Available online at www.sciencedirect.com
SCIENCE DIRECT®
Journal of Sound and Vibration 277 (2004) 501–509
JOURNAL OF SOUND AND VIBRATION
www.elsevier.com/locate/yjsvi

# An experiment on auditory and non-auditory disturbances caused by railway and road traffic noises in outdoor conditions

Hui Ma[a,*], Takashi Yano[b]

[a]Graduate School of Science and Technology, Kumamoto University, Kurokami 2-39-1, Kumamoto 860-8555, Japan
[b]Faculty of Engineering, Kumamoto University, Kumamoto 860-8555, Japan

Accepted 25 March 2004
Available online 27 July 2004

**Abstract**

In a laboratory experiment, disturbance caused by two types of noise (railway and road traffic noises) at three noise levels (55, 65 and 75 dB$L_{Aeq}$) in two kinds of stimulation conditions (listening and calculation) was investigated. Thirty Japanese and thirty Chinese subjects performed a listening or calculation task while each noise was presented for 6 min. The subjects assessed the disturbance of their activities using 5-point verbal scales constructed by ICBEN method. A railway bonus, mainly caused by noise masking, was found in the listening task but not in the calculation task. There was a significant difference between the effects of two noises on listening performance when noise level was 75 dB, but no difference was found between railway and road traffic noises on task performance. The results suggest that the disturbance evaluation is determined by several factors and that the interaction among the factors increases with the increase of noise level. Evaluation disturbance is not related to task performance in certain cases.


## 1. Introduction

Comparisons of social survey data in Euro-American countries on community responses to noises from different sources have shown that railway noise is less annoying than road traffic noise at the same noise level [1,2]. This finding is reflected in the noise regulation of some

*Corresponding author. Tel.: +81-96-342-3560; fax: +81-96-342-3569
*E-mail address:* mahui73@hotmail.com (H. Ma).

0022-460X/$ - see front matter 
doi:10.1016/j.jsv.2004.03.011

European countries as a "railway bonus". Fastl et al. [3] also found support for the railway bonus in a laboratory study of the loudness of railway and road traffic noises using responses from Japanese and German subjects.

Recent social surveys conducted in Japan [4,5] have, however, shown different results. Kaku and Yamada [4] indicated that although the dose–response relationships for conventional railway and road traffic noises were almost the same, conventional railway noise was slightly more annoying. Yano et al. [5] showed that railway noise interfered with auditory task significantly more than did road traffic noise.

The present laboratory study investigated whether the degree of activity interference differed between railway and road traffic noises. The following parameters were considered in this study: (1) noise sources (railway and road traffic noises); (2) noise levels ($L_{Aeq} = 55, 65$ and 75 dB); (3) different tasks, auditory (listening) and non-auditory (calculation); and (4) different subjects (Japanese and Chinese). To avoid the influence of situation bias on noise disturbance evaluation, both Japanese and Chinese subjects were kept at almost the same concentration level and comparable standardized verbal scales constructed according to the ICBEN method were used.

## 2. Method

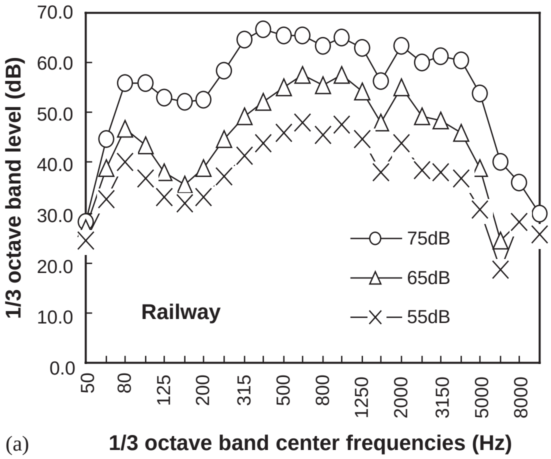
### 2.1. Subjects

The subjects were 30 Japanese from 22 to 35 years of age and 30 Chinese from 22 to 43 years of age. Most of them were graduate students of Kumamoto University, Japan. The numbers of male and female subjects were 14 and 16 for Japanese, and 15 and 15 for Chinese, respectively. The subjects were divided into 10 Japanese groups and 10 Chinese groups, which means that three subjects executed an experiment together.

### 2.2. Test sounds

Six kinds of noise (three railway and three road traffic noises) were used. The railway noise was recorded along a JR railway line in Kumamoto, Japan. The noise of each train passage was recorded simultaneously at 10 and 80 m distance perpendicular from the railway. Three 6 min railway noises consisting of five passages each were prepared from the two railway recordings according to previous experience [6]. The equivalent continuous A-weighted sound pressure levels ($L_{Aeq,\ 6\ min}$) of the three noises were 55, 65 and 75 dB, which are realistic noise levels in outdoor conditions. Road traffic noises from a commercial CD, which were recorded at 5 and 25 m distance perpendicular from the road shoulder, were used to minimize the influence of other sounds such as birds or insects. As with the railway noises, three 6-min road traffic noises with $L_{Aeq,\ 6\ min}$ of 55, 65 and 75 dB were prepared.

The frequency spectrum patterns for each noise source were similar (Fig. 1). However, the mid-frequency components of the railway noise were of higher intensity than that of the road traffic noise.



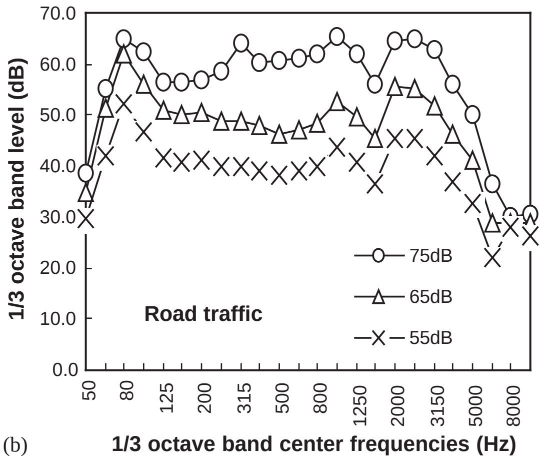




Fig. 1. (a)–(b) Spectra of test stimuli.

### 2.3. Tasks

In an auditory task that simulated conversation in daily life, subjects were asked to listen to statements read out by a Japanese or a Chinese female announcer and then judge whether the statements were reasonable or not. In order to avoid the influence of subjects' knowledge background and logic ability, all the statements were designed as simple as possible. If the subjects can hear the statements clearly, they can give the correct answers easily. The speech signals were recorded in an anechoic room and the sound levels of the Japanese and the Chinese speech were set around 55 dB ($L_{Aeq}$). There were six subsections with 20 statements each and the spectra of speech were almost the same among six task subsections and between Japanese and Chinese. After each 6 min reproduction of 20 statements, the subjects were asked to evaluate the disturbance of noise using a 5-point verbal scale.

In a calculation task, the subjects were required to fill in the blanks in some statistical forms on achievements of a basketball team and its players, using simple calculations. This calculation task simulates the usual intelligence activities in daily life. There were six forms prepared for the formal experiment and the time taken for each form was fixed at 6 min. After the 6 min, the noise stopped and the subjects were asked to evaluate the disturbance caused by the noise using a 5-point verbal scale.

The order of the 6 subsections in each task was the same for all subjects and the noise stimulus reproduced during each task subsection was arranged according to Latin square design.

### 2.4. Scale

The comparable verbal scales to measure the disturbance were "mattaku...nai", "sorehodo...nai", "tashio", "daibu" and "hijoni" in Japanese and "yi dian ye bu", "hao xiang you dian", "bi jiao", "xiang dang" and "te bie" in Chinese. These verbal scales were constructed by the ICBEN method [7] and are equivalent to the English scale, "not at all", "slightly", "moderately", "very" and "extremely".

## 3. Procedure

The experiment was executed in a typical anechoic room and the equipment is shown in Fig. 2. The procedure was as follows: (1) the subjects were given instructions which outlined the purpose and procedure of the experiment; (2) subjects sat in three stable chairs which were fixed on a radius of 3 m from the loudspeaker and with a distance of 0.8 m between them to keep sound levels the same at each chair; (3) after practice, subjects were instructed to perform a listening or a calculation task while the 6 min noise would be given; and (4) when the noise stopped, subjects evaluated the disturbance caused by the noise using the 5-point verbal scale.

## 4. Results

### 4.1. Analysis of variance

There are four factors that might have a potential influence on noise disturbance evaluation in the present study: noise sources, noise levels, tasks and subjects. Table 1 shows the results of analysis of variance. If only the main effects of single factors are considered, noise levels had the best relationship to disturbance evaluation. As for the interaction between two factors, the interaction of noise source and task also has an important impact on the subjective evaluation of noise disturbance.

### 4.2. Comparison of dose–response relationships between railway and road traffic noise

Fig. 3 shows the differences in disturbance between railway and road traffic noises and Table 2 is the $t$-test for equality of railway and road traffic noises on mean disturbance values. In the

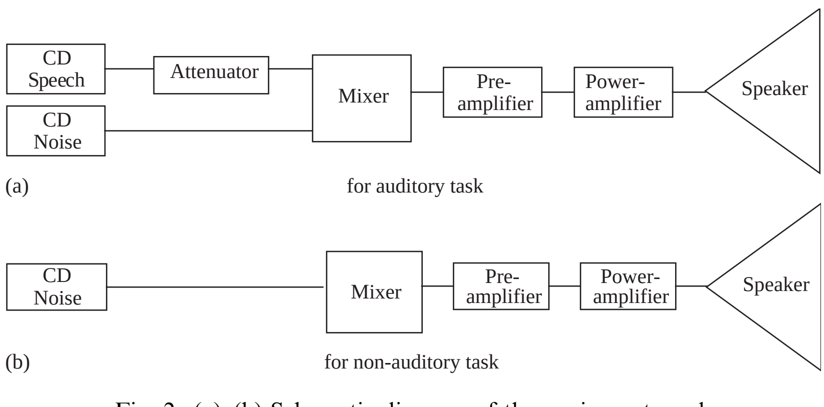



Fig. 2. (a)–(b) Schematic diagram of the equipment used.

Table 1
Analysis of variance

| Source | Type III sum of squares | df | Mean square | *F* | Sig. |
|---|---|---|---|---|---|
| Corrected model | 457.236 | 14 | 32.660 | 43.970 | 0.000 |
| Intercept | 6426.112 | 1 | 6426.112 | 8651.575 | 0.000 |
| SOURCE | 5.868 | 1 | 5.868 | 7.900 | 0.005 |
| LEVEL | 340.558 | 2 | 170.279 | 229.249 | 0.000 |
| TASK | 15.901 | 1 | 15.901 | 21.408 | 0.000 |
| SUBJECT | 10.035 | 1 | 10.035 | 13.510 | 0.000 |
| SOURCE*LEVEL | 15.703 | 2 | 7.851 | 10.570 | 0.000 |
| SOURCE*TASK | 23.112 | 1 | 23.112 | 31.117 | 0.000 |
| SOURCE*SUBJECT | 5.168 | 1 | 5.168 | 6.958 | 0.009 |
| LEVEL*TASK | 33.853 | 2 | 16.926 | 22.788 | 0.000 |
| LEVEL*SUBJECT | 1.869 | 2 | .935 | 1.258 | 0.285 |
| TASK*SUBJECT | 5.168 | 1 | 5.168 | 6.958 | 0.009 |
| Error | 523.651 | 705 | 0.743 | | |
| Total | 7407.000 | 720 | | | |
| Corrected total | 980.887 | 719 | | | |

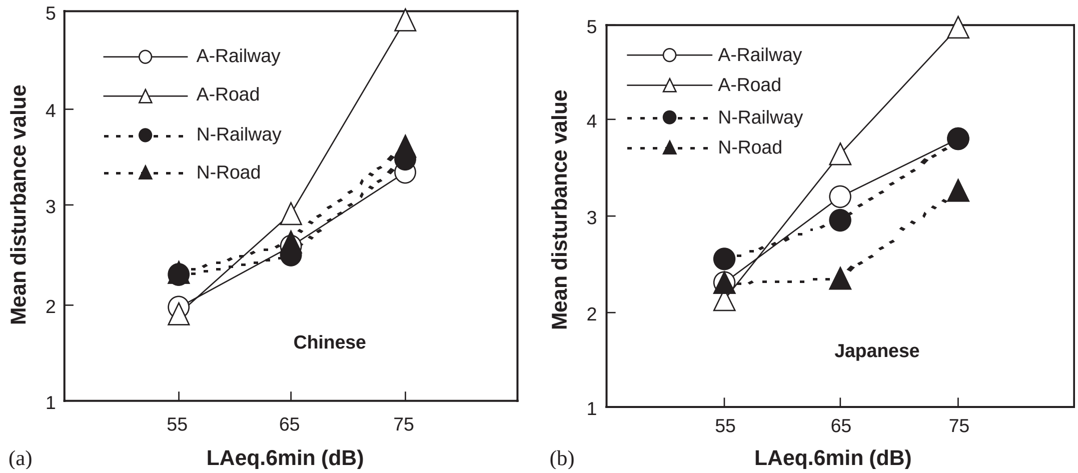



Fig. 3. (a)–(b) Comparison of dose–response relationships between railway and road traffic noises.

auditory task, road traffic noise was more disturbing than railway noise both for Japanese and Chinese subjects and particularly at 75 dB. However, in the non-auditory task there was no difference between these two noises for Chinese subjects and for Japanese subjects, railway noise is a little more disturbing than road traffic noise. These results suggest that there is a railway bonus for the auditory task but not for the non-auditory task. This is inconsistent with the finding reported in previous social survey studies [2,5] that listening disturbance caused by railway noise is larger than road traffic noise. This may partly be the effect of sound insulation since disturbance caused by road traffic noise decreases more sharply with sound level than disturbance due to

Table 2
Results of $t$-test on the comparison between two noise sources

| Subjects | Auditory task | | | Non-auditory task | | |
|---|---|---|---|---|---|---|
| | 55 dB ($L_{Aeq.}$6 min) | 65 dB ($L_{Aeq.}$6 min) | 75 dB ($L_{Aeq.}$6 min) | 55 dB ($L_{Aeq.}$6 min) | 65 dB ($L_{Aeq.}$6 min) | 75 dB ($L_{Aeq.}$6 min) |
| Chinese | 0.710 | 0.167 | 0.000** | 0.878 | 0.539 | 0.567 |
| Japanese | 0.470 | 0.047* | 0.000** | 0.269 | 0.020* | 0.070 |

*Means $p<0.05$.
**Means $p<0.01$.

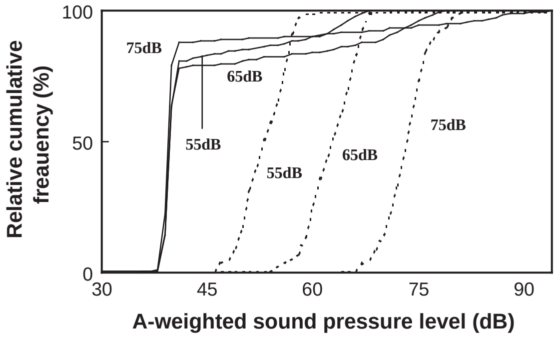



Fig. 4. Relative cumulative frequency of sound pressure level of noises (solid lines: railway noises; dashed lines: road traffic noises).

railway noise. At lower sound levels, the disturbance by road traffic noise seems to be less than by railway noise.

Fig. 4 shows the relative cumulative frequency of sound pressure levels of the different noises. Compared with railway noise, road traffic noise has a higher sound pressure level most of the time, though railway noise contains a few short-term high-pressure level sounds. Considering that the sound level of speech signal was set around $L_{Aeq}$ of 55 dB, road traffic noise had a stronger masking effect on the speech signal than railway noise. This suggests that the railway bonus found in the auditory task is mainly caused by noise masking.

### 4.3. Comparison of dose–response relationships between auditory and non-auditory tasks

Fig. 5 compares mean disturbance values between auditory and non-auditory tasks. There was no difference in disturbance caused by railway noise between auditory and non-auditory tasks. The characteristic of the tasks had little effect on the disturbance caused by railway noise and this trend was the same for both Japanese and Chinese subjects. In the case of road traffic noise, however, the trend of dose–response relationships was clearly different between auditory and non-auditory tasks. This difference was slightly larger for Japanese subjects than for Chinese.

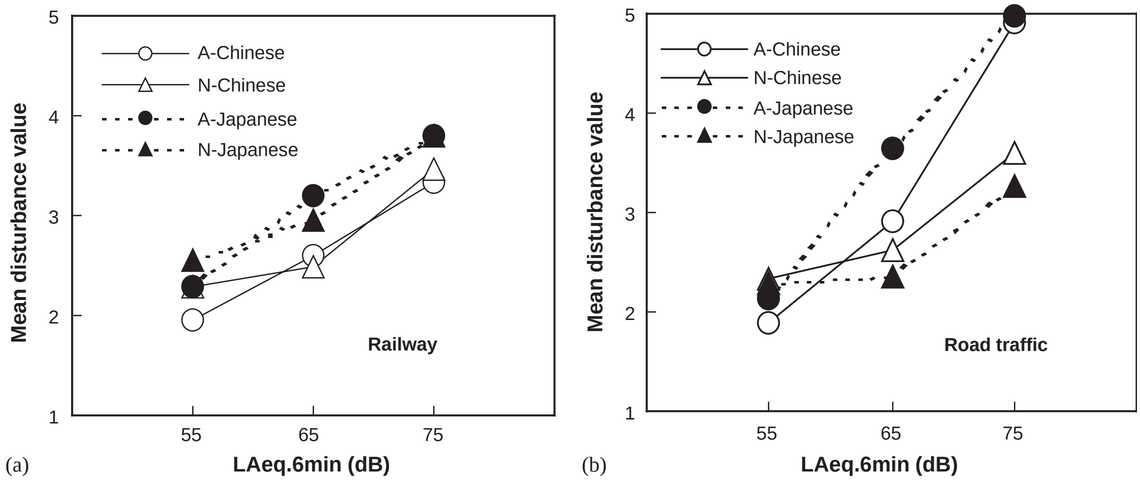



Fig. 5. (a)–(b) Comparison of dose–response relationships between two kinds of tasks: A—auditory task; N—non-auditory task.

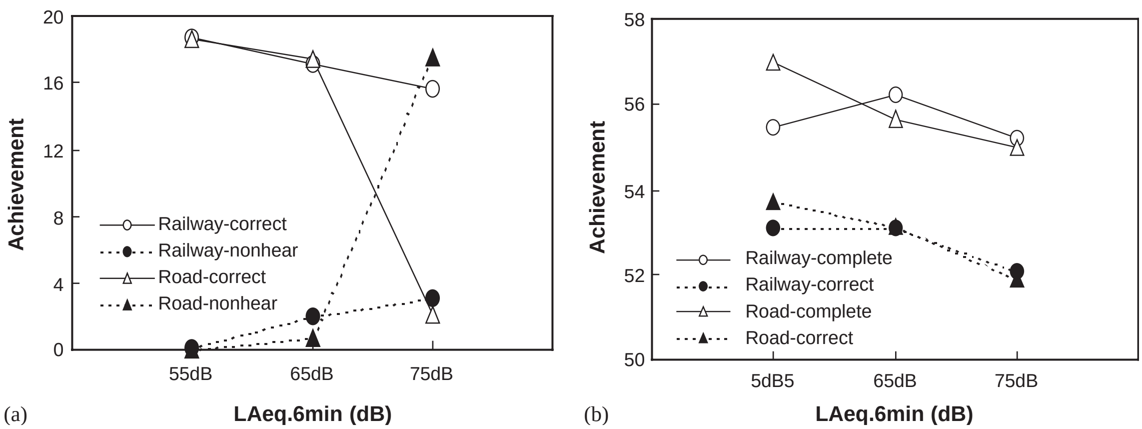



Fig. 6. Chinese subjects' performance for (a) auditory task and (b) non-auditory task.

## 4.4. Comparison of dose–response relationships between Japanese and Chinese subjects

In the non-auditory task, Chinese subjects indicated greater disturbance from road traffic noise than Japanese, but in the other conditions, Japanese subjects felt more disturbed by noises than Chinese. However, through the statistical analysis no systematic difference was found between Japanese and Chinese subjects' disturbance evaluation.

## 4.5. Noise disturbance on task performance

Fig. 6 shows the Chinese subjects' performance in auditory and non-auditory tasks (because the tendency of Japanese and Chinese response on task performance was almost same, Chinese subjects' results were used as a representative). No difference was found between the effects of railway and road traffic noises on task performance except that there was significant difference between the effect of these two noises on auditory performance when the noise level is at 75 dB. The statistic test showed that with the non-auditory task, neither noise level nor disturbance evaluation was correlated with task performance. With the auditory task, however, a high correlation was found between disturbance evaluation and task performance as well as between noise level and task performance. This difference mainly is because that the performance for the auditory task was more influenced by the acoustic characteristic of noise sources.

## 5. Discussion

The results indicate that in a non-auditory task there was no difference in disturbance between railway and road traffic noises. However, at middle and high levels in the auditory task there was a significant difference between railway and road traffic noises. The auditory disturbance induced by road traffic noise increased with noise level more rapidly than noise disturbance in other conditions. The influence of road traffic noise seems to depend on the characteristic of the task. Further research is necessary to explore the relationship between the task and the noise effect.

The railway bonus, which is mainly caused by noise masking, was found for the auditory task, especially when the noise level was more than 65 dB. This railway bonus seemed to increase with the increase of noise level. This is consistent with the finding of Fastl et al. [3]. With the non-auditory task, however, there is no railway bonus and Japanese subjects judged railway noise a little more disturbing in their calculation test than road traffic noise. This result suggests that activities or subjective stimulation levels influences the railway bonus.

The present study also shows that among the four factors examined, noise level had the best relationship to noise disturbance. Also, it comprised a stabilizing factor in the subjective evaluation of noise disturbance and its influence was independent of noise sources or tasks. However, no correlation was found between noise level and task performance with the non-auditory task but such a correlation was found with the auditory task. Other factors such as noise sources, tasks and subjects, showed little relationship to noise disturbance, but they may influence the subjective evaluation of noise disturbance through their interaction with each other. The interaction of noise sources and tasks is important because the difference in disturbance caused by road traffic noise depended on tasks.

## 6. Conclusion

Railway bonus was only found with the auditory task and there was no difference between these two noises with the non-auditory task. Compared with railway noise, the influence of road traffic noise changed depending on the task content.

The interaction of noise sources and tasks influenced the noise disturbance evaluation.

Task performance had no relation with noise level and disturbance evaluation with the non-auditory task but a relation was found with the auditory task.

## References

[1] J.M. Fields, J.G. Walker, Comparing the relationships between noise level and annoyance in different surveys: a railway noise vs. aircraft and road traffic comparison, *Journal of Sound and Vibration* 81 (1) (1982) 51–80.
[2] U. Moehler, Community response to railway noise: a review of social surveys, *Journal of Sound and Vibration* 120 (1988) 321–332.
[3] H. Fastl, S. Kuwano, S. Namba, Assessing the railway bonus in laboratory studies, *The Journal of the Acoustical Society of Japan (E)* 17 (3) (1996) 139–147.
[4] J. Kaku, I. Yamada, The possibility of a bonus for evaluating railway noise in Japan, *Journal of Sound and Vibration* 193 (1996) 445–450.
[5] T. Yano, T. Sato, K. Kawai, K. Kurosawa, Comparison of community response to road traffic and railway noises, *The Journal of the Acoustical Society of Japan* 54 (1998) 489–496.
[6] T. Yano, A. Kobayashi, Disturbance caused by various fluctuating single noises and combined community noises, *Environment International* 16 (1990) 567–574.
[7] J.M. Fields, R.G. d Jong, T. Gjestland, I.H. Flindell, R.F.S. Job, S. Kurra, P. Lercher, M. Vallet, R. Guski, U. Felscher-Suhr, R. Schumer, Standardized general-purpose noise reaction questions for community noise surveys: research and a recommendation, *Journal of Sound and Vibration* 242 (2001) 641–697.