ACOUSTICAL LETTER

Memory of the loudness of sounds in relation to overall impression

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1. Introduction

The overall impression of long-term sound will be judged on the basis of memory while instantaneous impression of the sound will be based on perception. It is important to examine the relation between perception and memory in the study of memory. Memory of long-term sound may be influenced by various factors. Among them cognitive and temporal factors may have a significant effect in the memory for sounds.

Namba and Kuwano have developed the method of continuous judgment by category [1–3] with their colleagues in order to examine the instantaneous impression corresponding to the temporal change of the sound at each moment and found that the overall impression is not always the same as the average of instantaneous loudness, but usually overall impression is overestimated compared with the average of instantaneous judgments.

In the present study, a new approach is introduced to examine the memory of environmental sound in relation to the instantaneous impression of the sound. That is, the loudness, the timing of the occurrence, serial order and order of recalling of the recalled sound sources are obtained from the sketches drawn by subjects and related to physical properties. Since environmental sound consists of various sounds whose sources are usually identified, it would not be difficult for subjects to memorize the sound sources.

2. Experiment

2.1. Stimulus

Environmental sound recorded in the suburban area near Eichstätt in Germany was used as a stimulus. The duration was 20 min. It included road traffic noise, noise from motor bike, train noise, train crossing, bird twittering, etc. The L_{Aeq} value was 76.3 dB. The sound level pattern is shown in the upper line in Fig. 1.

2.2. Procedure

The experiment consisted of the following three steps, each of which was conducted on different days. The experiments of the three steps were conduced with the same order with all the subjects, i.e. from Step A to Step C. The same sound was presented at each step.

Step A: Subjects listened to the sound without doing anything. After listening to the whole sound, subjects were asked to judge the overall impression of loudness using Category Subdivision Scale (CS Scale) [4]. That is, at first subjects were required to judge the loudness using 5 categories and next they were asked to subdivide the category chosen into fine grade from 1 to 10. This makes 50-point category scale. After overall judgment of loudness they were requested to recall the names of the sound sources.

Step B: Subjects were asked to judge the loudness continuously by matching the length of a line on a screen to the instantaneous impression of loudness [3]. They were also asked to judge the overall loudness by CS Scale after the instantaneous judgments.

Step C: Subjects were instructed to memorize the sound while listening to the sound. After listening to the whole sound, they were asked to recall each sound source and write down the names of the sound sources with the order of recalling at the appropriate position in a chart where the vertical line indicates the loudness and the horizontal line indicates the elapse of time.

2.3. Equipment

The sound was reproduced with a DAT recorder (Pioneer D-05) and presented to subjects' ears though headphones (Stax SDR-X Pro) in a sound proof room.

2.4. Subject

Five Japanese females and three Japanese males with normal hearing ability aged between 22 and 40 participated in the experiment. However, a part of the data of two subjects was missing and the data of six subjects were analyzed.

3. Results and discussion

3.1. Relation between instantaneous judgment and instantaneous sound level

There is a time lag (reaction time) between the presentation of sounds and the subjects' responses to them. The coefficient of correlation between physical values ($L_{Aeq,100\,ms}$) and subjects' responses sampled every 100 ms was calculated by sliding the interval between them. The time lag when the highest correlation was obtained was regarded as the reaction time. Taking the reaction time into account, the instantaneous judgments of six subjects sampled every 100 ms were averaged. The relation between $L_{Aeq,100\,ms}$ (upper line) and subjective responses (lower line) is shown in Fig. 1. High

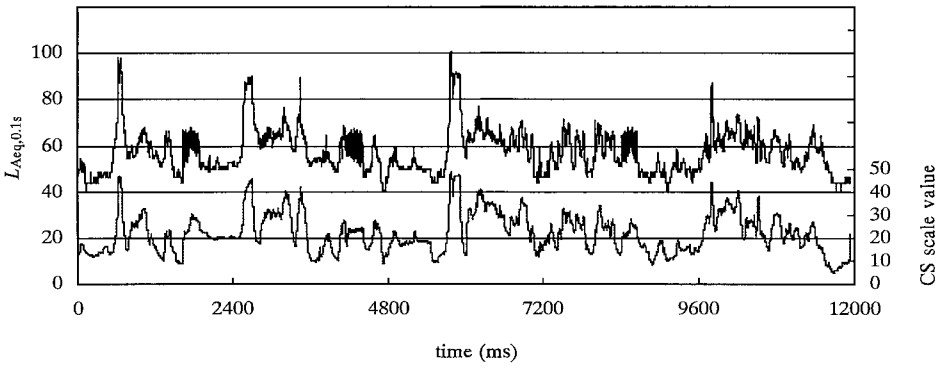


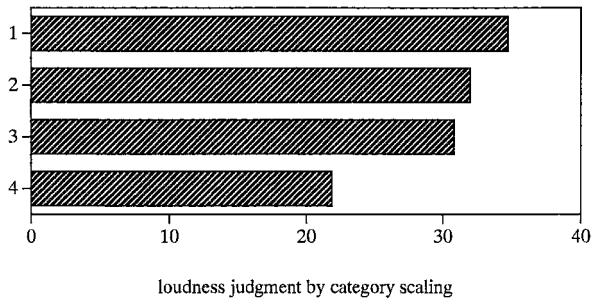
Fig. 1 Sound level pattern used in the experiment (upper line) and continuous judgment of loudness (lower line).

correlation was found between them ($r = 0.88$). This suggests that the instantaneous impression is mainly determined by instantaneous physical values.

3.2. Relation between instantaneous loudness and overall loudness

The overall judgments of loudness made in Steps A and B are shown in Fig. 2 together with the average of instantaneous judgments in Step B. The overall loudness was judged without continuous judgment in Step A and after continuous judgment in Step B. There was no statistically significant difference between overall loudness judged in Steps A and B. This suggests that there was no effect of continuous judgment on the overall judgment of loudness as far as the result of this experiment is concerned. The similar result is reported by Susini *et al.* [5].

The average of instantaneous judgments indicated by the length of a line was converted into 50-point category scale and compared with the overall loudness in Steps A and B. As shown in Fig. 2, the average of instantaneous judgments in Step B was significantly smaller than overall loudness in Steps A and B ($p < 0.05$). It was confirmed that the overall loudness is not the simple average of the instantaneous loudness as found in our former studies [1–3]. The fact that the overall judgment is louder than the average of instantaneous judgment suggests that low level residual noise made little contribution to determining the overall impression.



1: overall loudness (step A)
2: overall loudness (step B)
3: average of overall loudness of recalled sounds (step C)
4: average of instantaneous loudness (step B)

Fig. 2 Comparison of the four judgments of loudness.

3.3. Factors which determine the overall impression

Each subject recalled about 15–20 sounds on the average in Step C. Though the number and the kind of the recalled sound sources are different among subjects, the recalled sound sources may be regarded as the prominent sounds to the subject. The loudness was expressed on the vertical line of the response sheets. The average of loudness judgment of recalled sounds was calculated for each subject and the judgments of six subjects were averaged. This average is close to the overall judgments in Step A and Step B as shown in Fig. 2 and there was no statistically significant difference between them. It is noticed that the recalled sound sources were not always loud sounds, but many subjects recalled the sound of bird twittering whose sound level was fairly low. This result suggests that impressive sounds may contribute to determining the overall impression of loudness regardless of their sound levels.

3.4. Order of recall

Subjects were asked to write the order of recalling in Step C. Three patterns of recalling were found. (1) Subjects recalled in the order of loudness, i.e. from loud sounds to soft sounds. (2) Subjects first recalled the sounds presented at the beginning or at the end. This pattern of recalling meets the law of memory. (3) Subject recalled by grouping the sound sources. That is, for example, train noises were audible four times in 20 min and these four train noises were recalled first. Further analysis is needed in order to find the weight of the contribution of each sound to determining the overall impression.

3.5. Correct recall

Since it is difficult for subjects to recall the time precisely when each sound source appeared, the 20 min interval was divided into five portions. If the sound is plotted in the correct portion or adjacent portions, it was admitted as correct answer. The result is shown in Fig. 3. The percentages of correct answer are not always high. The train noise was fairly loud and seemed to be impressive. However, there were few subjects who recalled correctly all the four train noises. It is not easy to recall the sound sources, but it seems more difficult to recall the correct timing of the occurrence of each sound source.

3.6. Relation between sound level and loudness of recalled sounds

The maximum levels of train noise, road traffic noise,

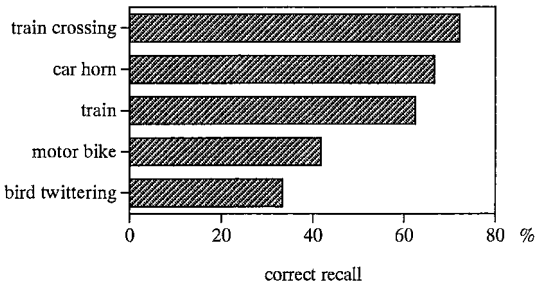


Fig. 3 Correct recall of the timing of occurrence of each sound source.

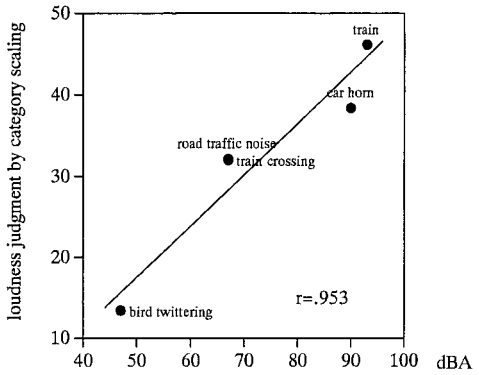


Fig. 4 Relation between recalled loudness in CS scale of each sound source and sound level.

train crossing, car horns, and bird twittering were correlated to the loudness judged in Step C. The result is shown in Fig. 4. High correlation was found between them. It was suggested that recalled loudness shows good correlation with physical values as far as the results of this experiment are concerned.

4. Final remarks

A new approach using instantaneous judgment and sketch for measuring auditory memory was introduced and the following results were found.

(1) It was found that there was no statistically significant difference between overall judgments of loudness in Step A (without instantaneous judgments) and Step B (with instantaneous judgment).

(2) It was confirmed in the experiment that the overall judgment of loudness is not the same as the simple average of instantaneous judgments as found in our former studies. This suggests that the weight of the contribution of each constituent sound to the overall impression may differ. The prominent sounds may contribute more greatly to determining the overall impression than less prominent sounds.

(3) The average of loudness judgments of recalled sounds in Step C showed no statistically significant difference from the overall judgments in Steps A and B. This suggests the contribution of soft sounds to the overall loudness. It is true that loud sounds tend to be prominent. However, in this experiment it was found that even soft sounds sometimes are prominent and impressive. It is important to find which sounds may become prominent.

(4) A high correlation was found between sound level and recalled loudness. This suggests that subjects can memorize the impression of loudness as well as the sound sources.

In this experiment the judgment and the recalling were made just after listening the sounds. The time lag between listening to the sound and the recalling may have a significant effect [1]. Which sound is easily recalled may depend on the serial order of presentation as indicated in the studies of memory [e.g. 6] and also the serial order may affect the overall impression [5]. Further investigation is needed by controlling various factors systematically and by taking the law of memory into consideration.

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