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Desirable properties for identification of auditory warning signals

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1. Introduction

Auditory signals can easily be recognized even if special attention is not paid to them. Therefore, they are often used in various situations in daily life. There is a flood of auditory signals from those used outdoors, e.g. starting signals of a train, sirens of a police car, an ambulance and a fire engine and a bell at a train crossing, to those used indoors, e.g. an alarm clock, a telephone bell, a chime at an entrance of a house and auditory signals from a washing machine or an electric rice cooker which tell us that washing is finished or rice is ready.

In the case of danger signals used for informing people of dangerous happenings such as a fire, it is necessary to be clearly recognized and identified. Danger signals should be audible even in noisy surroundings and have characteristics which make people perceive instinctively that something dangerous happens [1–4]. It would be accepted to use auditory danger signals even if they are unpleasant sounds.

On the other hand, portable telephones used in public spaces, for example, are often perceived as being nuisance by other people since the signal as well as the conversation is clearly outstanding. The alarm of a wrist watch becomes really noise when it rings carelessly during a concert. The use of auditory signals for private purposes should be restricted in public spaces as much as possible.

It would be admitted that auditory signals can be freely used at home. Nevertheless, it would be better not to use so many auditory signals, which may deteriorate the sound environment. When various kinds of auditory signals are used, it is necessary that each auditory signal should be clearly discriminated and give information from which equipment it comes and what it means.

The present study was designed to examine the necessity and desirable properties for auditory warning signals.

2. Questionnaire survey

A questionnaire survey was conducted to examine whether the auditory warning signals are needed or whether they are annoying.

2.1. Questionnaires

The following questions were asked for auditory warning signals equipped to home electric appliances and other equipment;

(1) whether the respondents use the equipment
(2) whether the equipment they use has an auditory warning signal
(3) whether the auditory signal is needed
(4) whether the auditory signal is annoying

2.2. Respondents

The questionnaire survey was conducted with the two groups of respondents: group 1 was 190 students from 18 to 22 years old and group 2 was 47 respondents aged between 22 and 58 (average 41.0).

2.3. Results

Cross analyses were conducted with respondents who answered that they were using each equipment. The percentages of the respondents using each equipment for group 1 were 96.8% for washing machine, 93.7% for rice cooker, 53.2% for electric pot, 66.8% for thermometer, 84.7% for airconditioner, 91.6% for microwave oven, 64.7% for wrist watch, 55.8% for public telephone and 92.6% for portable telephone. All respondents answered that they were using washing machine and rice cooker in group 2. The results of group 1 are shown in Figs. 1 and 2. It can be seen that the percentages of respondents who answered that the auditory warning signals were necessary are higher with those who used the equipment with auditory signals than those without signals. Also it is clear that the percentages of respondents who answered that the auditory warning signals were annoying are higher with those who answered that the warning signals (or equipment itself for portable telephones) were not necessary than the other group. The same tendency can be seen in group 2 concerning the signals attached to washing machines and rice cookers as shown in Figs. 3 and 4, though these sounds seem not annoying so much. These results suggest that the auditory warning signals, if they are attached, are convenient, but that they are not always necessary and that there are some people who are annoyed by the signals.

It is also noticed in Fig. 2 that high percentages of respondents answered that the sound of portable telephones are annoying even though they thought portable telephones are necessary.

3. Experiment

An experiment was conducted to examine whether auditory warning signals can be identified when they are listened to in a laboratory situation.

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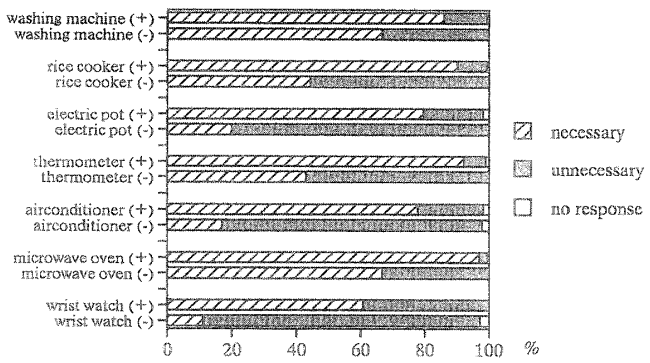

Fig. 1 Necessity of auditory warning signals. Results of cross analysis of group 1 are shown using whether auditory warning signals are attached (+) or not (−) as a key item.

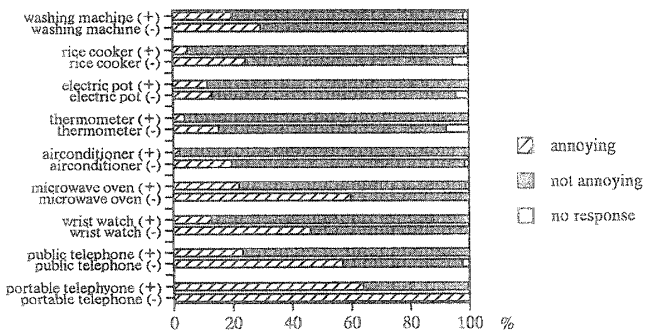

Fig. 2 Annoyance of auditory warning signals. Results of cross analysis of group 1 are shown using whether auditory warning signals are necessary (+) or not (−) as a key item. The necessity and annoyance of warning signal for telephone card were asked in the case of public telephone.

3.1. Stimulus

Thirteen kinds of electronically synthesized warning signals were used as stimuli. The list of stimuli is shown in Table 1. They were recorded with a sound level meter (ONO SOKKI, LA-220) and a DAT recorder (SONY, TCD-D3) at a position of the user of each equipment. The duration of the stimuli used was about 5 s and the values of L_{Aeq} were about 75 dBA except for Nos. 7 and 10 (signals of a washing machine and a clinical thermometer, respectively).

3.2. Procedure

The stimuli were presented in random order to subjects. Subjects were asked to identify the sound sources and write the names of the equipment on a questionnaire sheet.

3.3. Equipment

The stimuli were reproduced with a DAT recorder (VICTOR, XD-Z1100) and presented to the subjects through an amplifier (TOA TE-121) and loudspeakers (Victor WT-1802).

3.4. Subject

335 university students of about 19 years old participated in the experiment.

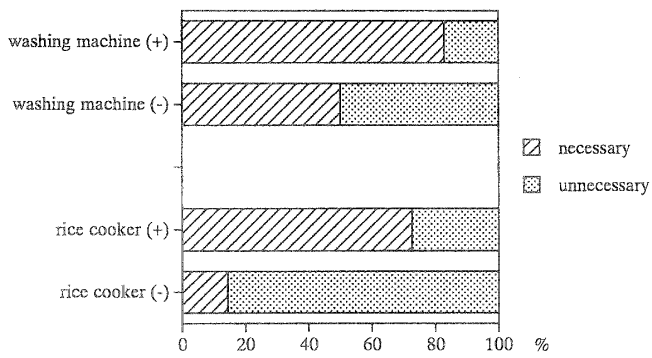

Fig. 3 Necessity of auditory warning signals. Results of cross analysis of group 2 are shown using whether auditory warning signals are attached (+) or not (−) as a key item.

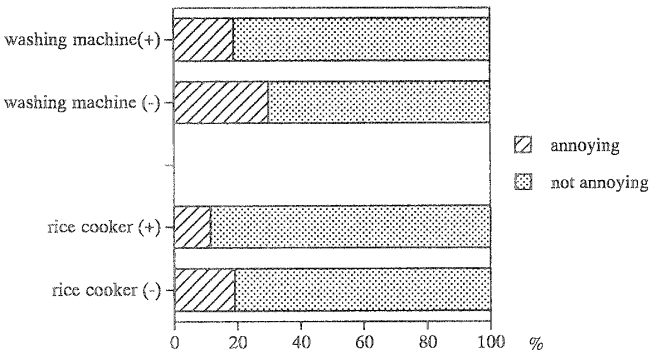

Fig. 4 Annoyance of auditory warning signals. Results of cross analysis of group 2 are shown using whether auditory warning signals are necessary (+) or not (−) as a key item.

Table 1 List of stimuli used in the experiment.

No.	Sound source	Information
1	Telephone (1)	telephone from outside
2	Telephone (2)	telephone between extensions
3	Telephone (3)	telephone within extensions
4	Portable telephone	telephone bell
5	Inter phone	bell of inter phone
6	Door chime	somebody is at the door
7	Washing machine	washing is finished
8	Electric rice cooker	rice is ready
9	Alarm clock	time to wake up
10	Thermometer	time is up
11	Kitchen timer	time is up
12	Alarm of a car (1)	notice for removing the key
13	Alarm of a car (2)	notice for turning off the light

3.5. Results

The percentage of correct answer to each sound source is shown in Fig. 5. Four kinds of signal of telephone were used in this experiment. It was found that they can be easily identified. This may be due to the fact that frequency

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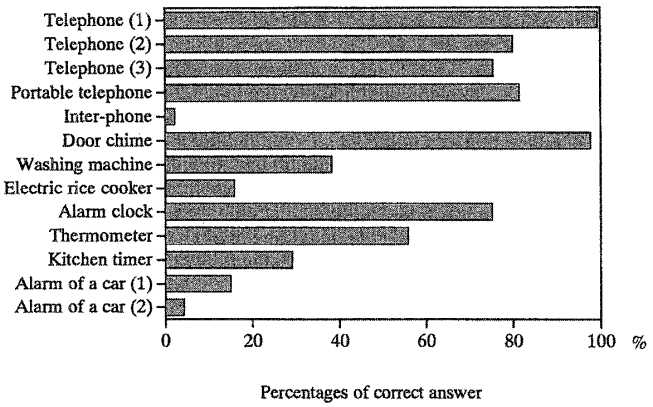

Fig. 5 Percentages of correct identification.

components are the same except for a portable telephone and repetition rate is the same except for the telephone No. 2. These properties may have been learned in our daily life and this may cause the high percentages of correct identification. Door chime and the signal of alarm clock were also found to be easily identified. On the other hand, auditory signals from an inter-phone, an electric rice cooker, and alarms of a car seem difficult to be identified. It was noticed that the auditory signal of a rice cooker was misunderstood with an alarm for gas sensor, which suggests that dangerous misunderstanding may happen.

The percentages of correct answer were plotted against fundamental frequency, number of frequency components, and repetition times in Figs. 6–8, respectively. It was found that the fundamental frequency has little correlation with identification. The percentages of correct answer showed weak correlation with the number of frequency components and the repetition times. This suggests that the factors related to timbre and temporal structure of the signals have an effect on the identification of signals.

4. Discussion

There are various purposes for auditory warning signals as follows.

(1) confirmation of switching
(2) notice of finishing (e.g. washing is finished, rice is ready)
(3) notice of abnormal situation (e.g. the door of refrigerator is kept open)
(4) caution (e.g. electric iron is fallen down and it may cause fire)

If the signal is used to inform dangerous happenings as in the case (4), it must be clearly detected by anybody in any situations. Different properties from those of warning signals for (1) to (3) are needed for the danger signal as described in our earlier studies [1–4] even if they are used at home.

Except for signals which tell dangerous situations, even if auditory signals are missed, it does not necessarily cause serious matters. The results of the questionnaire surveys suggest that once users have the appliances with warning signals, they tend to be accustomed to using them and feel them convenient. The same tendency was found with elderly people as shown in Fig. 9 [5]. It can be said from these results that warning signals are convenient, but not always necessary.

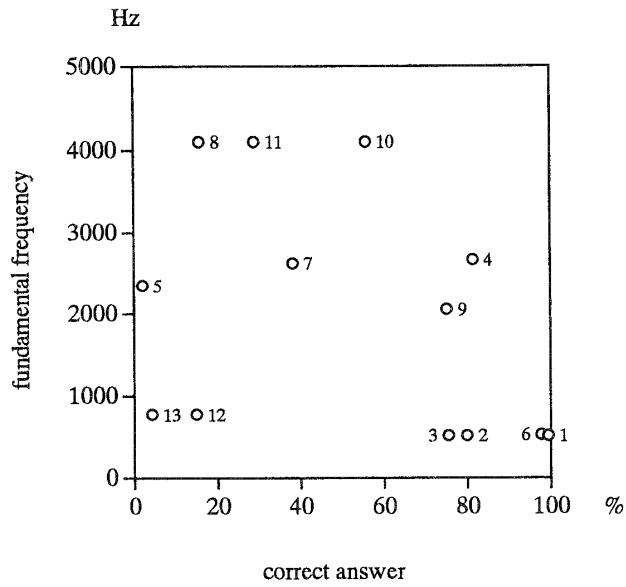

Fig. 6 Relation between fundamental frequency and the percentages of correct identification.

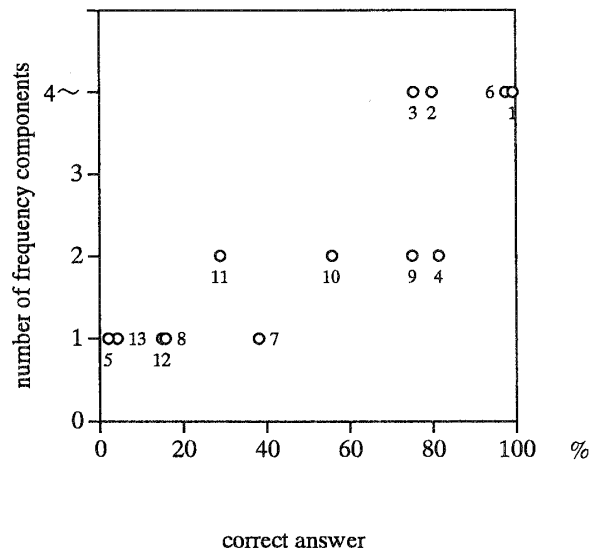

Fig. 7 Relation between the number of frequency components and the percentages of correct identification.

Therefore, if it is attached to the appliances, it should be audible, not be too loud, nor annoying, easy to be identified and if possible, pleasant.

The results of the experiment suggest that warning signals attached to home electric appliances are often confused with each other. It is dangerous if the warning signal of a gas sensor is misunderstood as that of a rice cooker. If the warning signals are used, they should be clearly identified. The results of experiment suggest that the signals can be more easily identified when they consist of more harmonic frequency components. The fact that the signal consists of many harmonic frequency components means that it has a wide frequency range. This has another merit that the signal is not

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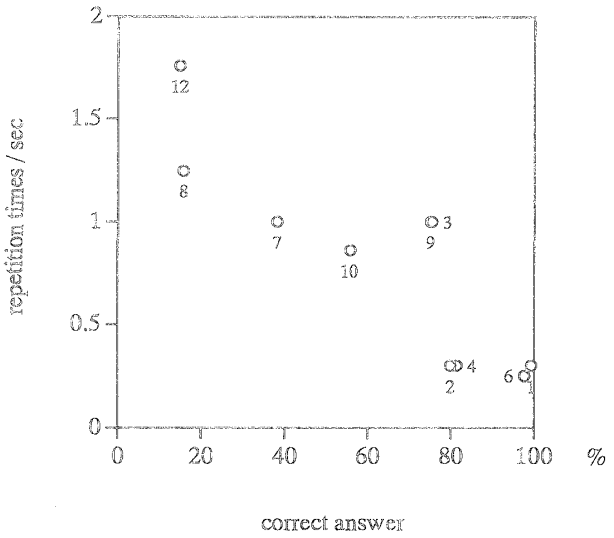

Fig. 8 Relation between repetition times and the percentages of correct identification. Data of steady-state sounds are excluded.

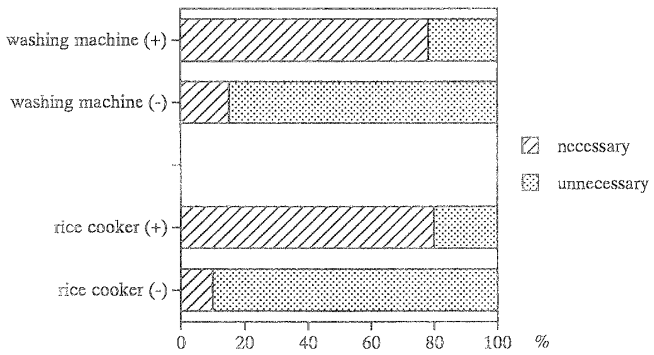

Fig. 9 Necessity of auditory warning signals. Results of cross analysis of the survey with elderly people are shown using whether auditory warning signals are attached (+) or not (−) as a key item. (Matsui *et al.* [5]).

easily masked by other environmental sounds. Also the signal is accepted as being more pleasant, the more harmonic frequency components it has [6]. Our hearing will deteriorate in high frequency region when we get older [7]. From this viewpoint, the fundamental frequency should be settled lower than those used at present [8,9] and around 1 kHz seems to be appropriate [10].

Recently users can choose their own favorite sounds including own composition of music for the signals of portable telephones. This can be applied to the warning signals of home electric appliances. If users select the signals by their own choice, they can easily identify which sound is from which appliance. Concerning the auditory warning signals which are used in public spaces, it would be better to reconsider whether they are really necessary. If the auditory signals are attached, their sound quality should be carefully chosen.

5. Conclusion

It was found from the experiment that the warning signals attached to the home electric appliances are easily confused with each other. Especially, it is serious that the warning signal for a gas sensor is mistaken as that of a rice cooker. The results of questionnaire survey indicate that they can do without warning signals, but that if it is attached, it is convenient. This indicates that if they are used, they should meet the following requirements.

(1) It should have a good timbre so that it won't deteriorate the sound environment at home. The signals which consist of many harmonics seem to be good for warning signals since they are easy to be identified, not masked by other environmental sounds, and seem to be pleasant.

(2) It is desirable that users can adjust the level so that it is not disturbing. Also it is better that users can switch off the signals.

(3) In order not to confuse the signals at home, it would be desirable that users can select the signals by their own choice.

References

[1] H. Höge, A. Schick, S. Kuwano, S. Namba, M. Boch and H. Lazarus, "Are there invariants of sound interpretation?—The case of danger signals", *Proc. 5th International Congress on Noise as a Public Health Problem*, 253–258 (1988).

[2] S. Kuwano, S. Namba, T. Hato and K. Miura, "Evaluation of danger signals using the method of selected description", *Proc. Spring Meet. Acoust. Soc. Jpn.*, 577–578 (1993) (in Japanese).

[3] S. Kuwano, S. Namba, H. Fastl and A. Schick, "Evaluation of the impression of danger signals—Comparison between Japanese and German subjects", in *Contribution to Psychological Acoustics*, A. Schick and M. Klatte, Eds. (BIS, Oldenburg, 1997), pp. 115–128.

[4] S. Kuwano, S. Namba, A. Schick, H. Höge, H. Fastl, T. Fillipou, M. Florentine and H. Moesch, "The timbre and annoyance of auditory warning signals in different countries", *Proc. International Congress on Noise Control Engineering*, 3201–3206 (2000).

[5] T. Matsui, S. Kuwano and M. Morimoto, "Social survey of noise problems with aged people", Tech. Rep. Noise, Acoust. Soc. Jpn. N-2000-10, 1–8 (2000) (in Japanese).

[6] T. Mizunami, S. Kuwano and S. Namba, "Perception and cognition of synthesized signals in sound environment", *Proc. Annual Meeting of the Japanese Society for Music Perception and Cognition*, 56–62 (2000) (in Japanese).

[7] ISO 7029, "Acoustics—Threshold of hearing by air conduction as a function of age and sex for otologically normal persons" (1984).

[8] S. Namba, S. Kuwano and T. Mizunami, "Subjective evaluation of synthesized signals", *Proc. 3rd Jt. Meet. between ASA and ASJ*, 451–454 (1996).

[9] K. Kurakata, K. Matsushita, Y. Kuba and Y. Kuchinomachi, "Audio signals in electric home appliances evaluated in terms of the hearing ability of older adults (Second report)", *J. Ergonomic Soc. Jpn.*, **35**, 277–285 (1999) (in Japanese).

[10] T. Mizunami, S. Kuwano and S. Namba, "Desirable properties of auditory warning signals", *Record of the 1998 Kansai-section Joint Convention of Institutes of Electrical Engineering, Japan*, G387 (1998) (in Japanese).

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