Design strategy for effective auditory signals in an apartment complex in Korea

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1. Introduction

Auditory signals are sounds conveying a message, such as alarms, the ringing tone of a telephone, and the sounds emitted by a microwave oven to indicate the end of operation [1]. Currently, auditory signals are widely used in various situations of our daily lives, but some are not properly designed. Because of the nature of hearing (e.g., we hear sounds from all directions and respond quickly), auditory signals are more effective than visual signals in many cases. However, if auditory signals are not designed properly, the sound signals may be perceived as noise.

Previously, auditory signals of electric home appliances [2], automobiles [3], and public spaces [4] have been examined. The studies found that auditory signals should not be unpleasant unless the purpose of the signals is to convey a sense of urgency. Furthermore, auditory signals should be easy to understand and memorize. The design guidelines for auditory signals are governed according to their functions by Japanese Industrial Standards [5,6].

We cannot choose arbitrary sounds for auditory signals. Auditory signals should be designed to be appropriate for their functions. The present study reports a design strategy for auditory signals to create a safe and comfortable space in an apartment complex.

2. Experimental rating of auditory signals

2.1. First experiment: impression of auditory signals

To clarify the impressions conveyed by new sets of auditory signals intended to be introduced to an apartment complex in Korea, a rating experiment was conducted employing a semantic differential method. The sets of auditory signals as experimental stimuli were created by a Korean sound designer.

The apartment complex was divided into individual and public spaces. For each space, three auditory signals were created for each function, such as an alarm or notification sound. Table 1 gives the features of each auditory signal. Seven-step scales given in Table 2 were used for the rating of the stimuli. The sound stimuli were presented randomly.

The background noise level in the experimental room was 27 dB.

The sound stimuli were presented via an audio interface (CardDeluxe CDX-01) and headphones (STAX Lambda Nova Classic System). The presented level of the sound stimuli was adjusted to its optimum loudness by each participant during their training sessions. The participants were asked to rate the impression of each sound after they listened to the sound more than once. Each experiment was divided into two sessions separated by a rest. The participants were 20 Japanese (12 males and eight females) and 10 Koreans (five males and five females). Twenty-eight of the participants were in their 20s or 30s. Each participant underwent a hearing test. The participants' hearing was normal except for two elderly Japanese participants aged 67 and 72 years.

Factor analysis was applied separately to the Japanese and Korean data, but the obtained tendencies were very similar. Therefore, factor analysis was subsequently applied to the data for all participants. Table 2 gives the factor loading of each factor for the two-factor solution after varimax diagonal rotation. The cumulated contribution of two factors was 83.3%. The first factor was interpreted as the *pleasantness* factor, because the loadings for the scales of "irritated–calm," "unpleasant–pleasant," and "bad–good" were high for the first factor. The second factor was interpreted as the factor of the *appropriateness* of auditory signals, because the scales having higher loaded for this factor were "not understandable–understandable," "not audible–audible," and "difficult to memorize–easy to memorize."

The factor scores for each sound stimulus are shown in Fig. 1. Auditory signals were selected from the two-dimensional spatial map of stimuli (Fig. 1). Basically, because the auditory signals are to be used in apartment complexes, higher scores of the appropriateness factor are desired, but higher scores of the pleasantness factor are also necessary for auditory signals having certain purposes. For example, a sense of pleasantness is not necessary for an alarm that indicates danger, but it is desired for notification sounds heard daily. Furthermore, for some auditory signals, the pleasantness is more important than the appropriateness, if the missing of the signal is not a serious problem.

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Table 1 Features of auditory signals as experimental stimuli.

Stimuli No.	Space & Situation	Message
1–3	Door of an elevator closing	Notification
4–6	Door of an elevator opening	Notification
7–9	Kitchen gas leak	Alarm
10–12	Input operation	Notification
13–15	Start of an announcement	Notification
16–18	End of an announcement	Notification
19–21	House fire	Alarm
22–24	Mistake in operation	Notification
25–27	Public entrance of a residential building	Notification
28–30	Interphone	Calling
31–33	Doorbell	Calling
34–36	Disaster	Alarm
37–39	Time signal	Notification
40–42	Opening and closing of park gate	Notification
43–45	Entrance of the apartment complex	Notification
46–48	Car traveling in the apartment complex	Caution
49–51	Car approaching the basement car park	Caution
52–54	Car leaving the basement car park	Caution
55–57	Detection of intruders	Alarm
58–60	Approaching a dangerous area	Warning

Table 2 Factor loadings for each rating scale after varimax diagonal rotation.

Rating scale	Factors	
	First	Second
irritated–calm	0.99	0.07
unpleasant–pleasant	0.94	0.26
bad–good	0.92	0.37
uncharming–charming	0.90	0.37
noisy–quiet	0.89	–0.25
cheap–luxury	0.85	0.17
sharp–dull	0.35	–0.29
not understandable–understandable	0.15	0.97
not audible–audible	0.14	0.94
difficult to memorize–easy to memorize	0.15	0.87
Contribution (%)	52.1	31.2

As an example, auditory signals for an alarm indicating danger are generally mapped in the second and third quadrants in Fig. 1. The sound stimuli 7, 8, 9, 34, 55, 59, and 60 in the third quadrant were not selected because of their lower scores of the appropriateness factor. The sound stimuli in the second quadrant were unpleasant, but this is not critical for the selection of alarm signals.

2.2. Second experiment: functional imagery of auditory signals

Auditory signals need to arouse imagery related to their message (i.e., functional imagery). The second experiment was conducted to clarify the functional imagery of the auditory signals. In this experiment, participants were informed of spaces and situations in which the auditory signals would be heard. The participants, experimental setup, and sound stimuli were similar to those in the first experiment.

Fig. 1 Factor scores for each experimental stimulus.

For each (assumed) space, three auditory signals were presented. After a training session, a rating experiment for 20 assumed places was carried out. The three sound stimuli were randomly presented. The participants orally ordered the three stimuli in terms of their suitability for the presented functional imagery; e.g., imagery related to a danger alarm or notification. The volume of sound stimuli was set to that of the first experiment. The participants could say if there was no suitable sound among the three stimuli.

The experimental results show that 36.7% of the participants stated that there was no suitable sound for the detection of a gas leak in a kitchen. The reasons for there being no suitable sound described by participants were that they did not feel a sense of emergency because the tempo of the sounds was too slow, or there was too much reverberation. The data for the kitchen were eliminated from further investigation, and the data for the 19 other places were used in the analysis. In the analysis of experimental data, a normalized-rank method was used. The scale values of suitability for each sound stimulus were obtained by transformation from the rank order to interval scale. The sound stimuli with negative scale values of suitability were excluded from selection. Furthermore, the scale values of the stimuli were statistically analyzed for each assumed place at a significance level of 0.05. Table 3 gives the auditory signals selected from the results of the first and second experiments.

2.3. Third experiment: effect of introducing auditory signals on the evaluation of scenery

In the third experiment, an on-site survey was conducted in a real apartment complex to examine the effect of introducing auditory signals on the impression of scenery and the effectiveness of auditory signals.

The survey location was a luxurious apartment complex (Banpo GSXi) in Seoul, Korea. The complex included 44 buildings and 3,410 households. The survey was carried out in public spaces of the apartment complex, both in spaces for traffic and spaces for pedestrians, as shown in Fig. 2. The selected auditory signals were No. 43 for the location in Fig. 2(a), No. 25 for the location in Fig. 2(b), No. 40 for the location in Fig. 2(c), and No. 54 for the location in Fig. 2(d). However, signal No. 54 was evaluated as unsuitable sound in

Fig. 2 Locations for the selected auditory signals in the third experiment.

Fig. 3 Average rating scores for each location in the third experiment.

Table 3 Auditory signals selected from the results of the first and second experiments.

Message	Situation	Selected auditory signals	
		Exp. 1	Exp. 2
Alarm	Fire	19–21	20 (≥ 21)
	Disaster	35, 36	35 (≥ 36)
	Intruder	56, 57	56 (≥ 57)
	Gas leak	× × ×	× × ×
Warning	Off limits	58	58 (> 59)*
Caution	Running car	46, 47	47 (> 46)*
	Drive in	49, 51	49
	Drive out	52, 54	54 (≥ 52)
Calling	Interphone	29–30	29 (≥ 28)
	Door bell	31	31 (≥ 32)
Notification	Place	43–45	43
		25–27	25 (≥ 27)
	Time	37–39	38
	Open & close	4, 6, 1–3	4, 1
		40, 42	40 (≥ 41)
	Start & end	13, 16	13 (> 14)*, 16
	Operation	10–12	10 (≥ 11)
		23, 24	23 (≥ 24)

*: Statistically significant difference, × × ×: Not applicable, $\geq$: Not significant.

a preliminary session because of mismatch with the scenery there. Instead, signal No. 52, which was rated equivalent to signal No. 54 in the results of the first and second experi-

ments, was used for the survey. The auditory signals were provided by a loudspeaker (Bose 101MM). The on-site survey consisted of a rating experiment carried out by two graduate students majoring in environmental acoustics and an interview of residents. The rating experiment was divided into two sessions separated by a pause. The first session was the rating of scenery without presenting auditory signals, and the second session was a similar experiment but with the presenting of the auditory signals. The rating sheet had nine five-step rating scales for the impression of scenery.

The results are shown in Fig. 3. The figure shows that the introduction of auditory signals generally did not seriously degrade the impression of the scenery. In the case of the entrance of the apartment complex (a), the ratings of preference, luxuriousness, attraction, and warmth, and the total evaluation were higher with the auditory signals (solid line) than without the auditory signals (dashed line). In the case of the public entrance of the residential building (b), although noisiness was rated higher and the preference rating was lower, the other ratings such as that of pleasantness were better with auditory signals than without auditory signals. In the case of the car gate of the apartment complex (c), the differences in the ratings of noisiness and brightness between the cases with and without the auditory signals were small, but the other ratings were better with the auditory signals than without them. In the case of the exit of the basement parking (d), the noisiness rating was lower and the other ratings were higher with the auditory signals than without them.

The interviews of people living at randomly selected residences in the apartment complex showed the effectiveness of the auditory signals and indicated points for improvement.

Many respondents complained of noisiness at the places (a) and (b), and they did not want to install another sound, such as auditory signals, there. These places were near a heavy traffic road and the A-weighted sound pressure level of there was 57 to 72 dB. We should seriously discuss the necessity of auditory signals in such noisy environments. Furthermore, respondents generally did not like loud, long and frequent auditory signals. These acoustic properties should be avoided for auditory signals except danger alarm.

3. Conclusions

In the present study, to design auditory signals for an apartment complex in Korea, the impression and functional imagery of auditory signals were examined in an experimental booth. Furthermore, at the actual apartment complex, a rating experiment and interviews were carried out to confirm the suitability of the selected auditory signals and to check the effect of the auditory signals on the impression of the scenery. This study thus presents a design strategy for introducing appropriate auditory signals into apartment complexes.

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