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OVERVIEW OF THE USE OF BINAURAL MEASUREMENTS TO EVALUATE SOUND QUALITY

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Abstract: This paper provides an overview of the use of binaural measurements and psychoacoustic evaluation of sound quality in various industries. Currently, product manufacturers focus on reducing the noise emitted by their products. Some product groups must comply with specified standards regarding sound power levels. However, not always the amount of sound produced is the only criterion that is taken into account. Sound quality and how customers perceive it is also important. Therefore, they focus on improving it. Psychoacoustics as a scientific discipline offers new perspectives and methods of optimizing the acoustic performance of products focused on sound quality.
Keywords: sound quality, psychoacoustics, binaural measurements, sound quality

INTRODUCTION

The basic concept of sound quality is to determine how people perceive it, which was proposed by Blauert in 1994 [1]. Sound quality, a characteristic of sound that influences listeners' perception, plays an important role in determining listener and customer satisfaction. With advances in noise control technologies, sound quality research, which examines how people recognize, evaluate and perceive sound, has become an important subject of interest, especially in the automotive, transportation, and electrical appliance industries around the world. [2][3]

The concept of sound quality, which can be applied to describe both positive (music, speech) and negative effects (noise), finds a generalization in the concept of sound quality of the product [4]. In its most general sense, the term also covers traditional aspects of sound quality, since concert halls, musical instruments, musical performances, sound equipment, noisy production machinery, equipment or automobile which are the cause of noise are also 'products' in the broad sense of the word.

Blauert and Jekosh [5] define product sound quality as "the adequacy of sound in the context of a specific technical objective and/or task". For all products that produce perceptible sound, the sound quality of the product is assessed with each use.

The goal of product sound quality is not only to make the sound pleasant, just as with noise control, the only goal is not to minimize the sound level. A more important factor than the pleasantness of sound is often the informational value of the sound. Passing on information about the state of operation of a product is often a factor that determines why sound perception is desirable. In particular, if the subject has been exposed to the sound of the product many times, the sound system serves as a very sensitive indicator of the functional state of the device that emits the sound. [6][7][8]

The artificial psychoacoustic head (Figure 1) is a self–contained measurement device that allows accurate binaural recordings to be performed immediately after switching on. Recordings can be stored directly on the memory card, which allows independent operation without the need for a computer. Thanks to the authentic recording and playback of any sound events and their digital archiving, the system enables a comparative and accurate assessment of various possible sound events. Because psychoacoustic head technology is compatible with traditional measurement technology, subjective and objective sound field analyzes can be combined in one survey. Thanks to the patented head geometry, it is possible to mathematically describe the reproduction of the geometry of the human head and shoulders, as well as the exact reproduction of all acoustically relevant parts of the human outer ear.[9][10]

Figure 1. Artificial Head Measurement System

The application possibilities of the artificial psychoacoustic head include:

- optimization of sound design of products,
- analysis and optimization of sound quality of technical products (cars, household appliances, power tools and others),
- product development and quality control through binaural measurements.

The field of environmental acoustics has undergone significant changes in the last two decades. The broad multidisciplinary discussions undertaken in the scientific community to better understand the large variations in noise annoyance responses fostered the development of a new, participatory, and positive-oriented approach known as the soundscape approach.

In contrast with the traditional approach, which aims at protecting and mitigating noise pollution based on outdoor noise simulation models and limit values derived from noise annoyance dose–response curves at a large territorial scale, the soundscape approach focuses on describing or designing the quality of acoustic environments, mainly at a local scale and through the involvement of individuals.

AUTOMOBILE INDUSTRY

Psychoacoustic investigation of sound quality in the automotive industry refers to virtually all sounds present in the acoustic environment of a vehicle, such as the sound of doors closing, starter sound, engine noise, tire noise, wind noise, electric window opening sound, air conditioning system noise and car radio sound. [11]

In Kousuke Noumura and Junji Yoshida [12] they talk about sound quality as an important factor that influences sales and customer interest. In the article Modeling perception and quantifying sound quality in the cabin, they write that in order to increase the overall marketability of a car, it is necessary to improve sound quality. In this article, they talk about sensory evaluation tests that are carried out on locals in the USA, Germany and Japan, and the perception of car interior sounds is analyzed.

The results of the statistical analysis indicate that perception is divided into two main categories: luxury and sports, and that even people with different preferences perceive luxury and sports equally.

The Japanese with the highest percentage preferring sound for sports acceleration, followed by Americans and Germans. In this research, an algorithm is proposed to calculate psychoacoustic metrics such as volume and force of fluctuation, which they say are basic metrics for evaluating sound quality.

The results of various studies have shown that both interaction effects, vibrations have both positive and negative effects on the perception of sound. It has been partially observed that vibration can reduce noise interference. [13]This effect is very interesting for sound and vibration design in the automotive industry. [14][15]

However, some studies have confirmed that there is no evidence of an interaction between sound and vibration. For example, Amman [16], assumes that there is no significant interaction between sound and vibration and states that "setting sound and vibration targets for automotive programmes that are independent of each other seems to be a justified approach.

Sound quality studies in the automotive industry also focus on sounds such as the sound of car doors closing. The sound from closing the vehicle doors has two main functions. First of all, it signals that the door has been closed correctly, which means that it must be loud enough for passengers to hear.

In addition, it can contribute to the overall impression of the car which is very important, since closing the door is one of the operations that the customer can perform when viewing the car in the dealer's lobby. It was the sound of doors closing that Etienne Parizet, Erald Guyader and Valery Nosulenko focused on in the article Analysis of the sound quality of closing car doors. They analyzed the perception of the sound from closing the car door, emphasizing the image of the quality of the car that the listener can have in mind with this sound. They carried out different experiments such as classification experiment, pair comparisons with the evaluation of similarity and preferences and, finally, the analysis of free verbalization.

The results showed that although volume appeared to be the most important sound parameter in previously published studies, this one did not. The reason, according to the authors, was likely that previous studies had only focused on nuisance caused by sounds. [17]

Studies of car sound quality also look at other parts of the vehicle, such as horn sound. Guillaume Lemaître et al. [18]In their research, Horn Sound Quality: A Psychoacoustic Study of Timbre, they focused on the sound of horns. The aim of their article was to study the perceived quality of horn sounds in order to help design new sounds in a psychoacoustic frame.

Figure 2. Measurement of the sound of closing car doors

Car horns are used for their main and legal function, which is to warn road users of potential danger. The sound of the horn must be clearly interpretable as a warning. But at the same time, horn manufacturers want to tune their sounds to match car categories and brand identities. Thus, horn sound design involves a trade–off between the need to customize the sound and the need to provide effective warning signals.

To meet these limitations, horn manufacturers want to create new sounds using a new device, made from an electronic synthesizer and speaker. In this context, the aim of this study was to identify the characteristics of horn sounds that convey information about danger to the listener. This will allow horn manufacturers to design new sounds that are still perceived as warning signs for cars. The aim was to provide horn manufacturers with acoustic specifications.

PUBLIC TRANSPORT

The automotive industry is not the only one in which psychoacoustic measurements are applied. The psychoacoustic assessment of sound quality, for example in the interior of trains, was devoted to Guillaume Lemaitre et al. [19] The research focused on the effect of background noise on a train on passenger activities. Their article "How does train background noise affect passengers' actions? – The establishment of noise thresholds" providing comfort to passengers refers to a study of passengers' perception of interior train noise in order to determine acoustic thresholds for different passenger activities. One of the main advantages of rail transport is that it allows passengers to engage in various activities while driving, such as reading, working, watching movies, etc. Therefore, in this research, they decided to determine the acoustic thresholds by conducting an experiment in which participants sat in a mockup of a high–speed train and performed tasks common to first and second class passengers (watching a TV series and reading text).

During the execution of the tasks, participants in the experiment were played different background sounds and evaluated to what extent these sounds affected their activities (acceptability rating). The results showed that, overall, reading text requires a quieter environment than watching a movie. Interestingly, the results also showed that only the volume of sounds affected participants' judgment when their attention was distracted from assigned tasks by sounds.

Our previous work with similar sounds showed that perception was also influenced by other, different sound characteristics when their attention was focused on sounds. Therefore, using a greener setup than in this experiment seems more appropriate for determining which aspects of train noise are important to consider.

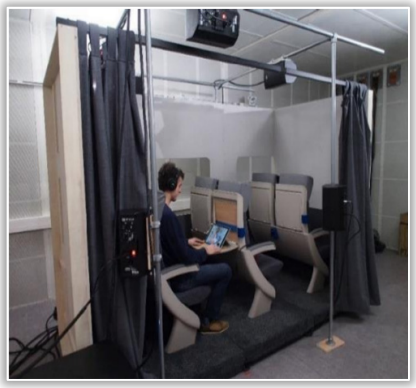

Figure 3. Person performing assigned tasks in a train block

Enlai Zhang et al. [20] also devoted themselves to acoustic comfort in public transport. Specifically, in their article Comprehensive evaluation model of acoustic comfort of the interior of an electric bus and its application, they dealt with acoustic comfort in a sample of eight electric buses. In this paper, 64 noise samples were obtained from eight electric buses, and their corresponding degrees of acoustic comfort are obtained by subjective evaluation tests using a score comparison method.

Measurements were taken with the air conditioning on and off as two working conditions. They also ran in two places in the bus, in the driver's seat and in the rear seat (Figure 3) and at speeds of 30 km/h and 50 km/h. During the test, the vehicles drove separately on a professional track, and with stable operation of the vehicle, a handheld–mounted handheld binaural acquisition system Squadriga II and BHS II was used to collect internal noise signals.

A jury of engineers, drivers and acoustics experts with extensive experience in bus noise was

organised for the subjective evaluation tests. Acoustic comfort was identified as a subjective evaluation index, a method of evaluating scores, and acoustic comfort was divided into ten standard levels from 1 to 10.

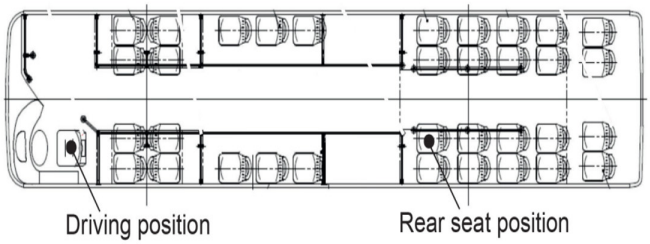

Figure 4. Measuring points on the bus

AIR CONDITIONERS

The rating of sound quality and acoustic comfort of users applies not only to the automotive industry, but also to various types of electrical appliances. For example, air conditioners are considered the main source of noise in the built environment. Both the sound level and sound quality of the air conditioner can really affect the acoustic comfort of the user.

The aim of the study, titled Multidimensional psychological assessment of air conditioning sounds and prediction using correlation parameters, authored by Yoshiharu Soeta and Ei Onogawa [21] was to find out factors that significantly influence the subjective response to the sound of air conditioners. Subjective loudness, sharpness, and harassment were evaluated using the pair comparison method.

A binaural microphone (BHS I, HEAD Acoustics) was used for measurement. The sounds were generated by three output units and one air conditioning input unit in a reflection–free room. The stimuli were presented to the participants binaurally using headphones (HD800, Sennheiser). Subjective volume, sharpness and annoyance caused by air conditioning sounds were evaluated.

Multiple linear regression analysis showed that the LAeq energy index was a significant factor influencing the perception of volume, sharpness and annoyance of air conditioning sounds.

Jin Yong Jeon [22] in the article Subjective and objective evaluation of air conditioning noise, it is devoted to the evaluation of sound comfort of air conditioning units.

The noise from the air conditioning system installed in the ceiling of the classrooms was evaluated by examining the subjective responses to air conditioning noise.

The results of multiple regression analysis of psychoacoustic parameters and subjective preferences showed sharpness as a major factor in describing the sound quality of air conditioning noise. A semantic differential test was also conducted to evaluate the sound quality characteristics of the air conditioner.

CONCLUSIONS

The authors of this article describe the possibilities and areas of use of binaural measurements in psychoacoustic evaluation of sound quality. Whereas the use of binaural recording and psychoacoustic analysis is well known in the field of product sound quality especially with respect to the automotive field, the application of these tools within the soundscape analysis is new. The article describes the use of these ratings in the automotive, public transport and other industries. The binaural recording using an artificial head is the only and simply method to capture sound events comparable to the human ears. Using calibrated equalized headphones it is possible to reproduce earsignals at the listener ear to create the same hearing event like in the original sound situation.

For more than 40 years applications of binaural recordings are being intensively used in the automotive industry to optimize vehicle interior sound. That means the advantage of this technology for the analysis of complex sound situations in combination with assessment and evaluation is proven since a long time.

Binaural perception has been acknowledged as a crucial aspect in evaluating acoustic environments as humans perceive acoustic environments through binaural hearing, which allows the perception of spatial characteristics in addition to spectral and temporal characteristics.

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