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Examination of the deteriorating factors of sound quality of home electric appliances

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ABSTRACT

Three experiments were conducted to examine the effect of the deteriorating factors on the impression of the sound quality of home electric appliances. The frequency components, the sound level and the envelope patterns were modified after careful listening to the sounds from various home electric appliances. Forty-one sounds including original sounds and their modified sounds were used in the experiments. In Experiment 1, the impression of sound quality was judged using semantic differential. In Experiment 2, paired comparison test was conduced in order to examine whether modification of sound quality could be detected. In Experiment 3, all the 41 sounds were connected in random sequence with a slight interval between the sounds and the instantaneous impression was judged using the method of continuous judgment by category while the participants were watching a video program. The results of the three experiments suggest that the sound level has an important effect on sound quality and the reduction of high frequency components improved the sound quality when the reduction of these components caused the reduction of sound level. The elimination of impulsive components had little effect as far as the impulsive components were short and they were not repeated many times.

INTRUDUCTION

Many home electric appliances are used at home and their sounds are often perceived as being unwanted sounds. It is desired to reduce their unpleasant impression. The reduction of sound level is a basic technology to improve the sound quality of machinery noises. Moreover, if the sounds include pure tone components and impulsive components, the elimination of these components may be an effective countermeasure.

In many cases, the sounds from home electric appliances are heard while people are doing daily life activities such as watching TV, reading books, cooking meals, etc. In such situations, the judgment of sound quality may possibly be different from the situation of careful listening to the sounds.

In this study, three experiments were conducted to examine the effect of the deteriorating factors on the impression of the sound quality of home electric appliances. The frequency components, the sound level and the envelope patterns were modified after careful listening to the sounds from various home electric appliances. Forty-one sounds including original sounds and their modified sounds were used in the experiments. In Experiment 1, the impression of sound quality was judged using semantic differential. In Experiment 2, paired comparison test was conduced in order to examine whether modification of sound quality could be detected. Experiment 3 was conducted simulating daily life situations. The sound quality was judged continuously using the method of continuous judgment by category [1-3] while the participants were watching a video program.

EXPERIMENT 1

Stimulus

Recorded sounds from four kinds of washing machine, two kinds of microwave oven, nine kinds of vacuum cleaner and four kinds of dish washing machine were carefully listened with physical analyses of their frequency components and level fluctuation and the portions to be improved were selected. These portions were modified by reducing sound levels or prominent frequency components or eliminating impulsive components. In total 41 sounds including 19 original sounds and 22 their modified sounds were used in Experiment 1. The duration was from 5 to 32 s. The duration was decided taking the operation of each machine into consideration.

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 as shown in Figure 1. 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. 41 sounds were presented in random order, except that the original and its modified sounds were presented successively. The order of the original sound and its modified sound was balanced.

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.

Participant

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

Results and discussion

Statistically significant coefficient of correlation was found 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.

An example of the semantic profiles is shown in Figure 1. This is the sound from a washing machine when it is finishing dehydrating. The original sound (No.5) indicated by red circles was perceived in negative impression. Since this sound included high frequency components, they were reduced in modified sound (No.6). As indicated by light blue diamonds in Figure 1, the impression was similar to the original sound. In this case, the value of L_{Aeq} did not decrease by the modification. When the high level portions in the middle frequency region (500 – 2000 Hz) was reduced by 20 dB in addition to the reduction of the high frequency components, the impression became better than the original sound as shown by dark triangles in Figure 1. In this case, the value of L_{Aeq} was reduced about 10 dB according to the modification of frequency components. Similar tendency was found in the sounds from vacuum cleaners, dish washing machines and microwave ovens. It seems that modification of frequency components may be effective when it causes the reduction of sound level. An example of the effect of elimination of impulsive components is shown in Figure 2. This is the sound from a microwave oven. The impression of the modified sound (No.35) seems to be better than the original sound (No.34) though the difference is small.

High correlation was found between L_{Aeq} and the impression of loudness and unpleasantness as shown in Figures 3 and 4, respectively. The results of Experiment 1 suggest that sound level has a great effect on the impression of sound quality.

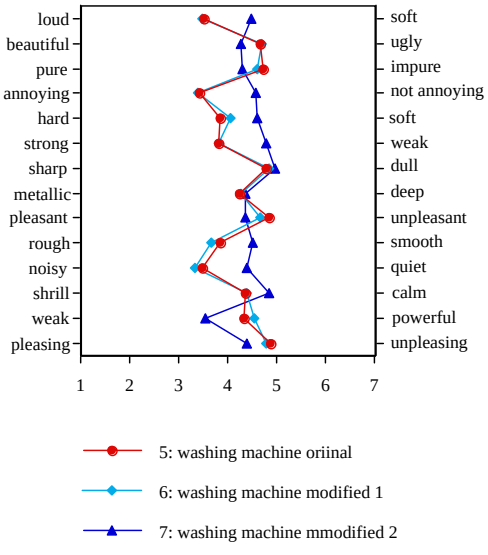

Figure 1

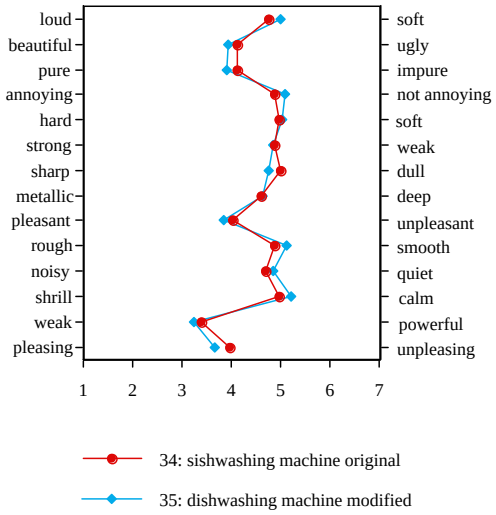

Figure 2

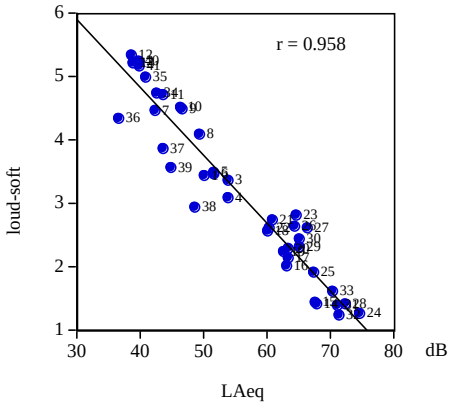

Figure 3

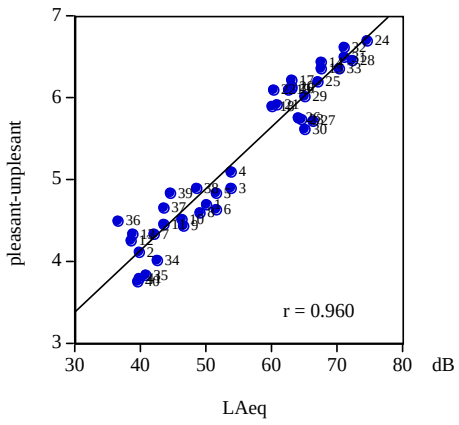

Figure 4

EXPERIMENT 2

Stimulus

There were 19 original sounds, i.e. four kinds of washing machine, two kinds of microwave oven, nine kinds of vacuum cleaner and four kinds of dishwashing machine. Since two kinds of modification were applied to the three sounds among them, there were 22 modified sounds. The 22 modified sounds were paired with their original sounds. All these sounds were the same as used in Experiment 1.

Procedure

The participants were asked to judge which sound of the pair had better sound quality or whether there was no difference between them. Two trials were conducted with each participant.

Apparatus

The same apparatus was used as in Experiment 1.

Participant

Five females and five males aged between 21 and 46 (average 29.3) participated in Experiment 2. All had normal hearing ability.

Results and discussion

The results are shown in Table 1. The difference in L_{Aeq} between the original sounds and the modified sounds was calculated and related with the percentage with which the modified sound was judged better. The result is shown in Figure 5. It was suggested that the improvement of sound quality was detected when the sound level decreased more than 3 dB. The differential limen of sound level is about 0.5 dB when it is measured with short white noise in an acoustically well-controlled condition. However, in daily life situations, people's response to noise changes one category when the sound level is changed about 5 dB [4]. Though Experiment 3 was conducted in a sound proof room, the sounds were those from home electric appliances and temporally varying in both frequency and sound level. Therefore, the differential limen seems to be larger than steady state sounds.

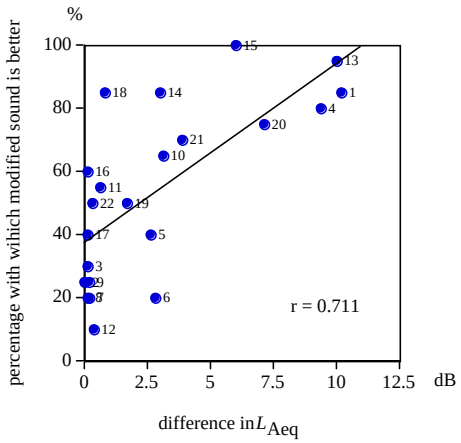

Figure 5

Table 1

	sound source	modifi -cation (see notes)	modified sound is better (%)	original sound is better (%)
1	washing	1	85	15
2	washing	2	25	60
3	washing	2	30	10
4	washing	2	80	20
5	washing	2	40	20
6	oven	2	20	40
7	oven	2	20	10
8	cleaner	2	20	5
9	cleaner	2	25	5
10	cleaner	1	65	15
11	cleaner	3	55	30
12	cleaner	2	10	15
13	cleaner	1	95	5
14	cleaner	1	85	10
15	cleaner	1	100	0
16	cleaner	2	60	5
17	cleaner	2	40	15
18	cleaner	4	85	5
19	dish	3	50	15
20	dish	2	75	15
21	dish	2	70	10
22	dish	3	50	10

1: reduction of sound level

2: modification of frequency components

3: elimination of impulsive components

4. elimination of banging sounds

An exception was the case of the pair No.18 where the sound level difference was 0.8 dB and 85% of the judgments showed that the modified sounds were judged better than the original sounds. This is the sound from a vacuum cleaner and many banging sounds were eliminated in the modified sound.

The results of Experiment 2 showed good agreement with Experiment 1 showing that the sound level has an important effect.

EXPERIMENT 3

In Experiments 1 and 2, the overall impression of sound quality was judged. In Experiment 3 the instantaneous impression of sound quality was judged using the method of continuous judgment by category [1-3]. In daily life situations the sounds from home electric appliances are heard while people are doing other daily life activities. In order to simulate daily life situations, the participants were asked to judge the sound quality while watching a video program by muting its sound track.

Stimulus

The forty-one sounds used in Experiment 1 were successively connected with the interval of 5ms. Two kinds of stimulus order were prepared. The scenery of a mountain stream was presented while the sounds were presented.

Procedure

The instantaneous impression of the sounds was judged using the method of continuous judgment by category. The participants were asked to judge continuously whether the sounds were noticeable or not, with 4 step categories from "1: not noticeable at all" to "4: very noticeable" while watching the video program and press the corresponding key on a computer keyboard.

Apparatus

The sounds were reproduced with a computer and presented via an audio interface (Roland UA-3FX), an amplifier (DENON PMA-1000IV) and loudspeakers (Diatone DS-800ZX) in a sound proof room. The video program was reproduced with a video recorder and presented on a TV monitor.

Participant

Five females and three males aged between 21 and 46 (average 30.3) participated in Experiment 3. All had normal hearing ability.

Results and discussion

The L_{Aeq} was measured every 100 ms. The responses of each participant were sampled every 100 ms and the responses of eight participants were averaged taking the reaction time into considerations. The relation between L_{Aeq} and the average of the responses of the participants is shown in Figures 6 and 7. The red line indicates the values of L_{Aeq} and the blue line subjective responses in these figures. Fairly high correlation can be seen between L_{Aeq} and the subjective responses in both cases (r=0.869 and r=0.841). This suggests that the sound level has a large effect on the sound quality. The impulsive components were included in some sounds. However, they seemed not to be paid special attention. This may due to the short duration of impulsive components.

The overall impression was asked using the same category scale as continuous judgments after the continuous judgment was over. In order to make the sounds less noticeable, it would be necessary to improve the sound quality.

FINAL REMARKS

Sound quality of sounds from home electric appliances was examined in three experiments. The sound level, frequency components and impulsive components were modified. The results of Experiment 1, where sound quality was judged using semantic differential, showed that the sound level had a large effect on sound quality and that the modification of frequency components had an effect when the modification was accompanied by sound level reduction. In Experiment 2, the original sound and its modified sound were compared directly to examine whether their difference was detected. The results showed the similar tendency to those of Experiment 1. In Experiment 3 where the sound quality was judged continuously while the participants were watching a video program, fairly high correlation was found between L_{Aeq} and the impression of sound quality and the effect of sound level was confirmed. Short impulsive components seemed not to be noticed.

The results of the three experiments suggest that the sound level has an important effect on sound quality and the reduction of high frequency components improved the sound quality when the reduction of these components caused the reduction of sound level.

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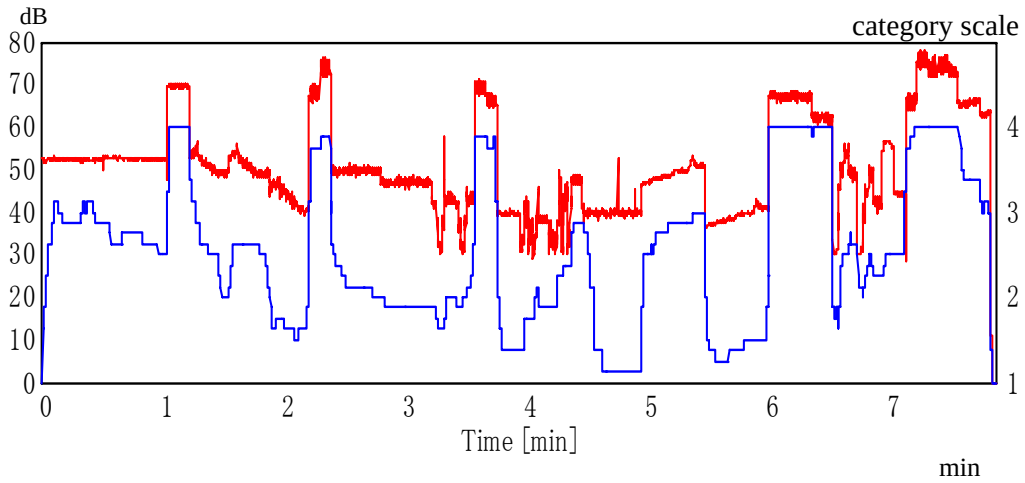

Figure 6 Red line indicates L_{Aeq} and blue line indicates subjective responses. The coefficient of correlation between them is 0.869.

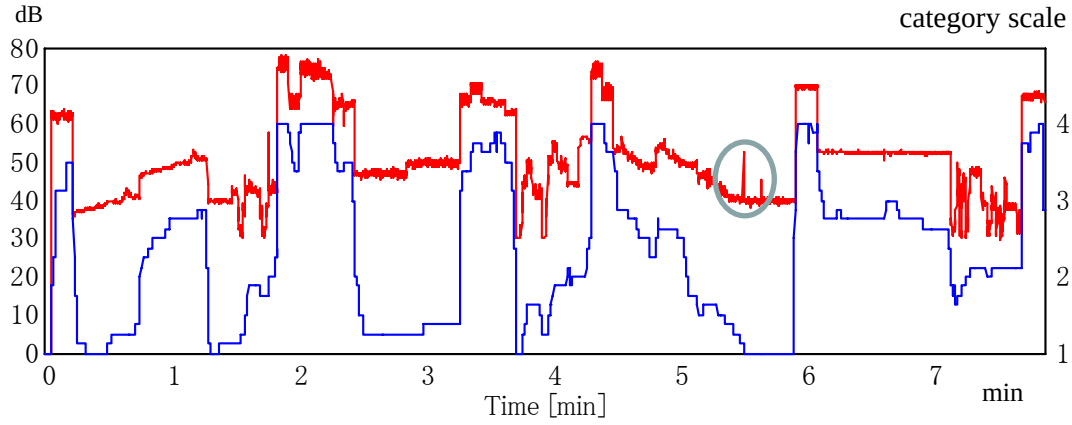

Figure 7 Red line indicates L_{Aeq} and blue line indicates subjective responses. The coefficient of correlation between them is 0.841.