PHYSIOLOGICAL RESPONSE AS AN INDICATOR OF SOUND QUALITY

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Introduction In the context of automotive industry, the assessment and optimization of the sound quality of vehicle interior noise has gained increasing importance for more than a decade. The joint research project SVEN (**S**ound quality of **V**ehicle **E**xterior **N**oise) granted by the European Union aims at investigating the possibilities of applying this methodological approach also to vehicle exterior noise. In a first step, descriptors have to be identified which allow to describe the sound quality experienced by man in typical traffic noise situations as well as in single pass-by noises of cars. Besides the subjective evaluation of sounds by means of questionnaires, psycho-physiological parameters have to be considered as they have proved to be meaningful in similar questions, e. g. in comparing the effects of noises recorded and displayed binaurally vs. monaurally.
In this paper, the first of a set of laboratory experiments is presented which studied human responses to *different types of road traffic noise* recorded in the city of Paris.

Methods From a compilation of 28 traffic noise recordings taken in different streets in Paris, a selection of 4 pairs of noises was made with respect to the following criteria:
- The stimuli of a pair should differ in one specific feature and otherwise resemble one another as much as possible.
- The differentiating feature should be relevant in terms of acoustical characteristics, e.g. in the reflection caused by differences in building or in traffic regulation.

From the 4 pairs, only one will be presented here exemplarily due to limited space. Presented is a comparison of city streets with medium traffic load (1.200 vh/h) and intersections, one with traffic lights and one with a roundabout. The duration of the original recordings was reduced to 4 min. each, and the sound level of each recording was adjusted to an L_{eq} of about 83 dBA.
Three different physiological variables have been measured during the experiment:
- fingerpulse amplitude (FPA) as a measure of the peripheral blood circulation
- skin conductance level (SCL) as a measure of the electric skin activity
- electro-myogram of the forearm (EMG) as a measure of the electric muscle activity.

All these parameters reflect changes of the physiological state of the body in a dimension of activation of the vegetative system elicited by external stimuli as well as by physical tension or emotional arousal. They have proven to be reliable measures of noise effects, but naturally respond also non-specifically to other stressors.
The physiological measurements have been taken continuously during the experiment. For the statistical analysis, means for specific time intervals (2 – 10 s) for each subject were calculated and transformed into percental changes in relation to the baseline value of 100 % (mean of the measurements taking during last 30 s rest before start of the noise).
In addition, the subjective evaluation of the noise stimuli by the subjects was measured by two questionnaires concerning general judgements of sounds and direct comparisons.
24 subjects (male students with unimpaired hearing, age from 24 to 29 years) participated in this experiment which took place in the anechoic chamber of the institute.

Results Fig. 1 shows as an example the results of one physiological parameter. The graphs illustrate the fingerpulse amplitude in percent of the baseline value during exposure to the two noises. The initial response during the first 30 s is shown in means of 2-s-intervals, the remaining time of exposure in means of 10-s-intervals.
Both graphs show a rapid decline of the amplitude as expected from research on noise effects reaching the minimum 8s after noise onset. In the condition "roundabout", the amplitude never shows such a strong reduction as the one with the traffic lights, and the graph shows an early recovery with values above 80 and even 90 %. On the contrary, the graph "traffic lights" keeps to a level around 70 % for the first minute and starts rising during the second minute before dropping down again sharply. Only in the last minute, both graphs draw nearer to each other at a quite low level of 70 %. So there is still a physiological response to the stimuli going on. For nearly all intervals from the 40th to 80th and 130th to 150th s, the means of the intervals differ from each other with statistical significance (t-test for paired samples, $p < 0.5$).

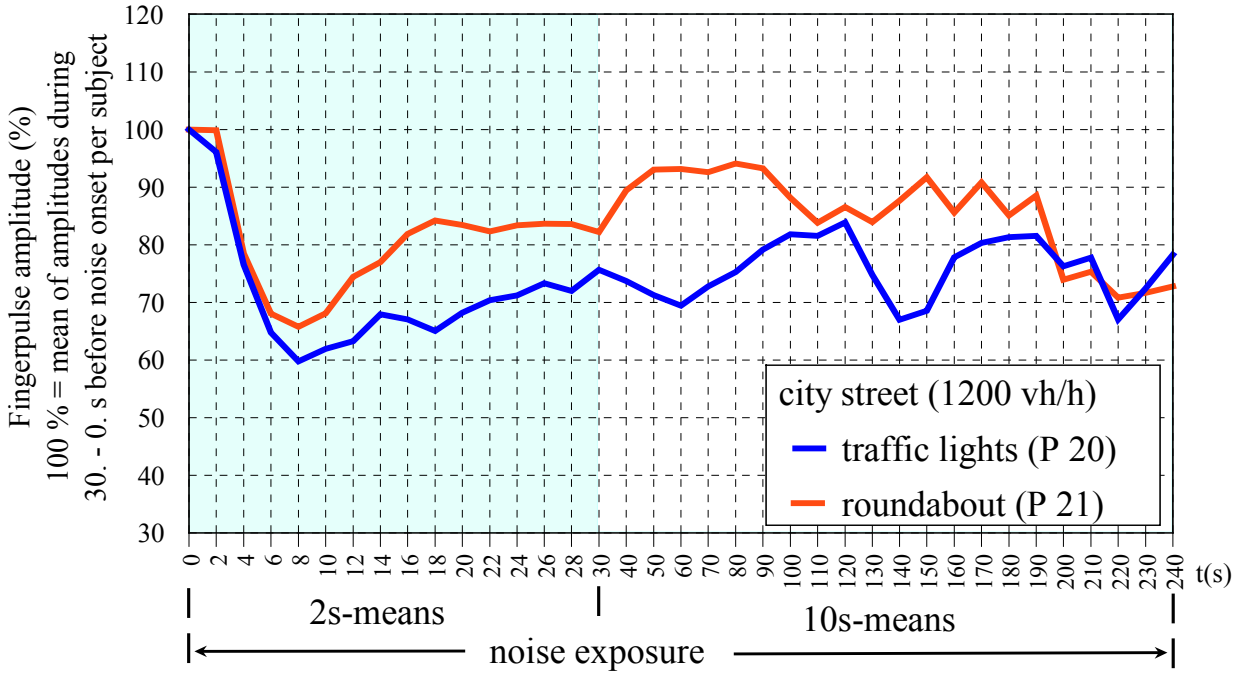

Figure 1. Fingerpulse amplitude with medium traffic load, traffic lights vs. roundabout

For the skin conductance level (SCL), also noticeable reactions show up during the same noise exposure. There is a steady increase in the initial phase after onset of each of the noise, as it can be expected from any alerting or activating stimulus. This response is a little bit more pronounced for the roundabout situation. But after one minute, the "roundabout" response already begins to return to the baseline, whereas the "traffic lights" graph still keeps to a level around 120 % for another minute and stays at a higher level than the other one up to the end. Weighting the temporal dimension, one can state that there is a stronger response to the "traffic lights" situation for most of the time. Also the results of the subjective evaluation reveal very clearly a more negative response to the traffic light situation.

Discussion In the pair-wise comparisons of similar traffic noises of the same sound intensity, distinct differences in reaction in the sense of activation, aversion or valence of the sounds can be found. The physiological responses show distinct differences also in the sound stimuli not discussed here. No contradictory results occurred. In addition, the results of the physiological responses and the subjective evaluation clearly support each other. Altogether, it seems

promising to apply such a multi-dimensional profile of response as used in this study as an indicator of the perceived quality of complex sounds. However, the question remains what exactly are acoustical parameters that provoke such differences in the pair-wise comparison.

Keywords: sound quality, traffic noise, physiological response