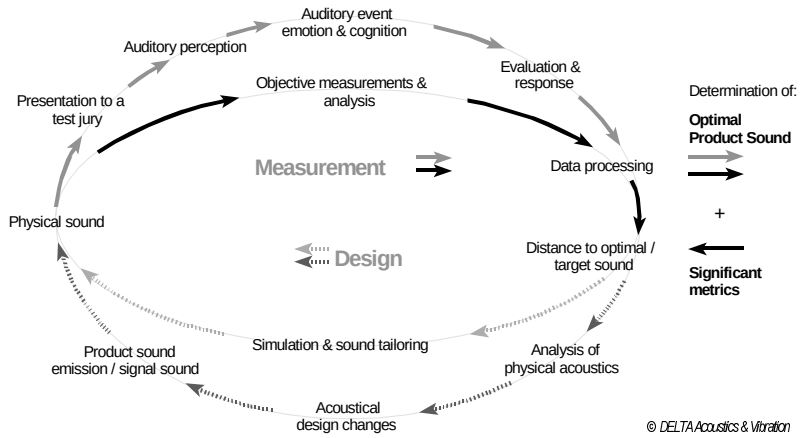

Figure 3: The Product Sound Wheel – a model for optimising Product Sound Quality

5 Practical Applications

During presentation a practical application will be discussed for products within the automotive and audio market.

- A carmaker wanted a silent power steering with a faint quality sound. The subsupplier asked for an analysis of the sound from the existing power steering systems, and specifications of the desired "sound" and suggestions to design changes. As a result of this project, new owners of that make can pride themselves on the quiet and harmonious sound of their power steering.
- All CD-players contain movable parts and, hence, all produce some small amount of noise. Whether this noise is heard or not depends on two things: How loud it is and how it is composed. Even when noise levels measured may be the same, certain combinations of frequencies can be annoying while others are scarcely audible. Even in low background situations using a team of trained listeners it was possible to come up with a set of metrics which reflect the findings of these listeners. So, now introduction of an on-line QC-system in the production based on these metrics is under consideration for this new product.

The key issue is that the product sound tools with listening tests as a central part have been used to design changes into the products in order to improve their product sound and hence their acceptability to the users.

6 Conclusion

In summation, a properly designed product sound is an effective form of communication providing information about the quality, function, and condition of a product. The optimisation of product sound is a multidimensional process with physical, psychoacoustic, and psychological aspects.

Product sound design tools are being used more and more to solve sound-related design problems and to develop products that yield a higher level of customer satisfaction. At the same time, product sound is emerging as an important marketing factor, as is the case with the famous Harley Davidson motorcycle sound, for example. The Product Sound Wheel is a useful aid in keeping product specifications as close as possible to the desired values throughout the iterative process of product sound design.

Whether a product sound is attractive is not determined by the sound alone and its relation to the function, but also by what the user is accustomed to, what the competitors' products do, and not least important, what the surroundings are willing to accept.

So, when discussing perceived product quality we must accept that it is a multidimensional discipline. For the combined stimuli more research is needed in order to describe the total response as indicated in our paper.

At DELTA Acoustics & Vibration we will work intensively in research during the next year on how to make measurements with test persons an efficient tool in the optimisation of perceived product quality.

References

[J. Bernsen, 1999], Sound in Design, Danish Design Center, Copenhagen.

[J. Blauert & U. Jekosch, 1996], Sound Quality evaluation – a multilayered problem, EEA-Tutorium, Antwerpen.

[C.L. Fog, 1998], Optimal Product Sound: Design and Construction Guidelines for Developing Products with Desirable Sound Characteristics and Minimal Noise, Report SPM 144 (in Danish), DELTA Acoustics & Vibration, Copenhagen.

[C.L. Fog, 1999], Use of Product Sound Optimisation Tools, 6th International Conference on Sound & Vibration, Copenhagen.

[C.L. Fog and T.H. Pedersen, 1998], Introduction to Product Sound Quality, Nordic Acoustical Meeting, Stockholm.

[T.H. Pedersen and C.L. Fog, 1998], Optimisation of Perceived Product Quality, Euro-Noise 98, München.

[H. Stone, J.L. Sidel, 1993], Sensory Evaluation Practices, Academic Press, San Diego.