Appliance of physiological measurements for assessing sound amenity

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1. INTRODUCTION

In the past decades, the prevention of possible health hazards caused by noise has been the most important goal of noise research. Physiological measurements, *e.g.* of heart frequency or of the finger-pulse amplitude, have turned out to be of immense help in this effort, even though the results of the physiological studies were not always unequivocal.

Today we are discussing whether we should define a new goal for our future research, namely creating a comfortable sound environment. The question arises if physiological measurements could be helpful for this purpose, too. Fundamentally, our answer is "yes." There will be a lot of questions similar to those in the research of noise effects, *e.g.*:

- What are the main factors in sound amenity?
- In which way do people react to them?
- Does a quantitative relation exist between certain parameters of sound amenity and human responses to them?

Obviously, different scientific disciplines will have to co-operate to answer these questions, and we feel that physiological measurements will be a part of this combined effort—in the same way, as it has worked out in the long history of noise research. But it is another question *which problems* could be solved by physiological research, and *by which means*. Those methods which have been useful in studying adverse effects of noise are not necessarily sensitive to sound amenity. To our knowledge, however, there are but a few studies exploring

physiological responses to pleasant noise stimuli, and we have to start nearly at zero.

In our talk today, therefore, we want to deal with two very basic questions related to the theme of the symposium:

- Are there any indications from past research that physiological measurements can successfully assess sound amenity?
- Which aims and which methods of research seem to be most promising with regard to sound amenity?

In order to answer these questions, we will discuss some material from three very different fields of research, and we will draw some conclusions for the first steps of future research.

2. NEW PERSPECTIVES IN THE RESEARCH ON NOISE EFFECTS

At the 14th International Congress on Acoustics in Beijing, we presented results of a laboratory study which compared physiological responses to industrial noises, at one time recorded and presented conventionally and at another time binaurally by means of an artificial head (Notbohm *et al.*, 1992). In short, there were clearly stronger responses on the finger-pulse amplitude as well as on skin conductance reaction from sounds recorded by artificial head as compared to conventional recording.

In a second step, we tried to identify an acoustical parameter which was responsible for the different effects of the two techniques for recording. The factor "spatial distribution" was varied by means of artificial head recording. The physiological re-

sponses proved to be much stronger when the industrial noise was perceived as if it was issuing from different directions. To give an example, Fig. 1 displays the pattern of the finger-pulse amplitude. During exposure to multi-directional noise, the amplitude does not reach the baseline at any time. Compared with the response to uni-directional noise, the mechanism of reregulation, which normally leads the finger-pulse amplitude back to its baseline, is delayed by multi-directional noise. This result might imply that the listener experiences a multi-directional incidence of sound as being more of a strain.

In a third experiment, we obtained similar results using pink noise instead of industrial noise. With moving sound signals, the pattern of the finger-pulse amplitude was disturbed more as compared to uni-directional or bidirectional sound stimuli.

This short summary of our study might indicate that binaural technique provides us with new perspectives with regard to investigating the effects of sound. With constant intensity of the noise stimuli, auditory spaciousness proved to have an influence on physiological responses. But the special properties of the artificial head system allow for variations on other acoustical parameters as well, such as the harshness or sharpness or sonority of a sound. Acoustics, in fact, defines dissonance by these parameters (Aures, 1984; Terhardt, 1984), and dissonance is a main component of the noisiness of a sound. By means of the binaural technique, each of these parameters could be varied experimentally and studied in its physiological effects. Thus, a

more profound understanding of the human response to these qualities of sound could arise. But still, the question remains if physiological measurements are sensitive enough to evaluate pleasant noise stimuli.

3. NOISE AND MUSIC

For a further approach to research on sound amenity, we have to deal with music as a highly sophisticated form of comfortable sound environment. In the early sixties, we studied differences in physiological responses while listening to classical music as compared to being exposed to white noise (Jansen and Klensch, 1964).

In former studies, it was demonstrated that the cardiac output of most subjects was reduced when exposed to noise for some minutes. To compare these responses with the effects of classical music, we chose the Allegro and Adagio from the 3rd "Brandenburgisches Konzert" by J. S. Bach, as this piece of music covers a wide range of frequencies and keeps a relatively constant volume of sound.

Both stimuli were presented twice for a duration of 7 min, with an intensity of 90 DIN-phon. There was a clear distinction in the mean change of cardiac output between the music and the noise stimulus: During exposure to white noise, the cardiac output decreased by 10 percent as compared with the baseline, whereas during classical music the reduction only amounted to 6 percent. Obviously, the broadband noise had a stronger influence on the blood circulation as compared with Bach's concerto. Figure 2 depicts the mean changes in cardiac

Fig. 1 Finger-pulse amplitude during uni- and multi-directional presentation of two industrial noises.

Fig. 2 Changes of physiological parameters during exposure to classical music resp. white noise.

output and blood pressure during exposure to classical music and to white noise.

These experiments were not continued in those days. With the growing importance of noise abatement, the problems and questions of noise research became more and more specialized, and the effects of music were of marginal interest. Aside from noise abatement, however, the field of scientific research on music has developed considerably and seized upon refined physiological methods. To this date, there is plenty of literature which has to be reviewed with regard to the physiology of sound amenity, *e.g.* recent studies (Petsche, 1987) describing changes in the electro-encephalogram (EEG) while listening to music.

Of course, sound amenity differs from music, as the effects of music are influenced by a variety of specific factors: the dynamic and rhythmical structure and the emotional content of the music, the attitude of the listener to his favourite music and its meaning in his living context, the musical education and experience of the listener and so on. In noise research, we are familiar with the problem that many people appreciate loud music and become most enthusiastic at sound intensities being of a risk for hearing.

Research on sound amenity will face similar problems in defining its subject and dealing with individual differences in the evaluation of a particular sound environment. Therefore, reviewing the vast literature on music might result in valuable suggestions in theoretical as well as in methodological respect.

4. RESEARCH ON THE EFFECTS OF RELAXATION

Finally, we want to refer to physiological studies on the effects of silence as the extreme contrast to noise. Silence has been investigated thoroughly in a specific context, *i.e.* outer and inner silence as an accompanying symptom of relaxation. In the early seventies, journals like "Science" or "Scientific American" published reports stating extraordinary physiological changes during practice of certain meditation techniques. Since then, plenty of studies have compared different techniques of relaxation with regard to their physiological effects (reviewed *e.g.* by Shapiro, 1982; Holmes, 1984). Up to now, results have been quite controversial concerning the effects of a particular technique as compared to others. Nevertheless, referring to relaxation in general, the results allow for some conclusions which are important for our subject:

- Physiological relaxation in a wakeful state of consciousness can be measured quantitatively just as it is done with the opposite state of arousal.

- A variety of physiological parameters proved to be appropriate for this purpose, *e.g.* heart frequency, frequency of respiration, electric activity of the muscles, the alpha-waves in the electro-encephalogram and so on.

Without doubt, relaxation in the sense of self-regulation of vegetative functions and relief from stress is one aspect to be considered in conjunction with a comfortable sound environment. During the last years, more and more "music for relaxation" is offered, mainly electronic music with a low content of structure or melody. Explicitly, this type of music claims to induce deep relaxation and well-being, but its effectiveness has never been tested. One approach to the investigation of sound amenity could consist of laboratory studies comparing the physiological effects of such music with the effects of just sitting in relaxation.

5. CONCLUSIONS

Returning to our initial questions, we can derive some conclusions from the material which we have discussed: There is evidence that physiological measurements are capable of assessing the effects of pleasant sound stimuli. The binaural technique provides new perspectives in studying the effects of isolated acoustical parameters being relevant for the

research on sound amenity. The results from research on the effects of music and of relaxation suggest that physiological measures are sensitive enough to prove responses in a non-aversive range of stimulation, *i.e.* in the range of relaxation and well-being. Basically, a fruitful field for research lies ahead.

Of course, theoretical and methodological issues have to be clarified. Sound amenity has to be defined very precisely, and we will probably have to deal with different dimensions of acoustical comfort. There might be a dimension of relaxation as well as a dimension of stimulation or exaltation both induced by pleasant sound stimuli, but for both dimensions, the physiological responses as well as the subjective evaluation of well-being might be different. Thus, we have to define which kind of comfortable sound environment we actually study, and even more than in noise research, the comfort experienced by subjects will depend on the personality of the listener, on his activities and the actual situation. Physiological measurements have to be combined with psychological studies of the subjective attitude to the sound stimulus and to the situation. And, maybe, physiological measurements should focus on central responses in the EEG instead of peripheral responses.

However, the main obstacle for investigating sound amenity is not scientific, but political. During the past decades, research on the health hazards caused by noise has been sponsored by the governments of the industrialized nations because society was interested in preventing hearing loss and extra-auditory effects of noise. During the last years,

we have to notice that noise is generally treated as a minor problem as compared to other environmental risks. It will take much effort to gain sufficient financial support for research on a comfortable sound environment. We have to argue convincingly that creating an agreeable sound environment really pays off in maintaining human health and well-being.

REFERENCES

- Aures, W. (1984). "Der Wohlklang: eine Funktion der Schärfe, Rauigkeit, Klanghaftigkeit und Lautheit," Deutsche Arbeitsgemeinschaft für Akustik (DAGA): Fortschr. Akust. **10**, 735-738 (Tagung der DAGA, Darmstadt).
- Holmes, D. S. (1984). "Meditation and somatic arousal reduction—A review of the experimental evidence," *Am. Psychol.* **39**, 1-10.
- Jansen, G. and Klensch, H. (1964). "Beeinflussung des Ballistogramms durch Schallreize und durch Musik," *Int. Z. Angew. Physiol. Einschl. Arbeitsphysiol.* **20**, 258-270.
- Notbohm, G., Schwarze, S. and Jansen, G. (1992). "Noise evaluation based on binaural hearing," *Proc. 14th ICA, Beijing*, Vol. 3, H2-2.
- Petsche, H. (1987). "Gehirnvorgänge beim Musikhören und deren Objektivierung durch das EEG," in *Musikpsychologie, Jahrbuch der Deutschen Gesellschaft für Musikpsychologie* 4 (Noetzel, Wilhelmshaven), pp. 7-28.
- Shapiro, D. H. (1982). "Overview: Clinical and physiological comparison of meditation with other self-control strategies," *Am. J. Psychiatr.* **139**, 267-274.
- Terhardt, E. (1984). "Wohlklang und Lärm aus psychophysikalischer Sicht," in *Beiträge zur Bedeutungslehre des Schalls*, A. Schick, K. P. Walcher, Eds. (Lang, Bern), pp. 403-409.