Sharpness evaluation of temporally varying sounds

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ABSTRACT
Sharpness is an important attribute when sound quality of machinery noise is considered. It has been reported that calculated sharpness shows good correspondence with the impression of sharpness. In most cases, the maximum value of calculated sharpness is used for the evaluation. In this study what kind of representative value is appropriate to express the impression of sharpness of temporally varying sounds. Forty-one kinds of the sound from home electric appliances and their modification were used as stimuli. Sharpness values were calculated every 100ms and three kinds of representative value, i.e. the arithmetic mean, the geometric mean and the maximum value, were related to the impression of sharpness. As the result, it was found that the arithmetic mean shows the highest correspondence with the impression of sharpness among the three.

Keywords: Sharpness, temporally varying sound
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1. INTRODUCTION
Sound quality is an important aspect in the psychological evaluation of machinery noises. Sound quality is multidimensional. Former studies (e.g. 1, 2) show that the three main factors are usually extracted by the factor analysis in various machinery noises. They are “powerful factor”, “metallic factor” and “pleasant factor”. It is important to find physical metrics that can show good correlation with the subjective impression in order to predict the subjective impression and design the products with good sound quality. In many studies (e.g. 2, 3) it has been reported that “powerful factor” shows good correlation with \( L_{Aeq} \) and loudness level. “Metallic factor” shows good correspondence with calculated sharpness (4, 5), which has been proposed by von Bismark (6). The authors reported that comfort index (CI) that consists of \( L_{Aeq} \) (or \( LL_z \)) and calculated sharpness will be a good metric of “pleasant factor” (7-9).

Many noises are temporally varying. \( L_{Aeq} \) can be applied to temporally varying sounds (e.g. 3, 10). Loudness level can also be applied to temporally varying sounds when loudness level is calculated e.g. every100ms and averaged on energy basis (11-13). However, in the case of calculated sharpness, the maximum value of sharpness of the sound is often used even if the sound is temporally varying. In this study, it is examined which is the best representative value of the calculated sharpness of temporally varying sounds in relation to subjective impression.

2. EXPERIMENT

2.1 Stimulus
The sounds from home electric appliances were used as stimuli. They were the sounds from four kinds of washing machine, two kinds of microwave oven, nine kinds of vacuum cleaner and

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four kinds of dish washing machine. These sounds were carefully listened to and the portions to be improved were selected in the light of physical analyses of their frequency components and level fluctuation. These selected portions were modified by reducing the sound levels, the prominent frequency components or eliminating impulsive components. In total 41 sounds including 19 original sounds and 22 their modified sounds were used in the experiment. The duration was from 5 to 32 s. The duration was decided taking the operation of each machine into consideration.

2.2 Procedure
The impression of sound quality was judged using semantic differential. The participants were asked to judge the impression of each sound using 14 adjective scales (14). The name of the sound source was informed to the participants by indicating it on each response sheet. Two trials were conducted with different order of stimulus presentation. Forty-one sounds were presented in random order, except that the original sound and its modified sound were presented successively. The order of the original sound and its modified sound was balanced.

2.3 Apparatus
The sounds were reproduced with a DAT recorder (Pioneer D-05) and presented to the participants through an amplifier (DENON PMA-2000IV) and loudspeakers (Diatone DS-800Z) in a sound proof room.

2.4 Participants
Nine females and eleven males aged between 21 and 46 (average 26.5) participated in the experiment. All of them had normal hearing ability.

3. RESULTS AND DISCUSSION
There was a statistically significant coefficient of correlation between two trials of each participant. This confirmed the reliability of the judgments and further analyses were conducted on the basis of 40 judgments by 20 participants.

Since the results of semantic differential as a whole have been reported (14), the results of sharpness judgment are examined in this paper in order to find the appropriate representative value of the calculated sharpness of temporally varying sounds. Calculated sharpness was obtained every 100 ms using the software (Onosokki OSCOPE). The arithmetic means, the geometric means and the maximum values of calculated sharpness were obtained for each sound and corresponded to the sharpness impression. These results are shown in Figures 1 - 3. As shown in these figures, it is clearly found that the arithmetic mean value of calculated sharpness shows the highest correlation with sharpness impression among the three representatives. The geometric mean value showed similar tendency to the arithmetic mean though correlation coefficient was a little lower.

Examples of the temporal change of calculated sharpness are shown in Figures 4 and 5. Figure 4 indicates the temporal change of calculated sharpness of a washing machine. As shown in this figure, the value of calculated sharpness is very high when washing started and ended compared with the other portions while the machine is operating. These impulsive components increased the maximum values of the calculated sharpness. However, it seems that the impulsive components are not always reflected to the subjective impression of sharpness and that the maximum values of calculated sharpness overestimated the subjective impression. Some sounds showed similar tendency though many sounds did not show such tendency. Figure 5 indicates the temporal change of the calculated sharpness of a dish washing machine. In this case, it can be seen that calculated sharpness varies widely over the time when the machine is operating.
Figure 1 Relation between the arithmetic mean of calculated sharpness and subjective impression of sharpness.

Figure 2 Relation between the geometric mean of calculated sharpness and subjective impression of sharpness.
Figure 3 Relation between the maximum value of calculated sharpness and subjective impression of sharpness.

Figure 4 Temporal change of calculated sharpness (washing machine)
In order to eliminate the effect of impulsive components at the beginning or at the end of the operation of the machines, the arithmetic mean, the geometric mean and the maximum value of calculated sharpness were obtained excluding both ends of temporal variation of the calculated sharpness. The results are shown in Figures 6-8. It is also found that the arithmetic mean value of calculated sharpness shows the highest correlation with the sharpness impression among the three.

Figure 6 Relation between the arithmetic mean of calculated sharpness and subjective impression of sharpness when the impulsive portions were deleted.
4. FINAL REMARKS

The representative value of calculated sharpness of temporally varying sounds was examined using the sounds from home electric appliances. It was found that the impression of sharpness showed the highest correlation with the arithmetic mean of the calculated sharpness among the three representative values examined in this study. It would be important to take the temporal fluctuation of sharpness into consideration when the sound quality of sounds is examined.
REFERENCES


