The effect of time interval between aircraft event noises to overall noisiness

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ABSTRACT

The effect of time interval between event noises on the overall noisiness of aircraft noise has been examined by carrying out two psychological experiments. Intermittent noises composed of aircraft noise for event noise and soft road traffic/railway noise for ambient noise were used as stimuli. In the 1st experiment, the time interval between aircraft noises was varied by changing the number of aircraft noises and the total duration of stimuli was kept equal. On the other hand, the time interval between aircraft noises was varied by changing the total duration of stimuli and the number of aircraft noises was kept equal in the 2nd experiment. Participants were requested to judge the instantaneous and overall noisiness using 'Method of continuous judgment by line length'. Results of both experiments showed that the overall noisiness was almost decided by L_{Aeq} of each stimulus as the first approximation. Additionally, it was found that noisiness for single event noise was the same if the energy of single event noises was equal in spite of the differences of time interval of each stimulus. These results suggest that the length of time interval doesn't affect instantaneous judgment of event noisiness and the hypothesis that quiet time length raises the overall noisiness of aircraft noise can be rejected.

INTRODUCTION

Some former studies have examined the relationship between background noise level and subjective noisiness and annoyance in laboratory experiments. For example, Pearsons (1966) conducted psychological experiments evaluating subjective noisiness of aircraft noise and reported that the noisiness decreased according to the increase of background noise level. Powell and Rice (1975) also conducted experimental studies changing background noise level and reported that subjective response to aircraft noise decreased with increasing background noise level. Namba and Kuwano (1980) reported that the noisiness of the aircraft noise did not increase according to aircraft noise level when background noise level was high. The results of social surveys focused on the effect of background noise level were also reported. Bottom (1971) conducted social survey designed to investigate the influence of background noise level on annoyance due to aircraft noise. It was found that annoyance due to aircraft noise was different even if NNI (Noise Number Index) was almost same. It was concluded that annoyance response to aircraft noise increased with decreasing background noise level. It was also suggested in social survey conducted around Korean airports that annoyance in low background noise

regions were much higher than those in high background noise regions, even though aircraft noise levels were the same (Lim et.al 2008).

From these studies, it can be considered that the quietness of background noise emphasized the impression of each event noise and raised the overall impression of aircraft noise because prominent sounds contributed greatly to the determination of overall impression. However, there are few studies focused on time interval between each event noise although the quiet impresion could be derived not only from background noise level but also from time length between each event noise. Two kinds of experiments were conducted by the athors in order to examine the effect of time interval on overall aircraft noisiness and some of the results were already reported (Morinaga et.al 2011, Morinaga et.al 2012, Morinaga et.al 2013). It was found that overall impression was decided by L_{Aeq} as the first approximation and instantaneous noisiness of event noise greatly contributes to overall noisiness. Additionally, it was suggested that the contribution of event noises to overall noisiness reduced by quiet impression of the time interval. These results does not support the hypothesis that quiet time length raises the overall noisiness of aircraft noise.

In the 1st experiment by the athors, it was suggested that time interval betwen event noises did not affect instantaneous event noisiness. Since the total duration of a stimulus was fixed in the experiment, in this paper, the result of 2nd experiment conducted changing total duration of a stimulus is shown to validate the hypothesis that quiet time length raises the overall noisiness of aircraft noise.

OUTLINE OF 1ST EXPERIMENT

Stimuli

Five kinds of intermittent noises composed of aircraft noise for event noise and soft road traffic noise for ambient noise were used as stimuli. The aircraft noises were recorded near Narita International Airport and the road traffic noise was recorded at a distant point from the Chuo Express Way in Tokyo. The specifications of five stimuli are shown in Table 1. Figure 1 shows the time-varying records of A-weighted sound pressure level (SPL) for each stimulus measured at the ear position of participants in the sound proof room. Two kinds of the presentation order of single event aircraft noise were prepared for each stimulus. Figure 1 shows one of them. Single event aircraft noises and road traffic noise for ambient noise were electrically mixed by sound editing software (Adobe Audition) and presented to participants through an audio interface (Roland, UA-25), an amplifier (BRYSTON, 4B SST2) and loudspeakers (PMC, IB1S). The equivalent continuous sound pressure level $L_{\mathrm{Aeq,T}}$ of the stimulus and the duration time of each stimulus (T) were equal among ST1-1, ST1-2 and ST1-3 even if the number of aircraft was different from each other. On the other hand, the average of L_{AE} of single event aircraft noises ($L_{AE,\mathrm{event}}$) among ST1-1, ST1-4, and ST1-5 were equal. The $L_{\mathrm{Aeq,T}}$ of road traffic noise used as ambient noise was kept 45 dB in all stimuli.

Participants

Twenty six people, fourteen females and twelve males aged between 19 and 61 years (Average: 36) with normal hearing ability, participated in this experiment.

Table 1: The specifications of stimuli in the 1st experiment.

Stimulus ID	$L_{Aeq,T}$ [dB]	T [s]	Average of $L_{AE,event}$ [dB]	Number of Aircraft	Total of Time interval between event noises (TI) [s]	Ratio of TI / T
ST1-1	62.3	600	87.1	2	576	0.96
ST1-2	62.3	600	82.4	6	528	0.88
ST1-3	62.2	600	77.1	18	384	0.64
ST1-4	67.3	600	87.4	6	528	0.88
ST1-5	72.2	600	87.4	18	384	0.64

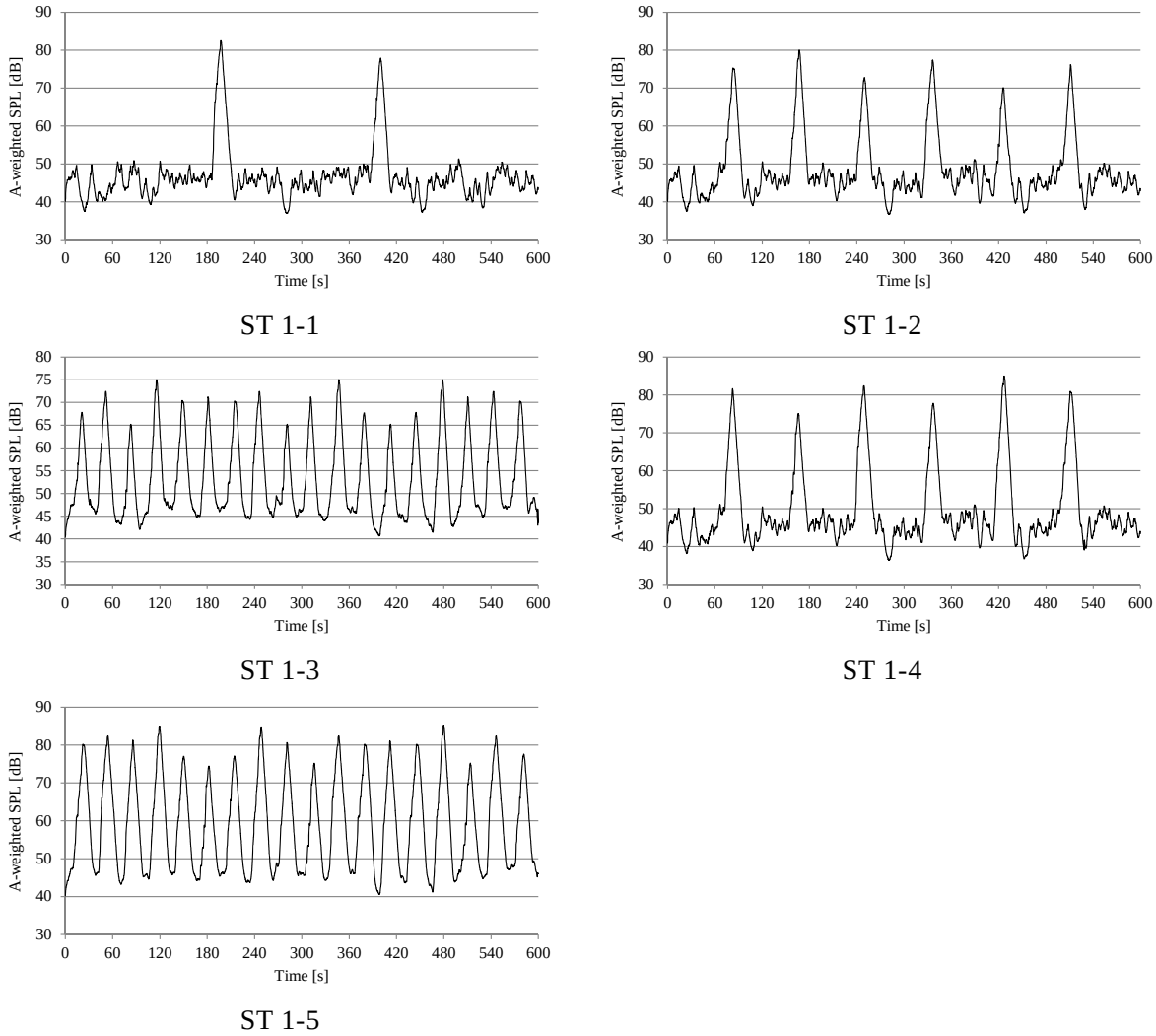


Figure 1: Stimuli used for 1st experiment

Procedure

The psychological experiment was conducted in a soundproof room established in a detached wooden house of Kobayasi Institute of Physical Research. The room size is 22.6 m^2, and the indoor ambient noise of less than 30 dB and the reverberation time of 0.22 seconds at 500 Hz were achieved by installing double windows and sound-absorption materials. The following two kinds of experiment were set up to examine the effect of time interval.

- Experiment A

Five kinds of stimulus were presented in random order to the participants who were allowed to read any favorite books and magazines. After having heard each 10-minute stimulus, they judged the overall noisiness of each stimulus using a line length displayed on a 42-inch monitor. Since the participants were not necessarily asked to pay attention to the stimuli, it can be considered that they were more likely to judge the overall impression under the condition similar to daily life.

- Experiment B

Experiment B was conducted a few hours after Experiment A. Five kinds of stimulus were presented in random order to the participants who were asked to judge the instantaneous noisiness of stimulus using the method of "continuous judgment by line length" (Kuwano and Namba 1990). That is, the participants adjusted the line length displayed on a 42-inch monitor using wireless mouse so that the length of a line corresponded to the instantaneous impression of noisiness. After the instantaneous judgment, the participants answered first the questionnaire in which they were asked about the difficulty of continuous judgment etc., and then they judged overall noisiness of each stimulus using the same line length procedure.

OUTLINE OF 2ND EXPERIMENT

Stimuli

Six kinds of intermittent noises composed of aircraft noise for event noise and soft road traffic/railway noise for ambient noise were used as stimuli. The sources of aircraft noises were same used in the 1st experiment. The road traffic and railway noises were recorded at a distant point from the Chuo Express Way and the Chuo Line of East Japan Railway in Tokyo, respectively. The specifications of six stimuli are shown in Table 2. Figure 2 shows the time-varying records of A-weighted sound pressure level for each stimulus measured at the ear position of participants in the sound proof room. Two kinds of the presentation order of single event aircraft noise were prepared for each stimulus. Figure 2 shows one of them. Single event aircraft noises and road traffic/railway noise for ambient noise were electrically mixed by sound editing software (Adobe Audition) and presented to participants through an audio interface (Roland, UA-25), an amplifier (BRYSTON, 4B SST2) and loudspeakers (PMC, IB1S). The equivalent sound pressure level $L_{\mathrm{Aeq,T}}$ of the stimulus and the number of aircraft noise were equal among ST2-1, ST2-4 and ST2-5 even if duration time of stimulus (T) was different from each other, which means total of time interval between event noises (TI) is different in each stimulus. On the other hand, the average of L_{AE} of single event aircraft noises ($L_{\mathrm{A}E,\mathrm{event}}$) among ST2-1, ST2-2, and ST2-3 were equal since the number of aircraft noises was equal though the total duration of stimuli was changed. The stimulus of ST2-6 was used for comparing with ST2-4 in the condition of equal L_{Aeq} and duration time. In the present study, fluctuating soft road traffic and railway noises were used for ambient noise. The $L_{\mathrm{Aeq,T}}$ of ambient noise was about 45dB in all stimuli as is the case with 1st experiment.

Participants

Twenty people, seven females and thirteen males aged between 19 and 40 years (Average: 25) with normal hearing ability, participated in this experiment.

Table 2: The specifications of stimuli in the 2nd experiment.

Stimulus ID	$L_{Aeq,T}$ [dB]	T [s]	Average of $L_{AE,event}$ [dB]	Number of Aircraft	Total of Time interval between event noises (TI) [s]	Ratio of TI / T
ST2-1	59.4	300	84.2	6	165	0.55
ST2-2	55.4	750	84.2	6	585	0.78
ST2-3	51.4	1890	84.2	6	1670	0.88
ST2-4	59.4	750	88.2	6	585	0.78
ST2-5	59.4	1890	92.2	6	1670	0.88
ST2-6	59.4	750	88.2	12	458	0.61

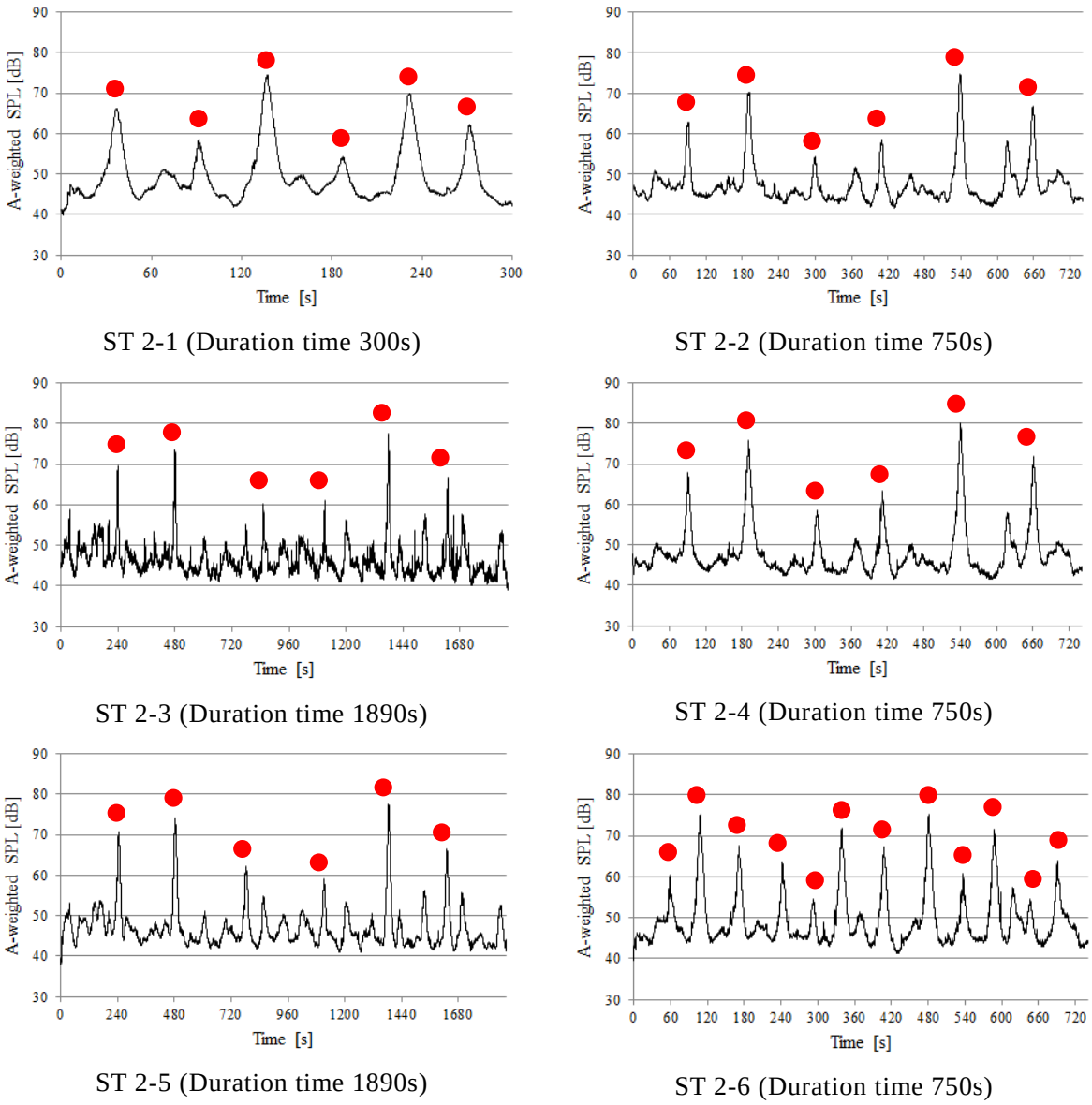


Figure 2: Stimuli used for 2nd experiment (Fulfilled red circle means aircraft event noise)

Procedure

The 2nd experiment was conducted by the same experimental room and same procedure as the 1st experiment.

RESULTS

Summary of the results of the 2 experiments

Table 3 summarizes the results of the all experiments using the average data of all participants excluding the data of 4 participants who operated a mouse incorrectly in the continuous judgments of Experiment B in the 1st experiment. The noisiness judgment is indicated by the line length.

Table 3: The results of experiments.

Stimulus ID	Specification of stimuli				Results of experiments			
					Exp. A	Exp. B		
	$L_{Aeq,T}$ [dB]	T [s]	Average of $L_{AE,event}$ [dB]	TI / T	Overall noisiness	Overall noisiness	Average of instantaneous noisiness	Average of instantaneous event noisiness
ST1-1	62.3	600	87.1	0.96	279.3	285.0	116.4	455.9
ST1-2	62.3	600	82.4	0.88	352.2	372.1	137.6	425.1
ST1-3	62.2	600	77.1	0.64	343.4	379.8	200.0	404.8
ST1-4	67.3	600	87.4	0.88	451.2	476.5	150.3	460.7
ST1-5	72.2	600	87.4	0.64	546.4	564.9	245.0	449.3
ST2-1	59.4	300	84.2	0.55	334.6	392.4	189.5	322.3
ST2-2	55.4	750	84.2	0.78	267.5	290.9	138.3	284.1
ST2-3	51.4	1890	84.2	0.88	215.7	243.9	118.4	291.9
ST2-4	59.4	750	88.2	0.78	419.0	360.3	154.2	330.3
ST2-5	59.4	1890	92.2	0.88	360.4	305.7	137.7	323.0
ST2-6	59.4	750	88.2	0.61	387.3	430.5	181.2	317.5

The correlation coefficients between A-weighted sound pressure levels and instantaneous evaluation by the line length in the experiment B in the 1st and 2nd experiments are shown in Table 4. Reaction time between the physical values and participants' responses was adjusted so that the correlation coefficient between them reached its maximum. The correlation coefficients calculated by using the data sampled by 100 ms in all stimuli. In the case of judgments for both overall and event noise alone, the correlation coefficients are extremely high. In the case of judgments for time interval between event noises, the correlation coefficients indicate significant correspondence, though the correlation coefficients are lower than those in the case of event noise portions. From these results, it can be considered that the participants judged instantaneous noisiness paying attention to the instantaneous level changes of the stimulus in both event noises and ambient noises in experiment B.

Table 4: Correlation coefficients between instantaneous judgment and A-weighted sound pressure level.

	ST 1-1	ST 1-2	ST 1-3	ST 1-4	ST 1-5	ST 2-1	ST 2-2	ST 2-3	ST 2-4	ST 2-5	ST 2-6
Overall	0.89*	0.92*	0.97*	0.94*	0.96*	0.96*	0.93*	0.87*	0.95*	0.91*	0.95*
Event noise (Aircraft noise)	0.93*	0.92*	0.96*	0.94*	0.96*	0.97*	0.96*	0.97*	0.97*	0.95*	0.96*
Time interval between event noises	0.46*	0.45*	0.45*	0.45*	0.56*	0.62*	0.73*	0.79*	0.71*	0.79*	0.67*

*: $p < 0.05$

The relationship between L_{Aeq} of each stimulus and the judgment of overall noisiness

The relationship between L_{Aeq} of each stimulus and the judgment of overall noisiness in all experiments are shown in Figure 3. It can be said that the results of all experiments are almost same and overall noisiness increases according to the increase of L_{Aeq} of each stimulus. Scheffe's multiple comparison was conducted for the stimuli that L_{Aeq} is almost same, and there are no significant differences in all comparisons. It is suggested that overall noisiness is almost decided by L_{Aeq} of each stimulus in spite of the differences of duration time and total of time interval of each stimulus. This result does not support the hypothesis that quiet time length raises the overall noisiness of intermittent noise.

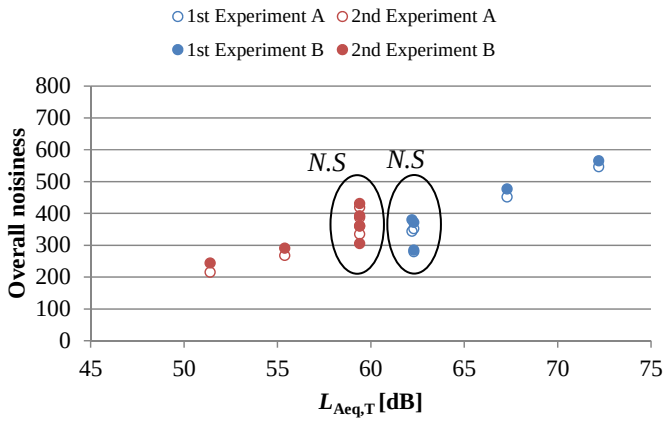
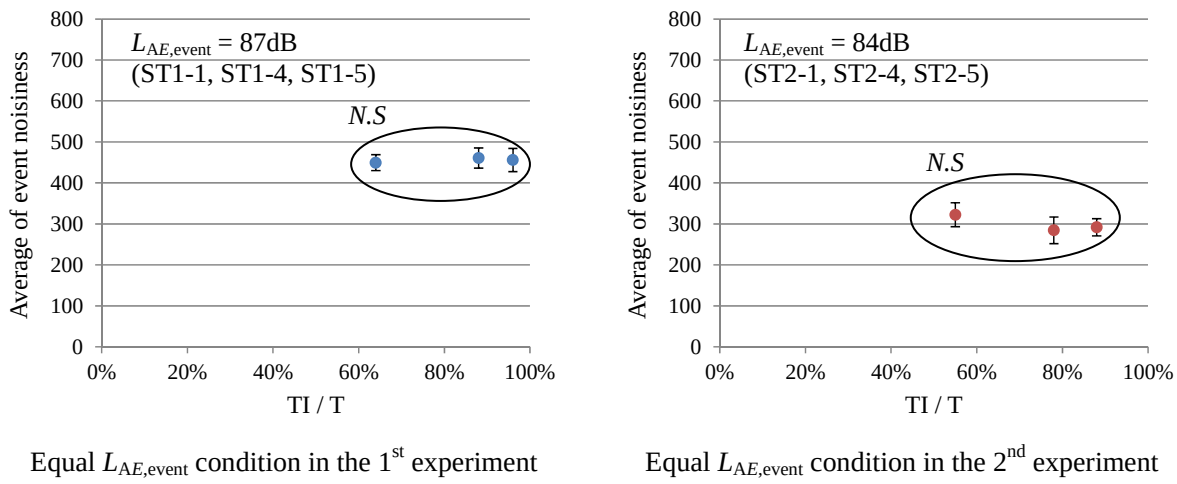


Figure 3: The relationship between L_{Aeq} of each stimulus and judgment of overall noisiness

The effects of time interval on each event noisiness

Figure 4 shows the comparison of the average of instantaneous judgments of event noise portions among stimuli that $L_{AE,event}$ are same. The result in both experiments indicates that noisiness for single event noise is the same if the energy of single event noises is equal in spite of the differences of time interval of each stimulus. These results suggest that quiet time length doesn't affect instantaneous judgment of event noisiness and the hypothesis shown in the Introduction can be rejected.



Equal $L_{AE,event}$ condition in the 1st experiment

Equal $L_{AE,event}$ condition in the 2nd experiment

Figure 4: –Comparison of average of instantaneous judgment of event noise portions among stimuli.

CONCLUDING REMARKS

In this paper, the effect of time interval on the event noisiness was examined based on the results of two psychological experiments using the method of continuous judgment by line length. As the results, overall impression was decided by L_{Aeq} of stimulus as the first approximation and noisiness for single event noise is the same if the energy of single event noises is equal in spite of the differences of time interval of each stimulus.

As is shown in the brief review in the beginning of this paper, there are many evidences that background noise level increases the subjective response to event noises. However, present experiments conducted changing the length of time interval suggest that the length of time interval doesn't affect instantaneous judgment of event noisiness and the hypothesis that quiet time length raises the overall noisiness of aircraft noise can be rejected. Referring our former studies, time interval might have a reduction effect on the event and overall noisiness in the case that time interval is long.

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