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VARIOUS FACTORS AFFECTING ANNOYANCE RESPONSE TO TRAIN NOISE

J Kaku

Kobayasi Institute of Physical Research, Tokyo, Japan

1. INTRODUCTION

Subjective impression of train noise is affected not only by the sound level but also by other factors including the timbre, duration, temporal variability, presence of impulsive component, etc. Through many research works in the past that investigated the influence of duration and rise time of noise on the impression of loudness, it has generally been understood that the loudness of single event noise such as train noise can be assessed by the sound exposure level [1-3]. In the author's previous study, the influence of impulsive sound caused by wheel flats or rail joints on the subjective impression were investigated. The results indicated that the impulsive sound increased the loudness of passing train noise by 3-5 dB at the same sound energy level [4].

In recent years, the speed of trains has increased considerably. However, the influence of factors such as the timbre of aerodynamic noise and the amazement by high-speed passing on the subjective impression has not yet been closely investigated. For the purpose of taking effective countermeasures against the increase of sound levels accompanying the acceleration of trains, it is necessary to make clear the difference in human response to normal and high-speed train noises.

In this report, we will discuss the above question based on the results of a laboratory experiment.

2. LABORATORY EXPERIMENT

Test sounds

Five kinds of Shinkansen noises, two kinds of train noises of conventional railway, and three kinds of aircraft noises totalling 10 were used as test sounds. 'Shinkansen' is the name of the high-speed railway in Japan. The aircraft noises were adopted as the same type of intermittent noise for

comparison. Table 1 shows the specifications of the test sounds. All passing train noises were recorded 25m away from the railway track. Measurement sites for Nos 1-3 test sounds are viaduct and ballast track sections without parapets on the Tokaido Shinkansen, those for No. 4 and 5 are viaduct and slab track sections with sound insulating barriers on the Tohoku Shinkansen and those for No. 6 and 7 are embankment and ballast track sections without parapets on the JR Chuo Line. Shinkansen of No. 5 is ultrahigh-speed test carriages of JR-East.
Aircraft noises of Nos 8-10 are landing noises recorded 1,600m, 6,300m and 9,200m away from the runaway edge of Chitose Airport.

Table 1 Specifications of test sounds.

No.	Source	Symbol	Number of cars	Speed (km/h)	Measured SPL $L_{Amax}(s)$ (dB)	L_{AE} (dB)	Duration $L_{Amax}(s)$-10 (sec)	Reproduced SPL $L_{Amax}(s)$ (dB)
1	Shinkansen Type-0	S-0	16	216	81	89.6	10.1	74
2	Shinkansen Type-100	S-100	16	214	80	88.5	10.0	73
3	Shinkansen Type-300	S-300	16	263	84	91.1	7.7	76
4	Shinkansen Type-200	S-200	16	211	75	83.2	8.6	70
5	Shinkansen Test Car	S-T.C	9	400	87	91.1	5.0	80
6	Conventional Type-201	C-1	10	79	82	91.4	13.3	75
7	Conventional Type-189	C-2	9	85	78	86.7	12.8	70
8	Aircraft B-747(Landing)	B4-1	—	—	92	96.2	6.3	84
9	Aircraft B-747(Landing)	B4-2	—	—	80	89.4	19.2	74
10	Aircraft B-747(Landing)	B4-3	—	—	70	81.2	33.1	61

Presentation of test sounds

The values in the rightmost column of Table 1 are the reproducing sound levels of test sounds exposed to the subjects. Taking into account the performance of speaker and fatigue of the subjects, the test sounds were reduced by 7 dB on average as compared with the sound levels measured at the site.

Characteristics of test sounds

Figure 1 shows the frequency characteristics of test sounds of five kinds of Shinkansen and conventional trains (C-1) and aircraft (B4-2). The octave band sound levels are displayed relatively by setting the overall sound levels to 0 dB. Many low frequency components between 63 and 125 Hz are contained in the noises of the Tohoku Shinkansen (□,◇) and a 4 kHz component resulting from fan noise is predominant in the noise of landing aircraft (×).

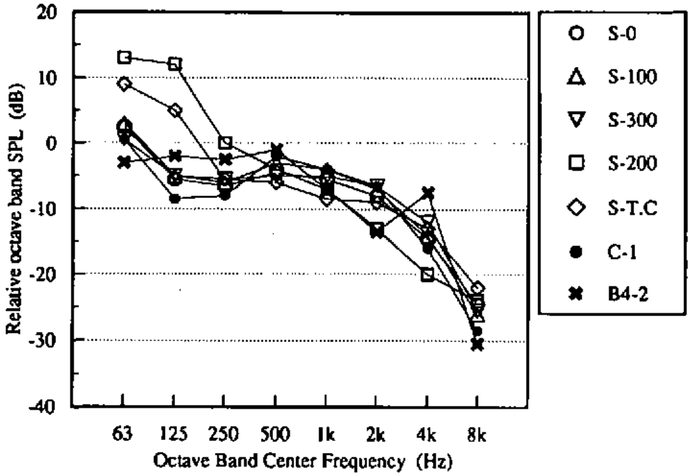

Fig.1 Frequency characteristics of test sounds.

Subjects

Thirty-three subjects, 17 females and 16 males (average age 32) and with normal hearing ability, participated in the experiment.

Procedure

Semantic differential (SD method) and magnitude estimation (ME method) were adopted to judge the quality and the loudness of test sounds [5,6].

Fourteen pairs of adjectives were used in the SD method as shown in Fig.2, and test sounds were reproduced repeatedly as requested by subjects until they finished the judgement. In the experiment using the ME method, two kinds of test tapes with different order of test sounds were prepared and all 33 subjects were tested two times.

In both experiments, the test was conducted with two or three subjects at a once in a soundproof room.

3. RESULTS

SD method

Figure 2 shows the results of semantic profiles obtained with typical six test sounds. From the results, it can be seen that the responses to S-T.C. are very high in items such as 'stringent', 'strong', 'powerful' or 'fast'. The train speed of 400 km/s and high exposure level compared with other trains may have impressed the subjects as a powerful sound. This tendency is similar to the case of aircraft (B4-1), but the responses shown in items such as 'metallic' and 'shrill' are also high.

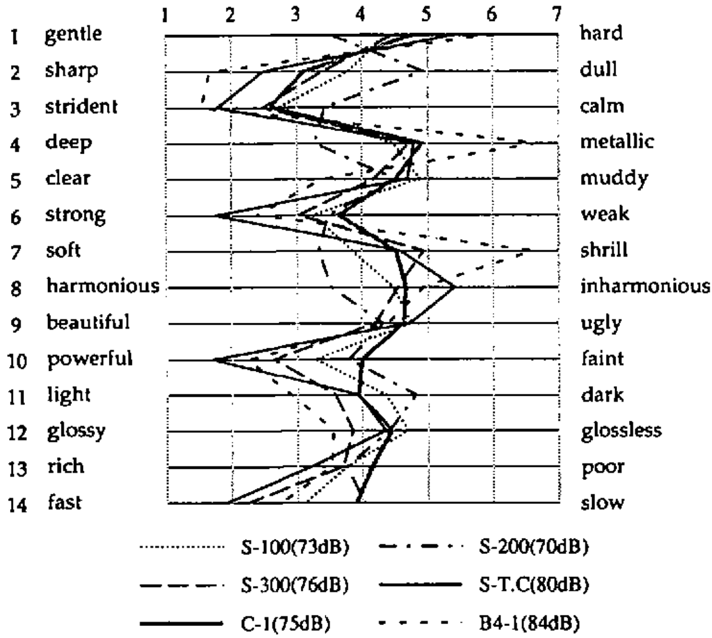

Fig.2 Results of semantic profiles for six test noises.

Every item for S-200 and C-1 is, on the contrary, judged neutrally and these test sounds are taken as impressionless sounds. S-200 is judged contrary to S-T.C. in items such as 'sharp', 'metallic' or 'harmonious' in particular and perceived as the softest sound of the five kinds of train noises. Nearly the same judgement is given to the test sounds of S-100 and S-300 and the difference of the train speed and exposure level is also indicated in the results.

In view of the results of judgement by SD method over the five kinds of train noises, a common thread of assessment of train noises can in general be identified, but it has become apparent that the impression is slightly different depending on the item of adjectives.

We will consider how the difference of impression influences the judgement of loudness of test sounds in the results of following ME method.

ME method

The correlation coefficient of the magnitude estimates between the two tests was calculated and data of those whose value showed 0.7 or more were adopted as effective. Values of seven subjects (six females and one male) did not reach this value and at the end, the data of 26 subjects were adopted.

Values allocated by the test subjects to each test sound were averaged geometrically and the mean value was plotted in compliance with the sound level of each test sound, the result of which is shown in Figures 3 (a) and (b). There is a very close relation between the sound level and the magnitude estimates judged by the subjects. As is clear from both figures, the correlation coefficient of L_{Amax} is 0.98 and greater than 0.92 of L_{AE}. From this observation, it can be seen that the subjects judged the loudness of test sounds by the maximum sound level not by the sound exposure level.

Judging from the results of the mean magnitude estimates of each test sound, the noise of Shinkansen tends to be assessed louder than that of conventional trains. Concerning this difference, it can be concluded that impressions such as 'strong' or 'powerful' shown in the results of judgement by the SD method are reflected in the judgement. From Figure 3 (b), it is evident that two train noises (S-200, S-T.C.) of the Tohoku Shinkansen tend to be perceived louder than those of other Shinkansen or conventional trains at the same L_{AE}. Though S-200 was perceived as a 'soft' and 'harmonious' sound in the judgement using the SD method, this is hardly reflected in the judgement of loudness using the ME method.

4. CONCLUSION

Quality and loudness of traffic noises including Shinkansen, conventional railway and aircraft were examined based on the results of a laboratory experiment.

The results of judgement by the SD method showed that high-speed train noises were assessed as 'powerful' and 'strident' sound because of the increase of sound levels and the perception of speed accompanying the acceleration of trains. On the other hand, train noises of conventional railway and some Shinkansen with noise barriers were assessed as a sound whose impression was vague as compared with high-speed trains.

The results of judgement by the ME method showed that there was a high correlation between the magnitude estimates and the sound levels, the correlation coefficient was 0.98 for L_{Amax} and 0.92 for L_{AE}. The difference of impressions shown in the judgement by the SD method was hardly reflected in the judgement by the ME method.

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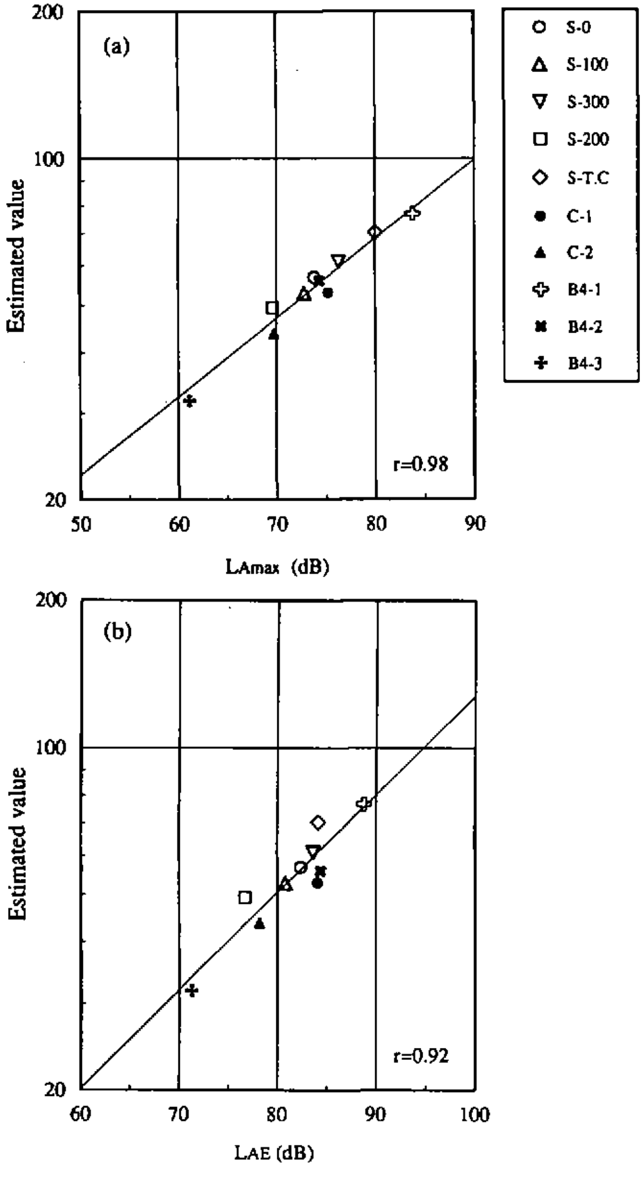

Fig.3 Relation between magnitude estimates and
LAmax (a), and LAE (b) of test sounds.