The relation between overall noisiness and instantaneous judgment of noise and the effect of background noise level on noisiness

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In order to evaluate community noise, the measurement of long-term noisiness is very important. However the conventional psychophysical method is inappropriate for this purpose. Using the newly developed "method of continuous judgment by category," the relationship between instantaneous judgment and long-term noisiness was examined. Aircraft noises overlapping background noises were adopted as stimuli. As a result, it was suggested that long-term noisiness was determined by the prominent parts of instantaneous judgment. And it was made clear that the aircraft noise to background noise ratio had much effect on the overall noisiness of aircraft noises.

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1. INTRODUCTION

It is important to evaluate the long-term noisiness of environmental noise, but very difficult to measure it in experimental situations. The long-term noisiness could be measured by a social survey, but a social survey is usually intended to research many kinds of social and personal factors which would affect the noisiness of noise as well as the noisiness itself, and is not always appropriate to make clear the relationship between the noisiness and the physical properties.

Concerning environmental noise, whose level is fluctuating at each moment, we have two kinds of impressions; those are instantaneous noisiness corresponding to the level fluctuation at each moment and overall (long-term) noisiness. As the long-term noisiness of such level-fluctuating noise is assumed to be a kind of summation or the average of instantaneous noisiness, the long-term noisiness could be predicted from instantaneous judgments, which are thought to have good correspondence with physical properties of sound. In order to measure the instantaneous judgment of noise, we

have developed a new method called "the method of continuous judgment by category¹⁾". This method has the advantages that it may be applied to stimuli of longer durations and it allows subjects to pay no attention to any specific stimuli such as aircraft noise.

To determine the relationship between instantaneous judgments and the long-term effects of noise, it is necessary to measure both of them using the same stimulus. And the stimulus should have an appropriate duration whose overall noisiness and instantaneous judgment can be easily judged.

Aircraft noises overlapping background noises were adopted as stimuli. Using these stimuli we could also examine the effect of the level of background noises on the judgment of the stimuli. This effect is supposed to be a very important factor of long-term noisiness²⁻⁴⁾. The durations of the stimuli were about 10 minutes. Moreover by giving a longer period between presentation of stimuli and judgment, the noisiness of stimuli of longer durations (60 min or 120 min) were also examined.

2. EXPERIMENT

In the experiment, the overall noisiness of 10-, 60- and 120-minutes stimuli were obtained and their relation with instantaneous judgment were examined. The effect of the level of background noise (abbreviated BN) on the noisiness of aircraft noise (abbreviated AN) was also tested.

2.1 Subjects

Twelve female subjects aged 20 to 40 years with normal hearing ability participated in the experiment. They were all housewives and, except for one subject, did not have any experience with psychological experiments before.

2.2 Stimuli and Apparatus

a) Five peak levels of ANs were used; 55, 60, 65, 70 and 75 dB(A). The noises were derived from a Boeing 747, Douglas DC-10, Lockheed L-1011, and Boeing 727. They were flying mode -7.5 km from the end of runway B of Osaka International Airport. The durations of the ANs were about 40 seconds. b) BNs were recorded on magnetic tapes at the center of a field and the side of a four-lane road in Osaka Prefecture. It included various kinds of distant sounds such as road traffic noise, birds twittering, human voices. The durations of the BNs were about 10 minutes. c) AN and BN were electrically mixed by a mixer (SONY MX710) and presented to each subject in a sound proof

room through an amplifier (YAMAHA CA1000III) and a loudspeaker (DIATONE DS301). The sound levels of AN and BN are shown in Table 1 and examples of the stimulus patterns are shown in Fig. 1. Leq of the ANs were calculated from the sound level measured every 500 ms. The peak level of AN is the maximum value during the AN presentation to the subjects. Leq , L_{10} and L_{50} of the BNs were calculated from the sound level measured every 5 s.

2.3 Procedure

There were two sessions in the experiment. In the one session only BN was presented (condition AN-), and in the other session electrically mixed AN and BN were presented (condition AN+). In the AN+ condition, the interval between ANs was about 2 minutes which was supposed to be a minimum interval of the flight schedule. Half of the subjects (6 subjects) did the AN+ condition first and the other half did the AN- condition first.

In each session six kinds of BNs were each presented at random. In order to obtain the instantaneous noisiness, the method of continuous judgment by category was adopted. The subjects judged the noisiness of the sound of each moment using seven categories from "intolerably noisy" to "not noisy at all" by touching one of seven micro-switches on a response box corresponding to each category. The responses of the subjects were con-

Table 1 Sound levels of aircraft and background noises.

No.	Background noise			Aircraft noise					AN+BN
	Leq	L_{10}	L_{50}	Peak level					Leq
				TR	DC10 B747	TR	DC10 B747	B727	
1	45.7	47.7	42.7	55	60	65	70	75	57.6
2	53.4	54.3	50.5	55	60	65	70	75	58.8
3	58.7	61.9	55.9	55	60	65	70	75	62.6
4	35.7	37.7	32.7	55	60	65	70	75	57.3
5	43.4	44.3	40.5	55	60	65	70	75	57.6
6	48.7	51.9	45.9	55	60	65	70	75	60.6

* No. 4-No. 6 are the stimuli, the levels of which are lowered by 10 dB from the levels of the stimuli No. 1-No. 3 respectively.

** The peak levels of aircraft noises presented to the subjects were a little higher (1.2-2.3 dB) than the values in this table. Since the durations of the peaks were short, they are shown in 5 dB steps.

Fig. 1 Examples of the sound level patterns of the stimuli used in the experiment.

Fig. 2 An example of the record.

tinuously recorded on a level recorder (B&K 2305). An example of the record is shown in Fig. 2. After the instantaneous judgment of each 10-minutes stimulus was finished, the subjects were asked to fill out a questionnaire, in which they were surveyed concerning the overall noisiness of the 10-minutes noise using the same seven categories used in the instantaneous judgment, the difficulty of the judgment, degree of fatigue, sound sources, the noisiest sound, the loudest sound, the most prominent sound, and the subjective duration of the experiment.

About one month after the experiment, we called each subject and asked her to judge the overall noisiness of each session, AN+ (60 min), AN- (60 min), and both sessions together (120 min). They easily judged this long-term noisiness. The reason we called after an interval of one month is that time is needed for averaging or grasping the impression of long-term noisiness. This period between presentation of stimuli and judgment was useful to avoid the overestimation of the latter parts of the stimulus series.

3. RESULTS AND DISCUSSION

1) Ten-minutes overall noisiness (OA_{10}) of AN- condition is highly correlated with Leq ($r=.977$, Fig. 3), L_{10} ($r=.975$) and L_{50} ($r=.976$). Therefore any measures are appropriate to evaluate the overall noisiness of BN. However in order to add the energy of AN and BN, energy based Leq is very convenient. Moreover Leq usually shows high correlation with subjective responses to noise⁵⁻⁸⁾. Therefore we would like to use Leq as an index in further discussion. Leq of AN+BN (Leq of AN+ condition) shown in the right column of Table 1 was calculated by adding the energy of AN and BN. The increase of Leq caused by

Fig. 3 Relation between 10-minutes overall noisiness (OA_{10}) and Leq in AN- condition.

High correlation can be noticed between them.

the overlapping of AN is larger when the level of BN (Leq of AN- condition) is lower. Table 2 shows the coefficient of correlation between Leq and subjective judgments (OA_{10} , the average of instantaneous judgment: $\bar{I}\bar{J}$, the difficulty of the judgment, etc.). The relation between Leq and OA_{10} in AN+ condition is shown in Fig. 4.

2) From the answers to the questionnaire the average scores of the difficulty and fatigue judgments showed that the subjects did not have difficulty or fatigue judging the instantaneous noisiness.

3) The category difference between OA_{10} of AN+ and OA_{10} of AN- was used as an index of the increase of the noisiness by the overlapping of aircraft noise on environmental noise. This category difference showed high negative correlation with Leq of BN (Fig. 5). This fact suggests that the increase of the noisiness caused by the overlapping of AN is affected by the level of BN. When the

Fig. 4 Relation between 10-minutes overall noisiness (OA_{10}) and Leq in AN+ condition.

Table 2-a Coefficient of correlation between Leq and subjective judgments.

		AN—						AN+					
		<i>Leq</i>	<i>OA</i> ₁₀	<i>IJ</i>	Duration	Diffi- culty	Fa- tigue	<i>Leq</i>	<i>OA</i> ₁₀	<i>IJ</i>	Duration	Diffi- culty	Fa- tigue
AN—	<i>OA</i> ₁₀	.977											
	<i>IJ</i>	.989	.970										
	Duration	— .471	— .543	— .504									
	Difficulty	.879	.828	.927	— .324								
	Fatigue	.741	.686	.806	— .121	.965							
AN+	<i>Leq</i>	.819	.844	.809	— .830	.618	.405						
	<i>OA</i> ₁₀	.979	.992	.980	— .592	.856	.710	.886					
	<i>IJ</i>	.977	.994	.958	— .563	.787	.624	.874	.987				
	Duration	— .087	— .173	— .093	— .080	.001	— .022	.206	— .063	— .132			
	Difficulty	.664	.673	.670	— .489	.642	.542	.797	.738	.678	.550		
	Fatigue	.653	.712	.565	— .512	.219	— .006	.733	.673	.770	— .186	.395	
AN+ — AN—	<i>OA</i> ₁₀	— .947	— .985	— .932	.463	— .769	— .637	— .765	— .954	— .976	.317	— .567	— .744

Table 2-b Coefficient of correlation between *Leq* and subjective judgements.

	OA ₆₀ & OA ₁₂₀	OA ₁₀	IJ
<i>Leq</i>	.996	.979	.979
OA ₆₀ & OA ₁₂₀	.993	.993	
OA ₁₀	1.000

Fig. 5 Category difference between 10-minutes overall noisiness of AN+ and AN- conditions is plotted against *Leq* of background noise. High negative correlation suggests that the effect of aircraft noises decreases as the level of background noise increases.

level of BN increased, the difference of the noisiness between AN+ and AN- conditions decreased. For example, when *Leq* of BN was about 60 dB(A), the category difference became zero. It means that under a noisy environment the flyover of aircraft is not of much effect.

4) In the position overlapping AN on BN, the average of instantaneous judgment (IJ of AN+) and *Leq* (*Leq* of AN+) were calculated. And in the corresponding parts of AN- condition, the average of instantaneous judgment (IJ of AN-) and *Leq* (*Leq* of AN-) were also calculated. These averages of instantaneous judgment were calculated giving the weight to each category corresponding to the percentage of time during which the category was used. The category difference between IJ of AN+ and IJ of AN- (abbreviated "IJ of AN+ - IJ of AN-") was used as an index of the increase of the noisiness by the overlapping of each aircraft noise on the background noise. *Leq* of AN+ to *Leq* of AN- ratio is a kind of signal

Fig. 6 Category difference between the average of instantaneous judgment of AN+ and AN- conditions ("IJ of AN+ - IJ of AN-") showed high correlation with *Leq* of AN+ to *Leq* of AN- ratio.

(aircraft noise) to noise (background noise) ratio, i.e. S/N. "IJ of AN+ - IJ of AN-" had high correlation with *Leq* of AN+ to *Leq* of AN- ratio as shown in Fig. 6.

From this result, the increase of the noisiness by flying of each AN is affected by *Leq* of BN. This same tendency can be seen in our previous experiment⁹⁾ using the ANs under the landing path which had shorter duration and higher frequency components.

5) In AN+ condition, AN was chosen as the noisiest, the loudest and the most prominent sound of all. However the percentage of each judgment was different from one another. The loudest judgment of AN showed the highest percentage (70.8%) and the most prominent judgment of AN showed the lowest percentage (40.3%). This fact suggests that the loudest sound is not always the noisiest sound, nor the most prominent sound. The same tendency was found in the judgment of road traffic noise in AN- condition.

Fig. 7 Relation between the percentages of the noisiest judgment of aircraft noises and Leq of background noise. Under a quiet background noise aircraft noises were judged very noisy, but the percentages decreased according to the increase of the level of background noise.

Fig. 8 10- and 60- & 120-minutes overall noisiness are plotted against Leq . Both of them are affected by Leq .

Figure 7 shows the relation between the noisiest judgment of AN and Leq of BN. Negative correlation was found between them, i.e. the percentage of the noisiest judgment of AN decreased as Leq of BN increased. In fact under the noisy BN condition the noisiest sound was not AN, but road traffic noise.

All the results of 10-minutes overall judgment, instantaneous judgment and the noisiest judgment confirmed the effect of the level of BN on the noisiness of AN.

6) In the experiment, the relation between overall noisiness and instantaneous judgment was examined using three kinds of subjective responses. They were 60- and 120-minutes overall noisiness (OA_{60} , OA_{120}) judged one month after the experiment, the average of six or twelve 10-minutes overall noisiness (OA_{10}) and the average of instantaneous judgment (IJ).

The relation between Leq and OA_{60} & OA_{120} , OA_{10} is shown in Table 2-b and Fig. 8, which suggests that long-term (60 min or 120 min) noisiness is also affected by Leq .

7) Figure 9 shows the relation between OA_{10} and IJ . High correlation and small RMS (root mean square of the difference between both judgments) show the agreement of both judgments. This fact suggests that OA_{10} is determined by the average of instantaneous judgment under the condition that both stimulus duration and the interval between stimulus presentation (instantaneous judgment) and overall judgment are not so long.

8) OA_{60} & OA_{120} and OA_{10} are plotted against IJ in Fig. 10. OA_{60} & OA_{120} increased in proportion to OA_{10} and IJ , but OA_{60} & OA_{120} was overestimated compared with the average of instantaneous judgment.

Fig. 9 Relation between 10-minutes overall noisiness and the average of instantaneous judgment.

High correlation and small RMS show the agreement of both judgments.

Fig. 10 10- and 60- & 120-minutes overall noisiness are plotted against the average of instantaneous judgment.

60- & 120-minutes overall noisiness showed overestimation compared with the average of instantaneous judgment, which suggests that 60- & 120-minutes overall noisiness is determined by the prominent parts of instantaneous judgment.

ment. This fact suggests that the lower level parts were neglected in the judgment of long-term noisiness. And this is the same tendency as was found in our previous experiment on road traffic noise (20 min).¹⁰⁾

4. CONCLUSION

1) The increase of Leq caused by the overlapping of AN is larger when the level of BN is lower. Therefore the category difference between OA_{10} of AN+ and OA_{10} of AN- became larger in low BN conditions. This fact suggests that the effect of the overlapping of AN on a certain BN depends on the level of BN.

2) The category difference between the instantaneous judgment of AN (AN+) and the instantaneous judgment of BN (AN-) was highly correlated with the relation between the levels of AN and BN (S/N). The same tendency was found in our previous experiment.⁹⁾

3) The noisiest judgment of AN decreased as the level of BN increased. The noisiest sound was

AN under the quiet BN condition, but it was road traffic noise under the noisy BN condition.

4) The long-term noisiness was found to increase in proportion to the increase of Leq , but it was overestimated compared with the average of instantaneous judgment.

From these findings it was suggested that the long-term noisiness is not an average of instantaneous judgment, but determined by the prominent parts of instantaneous judgment, and that the increase of noisiness by the overlapping of AN on BN is dependent on the relation between the levels of AN and BN, i.e. S/N. Under the high BN condition the noisiness does not increase even when AN is overlapped on BN, and under the low BN condition the noisiness is entirely dependent on AN.

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