The importance of sound pressure level in the assessment of sound quality

Claudia Gärtner, Gert Notbohm, & Sieglinde Schwarze

Institute of Occupational Medicine and Social Medicine, Heinrich-Heine-University, 40225 Düsseldorf, Universitätsstrasse 1, Germany, Email: gaertner@uni-duesseldorf.de

Introduction

The sound quality concept has been of importance in the context of car interior noise and the improvement of driving comfort for some decades. The SVEN project (**S**ound quality of **V**ehicle **E**xterior **N**oise) funded by the European Commission deals with the applicability of this approach to the exterior noise of cars and its environmental impact [1]. In several experiments descriptors have been identified that describe the sound quality experienced by man in typical traffic noise situations as well as with single pass-by noises of different cars [2, 3]. Besides the subjective evaluation of sounds by psychometric measures, physiological parameters [4] were used to identify the individual response to vehicle exterior noise.

In this paper, the third of a set of laboratory experiments is presented which focused on the influence of sound level on the psychophysiological responses to pass-by noises. In all of the previous experiments the L_{eq} of the different noises had been adjusted to 83 dBA in order to elicit strong and reliable physiological responses. In another experiment on subjective evaluation carried out by our Swedish project partners a lower sound level was used. As a result, variations in the preference of the traffic noises applied could be found between German and Swedish Ss which might be due to the sound level used in the particular series [4]. Of course, sound level is known to have a major impact on physiological responses to noise. But in addition, the application of different sound levels could mask the effect of other acoustical features in a different way. Therefore, the effect of a higher and a lower sound level of pass-by noises of two cars has been analyzed in this experiment.

Methods

Sound Stimuli

Single car pass-by noises of two middle-class car (***diesel engine***, capacity of 1,9 litre, 72 kW and ***petrol engine***, capacity of 1,7 litre, 70 kw) had been recorded under the driving condition 70 km/h, 3rd gear, constant speed on a test driving area by our project partners. The recordings were adjusted to a more complex sound situation of 2 min. duration consisting of repeated pass-by noises from the left and the right side. Subjects listened to the noises with the original sound level of about 73 dBA as recorded on the test track and to the same noises elevated to an L_{eq} of 83 dBA.

Measures of Effect

Physiological responses were measured by three *physiological variables*: The fingerpulse amplitude (FPA) as a measure of the peripheral blood circulation, the skin conductance level (SCL) as a measure of the electric skin activity, and the electro-myogram of the forearm (EMG) as a measure of the electric muscle activity.

The physiological measurements were taken continuously during the experiment. For the statistical analysis, means of specific time intervals (2 – 10 s) were calculated for each subject and transformed into percental changes in relation to the baseline value (mean of the measurements taken during last 30 s before start of the noise = 100 %).

In addition, the *subjective evaluation* of the noises was assessed by several questionnaires. The subjects were asked after each sound stimulus to compare two noises directly with respect to the attributes *loud, dangerous, unpleasant,* and *annoying.* They were also asked to give three general judgements of the pass-by noises concerning their dislike of the noise and their feelings of unpleasantness and activation on a scale ranging from 1 to 9, respectively from – 4 to + 4.

Study Realization

The sample consisted of 24 male students with an age ranging from 20 to 29 years. All participants received a financial gratification for their participation. Before the beginning of the experiment their hearing was checked by means of pure tone threshold audiometry in an introductory meeting for enlistment.

The experiments took place in the anechoic chamber of the Institute of Occupational Medicine and Social Medicine from January to February 2003. For each subject there was one experimental session, and there was only one subject performing the tests at a time.

Results

Fingerpulse Amplitude (FPA)

Elevated sound pressure level of L_{eq} = 83 dBA

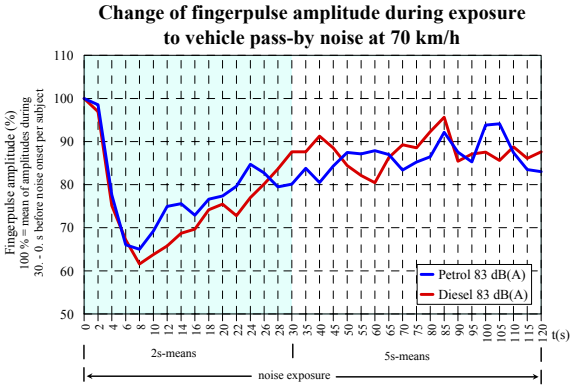

Figure 1: Response of FPA to the elevated L_{eq} (83 dBA) of pass by noises of middle-class cars with diesel or petrol engine at 70 km/h constant speed, 3rd gear.

Figure 1 depicts the mean change of the FPA during two minutes of exposure to the recordings of the pass-by noises with the elevated sound level of 83 dBA. The graphs show a rapid decline after noise onset reaching their minimum after 6 - 10 seconds followed by a gradual recovery towards the baseline. Such a reaction normally

occurs during any exposure to noise of sufficient sound level. The FPA caused by the noise of the diesel car shows the strongest decline going down towards 60% of the baseline with a slight recovery after 40 sec. close to 90% and then dropping down again to 80 % after a few seconds.

Original sound pressure level of L_{eq} = 73 dBA

Figure 2 shows the percental change of the FPA during exposure to the original L_{eq} (73 dBA) of the pass-by noises. Both graphs show a rapid decline right after noise onset with a stronger reaction to the noise of the diesel car. Both graphs start climbing back towards the baseline level after 6-8 sec. with the FPA caused by the noise of the petrol car reaching the baseline after 22 seconds. During the whole noise exposure the FPAs for the original sound level are much weaker than those for the elevated one.

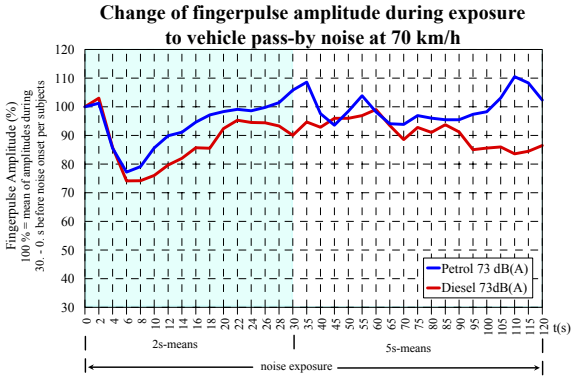

Figure 2: Response of FPA to the original L_{eq} (73 dBA) of pass-by noises of middle-class cars with diesel or petrol engine at 70 km/h constant speed, 3rd gear

General Judgements

Due to limited space only the results for the general judgements are presented here. They offer an opportunity to measure the subjective evaluation of different pass-by noises by the subjects.Table 1 gives an overview of the results for the two dimensions pleasantness and activation. It can be seen that the subjects feel more unpleasant and more activated during the presentation of the noise of the diesel engine. This difference is stronger for the elevated sound level than for the lower original level.

Pass-by noises (70 km/h, 3rd gear)	**L_{eq} = 83 dBA** Petrol	Diesel	**L_{eq} = 73 dBA** Petrol	Diesel
general judgements	$\bar{x}$	$\bar{x}$	$\bar{x}$	$\bar{x}$
I feel pleasant (-4) to unpleasant (+4)	0,67	1,46	-1,04	-0,58
I feel deactivated (-4) to activated (+4)	0,54	0,71	-0,79	-0,63

Table 1: General judgements of pass-by noises of middle-class cars with diesel or petrol engine at 70 km/h constant speed, 3rd gear for the feelings of unpleasantness and activation for both sound levels (83 dBA / 73 dBA).

Similar results can be observed for the dimension dislike. Again the noise of the diesel engine is evaluated more negatively with a stronger subjective response for the elevated sound level.

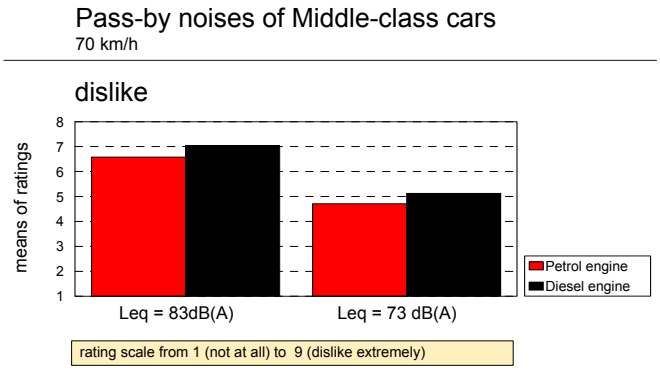

Figure 3: General judgement of dislike of pass-by noises of middle-class cars with diesel or petrol engine at 70 km/h constant speed, 3rd gear for both sound levels (L_{eq} 83 dBA / L_{eq} 73 dBA).

Discussion

The results indicate that with both sound levels the sound of the car with the petrol engine was evaluated more positively than the diesel car. Also, both cars were judged more favourably when presented with the lower level than with the elevated one. The same tendency occurred for the physiological reactions. There was a clearly stronger physiological reaction to the sound of the diesel car in both cases. As expected, physiological reactions proved to be much stronger with the elevated than with the original sound pressure level. Therefore, it seems to be justified to prefer higher levels instead of lower ones in order to be sure of marked, clear responses. This holds true also for the results obtained with the other physiological parameters. Subjective evaluation and physiological reactions correspond with each other in both cases, which underlines the validity of the measurements taken.

What appears to be important is the fact that there has been no change of the order of the preference of the different cars. With the higher and also with the lower level the noise of the diesel engine is liked less and elicits a stronger response of the physiological parameters. So it seems that there hasn't been any change of perception of acoustic features by using a lower level. Of course, these observations have to be confirmed by future experiments with other types of noise or with other sound characteristics because cognitive processes might be involved, too [5].

References

[1] Krebber, W., Sottek, R. and Genuit, K., Sound quality of vehicle exterior noise. *Sociedad Espanola de Acustica (Ed)* Special issue of the Revista Acustica, Vol. XXXIII, 2002. CD-ROM: ISBN: 84-87985-06-8

[2] Notbohm, G. and Schwarze, S., Evaluation of transportation noise by means of psycho-physiological measures. Proc. Inter-Noise 2002, Dearborne, Michigan, USA . CD-ROM: tn02_s5_17

[3] Notbohm, G, Gärtner, C. and Schwarze, S., Psycho-physiological responses to the perception of vehicle pass-by noises. Euronoise Naples 2003, Proc. 5th European Conference on Noise Control. CD-ROM: ISBN 88-88942-00-9, 134-IP

[4] Notbohm, G., Västfjäll, D., Gaertner C. & Schwarze, S.: Evaluation of the Sound of Traffic Noises in Laboratory Experiments. Euronoise Naples 2003. Proc. of the 5th European Conference on Noise Control , ISBN 88-88942-00-9, 145-IP,

[5] Gärtner, C.; Notbohm, G. and Schwarze, S., Perception of sound quality of vehicle pass-by noises after technical modification. Euronoise Naples 2003, Proc. 5th European Conference on Noise Control. CD-ROM: ISBN 88-88942-00-9, 135-IP