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Subjective impression of auditory danger signals in different countries

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1. Introduction

Signals of various sensory modalities may be used as warning signals which inform people of dangerous happenings. Among them, auditory signals have advantages that they are non-directional and can be transferred in wide areas. It would be desirable to meet the following requirements in order that the auditory warning signals used in dangerous situations should be effective:

(1) They are easily detected in noisy situations.
(2) They are easily detected by people of any generations.
(3) They are easily universally recognized as a warning signal.

The results of our former studies concerning the aspect of (3) suggest that there is a cross-cultural difference in the impression of some signals and that, generally speaking, frequency-modulated sounds are perceived as being dangerous in Japan and Germany [1–3].

On the basis of these results, the present study was designed to investigate the effects of frequency components and temporal factors on the impression of dangerousness with systematically controlled synthetic sounds. Cross-cultural comparison was made among four places in three countries.

2. Experiment

2.1. Stimuli

Systematically controlled synthetic sounds were used as stimuli. The stimuli consisted of a sound of 500 ms which was repeated 10 times with or without off-time. The frequency was shifted from low to high in two octaves. Six kinds of frequency components and four kinds of off-time were used as shown in Table 1. These 24 kinds of sound were prepared with (Nos. 1–24) and without (Nos. 25–48) low-frequency components around 100 Hz. In total 48 kinds of sound were used. The maximum level of each signal (L_{AFmax}) was 75 dB.

2.2. Procedure

The timbre of the stimuli was judged using semantic differential. Sixteen pairs of adjectives were used. They are shown in Fig. 2. The experiment was conducted in Osaka in Japan, Oldenburg and Munich in Germany and Boston in the US. Adjectives were indicated in Japanese in Osaka, in German in Oldenburg and in English in Munich and Boston. The Japanese adjective scales were translated into English and German on the basis of our former studies [4]. The experimental procedures and equipment used in the experiments were not always the same in the four testing environments. In Osaka the experiment was conducted in a sound proof room with one participant at a time. All the participants were tested in the experiment twice on different days. In Oldenburg the experiment was conducted once with all the participants together in a sound proof room. In Munich the experiment was conducted in a sound proof room with small groups of participants. All the participants were tested in the experiment twice on different days. In Boston the experiment was conducted in a sound proof room with one participant at a time. Ten participants were test in the experiment twice on different days, but the other fourteen participants were tested only once. A training using four sounds used in the experiment was given to all the participants in the four testing environments.

2.3. Participants

Eleven females and nine males aged between 19 and 40 years old participated in Osaka, twelve females and fourteen males aged between 19 and 40 years old in Oldenburg, two females and nine males aged between 23 and 55 years old in Munich and fourteen females and ten males aged between 18 and 51 in Boston.

3. Results and discussion

3.1. Impression of the signals

Reliability was examined by calculating the coefficients of correlation between two trials or between training and experiment. The coefficients of correlation between the averages examined were 0.924 in Japan, 0.915 in Oldenburg, 0.962 in Munich and 0.876 in Boston and all of them are statistically significant ($p < 0.001$). Since the reliability of the judgment of the participants was confirmed in each place, all the judgments were used for the following analyses.

The adjective scale values for “safe–dangerous” are

Table 1 Stimulus conditions. The stimuli Nos. 1–24 include additional low frequency components around 100 Hz.

No.		Frequency (Hz)	Off-time (ms)
1	25	125 → 500	0
2	26	125 → 500	100
3	27	125 → 500	300
4	28	125 → 500	500
5	29	250 → 1k	0
6	30	250 → 1k	100
7	31	250 → 1k	300
8	32	250 → 1k	500
9	33	500 → 2k	0
10	34	500 → 2k	100
11	35	500 → 2k	300
12	36	500 → 2k	500
13	37	1k → 4k	0
14	38	1k → 4k	100
15	39	1k → 4k	300
16	40	1k → 4k	500
17	41	2k → 8k	0
18	42	2k → 8k	100
19	43	2k → 8k	300
20	44	2k → 8k	500
21	45	(125 → 500) + (500 → 2k)	0
22	46	(125 → 500) + (500 → 2k)	100
23	47	(125 → 500) + (500 → 2k)	300
24	48	(125 → 500) + (500 → 2k)	500

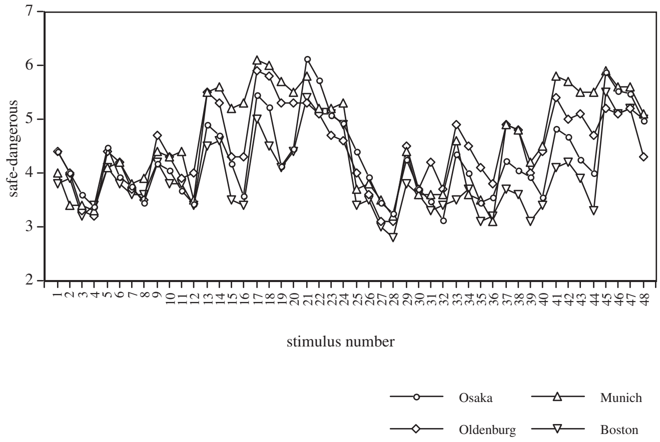

Fig. 1 Scale values of “safe–dangerous” for each stimulus.

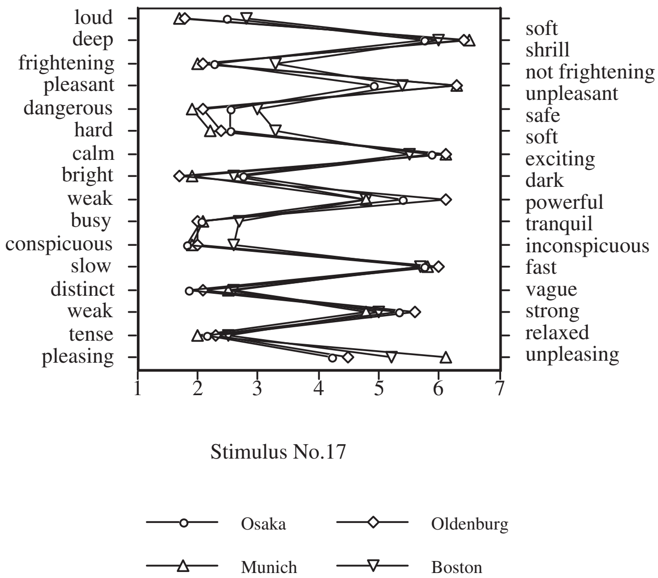

Fig. 2 Semantic profiles of the stimulus No. 17.

shown in Fig. 1. It was found that stimuli Nos. 21 and 45 were perceived as being dangerous among the 48 stimuli in all the four places and also No. 17 and 41 in Munich and Oldenburg. The stimuli No. 17 and 41 are the sounds with high frequencies and the stimuli No. 21 and 45 are with wide frequency range. Semantic profiles of the stimuli No. 17 and 21 are shown in Figs. 2 and 3. It can be seen that these sounds give the impression “dangerous,” “exciting,” “powerful,” “busy,” “tense” and “unpleasant.”

3.2. Effect of off-time

The relations between the adjective scale values for “safe–dangerous” and off-time are shown in Fig. 4. The impression becomes more dangerous as the off-time becomes shorter in all four testing environments (Man’s test $p < 0.5$).

3.3. Effect of frequency components

The relations between the average scale values for “safe–dangerous” for the stimuli Nos. 25–48 and the lowest frequency of the sounds are shown in Fig. 5. There is a tendency that the impression of danger becomes stronger as the frequency becomes higher in all four testing environments, except for the stimuli Nos. 45 to 48. These stimuli encompass a wide frequency range and were perceived as being dangerous.

The effect of low-frequency component around 100 Hz was examined by comparing the results of the stimuli Nos. 1–24 (with low frequency component around 100 Hz) with those of the stimuli Nos. 25–48 (without). It was found that the stimuli Nos. 1–24 were judged significantly more dangerous than the stimuli Nos. 25–48 with T-test which is a non-parametic statistical test ($p < 0.5$) though the average difference is very small (about 0.2 category). This also indicates that the sounds with wide frequency range are appropriate as a warning signal.

4. Conclusion

Though some experimental procedures are different among the four test environments, the tendencies of the results of the experiments conducted in Osaka, Oldenburg, Munich and Boston were similar. It was suggested that the signal whose frequency shifts from low to high over a wide

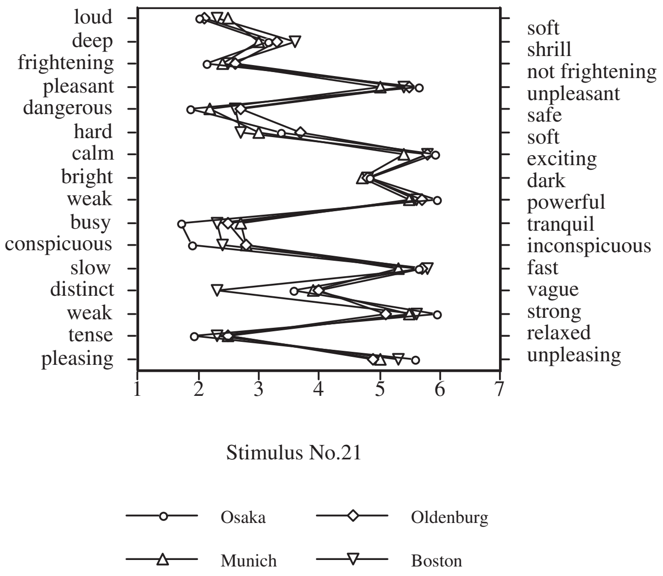

Fig. 3 Semantic profiles of the stimulus No. 21.

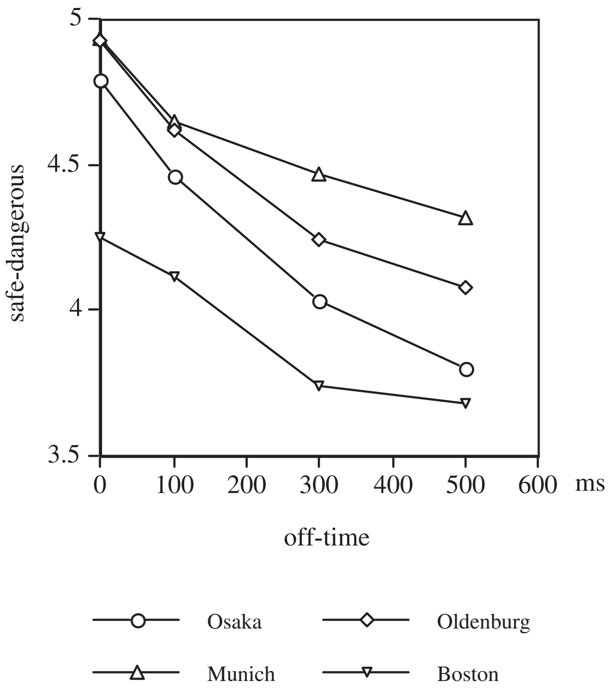

Fig. 4 Relation between scale values of "safe–dangerous" and off-time.

range gives the impression of dangerousness and that the impression becomes more dangerous as the off-time becomes shorter. Signals with these properties are appropriate for the auditory warning signal. When the signal consists of a wide frequency range and the frequency sweeps from low to high, it would be difficult to be masked in noisy situations [5] and can be detected by the people who have some usable hearing to identify the signal in some frequency region. Therefore, the present data indicate that the most easily universally recog-

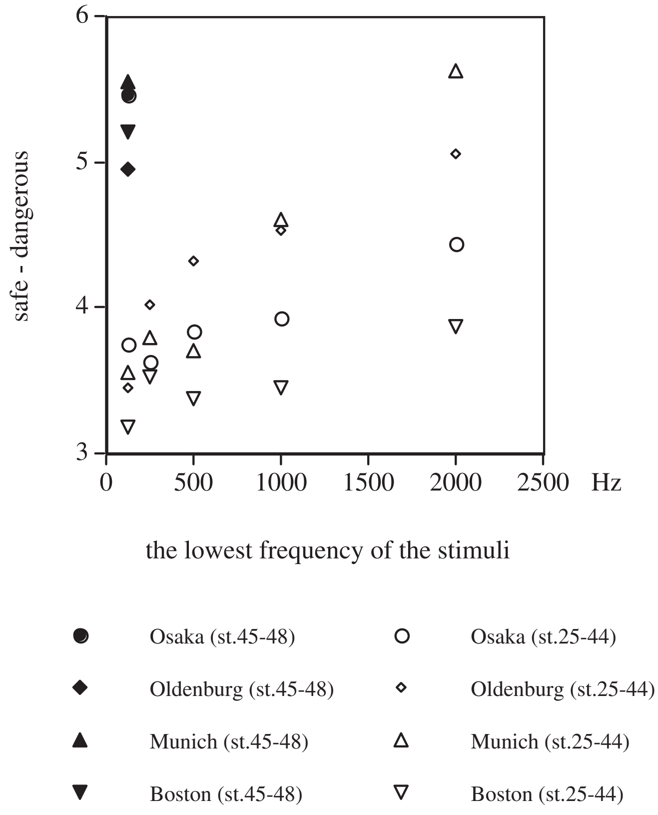

Fig. 5 Relation between scale values of "safe–dangerous" and the lowest frequency of the stimuli.

nizable warning signal to be incorporated into an international standard for warning signals.

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