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CROSS-CULTURAL STUDY ON THE LOUDNESS EVALUATION OF ENVIRONMENTAL NOISE

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ABSTRACT

Psychoacoustical experiments were carried out to investigate the subjective impression of loudness of environmental noise with European and Japanese subjects. Though the sites and the procedures of the experiments were not always the same, there was little difference between the reactions of both groups of subjects regarding the judgement of instantaneous loudness and overall loudness. Furthermore, the results of the experiments demonstrate that road traffic noise has a greater effect on the overall judgment of mixed noises, which consisted of road traffic and railway noises, than railway noise.

1 - INTRODUCTION

It is generally accepted that the long-term impression of environmental noise, which consists of a combination of various noises that vary with time, is mainly formed by the weighted accumulation of short-term impressions of the noise. Several psychoacoustical studies have been conducted to make clear the relationship between the short-term impressions and the long-term impression. Namba and Kuwano [1] Kuwano and Namba [2] developed a method called "the method of continuous judgement by category" to evaluate the instantaneous loudness of sounds and have made the above study on the basis of laboratory experiments. On the other hand, Hellbrueck & Zeitler [3] employed another method to judge the integrated loudness of sounds every 15 seconds, which was based upon the results of auditory memory research, and have applied it to the same research in the field experiments. The former study [2] shows that an instantaneous judgment of loudness is determined by the sound energy averaged during the period of 2-3 seconds preceding each judgment, and that overall loudness is likely to be evaluated higher than mean of instantaneous loudness. The latter study [3] shows that the short term impression of loudness corresponds well to the equivalent sound pressure level (L_{Aeq}) up to 15 seconds.

In many European countries, such as Germany, Holland, Austria, and Switzerland for example, a favoring policy, known as the 'railway bonus', is applied to railway noise in the establishment of noise standards. This policy holds that railway noise has less of a damaging impact on people than road traffic noise at the same sound level, and it was introduced according to the results of many social surveys. In Japan on the other hand, although there are reports that confirm the validity of the railway bonus from the results of

laboratory experiments [4], the results of social surveys do not uphold the conclusion that the damaging impact of railway noise is small [5]. This difference between the European and Japanese evaluation of environmental noise can be attributed to the contribution of non-physical factors such as the interests or the public nature involved with sound source, however, the question remains unanswered.

This research seeks to further elucidate the relationship between the impression of short-term or instantaneous loudness of environmental noises and the impression of the overall loudness. This research also seeks to investigate whether there are any differences in the judgment of loudness between European and Japanese subjects, by presenting the same sound stimuli to the subjects.

2 - EXPERIMENTS

Two psychoacoustical experiments were carried out by using real environmental sounds as test stimuli.

2.1 - Experiment-1: comparison between German and Japanese subjects

In Germany, two experiments were conducted; one in a laboratory and the other in the field. A recorded sound (a) which consisted of road traffic and railway noises was used as a stimulus in the laboratory experiment, and a real environment noise (b) was the stimulus of the field experiment. In Japan, both experiments were conducted in a laboratory using the same stimuli as used in the German experiments. The duration of each stimulus was 15 min. for the stimulus (a) and 20 min. for the stimulus (b), and the values of L_{Aeq} were 75~77dB.

Subjects judged the short-term loudness of the sounds every 15 seconds using category subdivision scaling (CS Scaling) in Germany, while in Japan subjects judged the instantaneous loudness of sounds continuously using 7 point categories. As the instantaneous judgement was necessarily delayed owing to response time, the responses of each subject were shifted on the time axis until the coefficient of correlation between the instantaneous sound level and the response at 0.1s intervals reached the maximum value. In both cases, the lowest category was "very soft" and the highest category was "very loud". The subjects were also asked to judge the overall loudness of the stimuli using the same categories after the continuous judgement of loudness.

Five Germans, three females and two males aged between 21 and 28 years, participated as test subjects in Germany, and eight Japanese, five females and three males aged between 20 and 38 years participated in Japan. The individual responses of the continuous loudness were averaged among each group.

2.2 - Experiment-2: comparison between European and Japanese subjects

This experiment was conducted in Japan. Road traffic and railway noises were systematically edited in various combinations during 10-minute period. As for road traffic, two kinds of recorded noise from an ordinary road and an expressway were used. The value of $L_{Aeq,10\text{ min}}$ of each noise source was varied from 50 dB to 70 dB in 10 dB steps. Therefore, The total number of stimuli was 18, i.e., the combinations of six road traffic noises and three railway noises. These sounds were reproduced with a DAT recorder and presented to subjects through an amplifier and loudspeakers in a sound proof room.

Six European subjects, a female (Hungarian) and five males (two Germans, a British, a Hungarian, and an Italian) aged between 24 and 49 years, and ten Japanese subjects, five females and five males aged between 20 and 46 years, participated in the experiment. Both groups of subjects were divided into two groups and stimuli were presented by the reversed order among the groups. The procedure of the judgement of loudness was almost the same as used in the Experiment-1 in Japan. The subjects were also asked to judge the overall loudness of each noise source in Experiment-2.

3 - RESULTS AND DISCUSSIONS

3.1 - Experiment-1

The relationships between continuous judgement of loudness and sound level are shown in Fig. 1 (German subjects) and in Fig. 2 (Japanese subjects). The coefficients of correlation between the sound level and the subjective responses in the two stimuli, (a) and (b), were 0.886 and 0.902 for the German subjects, and 0.854 and 0.888 for the Japanese subjects respectively. In both cases the impression of the loudness of the sound corresponds well to the sound level and it can be seen that the experimental condition has little influence on the short-term impression of loudness.

Table 1 shows the overall loudness of the stimulus and the mean of the continuous loudness. The 0-50 CS-scaling used in the German experiments was converted into 7 point categories using the following equation.

$$\text{Category (1 - 7)} = 6 \times \text{CS} 50 + 1$$

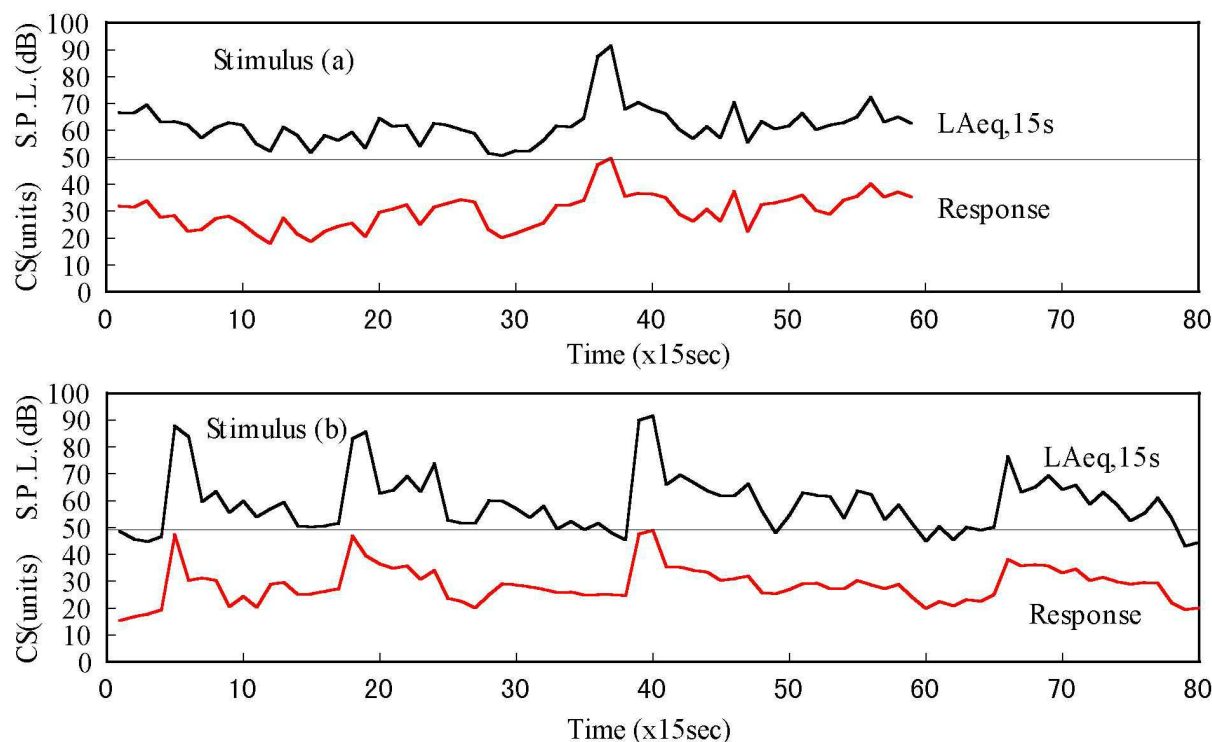


Figure 1: Results of experiment-1 with German subjects.

As is clear from the table, both groups of subjects judged stimulus (b) softer than stimulus (a), even though the L_{Aeq} value of stimulus (b) was a little higher than that of stimulus (a). The reason why the stimulus (b) was judged softer than the stimulus (a) may be that there were time spans of comparatively low sound level between 4 trains in the stimulus (b) and this had an impact on the impression of overall loudness. It can also be seen that the Japanese subjects showed a greater difference than the German subjects between the overall loudness and the mean of the continuous loudness.

Stimulus	L_{Aeq} (dB) Total / Railway	Judgement of loudness	
		Germans Overall / Mean	Japanese Overall / Mean
(a)	$L_{Aeq,15min}$: 75.5 / 75.2	4.79 / 4.60	4.75 / 4.17
(b)	$L_{Aeq,20min}$: 77.1 / 76.9	4.29 / 4.45	4.38 / 3.72

Table 1: Results of experiment-1.

3.2 - Experiment-2

An example of the relationship between the continuous judgement of loudness and sound level is shown in Fig. 3. The stimulus shown here is the case that the values of $L_{Aeq,10min}$ of both road traffic noise and railway noise were 60dB. As in experiment-1, both European and Japanese subjects demonstrate a good correspondence between the impression of instantaneous loudness and the instantaneous sound level.

Figure 4 shows the relationship between the mean of the instantaneous loudness and the overall loudness. From these results it can be seen that there is a linear relationship between the average of the continuous loudness and the overall loudness. It is clearly seen here again that the Japanese subjects show a tendency to judge the overall loudness louder than the mean of continuous loudness.

Figure 5 shows the overall loudness of the road traffic noise, the railway noise, and the total noise as a whole judged by European and Japanese subjects, using the $L_{Aeq,10min}$ of the road traffic noise as the parameter. As the number of the data which showed the significant difference at 5%-level between the results obtained with two kinds of road traffic noise were 2 for Japanese subjects and 1 for European subjects out of 27 data, both results were averaged. It is clear from the figure that when the road traffic noise has a high level, the railway noise does not contribute to the overall loudness at all. But when the road traffic noise is low, the overall loudness is somewhat affected by the loudness of the railway noise. It may be due to the difference of continuity and intermittence.

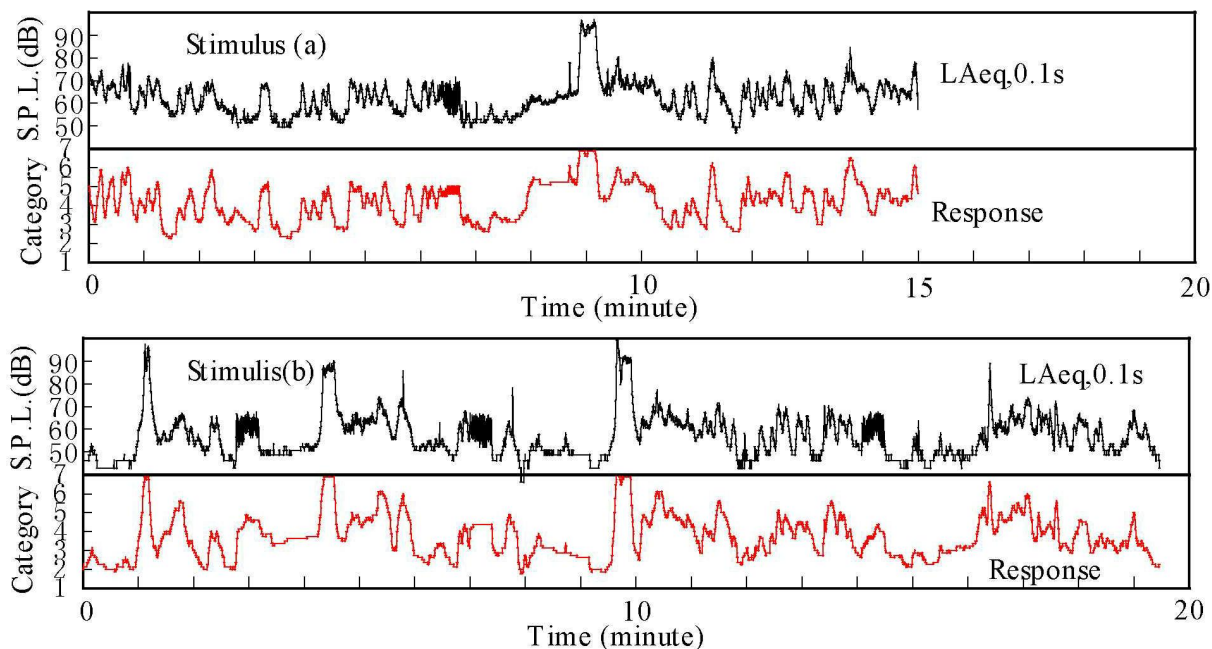


Figure 2: Results of experiment-1 with Japanese subjects.

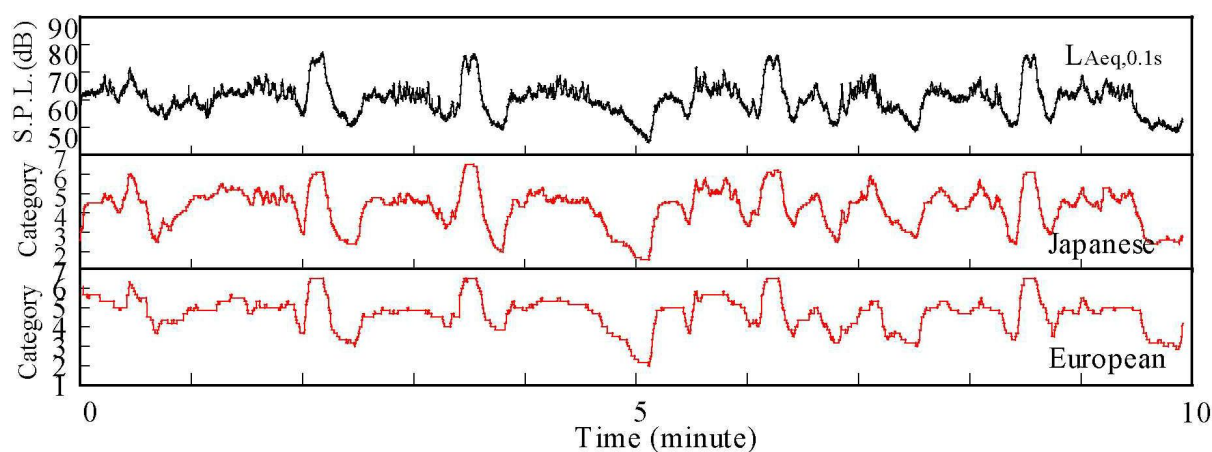


Figure 3: An example of the results of experiment-2; the values of $L_{Aeq,10min}$ of road traffic noise and railway noise were 60 dB.

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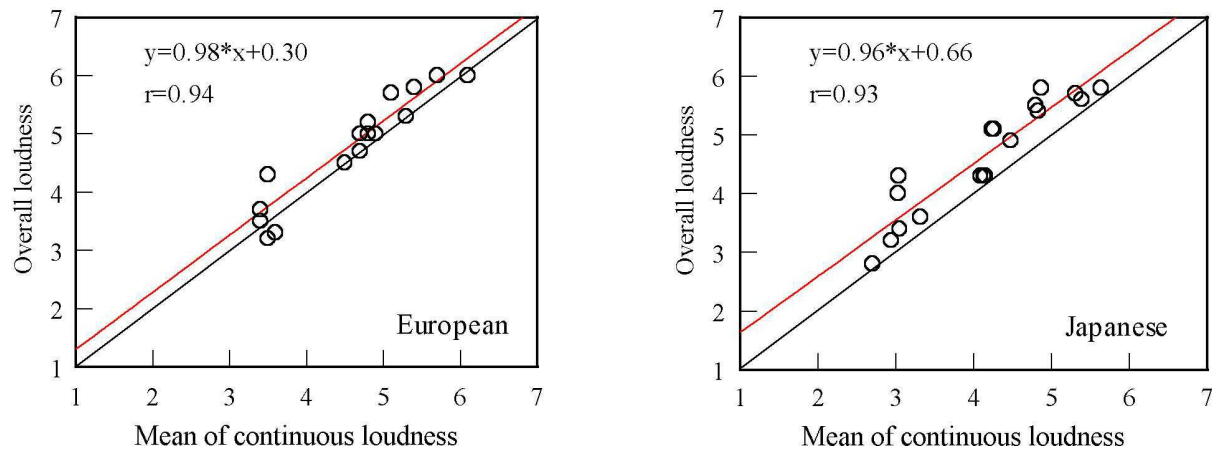


Figure 4: The relation between the mean of continuous loudness and the overall loudness.

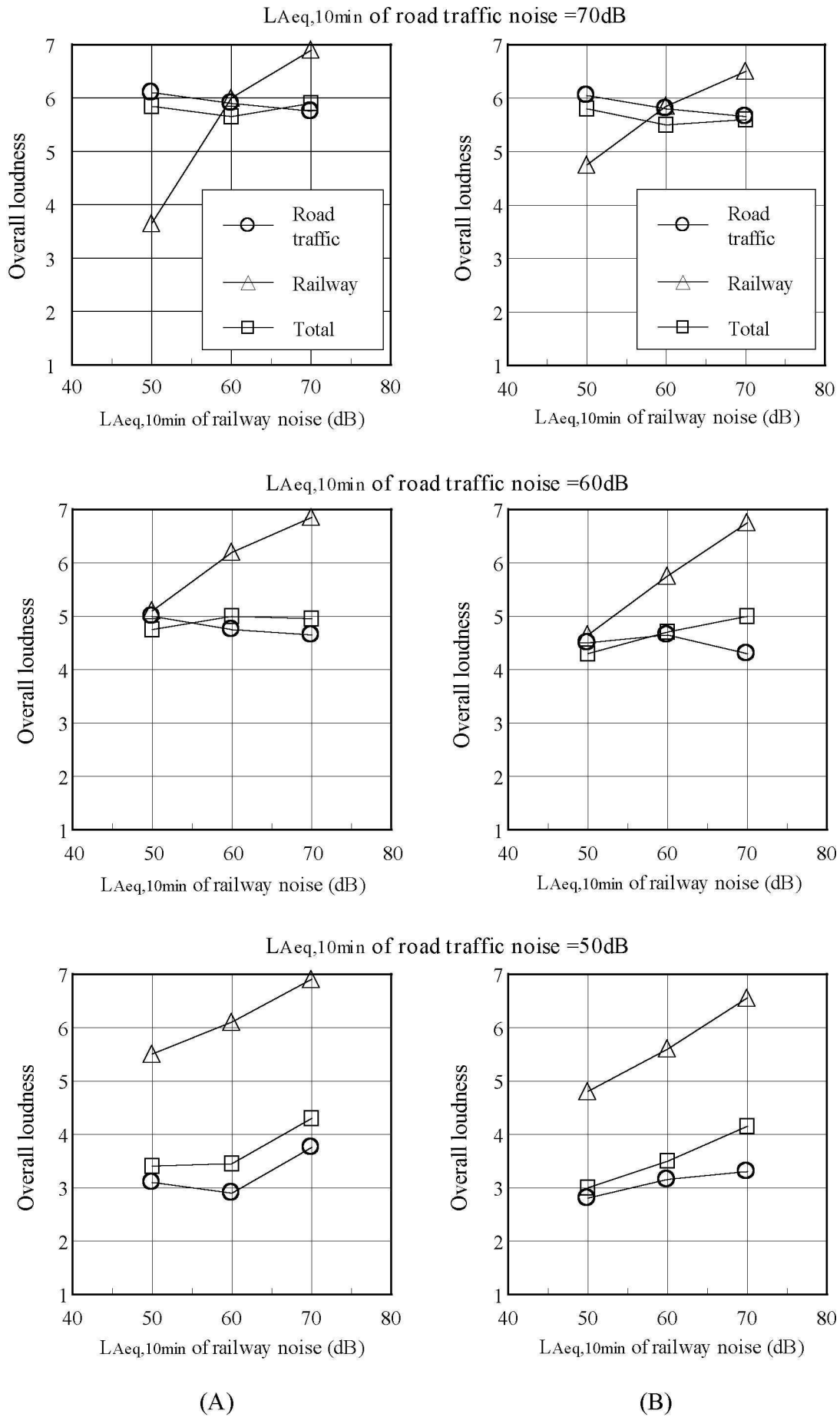


Figure 5: Comparison of overall loudness of each component noise and the total noise between European subjects (A) and Japanese subjects (B).