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RELATION BETWEEN THE OVERALL IMPRESSION OF THE SOUND ENVIRONMENT AND TYPES AND LOUDNESS OF ENVIRONMENTAL SOUNDS

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This paper reports an experimental study determining the effects of the type and loudness of individual sounds on the overall impression of the sound environment. Field and laboratory experiments were carried out. In each experiment, subjects evaluated the sound environment presented, which consisted of combinations of three individual sounds of road traffic, singing crickets and the murmuring of a river, with five bipolar adjective scales such as Good–Bad, Active–Calm and Natural–Artificial. Overall loudness had the strongest effect on most types of evaluations; relative SPL has a greater effect than overall loudness on a particular evaluation of the natural–artificial scale. The test sounds in the field experiment were generally evaluated as more *good* and more *natural* than those in the laboratory. The results of comparisons between laboratory and field sounds indicate a difference in the trend between them. This difference may be explained by the term of selective listening but that needs further investigation.

1. INTRODUCTION

When designing the sound environment in a public space, for example in the case of planning a park in an urban area, we believe that a promotion of pleasant sounds such as natural sounds should be taken into account in addition to noise reduction. Since surrounding noises cannot be satisfactorily controlled in an open space like a park, we feel that it would be better to set a goal of reducing the noises to the extent that we can enjoy pleasant sounds, such as setting a noise reduction level for the surrounding road traffic noise to enjoy the sounds of birds or crickets singing at about 40 or 50 dB(A) in a park. We also believe that this type of goal can be described in terms of the physical quantity, such as overall/ relative loudness of existing sounds, and that it is possible to obtain a concrete value of the sound pressure level (*SPL*) in psychological evaluation experiments. In a previous experiment [1], we found that the main factors in an evaluation of the overall sound environment are the type and overall/relative loudness of environmental sounds. In this study we carried out a more detailed laboratory experiment to statistically determine the effect of the loudness factors and a field experiment to examine the difference between a field and a laboratory study.

2. EXPERIMENT

2.1. LABORATORY EXPERIMENT

The subjects were students in their 20 ($n = 31$). They listened to test sounds in an anechoic room presented monaurally from a speaker located 3 m away. They were asked to evaluate

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TABLE 1

Test sounds in the laboratory experiment

Type of sound	Overall *SPL* (dB(A))	Relative *SPL* (dB(A))
Road traffic (*Traffic*)	40, 50, 60	2 sounds: − 20, − 10, 0, 10, 20
Singing autumn crickets (*Crickets*)		3 sounds: − 10, 0, 10
Murmuring of a river (*River*)		

TABLE 2

Five adjective pair scales

Active–Calm
Good–Bad
Natural–Artificial
Sense community feeling–Not
Noisy-Comfortable

the test sounds using five adjective pairs as seven-point scales (Table 2) and three scales of audibility (heard, heard slightly, not heard), one for each of the three sounds in the test sounds.

The test sounds were 75 simulated environmental sounds (Table 1) that were made by mixing three types of sounds: road traffic (*Traffic*), the murmuring of a river (*River*), and singing autumn insects, such as crickets (*Crickets*). Here we used the same types of sounds as those heard in the field experiment. The loudness factors of the test sounds were controlled by overall/relative A-weighted *SPL*. Each test sound was presented for approximately 1 min: for the first 30 s, they were asked not to evaluate the sound but to imagine the scene that they heard the sound on their way home in the evening. They then started to evaluate the sound.

2.2. FIELD EXPERIMENT

The field experiment was conducted in a riverside area in Kumamoto City, Japan. The location of the experiment was chosen taking into account to the following: (1) mainly *Traffic*, *Crickets* and *River* could be heard; (2) there was a "simple sound environment," meaning few kinds of sounds, sounds from an almost-fixed zone and little fluctuation in the SPL. In the area, *Traffic* was heard mainly from a major road over a bridge across the river, *River* from a particular shoal in the river and *Crickets* from several bushes. Fourteen points for evaluation were then chosen based on the SPL of each sound (*Traffic*, *Crickets*, *River*) (Table 3). Subjects, evaluation scales, and instructions given to subjects were the same as those in the laboratory experiment. The experiment was carried out at around sunset in October, when *Crickets* could be clearly heard.

3. RESULTS OF THE LABORATORY EXPERIMENT

Figure 1 shows the average evaluation values among the subjects in which numerical values from one to seven are applied to the seven-point scales. Table 4 shows the *effect* of

TABLE 3

Evaluation points in the field experiment

Point	Major sounds†	Distance from major road (m)	*SPL* of traffic‡ (= Overall SPL) (dB(A))	Relative *SPL* with traffic§ (dB(A))
1	*Traffic*, *Crickets*	110	46	− 7: Crickets
2	*Traffic*, *Crickets*	90	45	− 12: Crickets
3	*Traffic*, *Crickets*	90	50	− 24: Crickets
4	*Traffic*, *Crickets*	60	50	− 29: Crickets
5	*Traffic*, *Crickets*	60	47	− 18: Crickets
6	*Traffic*, *Crickets*	80	49	− 25: Crickets
7	*Traffic*	20	53	Traffic only
8	*Traffic*	50	49	Traffic only
9	*Traffic*	10	56	Traffic only
10	*Traffic*	20	49	Traffic only
11	*Traffic*, *River*	50	49	− 11: River
12	*Traffic*, *River*	80	52	− 13: River
13	*Traffic*, *River*	100	53	− 15: River
14	*Traffic*, *River*	120	48	− 24: River

†Subjects also could hear several minor sounds such as dog's barking and construction noise.
‡The *SPL* of *Traffic* is the loudest sound at every point.
§It was difficult to identify the *SPL* of *River* or *Crickets* that had a lower *SPL* than *Traffic*. We thus identified their *SPL* by means of a subjective audibility experiment after the field experiment.

overall/relative *SPL* calculated by analysis of variance. *Effect* is described here as the standard deviation of the evaluation value accounted for by the variable or the residual, calculated in the process of analysis of variance. The residual includes individual differences and experimental errors. It is thereby possible to examine the effects of factors by comparing the standard deviation of the factors to that of the residual.

(1) *Type of sound*: *Traffic* was evaluated as bad, noisy, active and artificial. *Crickets* and *River* were evaluated as good, comfortable, calm and natural. There was no trend in the sense community feeling scale.
(2) *Overall SPL*: The evaluation shifted toward bad, noisy, active and artificial as the overall *SPL* became higher. These effects were greater than effects of relative *SPL* and the residual on most scales.
(3) *Relative SPL*: The effects of relative *SPL* were noted for every evaluation scale. For the natural-artificial scale, the effect is greater than that of overall *SPL*. In general, the evaluation values are almost constant when the *SPL* of *Traffic* was equal to or greater than another sound, while the value changed continuously with relative SPL in the natural–artificial evaluation.
(4) *Masking*: The sound of *Crickets* had a sufficiently high frequency not to be masked by other sounds, while the sounds of *Traffic* and *River* have a similar frequency profile and could be masked by each other. In the evaluation of audibility of *Traffic–River* sounds, almost all subjects evaluated the quieter sound as *not heard* when one sound was 20 dB louder than the other. However, almost all subjects evaluated *Traffic–Crickets* sounds as *heard slightly* with the same condition as above. There was also a difference that is considered to be caused by masking: the evaluation of *Traffic–River* changed more with relative SPL than *Traffic–Crickets*; there was a difference between the evaluation values of test sounds of the *Crickets* alone and

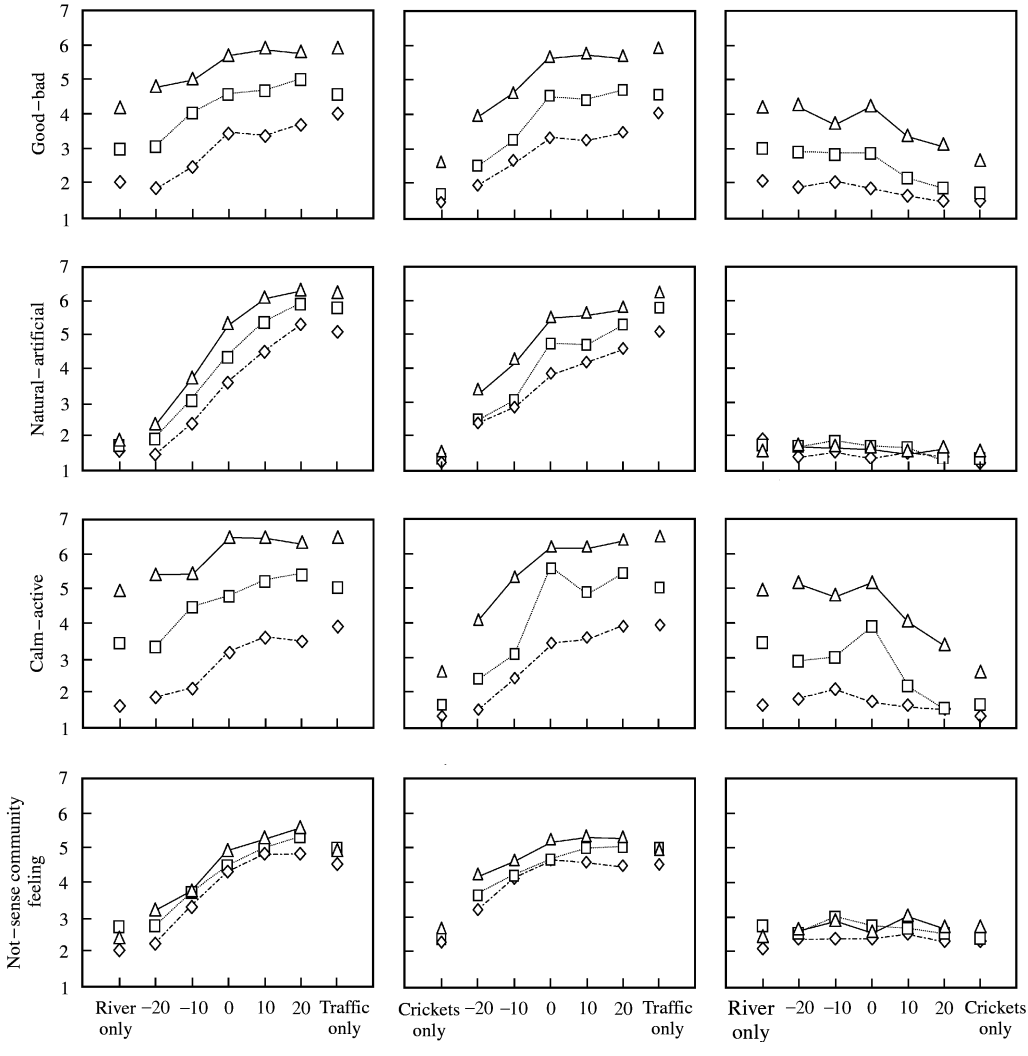

Figure 1. Evaluations in laboratory experiment. The values of the transverse axis show the relative *SPL* between two sounds. Overall *SPL* is shown as —△—, 60 dB; —□—, 50 dB and - - -◇- - -, 40 dB. + 3 dB when relative *SPL* is 0 dB. Results of *Good-Bad* and *Comfortable–Noisy* are similar.

Traffic–Crickets with one sound being 20 dB louder than the other, while no such trend was observed between *River* alone and *Traffic–River*. These results indicate that *Traffic* and *River* mask each other and that the louder sound suppresses the effect of the quieter one.

4. COMPARISON BETWEEN FIELD AND LABORATORY

Figure 2 shows a comparison between the results of the field and laboratory experiments, in which the values of the laboratory experiment that correspond to those of field are calculated by prorating the values of the peripheral condition.

Considerable differences were found between the laboratory and the fields. The sounds were evaluated as more *good*, *comfortable*, *calm* and *natural* in the field than in the

TABLE 4

Effect of factors

Subjective scale	Test sound	Effect (standard deviation)		
		Overall *SPL*	Relative *SPL*	Residual
Good–Bad	*Traffic–Crickets*	**0·8**	0·6	0·6
	Traffic–River	**0·9**	0·5	0·5
	River–Crickets	**0·7**	0·3	0·7
Comfortable–Noisy	*Traffic–Crickets*	**0·9**	**0·6**	0·5
	Traffic–River	**1·0**	0·5	0·5
	River–Crickets	**0·8**	0·4	0·7
Natural–Artificial	*Traffic–Crickets*	**0·5**	**0·8**	0·5
	Traffic–River	0·5	**1·1**	0·5
	River–Crickets	*0·1*	*0·1*	*0·3*
Calm–Active	*Traffic–Crickets*	**1·0**	**0·8**	0·5
	Traffic–River	**1·1**	**0·5**	0·5
	River–Crickets	**1·0**	0·4	0·7
Sense community feeling–Not	*Traffic–Crickets*	0·3	0·4	0·8
	Traffic–River	0·2	0·7	0·8
	River–Crickets	*0·1*	*0·1*	0·9

Note: **Bold letters** indicate a greater effect than the residual. *Italic letters* indicate the effect that there is no significant difference at 1% risk.

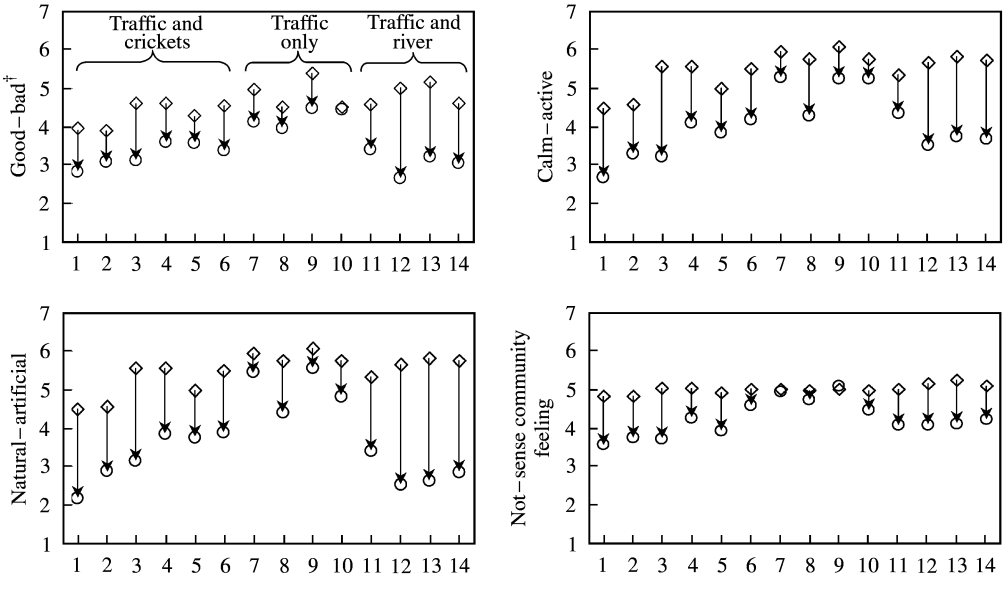

Figure 2. Comparison between field and laboratory experiments. The vertical axis shows the average value of subjects' evaluations and the transverse axis shows the number of evaluation points. ◇, evaluation value of laboratory experiment; ○, evaluation value of field experiment. † Results of *Good–Bad* and *Comfortable–Noisy* are similar.

laboratory, especially in the natural–artificial evaluation in which the difference was at most three points on a seven-point scale. The sounds of *traffic* being louder than *Crickets* or *River* in the field experiment were evaluated almost equal to the sounds of *Crickets* or *River* being

louder than *Traffic* in the laboratory experiment. These differences were greater at the points where *River* or *Crickets* were heard and less at the points where only *Traffic* was heard.

5. COMMENTS

We determined the effects of factors of overall and relative *SPL* of individual sounds on the evaluation of combined sounds in the laboratory experiment. A comparison of the results of the laboratory and field experiments showed a different trend between them, and we conclude that the results of the laboratory study cannot be applied directly to real-life conditions. On the other hand, laboratory studies are needed because it is difficult to test the effect of *SPL* in the field because of the unstable sound conditions. In our judgment, the following factors can explain the difference between laboratory and field experiments. Factors $\#1$ and $\#2$ are assumed to be mainly from visual information.

(1) Information concerning the perception of objects that make no sound, such as buildings, sky, etc.
(2) Information that is not or only slightly perceived aurally, such as the distance from a noise source and the relation between the object and oneself; an example is whether cars are moving toward or away from the listener.
(3) Selection of sounds for evaluation: which sound is evaluated or which sound is given more weight is considered to be selected based on perceived information, including $\#1$ and $\#2$, and the subject's mental condition.

In the field experiment, we can explain the difference in results with factor $\#3$. We also noticed at point $\#1$ in the field experiment that we could hear *Crickets* as the dominant sound, while *Traffic* was actually a few dB louder than *Crickets*.

While factor $\#1$ and $\#2$ are concerned with how to present sounds to subjects or how to instruct them and therefore are matters of procedure of the experiment, we consider that factor $\#3$, which is concerned with a characteristic of peoples' perception of environmental sounds, needs further investigation.

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