



PERCEPTION OF PRODUCT SOUND QUALITY AND SOUND QUALITY IN SOUNDSCAPES

PACS:

Brigitte Schulte-Fortkamp¹; Klaus Genuit²; André Fiebig³

¹Technical University Berlin, Einsteinufer 25, 10857, Berlin, Germany; brigitte.schulte-fortkamp@tu-berlin.de

²HEAD acoustics GmbH, Ebertstrasse 30a, Herzogenrath, Germany; klaus.genuit@head-acoustics.de

³HEAD acoustics GmbH, Ebertstrasse 30a, Herzogenrath, Germany; andre.fiebig@head-acoustics.de

ABSTRACT

In the scope of product sound optimization the consideration of sound quality aspects has already a tradition. For decades, sound quality concepts were developed and listening tests were carried out for the development of models and metrics reflecting subjective sound evaluation with respect to specific products.

The concept of Soundscape includes evaluation procedures in some cases similar to the Sound Quality concept. The question arises whether available concepts and models from Sound Quality concepts can be used for an adequate analysis of environmental noise. It has to be discussed with respect to parallels between “environmental noise” and “product sound” sources in the way of evaluating especially with regard to vehicle/traffic noise. Vehicle noise, interior as well as exterior, is subject to sound design processes for a long time in order to enhance the perceived quality of the product. Regarding the potential improvement of exterior sound quality, will this result in a reduced annoyance caused by traffic noise? Thus, European research projects (e.g. SVEN, QCity, Obelics) dealing with vehicle and traffic noise as well as product sound quality studies will be reread and discussed under the perspective of their applicability for environmental sound quality issues.

INTRODUCTION

The evaluation of the perception of acoustic environments needs an interactive, integrating, transdisciplinary concept. [1] *Contextual interdependencies*, socio-acoustic, and psychological methods, the significance of the modifiers within the guided decision-making process as well as the importance of sensorial modifiers as they make up the foundation of the research process have to be investigated.

In many studies focusing on sound quality the observation of context in general becomes an essential issue. If the experimental setup, instruction or even the respective stages of the experiment are regarded as contextual, the subject with its individual (acoustical) socialization imbedded in a *socio-cultural background* specifically reacts to the stimulus, i.e. sound evaluation or the evaluation of product-related sound quality always implies evaluation of lifestyles depending upon acceptance and therefore is intimately related to the daily routine of the subject. Thus, it is essential that the instructions are given to direct the subjects' response strategy towards an everyday situation in order to enable the reactivation of cognitive processes elaborated in actual situations. [2] Since the evaluations of sounds are highly context-sensitive [3], the stimuli must be presented in a way that allows the subject to experience the stimuli in a familiar way.

But, there is no usage-oriented experimental instruction which sufficiently defines the contextual rapport within a given sound evaluation setup. The concept of sound quality evaluation needs to be broadened to integrate a subjective and psycho-social approach.

As expected, investigations of product sound quality have shown that the process of product sound evaluation is multidimensional and cannot be reduced to simple singular numbers. Further factors, e.g. the *meaning* of the source (product), *ambiance*, *interactivity*, *attitude* and

the listener's *expectations* and *experiences* concerning the product and its use are significant parameters which have to be considered to completely comprehend the perception and evaluation with regard to specific stimuli. Thus, besides conventional methods, explorative methods are successfully applied in the field of product sound quality study. In order to collect significant data, procedures take place in authentic context with a minimum of artificiality to maintain spontaneity, genuineness and naturalness of the examined situation and to receive natural reactions towards the product noise. The sound evaluation of machines, engines or devices takes place while the subject is applying the object in a known manner. [4]

Of course, these procedures and methods are also used in the scope of soundscape studies [5]. Subjects evaluate environmental sound in typical environments; interviews directly take place in the respective apartment of the interviewees under the impact of familiar environmental sound, which causes specific (but not artificially forced) emotions and feelings. The verbalization of these sensations is most valid and meaningful. Perception is not reducible on effects of so called objective parameters of an environment; moreover it is influenced by personal and contextual factors, which is also true for the moderator soundscape. However, in contrast to product sound quality studies, where sound is mostly judged in connection with the typical product use, studies in the scope of community noise often neglect the importance of the soundscape imbedded in a specific socio-cultural background, with its specific *visual cues* creating an particular atmosphere, the *activities* of the subjects living in the investigated site, etc. Up to now, indicators based on time-averaged physical values are dominating and the mentioned important aspects do not (or rarely) enter policy decision-making processes.

All in all, new approaches in sound quality evaluation and also in soundscape have a corresponding approach concerning the concept of evaluation of perception, the new expert concept; a potential synergy has to be considered.

THE LACK OF QUALITY ASPECTS IN COMMUNITY NOISE RESEARCH

In the context of community noise, there is a common consent about the necessity of additional parameters beside the A-weighted sound pressure level.[6] Nevertheless, as mentioned above the A-weighted energy-equivalent SPL still dominates the legislation and noise policy. New research findings and slow-growing insights in a more complex connection between sound and its perception/evaluation, besides simple dose-response curves based on sound pressure levels, are met by policy with simple bonus/malus (penalty) values. However, the L_{Aeq} as well as generalized penalties are neither sufficient for the understanding of the human perception and evaluation of environmental noise nor adequate for the description of an urban soundscape.

Essentially, the introduction of new parameters, the more sophisticated use of already existing parameters, and a merging approach from different measurement procedures appear to be inevitable. [7] For example, psychoacoustic parameters should be applied in order to measure and assess environmental sound more properly. With the help of psychoacoustic parameters, mainly based on standardized procedures of measurement and analysis, it will be possible to explain some contributors of annoyance caused by environmental noise. Consequently, for a promising determination of community noise levels, one needs even more information about signal processing of human hearing in addition to the parameters that are already known, as for example loudness, sharpness, and roughness.

The calculation or even the measurement of the sound pressure levels caused by traffic (road vehicles, railway, aircraft, etc) is not sufficient in order to determine the factual level of annoyance and to properly estimate the evaluation of sound quality. E.g. two different vehicles driving by and causing the same sound pressure level can be perceived quite differently. The qualitative differences in sound are caused by the different temporal distribution, superposition effects of noise sources and the ranking of noise sources even for different vehicles of the same class.

A further important aspect concerns the source identification/source recognition, which causes a specific reaction towards the noise.

In this context, it is important to consider that with the identification of the source a specific cognitive representation of the objects takes place. For example, traffic noise evaluations are influenced by the value given to the respective sound source. This means it is to the social value of the noise as a semantic cue and not as an intrinsic property of the acoustic signal how the noise event is actually evaluated. Physical intensity becomes (cognitively) relevant in connection with a specific meaningful sound category, or to a set of properties defining such

category, which is partially detached from the physical properties of the source. Thus, environmental sounds can be understood as meaningful events that affect people. [8] In order to adequately reflect the listed aspects of environmental noise it is necessary to “[...] put some quality into environmental criteria”. [9] A shift from studies only dealing with noise annoyance and SPL-reduction strategies to more qualitative evaluations of the quality of soundscapes is necessary to overcome the limits of the actual, often ineffective noise policy .

PRODUCT SOUND QUALITY CONCEPTS

In the past, a number of projects and surveys have dealt with the issue of the perception and evaluation of vehicle noise. In order to improve our understanding of this subject and in order to define adequate and significant methods of analysis, a detailed review of precedent surveys and literature is necessary. For example, the European project SVEN (Sound Quality of Vehicle Exterior Noise) investigated the perceived sound quality of vehicle noise. [10] There, it could be confirmed that the urban structure and architecture has an important impact on the perception and evaluation of traffic noise. It could be observed that U-shaped streets are subjectively judged as being less annoying than open-shaped streets (both for the same L_{eq}). In the case of low traffic density, this is because in U-shaped streets vehicles can be heard earlier and their arrival can be anticipated. In L-shaped streets, the sound sources approach suddenly and the unexpected noise events evoke stress related reactions in the test person. In contrast, the vehicles in the U-shaped street are subjectively perceived to be less dangerous.

Furthermore, annoyance of exposed individuals rises with increasing traffic density. On the other hand, in a situation with low traffic density, single noise events stand out. This results in a high level of annoyance although the L_{eq} is low. Thus, it could be concluded that the *temporal distribution* of sound sources plays an important role with respect to the evaluation of environmental noise.

In the European project, OBELICS (Objective Evaluation of Interior Car Sound) [11], the focus was set on the perception of vehicle interior noise. The main objective was to understand the basis of sound language and sound perception and to derive methods and tools for an objective evaluation of vehicle interior sound. A few psychoacoustic parameters corresponding to specific auditory sensations and evaluations respectively could be discovered. Furthermore, the impact of further *sensory dimensions*, like vibration, on the perceived loudness was investigated in detail. These surveys show the importance of *context* and the relevance of further (psychoacoustic) parameters beside the A-weighted SPL. Moreover, an interesting result of the project concerning the evaluation of interior car sound was the observation of *“intercultural” effects*. [12] This finding suggests that noise evaluation is not “a priori” given unaffected by socio-cultural background, experience and acoustical socialization. In this note the evaluation of noise is a phenomenon which is closely connected with the experience and expectation of the evaluator. Consequently, an individual’s current perspectives and interpretations are significantly conditioned by the beliefs that he or she has retained from his or her previous transactions with the environment. That is, the person’s past experience considerably constrains what she or he perceives in the present as Wicker compatibly stated. [13]

These observed phenomena could be established by means of further studies in the scope of environmental noise research. A case study, carried out in a residential area in urban city, illustrates the importance of aspects and parameters, which cannot be described with the help of simple physical quantities.[14] The examined site, where various interviews with the residents were conducted, was a two-lane road divided by a green space, right in the urban center of the city, and with a distinct architectural atmosphere because of the combination of rural and urban aspects. It was expected to descry connections between the soundscape evaluation and the environmental make-up. Perceptive variables like acceptance, expectation, fit, claim of recreation, knowledge, general contentment were relevant parameters in the context of the evaluation of the examined soundscape. These parameters depend on the *socio-cultural background* of the exposed subject. It was observed that specific activities causing noise were accepted or tolerated, such as chatting people, the sound of nightly tavern talks or playing kids, whereas other actions and objects, like helicopters, sightseeing-buses, tourists, are refused and classified as always disturbing, since they contribute apparently nothing or minor to the local

collective identity. Besides the social influence the possibility of associating a physical stimulus with an unequivocal source and reason modify the evaluation considerably as well.

Furthermore, another important result was the importance of low frequency noise to the evaluation of environmental noise. Low frequency noise originated from the tires rolling over the cobblestone road surface. The A-weighting filters out low frequency components almost completely so that they do not contribute to the A-weighted SPL value. However, these spectral components strongly influence the level of annoyance perceived by the residents. Therefore, the low frequency energy of noise events has to be taken into account, although the low frequency content does not exceed the defined tolerable limits (such as DIN 45680, TA Lärm). The question here is whether evaluation methods of product sound quality will be of relevant use for evaluation of environmental areas.

NEW QUALITATIVE PARAMETERS

Applying a new subject-centered method in the context of target sound determination of products several qualitative parameters were detected. The applied method [4] gave the opportunity to explore the product-related environment considerably as a whole, with all relevant sensory parameters. These parameters are listed and explained shortly below. The first parameter detected in the surveys was *Passung* (adequacy of sound impression and product (e.g. vehicle's) performance), which means a correspondence between the experienced situation and perceived stimuli as well as a correspondence between generated expectations and perceived reality. Secondly, the parameter *truthfulness* was identified in product sound quality studies. A truthful sound characterizes a sound, which represents the actual performance of a product (e.g. a vehicle) without exaggeration. The third detected parameter was *cogency* implying that sound of the product provides confidence. Furthermore, a parameter was found which can be classified with *stability of character*. It means that the perceived sound changes are always in accordance with the experienced situations concerning the application of a product. It allows that the subject can anticipate the sound, which subconsciously takes place and lead to a feeling of safety and controllability. This means that a feeling of control is suggested supported by the sound of the product.

However, it could be found that for achievement of a high level of contentment, all sensory dimensions have to be taken into account (acoustics, vibration, optics, olfactory, haptics). It seems to be necessary to consider the parallelism of dimensions of perception.

LIMITS AND BENEFITS

Several aspects of environmental noise perception and evaluation cannot be adequately considered by means of product sound quality concepts and methods, since the context, the exposition to normally isolated sound sources (investigated products), the specific product-related interactivity and action are quite removed from the complexity of everyday life situations with lots of sound sources as well as other sensorial impacts, activities, etc. which give the experienced event its singularity. Thus, the transfer of the results from product sound quality evaluation into the era of soundscapes without a critical analysis is not possible. However, what can we learn from the product sound quality parameters and concepts concerning the evaluation of environmental noise?

First of all, product sound quality concepts are disengaging from the annoyance (or non-annoyance) level as the only descriptor of the examined noise. Of course, noise (and its meaning respectively) in the context of products can be more than only being annoying. Product sound can stimulate certain feelings, such as pleasantness, excitement, agitation, contentment, etc, which matches the customer's expectations or lead to the complete rejection of the product. In the context of environmental sound, it appears highly probable that noise can provoke comparable feelings as well; environmental noise can be adequate, pleasant, familiar, lifestyle-representing, helpful for orientation, irritating, etc. Such attributes and their meaning respectively have a great impact on the evaluation of the soundscape. The acoustical properties of signal and the respective assigned meaning and interpretation of the signal affect significantly

the noise evaluation. Therefore, environmental noise cannot be only assessed under the perspective of the caused annoyance level. For example, the identified parameter *Passung* and its influence of the evaluation of acoustic environments have to be scrutinized in detail in order to examine its meaning for the “soundscape research”. As mentioned above, the microscopic investigation dealing with the residents’ evaluation of the environmental noise in an urban site has shown that specific sound sources are fitting in the soundscape, whereas other sources are partially or even completely refused and are evaluated as annoying and disturbing. Here, the investigation of the noise exposure by means of physical quantities alone does not allow an understanding of these soundscape-related evaluations.

In fact, contextual, meaning (cognitive representations), source identification effects as well as the socio-cultural background and lifestyle influences affect the perception and evaluation of environmental noise. In this context, further studies of potential parallelism of product sound quality concepts and sound quality research in soundscapes will help to identify and understand the differences as well as analogies in the perception and evaluation of noise between the different areas. An identification of the similarities and differences of noise in dependence on the source, context, activity, etc. – whether in case of the use of a single product or in case of a situation where a resident is exposed to environmental noise – will allow for a deeper understanding of the evaluation of noise.

CONCLUSIONS

A human being does not evaluate stimuli on the basis of a single dimension in reality. In fact, it is an interaction between the various levels of perception, which “create” the evaluation of a stimulus. Therefore, there is a need for transdisciplinary concepts and methods, which consider qualitative and quantitative parameters and help to combine these different multi-layered aspects, which are involved in the process of perception and evaluation. This statement points out the importance of using a qualitative approach in the survey, as heuristics to further quantitative measurement techniques. [15]

A broad, transdisciplinary approach could also include the application of acoustical diaries, a subject-centred method. With it, a combination of physical and socio-scientific measurement procedures can be achieved. [16] With the help of this knowledge gained factors “behind” the dose-response curves can be determined and perception-related decisions can be possibly derived to handle environmental noise problems adequately.

All in all, the exploration of noise evaluation processes must be in the focus of future scientific research. One significant step is the detailed, extensive study of surveys dealing with ostensible different issues, such as initially carried out in the paper at hand, because it could offer insights about “universal” mechanism in the process of the perception and evaluation of noise. However, the study of environmental noise and its impact on residents is still not reducible to simple interrelations; the evaluation process in the context of environmental noise cannot be understood by eliminating its complexity, but rather by accepting its complexity.

In particular, the combination and integration of qualitative and quantitative data into a broad concept must be explored. In future studies these processes should be analyzed with the help of an “open”, multi-criteria soundscape approach, which overcome sectoral barriers.

References:

- [1] B. Schulte-Fortkamp, A. Fiebig: Sound analysis in a residential area: an evaluation of noise and people's mind , Acta Acustica united with Acustica, Vol. 92 (2006), No. 6, 952-958, S. Hirzel Verlag
- [2] C. Guastavino, B.F.G Katz, J.D. Polack, D.J. Levitin, D. Dubois: Ecological validity of soundscape reproduction, Acta Acustica united with Acustica, Vol. 91 (2005), No. 2, 333-341, S. Hirzel Verlag
- [3] B. Schulte-Fortkamp: The meaning of annoyance in relation to the quality of acoustic environments. Noise and Health - An Interdisciplinary International Journal (2002), Vol 4, Issue 15, Cambridge
- [4] B. Schulte-Fortkamp, A. Fiebig, K. Genuit: New approach for the development of vehicle target sounds, Proceedings of Internoise 2006 (2006), Honolulu, Hawaii, USA
- [5] Muckel, P., Ensel, L., Schulte-Fortkamp, B. (1999), Exploration of associated imaginations on sound perception (AISP): A method for helping people to describe and to evaluate their sound perceptions, J. Acoust. Soc. of Am. (1999), Vol. 105, No.2, Pt 2, 1279
- [6] P. Schomer: Alternative methods to A-weighting for environmental noise assessment, Proceedings of Internoise 2002 (2002), Dearborn, MI, USA
- [7] K. Genuit, A. Fiebig: Psychoacoustics and its benefit for the soundscape approach, Acta Acustica united with Acustica, Vol. 92 (2006), No. 6, 952-958, S. Hirzel Verlag
- [8] D. Dubois, C. Guastavino, M. Raimbault: A cognitive approach to urban soundscapes: using verbal data to access everyday life auditory categories, Acta Acustica united with Acustica, Vol. 92 (2006), No. 6, 865-874, S. Hirzel Verlag
- [9] Editorial, Sound quality – The contradiction, In: Noise and Vibration worldwide, June 2001, Vol. 32, No.6, Multi-Science Publishing, UK, 2001.]
- [10] Sound Quality of Vehicle Exterior Noise (SVEN), GROWTH G6RD-CT-1999-00113, 2000-2003
- [11] Objective Evaluation of Interior Car Sound (OBELICS), Brite EURAM BE-96-3727, 1999-2002
- [12] W. Krebber, A. Adams, A., N. Chourad, K. Genuit, T. Hempel, R.v. Hofe, G. Irato, P.v.d. Pongseele, B. Saint-Loubry, B. Schulte-Fortkamp, R. Sottek, R. Weber: Objective evaluation of interior car sound - the OBELICS project, DAGA (2000), Fortschritte der Akustik, 186, Oldenburg, Germany
- [13] A.W. Wicker: Ecological psychology: Historical contexts, current conception, prospective directions, In: R.B. Bechtel, A. Churchman, Handbook of Environmental Psychology (2002), New York, John Wiley & Sons, Inc.
- [14] A. Fiebig, B. Schulte-Fortkamp: The importance of the Grounded Theory with respect to soundscape evaluation. DAGA (2004), Strasbourg, France, CD
- [15] B. Schulte-Fortkamp: Combined qualitative and quantitative measurements to evaluate noises from combined sources. In: J. Acoust. Soc. Am., Vol. 103 (1998), No.5, Pt 2, 1998, 2876 and Proceedings 16th International Congress on Acoustics and 135th Meeting Acoustical Society of America, Vol . 2, 1135
- [16] A. Fiebig, B. Schulte-Fortkamp, K. Genuit: New options for the determination of environmental noise quality, Proceedings of Internoise 2006 (2006), Honolulu, Hawaii, USA