Psychoacoustic investigations on the efficiency of different noise barriers

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ABSTRACT

In addition to conventional noise barriers along rail tracks new innovative noise barriers can be applied, as for example a small noise barrier which is mounted without any further groundwork upon the sleepers. Besides a much easier approval procedure the advantage of this so called "mini noise barrier" is the fact that it can be attached between the two tracks in case of double-track lines. Calculated predictions of the noise reduction at various scenarios have just been presented at the DAGA 2016 [1].

In the present study the predicted level differences at the immission point are applied to recordings of train passes using digital filters. Following this way, different noise barrier scenarios are simulated and subjective evaluations are performed to receive data about the actual effect of different noise protection measures for the residents. The differences between the standardized calculation methods for traffic noise in A-weighted noise levels are compared with the psychoacoustic results.

Keywords: Train, Noise barrier, Psychoacoustics I-INCE Classification of Subjects Number(s): 63

1. INTRODUCTION

In the practice of noise mapping and noise action planning the question often arises how far residents really profit by noise abatement measures. The indication of a level value is not always sufficient and does not represent the actual improvement by the noise protection measure.

Hence, the aim of this study is to analyze the perceived improvement by two different noise protection barriers for residents at a distance of 25m by performing psychoacoustic experiments. For this purpose calculated filter of noise barriers were applied to recordings of various train passes. All train passes were evaluated regarding their annoyance, their loudness and their sharpness.

2. STIMULI

2.1 Train passes

In a distance of 25m to the middle of the rail track and a height of 3,5m measurements of typical train passes were conducted. A total of 11 train passes were selected: four freight trains (GZ), one passenger train (IC), three high speed trains (ICE) and three local passenger trains (NVZ). The train passes lasted between 11 seconds and 47 seconds. Figure 1 shows four of the eleven train passes exemplarily.

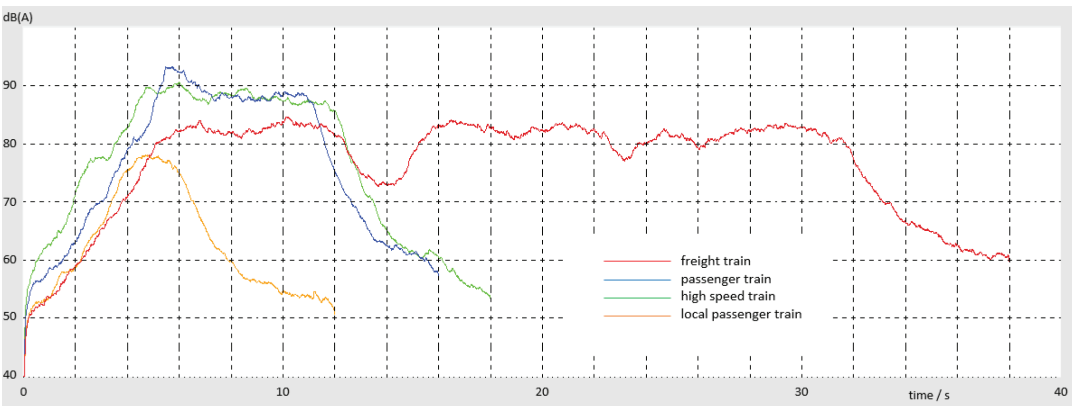

Figure 1 – A-weighted level versus time of 4 different train passes

2.2 Noise barriers

Two different noise barriers were simulated: one conventional noise barrier with a height of 2 meters at a distance of 3,8 meters to the middle of the track, the second one was the ”mini noise barrier” with a height of 0,5 meters [1]. This mini noise barrier is mounted directly on the sleepers close to the track (Point of diffraction in 1,4 meter distance to the middle of the track). Figure 2 shows the calculated spectral noise reduction levels according to ISO 9613 for both noise barriers.

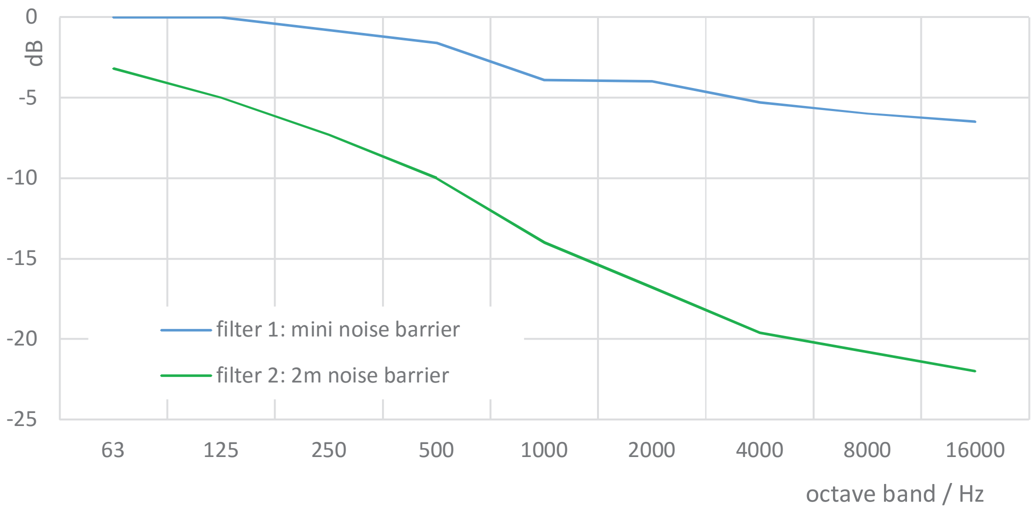

Figure 2 – Level differences for the two calculated noise barriers at 25m distance and 3,5m height

These filter functions were applied to all 11 train passes to simulate the train passes with the noise barriers for the subjective evaluations. This resulted in 33 train passes. Table 1 gives an overview of all A-weighted average and maximum levels relating to the train pass and the duration of all train passes.

Table 1 – Parameters of all stimuli

train	measure	L_{Aeq}	L_{AFmax}	length s
GZ V002	without	92,3	97,6	27
	filter 1	89,0	94,2	
	filter 2	79,2	84,5	
GZ V096	without	85,6	90,1	47
	filter 1	82,7	86,9	
	filter 2	73,5	77,5	
GZ V128	without	81,0	85,3	37
	filter 1	77,8	82,0	
	filter 2	68,2	72,5	
GZ V152	without	84,7	95,9	35
	filter 1	81,4	92,3	
	filter 2	71,5	82,1	
IC V032	without	86,2	93,9	15
	filter 1	82,4	90,3	
	filter 2	71,9	80,6	
ICE V154	without	85,5	91,3	17
	filter 1	81,8	87,4	
	filter 2	71,4	77,8	
ICE1 V049	without	76,7	81,3	13
	filter 1	73,1	77,8	
	filter 2	62,8	68,0	

ICE1_V064	without	79,0	85,6	13
	filter 1	75,5	82,0	
	filter 2	65,6	71,9	
NVZ_V092	without	71,5	79,2	13
	filter 1	67,5	75,5	
	filter 2	57,4	65,2	
NVZ_V118	without	71,2	78,7	11
	filter 1	67,5	75,0	
	filter 2	57,2	64,4	
NVZ_V141	without	71,3	78,8	11
	filter 1	67,6	74,9	
	filter 2	57,2	64,4	

The noise reduction of the mini noise barrier is 3,6 dB(A) in the average and in case of the 2m noise barrier 13,6 dB(A) related to the average noise levels. Noise reductions of about 3 dB(A) are often regarded as hardly noticeable [2].

Since the noise barriers diminish mainly the high frequencies, it was hypothesized that the perceived loudness and especially the perceived sharpness should decrease significantly.

3. PSYCHOACOUSTIC EXPERIMENTS

3.1 Magnitudes and Methods

The aim of the experiments was to measure the efficiency of the different noise barriers. Three different magnitudes were inquired by psychoacoustic experiments: the annoyance, the loudness and the sharpness.

Even if a comparison method, for example magnitude estimation with anchor sound or paired comparison could give good results of the differences, an absolute scaling method was chosen to implement a more realistic scenario for the evaluation [2].

A category scale with the recommended categories for intensity [3] was used: “gar nicht” (not at all), “kaum” (hardly), “mittelmäßig” (moderate), “ziemlich” (rather) and “außerordentlich” (extremely). To enable a more detailed evaluation this category scale was additionally subdivided into 10-step scales. Figure 3 shows the scale that was presented to the subjects. After listening to one train pass, the subjects had to enter the respective numbers into their protocol. If required, the train pass was repeated for the evaluation.

gar nicht	kaum	mittelmäßig	ziemlich	außerordentlich
0	1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40

Figure 3 – category scale for subjective evaluations

At the beginning of the experiment, three testing evaluations were carried out. All of the 33 stimuli were presented three times in random order.

3.2 Equipment and Subjects

The experiments were conducted in a quiet room via a set of four STAX-headphones (SR-307). Fourteen normally hearing subjects of the age between 22 and 46 years (median 33 years) took part in the experiments.

4. RESULTS

4.1 Annoyance

Figure 4 shows the median and the interquartile ranges of all subjects. The data of the sounds without any noise barrier are plotted in blue, the two different noise barriers are figured in orange (mini noise barrier) and green (2m noise barrier). A statistical analysis (bilateral heteroscedastic t-test) based on the individual judgements between "without" and "2m noise barrier" shows significant differences (significance level of 5%) for all train passes. An analysis between "without" and "mini noise barrier" results in significant differences for all train passes except for the train pass NVZ_141.

The efficiency of the mini noise barrier amounts in the mean between 1 and 6 category points, the efficiency of the 2m noise barrier between 10 and 17 category points.

Into the category "extremely annoying", there are altogether five train passes without noise barrier: three of the four freight trains, the IC and one of the three ICEs. The mini noise barrier yields for four of these five train passes a change into the next category "rather" annoying. The 2m noise barrier however makes the subjects change their judgement from "extremely" and "rather" annoying to two categories lower namely "moderate" annoying. The best effect of both noise barriers can be determined for the more annoying train passes.

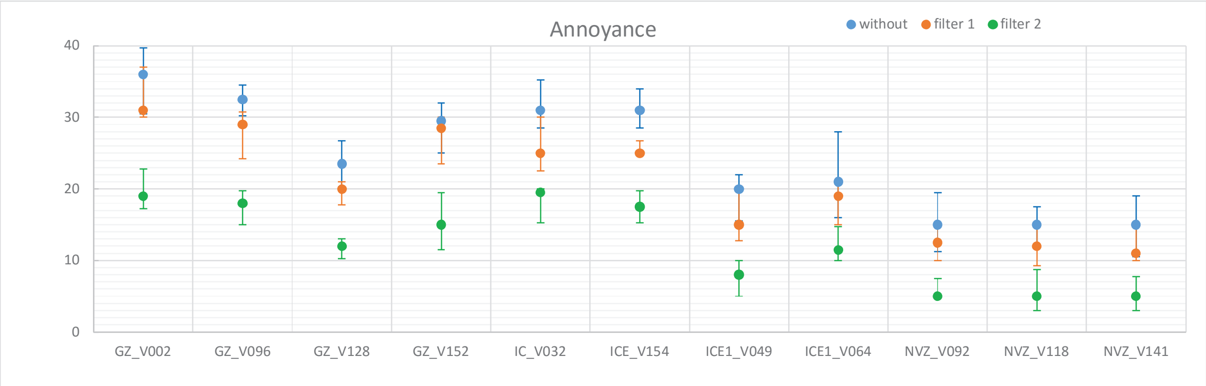

Figure 4 – Results for the magnitude **annoyance** for all 11 train passes without noise barrier (blue), with the mini noise barrier (orange) and the 2m noise barrier (green)

4.2 Loudness

Figure 5 shows the results for the magnitude loudness of all subjects. Again, the three different variants (without noise barrier, with mini noise barrier and with 2m noise barrier) are plotted in different colors.

The application of a mini noise barrier reduces the perceived loudness between 1,5 and 7,5 category points, the use of a 2m noise barrier between 8 and 17 category points. The results of the loudness are quite similar to those of the annoyance: four train passes are perceived as "extremely" loud. For three of these four train passes the mini noise barrier causes an improvement into the category "rather" loud. For all "extremely" and "rather" loud train passes the 2m noise barrier causes a change into the categories "moderate" or "rather" loud.

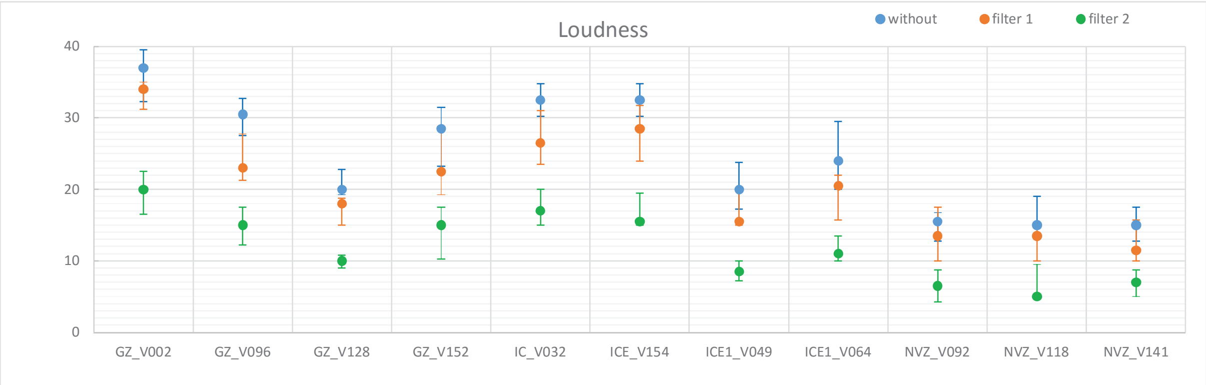

Figure 5 – Results for the magnitude **loudness** for all 11 train passes without noise barrier (blue), with the mini noise barrier (orange) and the 2m noise barrier (green)

A significance test (individual judgments, bilateral heteroscedastic t-test, 5% significance level) between “without” and “mini noise barrier” and “without” and “2m noise barrier” shows significant differences for all cases except for the train passes NVZ_V118 and NVZ_V141 between “without” and “mini noise barrier”.

4.3 Sharpness

The absolute evaluated categories regarding the sharpness are lower than for annoyance or loudness. So, only one train pass is perceived as “extremely” sharp, all the other train passes without noise barrier are evaluated between “rather” and “moderate” sharp. The application of a mini noise barrier already shows results in sharpness reductions between 1,5 and 9 category point, the application of the 2m noise barrier between 6,5 and 17 category points. The differences between “without” and “2m noise barrier” are all significant, the differences between “without” and “mini noise barrier” are significant except for the train passes GZ_V002, IC_V032, NVZ_V092 and NVZ_V141.

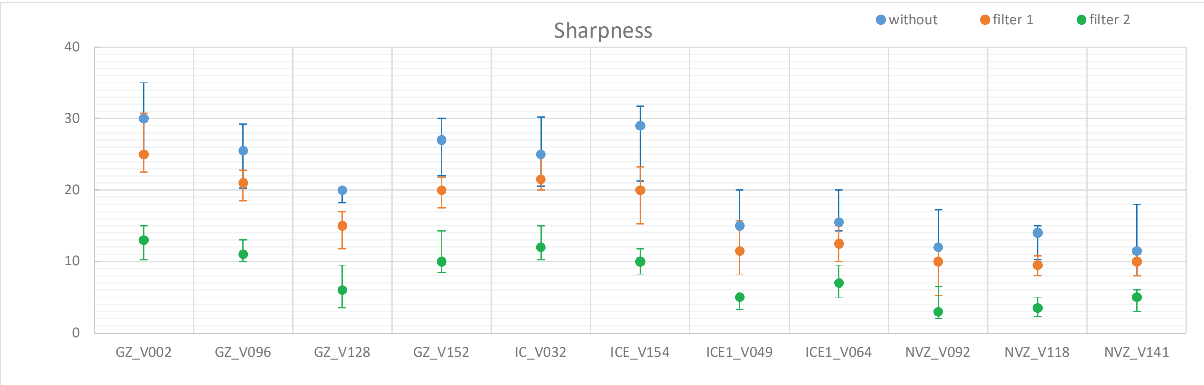

Figure 6 – Results for the magnitude **sharpness** for all 11 train passes without noise barrier (blue), with the mini noise barrier (orange) and the 2m noise barrier (green)

The results of the magnitude sharpness show higher interquartile ranges, especially for the train passes without noise barrier. This means that the subjects agree with each other more concerning the sharpness of the 2m noise barrier than for the pass by without noise barrier.

5. DISCUSSION

Figure 7 faces the results of the subjective evaluations for annoyance and loudness to the values of the average and maximum levels of the train passes of table 1. The high correlation between annoyance and loudness and the levels is obvious.

Even if the train passes have very different lengths (between 11 and 47 seconds) and contain partially very characteristic noise features, as e.g. squeaking of rattling, the evaluation of annoyance seems to align very close to the evaluation of loudness. Both magnitudes are highly linked with the average level and the maximum level of the train passes. So the relationship between the level reduction of a noise protection measure and the real efficiency for the residents can be derived from figure 6: the reduction of the L_{Aeq} as well as the L_{AFmax} of 11 dB(A) represents an improvement in annoyance by an entire category (10 category points).

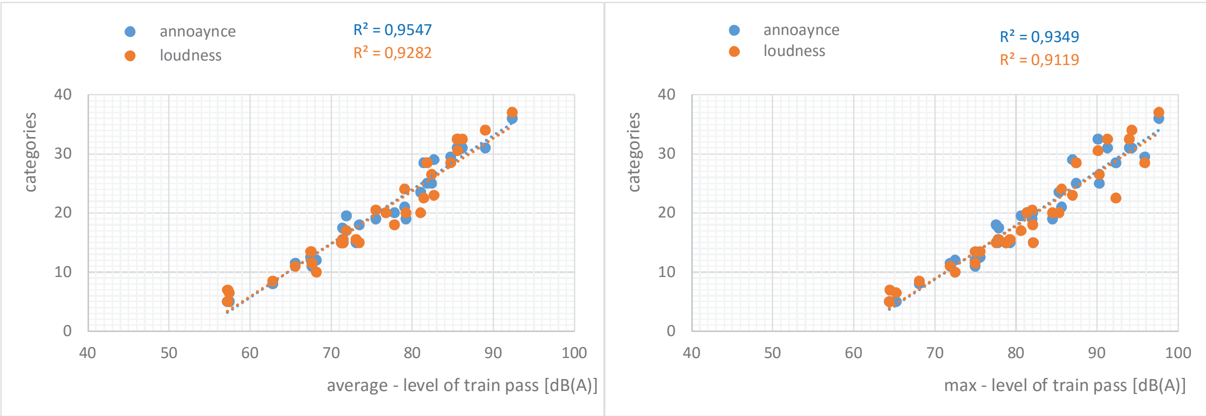

Figure 6 – Correlation between annoyance (blue) resp. loudness (orange) and the L_{Aeq} (left figure) and the L_{AFmax} (right figure) of the train passes

6. CONCLUSION

As expected there are significant differences between the scenario“2m noise barrier” and the scenario “without noise barrier”. The differences in annoyance amount between 10 and 17 category points.

But also the mini noise barrier achieves significant differences in annoyance, loudness and sharpness for most of the evaluated train passes. In mean there are differences in annoyance of 1 to 6 category points available. In most of the cases this difference is statistically significant, especially in the case of the train passes that cause a higher annoyance or loudness perception.

To yield a reduction of annoyance of one entire category, a level reduction for the L_{Aeq} of 11 dB(A) by the noise protection barrier is necessary.

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