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SUBJECTIVE EVALUATION OF NOISE IMMISSIONS FROM TRANSRAPID

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1. INTRODUCTION

The German government decided in 1994 to connect the cities of Berlin and Hamburg by a magnetic levitation train, called Transrapid. A test track of the Transrapid with a length of about 30 km exists in North Germany (Emsland), where the details of the noise emissions of the Transrapid can be studied. In recent years, in particular by aerodynamic measures, considerable reductions in noise emission could be achieved. For an overview of noise emission data for the Transrapid TR07/2, the reader is refered to the literature (e.g. [16], [18], [19], [20]).

While measurements on the test track of the Transrapid allow detailed studies of noise emissions, strictly speaking the total range of possible disturbance effects from the noise immissions can be assessed only after the completion of the line connecting the cities of Berlin and Hamburg. However, by means of psychoacoustic evaluations, some predictions with respect to the evaluation of the noise immissions from Transrapid can be inferred from laboratory studies.

Along these lines, psychoacoustic experiments were put forward with the goal, to predict possible subjective disturbances from the noise immissions from Transrapid. Before the details of the experiments are given, it is reasonable to elucidate their overall background. In particular, the correlations between the evaluation of noise immissions in the laboratory versus the field have to be discussed. The advantage of field studies is the fact that the persons are interviewed about the noise evaluation in their usual habitat (e.g. [14], [17], [10]). On the other hand, the great advantage of laboratory studies is that stimulus parameters can be varied independently, and the impact of different aspects on overall evaluation can be studied in great detail. In addition, as with the Transrapid connecting the cities of Berlin and Hamburg, noise immissions which in

reality do not yet exist, can be simulated in the lab. In summary, in particular in the planning status, the evaluation of noise immissions in psychoacoustic experiments is very feasible.

Psychoacoustic metrics for the quantitative description of noise immissions have been developed in cooperation with colleagues from Osaka University, Japan ([9], [15]). As a first example, psychoacoustic procedures were developed for the evaluation of road traffic noise [1], and the psychoacoustic procedures used for the evaluation of noise immissions were improved [3]. In cooperation with colleagues from the University of Innsbruck, Austria [13] results from field studies and laboratory studies were compared for noise immissions from road traffic noise. Results from field studies and laboratory studies showed good agreement ([23], [5]), adding further to the relevance of psychoacoustic experiments in the laboratory with respect to evaluations of noise immissions.

Not only road traffic noise, but also aircraft noise can be assessed successfully in psychoacoustic experiments [2]. In particular, the benefit of phasing out old loud (stage 2) aircraft could be predicted quantitatively [4]. From field studies it is known that at same L_{eq}, road traffic noise is preferred in comparison to aircraft noise ([11], [22]). This "aircraft malus" could also be verified in psychoacoustic experiments in the laboratory [6], indicating again the strong predictive value of psychoacoustic studies of noise immissions.

With respect to railway noise, in field studies the contrary to the "aircraft malus", namely a "railway bonus" could be verified ([14], [12], [21]). The term "railway bonus" denotes the fact that at same L_{eq}, railway noise is less annoying than road traffic noise. Therefore, in several European countries a "railway bonus" of 5 dB(A) is subtracted from the measured L_{eq} values [10]. In extended psychoacoustic studies ([7], [8]), the "railway bonus" could be ascertained also in psychoacoustic experiments.

In this paper, the subjective evaluation of noise immissions from Transrapid is assessed. In particular, it is studied, whether the developed psychoacoustic metrics can be successfully applied also for the noise immissions produced by a magnetic levitation train. In view of the "railway bonus" it is of interest, whether the noises from the Transrapid are identified as "train noise". In this context, the subjective evaluation of noise immissions from conventional railways versus the Transrapid plays a crucial part.

2. EXPERIMENTS

Fifteen subjects with normal hearing abilities and an age between 24 and 51 years (median 27 years) participated in the experiments. The sounds were presented diotically in a sound proof booth via an electrodynamic headphone (Beyer DT 48) with a free field equalizer [25].

Figure 1 shows the loudness-time patterns of the sounds used in a pilot study as measured by a loudness meter according to Zwicker and

Fastl [24]. Both sounds have the same duration of 15 minutes, and an A-weighted energy-eqiuvalent-level of L_{eq} = 54 dB(A). The simulated noise immissions consist of a soft background noise (road traffic noise with about 4 sone or 47 dB(A), respectively) and three passby sounds in a distance of 25 m. Figure 1a shows the passby sounds of an intercity train (IC) with 134 km/h, a freight train with 93 km/h, and an ICE train with 248 km/h. The original levels of these trains had to be attenuated by some 16 dB in order to reach the L_{eq} of 54 dB(A) measured for the noise immissions from the Transrapid. In figure 1b, the passby sounds of the Transrapid at a speed of 200 km/h, which will be typical in urban areas, are displayed. The level difference of 16 dB, necessary to obtain the same L_{eq} for conventional railway noise and noise from Transrapid, indicates that the noise emission from the Transrapid TR07/2 is relatively low.

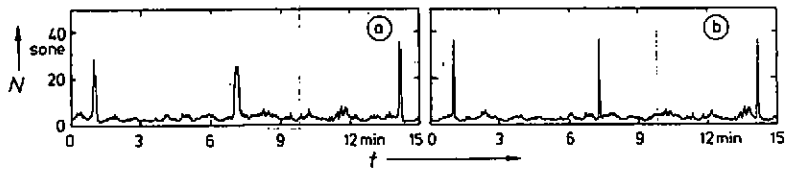

Fig. 1: *Loudness-time functions of the noises studied as measured by a loudness meter according to Zwicker and Fastl [24]. Energy-equivalent-level L_{eq} = 54 dB(A) in both cases. Road traffic noise as background noise with 4 sone plus*
(a): IC with 134 km/h, freight train with 93 km/h, ICE with 248 km/h
(b): Transrapid with 200 km/h.

Since the psychoacoustic methods to evaluate noise immissions are described in detail in the literature (e.g. [8]), in this paper only some important features are given: During the experiment of 15 minutes duration, the subject tracks the instantaneous loudness of the sound by varying the length of a line, displayed on the monitor of a PC. After 15 minutes sound presentation, the subject gets a questionnaire, requesting to name all sound sources heard as well as the most prominent source. The overall loudness of the 15 minute noise immission is scaled by three different methods: seven category scale, absolute magnitude estimation, line-length. Finally, the subject gives comments about the difficulty of the experiment. For further detail, the reader is refered to the literature [7].

3. RESULTS

An analysis of the questionnaires yielded the following results:
Despite the fact that none of the subjects had heard the sound from a Transrapid before, all of them identified the Transrapid noise as "train noise". This means that the noises from conventional trains versus Transrapid are evaluated to be rather similar. Thus, it is not astonishing that for both sounds displayed in figure 1, as most prominent sound source,

"train noise" was mentioned. From the comments it became clear that most subjects can do the experiments without any difficulty; some subjects indicated that they have to pay attention, or that they feel tired.

Figure 2 shows the results of the subjective evaluation of the noise immissions by means of seven categories from "very soft" (1) to "very loud" (7). The left panel shows the data for conventional railway noise, the right panel for noise from Transrapid TR07/2. Both noise immissions are assigned categories between "slightly soft" (3) and "slightly loud" (5) with a dominance of the category "neither loud nor soft" (4).

The results displayed in figure 2 indicate that at the same energy-equivalent-level L_{eq}, noise immissions from conventional railway and Transrapid are essentially assigned the same categories. This result suggests a rather similar subjective evaluation.

With respect to magnitude estimation of global loudness, first for each subject the ratio of the number given for Transrapid versus conventional railway was calculated. From the resulting values medians and interquartiles were derived. The average noise immission produced by the conventional railway (figure 1a) is by about 2% larger than the noise immission from Transrapid (figure 1b). This means again that for <u>same</u> L_{eq}, noise immissions from conventional railway versus Transrapid produced essentially the same global loudness.

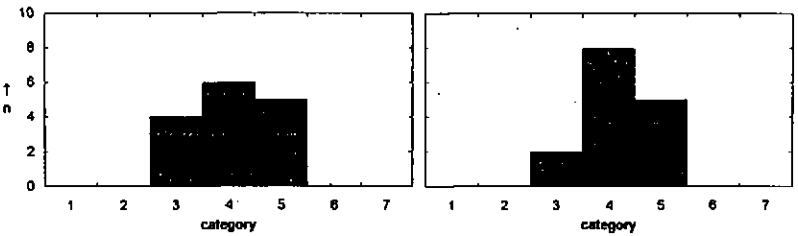

Fig 2: *Evaluation of the noise immissions by means of categories between "very soft" (1) and "very loud" (7).*
Left panel: conventional railway noise; right panel: noise from Transrapid.
n: number of subjects.

The results obtained with the method of line length are displayed in figure 3, as medians with interquartile ranges. The upper values are given for conventional railway noise (DB), the lower values correspond to noise immissions from Transrapid (TR).

As indicated on the abscissa of figure 3, the length of the line on the questionnaire is 150 mm. Regarding the medians, the noise immission from the conventional railway (DB) is assigned a line-length of l = 69 mm, whereas the noise immission from the Transrapid is assigned a length of l = 71 mm. This means again that at same L_{eq}, conventional train noise and noise from Transrapid produced practically the same global loudness.

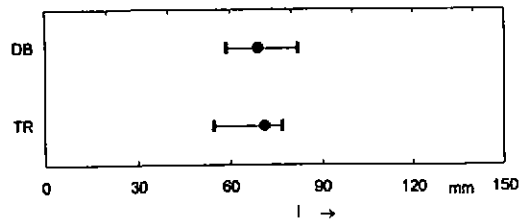

Fig. 3: *Evaluation of global loudness from noise immissions by means of the line-length l. DB: conventional railway, TR: Transrapid. Medians and interquartiles.*

4. SUMMARY AND OUTLOOK

Psychoacoustic metrics for the evaluation of noise immissions have proven successful for road traffic noise, aircraft noise, and railway noise. These metrics also can be used for the assessment of noise immissions from a magnetic levitation train, called Transrapid.

The sounds from the Transrapid are unknown to "naive" subjects, and labelled by them as "train noise". At same L_{eq} = 54 dB(A), the methods category scaling, magnitude estimation, and line-length yield the same global loudness for conventional railway noise versus noise from Transrapid. These results suggest a "railway bonus" also for the Transrapid, since conventional railway noise and noise from Transrapid TR07/2 are perceived to be very similar.

In this paper, data from a pilot study are given. In further studies, different values of L_{eq} as well as different speeds and distances from Transrapid will be investigated. In particular, studies are planned with respect to noise immissions from Transrapid with 400 km/h in 100 m distance. This situation can be regarded as typical for rural districts along the planned line connecting the cities of Berlin and Hamburg.

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