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TEMPORAL ASPECTS IN THE EVALUATION OF ENVIRONMENTAL NOISE

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ABSTRACT
The frame of reference has a significant effect on the evaluation of environmental noise. Hearing is the perception which conveys information along the temporal stream and temporal aspects play an important role in the evaluation of noise. In this paper the effect of frame of reference was discussed in relation to the temporal aspects dividing the time span into three categories; perceptual moment, perceptual present and auditory memory.

1 - INTRODUCTION
Psychological evaluation of environmental noise is affected not only by the physical properties of the noise but by the frame of reference in which the noise is evaluated. The frame of reference consists of various factors such as the context of the noise and social and cultural background of the listeners [1-3]. Hearing is the perception which conveys information along the temporal stream and temporal aspects play an important role in the evaluation of noise. Therefore, the temporal aspects also contribute to forming the frame of reference in the evaluation of noise. In this paper, the evaluation of environmental noise will be discussed in relation to the temporal aspects of the frame of reference.
Subjective temporal stream is quite different from physical one. Physically time runs from the past to the present and to the future at a constant speed. On the other hand subjectively the speed of elapse of time is not constant and sometimes it goes back even from the present to the past. The time resolution is not constant either. Our hearing is very sensitive to a minute temporal difference and we can detect a very short gap in the sound stream [4], while we roughly grasp the whole range of a long-term event by neglecting insignificant portions. When the environmental noise is evaluated, different frame of reference is used according to the duration of the noise and to the task given to subjects.
Subjective temporal span can be divided into the three categories; perceptual moment, perceptual present and auditory memory.

1.1 - Perceptual moment
If two sounds, A and B with very short duration, e.g. a few milliseconds, are presented successively with a short interval, we cannot identify whether A is followed by B or vice versa. The time span where the temporal order of sounds cannot be identified is called "perceptual moment" [5]. The duration of perceptual moment may be less than about 100 msec, which is different depending on the attribute or method of measurement [5, 6]. In this time span, though the temporal order of the sounds cannot be identified, we can identify the sound by the difference of sound quality. Also their localization can be detected as indicated by Haas effect [7].

1.2 - Perceptual present
Physically "present" is a point, however, psychologically there is a time span in which all the events generated are perceived simultaneously. Woodrow [8] said, "If one listens to the ticks of a clock, he may notice that he is aware of several clicks at once. It may be asked, therefore, how many ticks before the last one, or how many successive ticks, can be heard simultaneously. More generally the problem may be stated as that of the physical time over which stimuli may be spread and yet all be perceived as present." Woodrow defined this time as the threshold of unitary duration or the upper limit of the perceptual

(psychological) present. According to Fraisse [9], two close sounds belong to the same perceived present when the interval is approximately 1.8 - 2 sec. It is also reported that maximum duration of perceptual present is 7 to 8 sec [10]. It seems that the limit of the perceptual present may be affected by various psychological factors, e.g, materials (speech, music, or noise), redundancy, expectancy, interval between sounds, duration of elements, individual difference among subjects, etc. Therefore, the duration of perceptual present cannot be fixed. However, there is no doubt that the perceptual present has a certain duration. It is not a point like the physical present.
In the time span of perceptual present, the temporal order or stream can be identified. That is, whether sound A is presented before or after sound B can be identified and therefore the meaning of speech or the melody of musical performance can be understood.

1.3 - Auditory memory

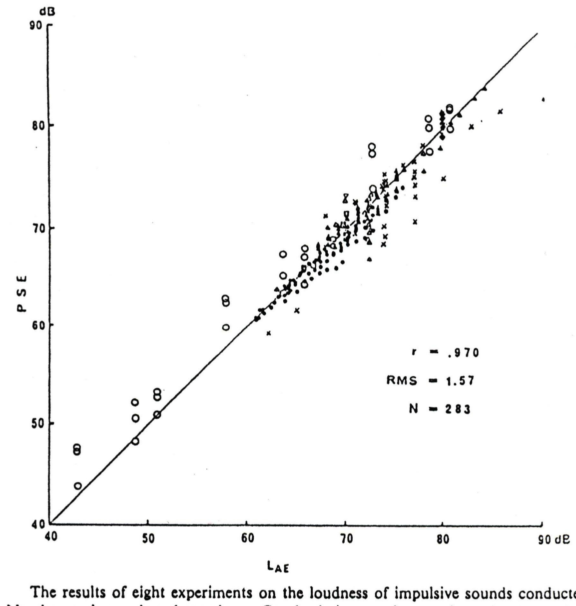
When listening to a sound longer than perceptual present, the preceding portion of the sound is being stored in the memory with the elapse of time and the overall impression of the sound is judged on the basis of memory. Many studies have been conducted concerning auditory memory [e.g.11, 12]. Various factors may affect the impression of long-term sounds. It may be considered that the sounds and/or the portions of the sounds which can easily be recalled may have greater effect on the judgment of overall impression than the other sounds and/or the other portions.

2 - EVALUATION OF ENVIRONMENTAL NOISE

The evaluation of environmental noise will be discussed in relation to these three time spans. In the evaluation of noise, it is necessary to measure subjective responses to noise and to find physical indices which show good correspondence with subjective responses. In these measurements, it is important to use appropriate tools according to the purpose of the measurement.

2.1 - Perceptual moment in the evaluation of environmental noise

When the duration of a sound is shorter than perceptual moment, the impression of loudness, pitch and timbre can be perceived, but temporal sequence is not clear. Fundamental research of perceptual moment indicates that the duration of perceptual moment is less than about 100 msec. From the viewpoint of the evaluation of environmental noise, perceptual moment is considered to be the period during which our impression of the noise is integrated. In this meaning the impulsive noise is a typical example of an event in perceptual moment. The physical duration of impulsive noise may become about 1 sec when it is generated in a reverberant place. However, subjective duration is not equal to physical duration [13]. The perception of on-set and off-set of a sound is not clear when the sound has a gradual rise and/or decay. Subjective duration differs depending on the envelope pattern of the sounds. The duration of steady state sounds and sounds with long rise time and short decay is perceived longer than physical duration owing to the after effect after the cessation of the sounds. On the other hand, the duration of sounds with short attack and long decay as found in most impulsive noises is perceived shorter than physical duration since the latter low level portion may be masked by the preceding high level portion [14]. Therefore, perceptual moment may possibly become longer than 100 msec. It is considered that listeners would perceive an impulsive noise as a single event which occurs in perceptual moment.
(1) Loudness of impulsive sounds
The event in perceptual moment may be integrated as a single event. In our former studies of the loudness of impulsive sounds [15], L_{AE} (sound exposure level) was found to show a good correspondence with the loudness. The results of our former eight experiments conducted since 1968 are plotted together in Fig. 1 [16]. High correlation can be seen between the loudness and L_{AE}. A round robin test on the evaluation of impulsive sounds was conducted in Japan and similar results were found [17, 18]. These results suggest that in the perception of impulsive sounds the energy of impulsive sounds is integrated as a unit and that L_{AE} is a good index of the loudness of a single event of an impulsive sound.
(2) Effect of temporal pattern
Though the temporal sequence in a single event of an impulsive sound cannot be identified, the difference of the temporal pattern may be perceived as the difference of sound quality. Examples of the temporal change of calculated sharpness [19] of sounds generated by hitting a golf ball by a golf club are shown in Figs. 2 and 3 [20]. Closed circles in these figures indicate the time when a ball was hit. The "sharpness" was calculated every 20 msec with a work station (Cortex Psychoanalyzer CF90). It is clear that there is a difference in the pattern of the temporal change of calculated sharpness in these two examples. Close examination of the temporal change of sharpness suggested that sharpness during 60 ms after hitting seems to have an effect on the impression of sound quality. The difference between sharpness at the point of hitting (S_0) and that of 60 ms later (S_{60}) was calculate and related to the impression of sound quality.



The results of eight experiments on the loudness of impulsive sounds conducted by Namba *et al.* are plotted together. Good relation can be seen between L_{AE} and loudness expressed by PSE.

▲ Kuwano, Namba and Kato (1978) — impulsive sound with reverberation part
○ Namba, Kuwano and Kato (1974) — sound with rise time
□ Namba, Kuwano and Kato (1976) — sound with intensity increment (1)
● Namba and Kuwano (1981) — sound with intensity increment (2)
◆ Kuwano, Namba and Nakajima (1980) — impulsive sound with amplitude-modulated decaying part
▽ Nakajima, Kuwano and Namba (1979) — sound with rise time and sound with fall time
△ Nakajima, Kuwano and Namba (1980) — sound with intensity increment (3)
× Nakajima, Kuwano and Namba (1983) — sound with intensity increment (4)

Figure 1.

The result is shown in Fig. 4. Good relation between them suggests that the temporal change of the initial portions of the impulsive sound may be an important factor for the evaluation of sound quality.

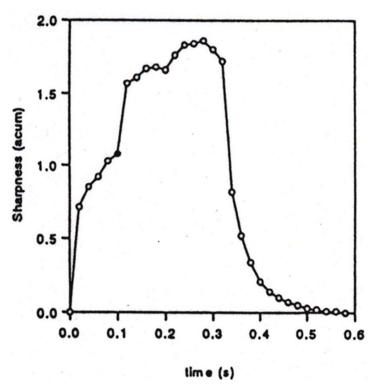


Figure 2.

The loudness of impulsive sounds can be evaluated by L_{AE} as the first approximation. However, the temporal pattern of the sounds has a slight, but systematical effect on the loudness. The difference between L_{AE} and PSE is examined in each pattern of impulsive sounds. As an example, the result of the experiment using non-steady state sounds is introduced [21]. The stimulus patterns are shown in Fig. 5. The temporal position of the increment was systematically shifted. The result is shown in Fig. 6. The loudness of the pattern 1 in which the increment was located at the beginning of the pedestal was significantly louder than the other patterns even though the values of L_{AE} were the same in all the patterns. One of the reasons of this result may be due to the dynamic characteristics of hearing.
(3) Model of dynamic characteristics of hearing
A model of the dynamic characteristics of hearing was proposed by Fastl on the basis of the experiment of masking [22]. Another dynamic model based on the loudness judgment of non-steady state sound was

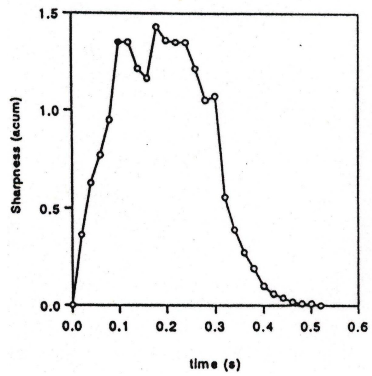


Figure 3.

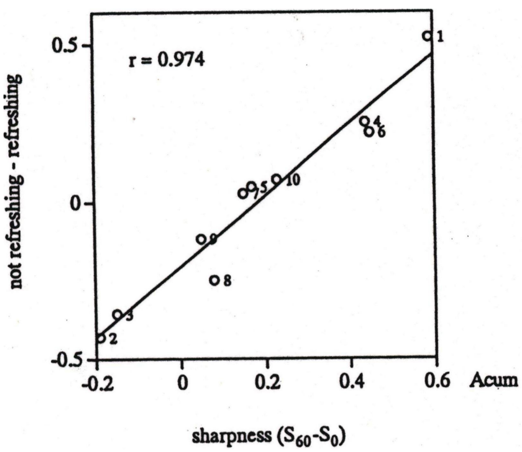


Figure 4.

proposed by Namba et al. as shown in Fig. 7 [21]. This model shows an overshoot at the beginning of pedestal, a suppression in the middle and after-effect beyond the cessation of the pedestal.
This model was confirmed by masking experiments [23]. The effects of simultaneous and forward masking were examined using steady state sounds and sounds with long decay (i.e. decaying sound), which often exist in our daily life, as a masker. When a steady state noise is used as a masker, the same results were obtained as usually found. That is, there are an overshoot at the beginning of the stimulus and after effect after the cessation of the sound. On the other hand, when decaying sounds are used as a masker, there is no after-effect except for sounds with short decaying time. This model can be applied not only to a single event, but to pulse trains as introduced in the latter section in this paper.

2.2 - Perceptual present in the evaluation of environmental noise

According to Fraisse [9], two close sounds belong to the same perceived present when the interval is approximately 1.8 - 2 sec. This interval seems to represent an appropriate perceptual present. From daily life experience, the concept of perceptual present can easily be understood, but it is not easy to measure the limit of perceptual present in experimental situations. In order to measure this duration, phenomenological observations will be needed and conventional psychophysical methods may not be applied. A new method called "the method of continuous judgment by category" [24-26] has been developed and the duration of perceptual present was examined.
(1) Introduction of the method of continuous judgment by category
When a vehicle is approaching, we feel that the sound is becoming louder and louder. When it is leaving, we feel that the sound is becoming softer and softer. It is impossible to obtain this kind of continuous judgment by conventional psychological methods. Namba and Kuwano et al. [e.g. 24-26] have developed a method called "the method of continuous judgment by category" in order to obtain the instantaneous judgment continuously. In the experiment with the method of continuous judgment by category, subjects are asked to judge the instantaneous impression of the sound using 7 categories from very soft to very loud and to press a key on a computer keyboard corresponding to their impression at that time. Subjects

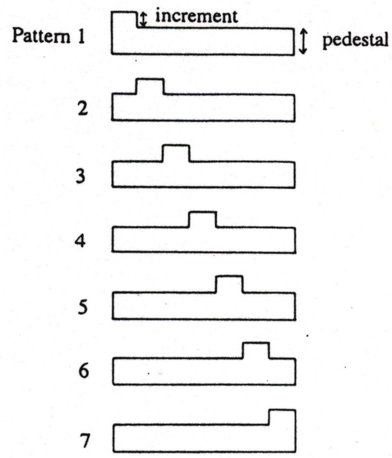


Figure 5.

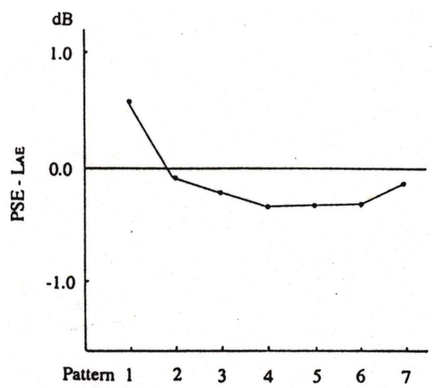


Figure 6.

need not respond if their impression does not change. When they press a key, it is presented on a monitor and the impression registered on the monitor is considered to remain. When their impression changes, they are required to press the corresponding key.

Valuable information can be obtained by relating instantaneous judgments and instantaneous physical properties of the sounds and by relating instantaneous judgments and overall impression of a whole range of the sounds.

(2) Estimation of perceptual present

The instantaneous impression of loudness of road traffic noise of about 20 min was judged using the method of continuous judgment by category [25]. Sound level reproduced from the loudspeaker was sampled and measured every 100 msec and corresponded to the responses of subjects sampled every 100 msec. The coefficient of correlation between sound level of every 100 msec and subject's responses of every 100 msec was calculated by shifting the interval between them. The time interval when the highest correlation was obtained was regarded as the reaction time. The responses of eight subjects were averaged taking the reaction time into account.

In order to estimate perceptual present, the sound energy was averaged during time interval from 0.5 to 6.0 sec and corresponded to the subject's responses sampled every 100 msec. The highest correlation was found when the averaging time was 2.5 sec. If the coefficient of correlation between the averaged physical values and the continuous judgment by category in this study is regarded as an index of the perceptual present, the averaging time which shows the highest correlation with the instantaneous loudness may represent the most appropriate duration of the perceptual present. The duration of 2.5 sec, which showed the highest correlation in the this experiment, is the value close to those proposed as perceptual present by other researchers using other approaches [27].

(3) Loudness

The auditory event which happens in perceptual present is perceived as present, but physically it has some duration and the temporal sequence in the event can be identified. The duration of perceptual

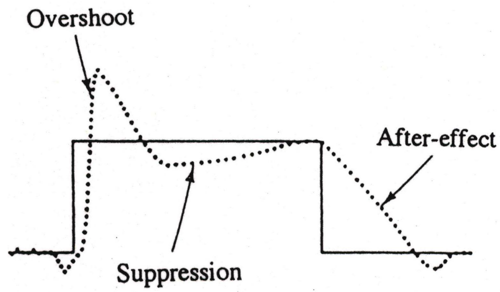


Figure 7.

present is longer than critical duration which is the upper limit of temporal integration. Therefore, the impression of the auditory event in perceptual present is judged on the basis of averaging.
Namba and Kuwano, et al. have conducted a series of experiments using artificial and actual noises and found that L_{Aeq} (Equivalent Continuous A-weighted Sound Pressure Level; i.e. A-weighted mean energy level) shows a good correspondence with subjective impression. The results of the former 11 experiments are plotted together in Fig. 8 [28]. Each of the experiment was conducted independently with each sound source. Therefore, the frame of reference was the same within each experiment. It is found that the loudness shows good correspondence with the mean energy level. When the duration and the sound source were the same, i.e. when the frame of reference is the same with all the sounds to be judged in a context, L_{Aeq} is a good measure of the loudness of temporally varying sounds.

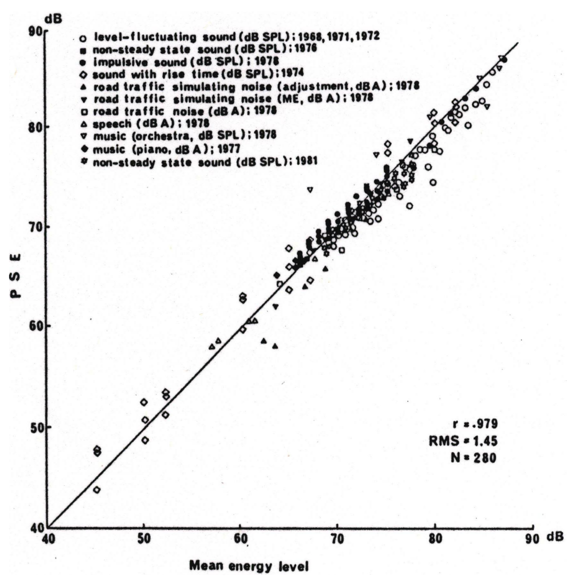


Figure 8.

2.3 - Auditory memory in the evaluation of environmental noise
When the duration of sounds becomes longer beyond perceptual present, the impression of the sound is judged on the basis of memory. Various factors may affect the impression of the sounds, e.g. cognitive, social and cultural factors. The overall impression of the sound may be determined by the weighted average of various factors.
(1) Loudness of temporally varying sounds
L_{Aeq} is a good measure for temporally varying sounds as the first approximation. However, when the frame of reference is different, the deviation from L_{Aeq} may be found. In the experiment shown in Fig. 9 [29], various sounds such as aircraft noise, train noise, road traffic noise, etc. were included in a stimulus context and presented to subjects in random order. Their loudness was judged using magnitude estimation. PSE's were calculated using a power function of road traffic noise as a reference. It can be seen that L_{Aeq} is a good measure of the loudness of various sounds as the first approximation. Strictly speaking, however, there is a slight, but significant difference among sound sources. When the level is

high, aircraft noise was judged louder than train noise, for example. It was confirmed that cognitive factor has a significant effect on the judgment of loudness [29-31].
In September 1998, the Environmental Quality Standard of Noise has been revised in Japan adopting L_{Aeq} as the index of noise criteria. This standard is mainly for road traffic noise. In Japan at present different measures are adopted for the Environmental Quality Standard of Aircraft Noise and Super Express Train Noise. It would be better to use L_{Aeq} as a basic measure for these noise sources as well and the values of criteria should be determined for each sound source taking the temporal and cognitive effects into consideration.

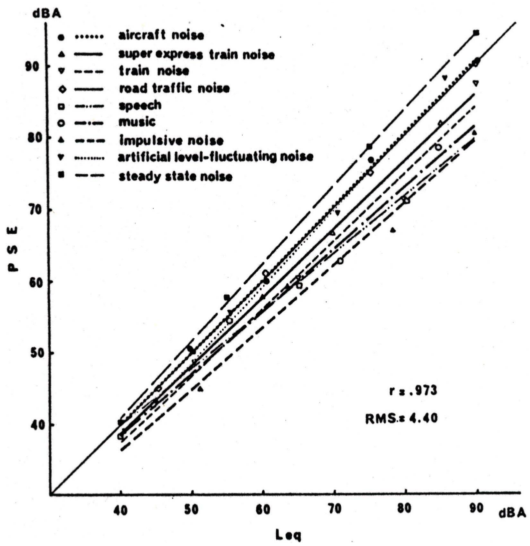


Figure 9.

(2) Habituation
Another phenomenon related to temporal steam of sound is habituation. When we are continuously exposed to noise, the responses to the noise gradually diminish and finally the noise is not noticed at all. This phenomenon is called habituation. The sound which is habituated to indicates that it is less prominent. In order to examine the weighting in the judgment of overall impression of long-term sounds, it may be helpful to find the properties of sounds which are easily habituated to. It is difficult to measure habituation by conventional psychological methods since subjects have to pay attention to the stimuli in these methods. Habituation was measured using no response and/or the number of responses as an index of habituation by the method of continuous judgment by category [32, 33]. In one of the experiments [33] the same portion was set at the beginning and at the end of 30 min stimulus. The number of responses to these portions was compared and it was found that there was a difference among sounds in the degree of habituation.

3 - RELATION BETWEEN PERCEPTION AND MEMORY

3.1 - Application of the model of dynamic characteristics of hearing

Perceptual moment may be a fundamental unit of the perception of longer sounds. The impression of longer sounds may be judged on the basis of perceptual moment. The model of dynamic characteristics of hearing was derived using a single event of impulsive noise which exists in perceptual moment. In actual situations it often happens that pulses occur successively. The application of the model to successive pulse trains was examined. Piano performance is a typical example of this case. Musical performance and noise evaluation may not be considered in the same context, but it can be admitted to take music performance as an example when the applicability of the model is confirmed.
When steady-state sounds are successively presented with short intervals, they are perceived as being continuous without interval [22]. On the other hand, there is no after-effect in decaying sounds [23] and when they overlap each other, the tail of the preceding sound is masked by the overshoot portion of the following sound. This makes us insensitive to the overlapping of the sounds. In the case of piano performance, for example, sounds should be overlapping in order that they might be perceived as being played in "legato", i.e. smoothly connected. Smooth impression of legato may be perceived when sounds are continuously succeeded to each other and they do not give impure impression [34].

In order to examine the validity of the dynamic model of hearing, a passage from "Pictures at an Exhibition" composed by Mussorgsky was played with decaying sounds and steady state sounds using Programmable Sound Control System II [35] by systematically varying the interval and overlapping between sounds. It was found that steady state sounds were judged "marginally connected" when they were physically separated. On the other hand, decaying sounds were judged "marginally connected" when they were physically overlapping. These results suggest that the dynamic model proposed by Namba et al. [21] can contribute to predicting the perception of sound quality of a train of sounds.
Another example of the application of this model was found in the improvement of the impression of gear noise in a car [36]. The adverse impression of impulsiveness could be reduced by changing the intervals of impulsive noises on the basis of this model.

3.2 - Relation between overall judgment and instantaneous judgment

It is not easy to find the determinants of overall impressions of long-term fluctuating sounds. Overall impression is not determined by a simple summation of the impression of a number of determinants of individual stimuli or of all the stimuli at each moment which constitute the environment, as Gestalt Psychologists insisted [37]. Overall impression and instantaneous impressions are not independent of each other. The overall impression may be determined by giving a kind of subjective weight to the impression of each constituent stimulus. The impression of each constituent stimulus is also affected by the frame of reference formed by the overall context and past experiences [2].
For the evaluation of long-term fluctuating sounds, it would be helpful to measure instantaneous impression and overall impression as well. In the experiment using the method of continuous judgment by category, after the continuous judgments subjects are asked to fill in a questionnaire, in which various questions on the overall impression are included so that information for interpreting the experimental data can be obtained. The time interval between the presentation of sounds and the overall judgment should be chosen carefully. If it is too short, the overall judgments may be made on the basis of the latter portion of the sounds. If it is too long, the impression may become unclear.
An example showing the relationship of overall judgment and the average of instantaneous judgments is given in Fig. 10 [24]. It can be seen that the overall impression just after the instantaneous judgments (open circles) indicates slightly greater loudness than the average of instantaneous judgments. However, overall judgments made one month after the instantaneous judgments (closed circles) indicate much greater loudness than the overall judgment just after the instantaneous judgment. This may reflect a law of memory. As time passes, the impression of the prominent portion becomes stronger and that of the less prominent portion becomes weaker.

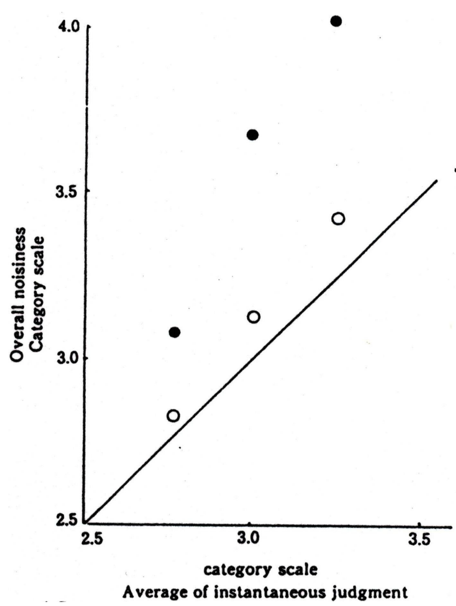


Figure 10.

Another example is shown in Fig. 11 [25]. Overall impression was judged louder than the simple average of instantaneous judgment. In order to find which part of the instantaneous loudness determines the overall loudness, instantaneous loudness was averaged using a cutoff point of 10, 20 and 30 dB lower than the maximum level, omitting the lower-level portions. It is noticed that the average with 30 dB cutoff point showed the values close to the overall loudness (Fig. 12). This result suggests that prominent portion has greater effect on the overall judgment than the other portions. It is interesting and important to find the factors which contribute to the overall impression.

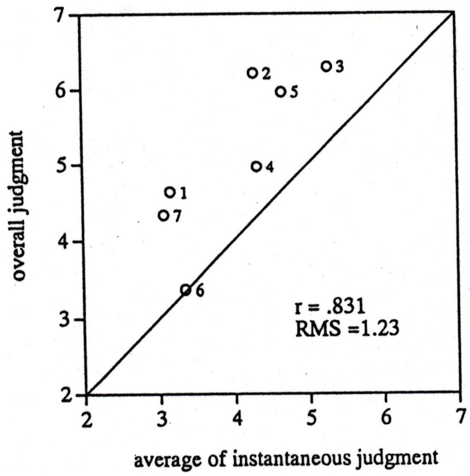


Figure 11.

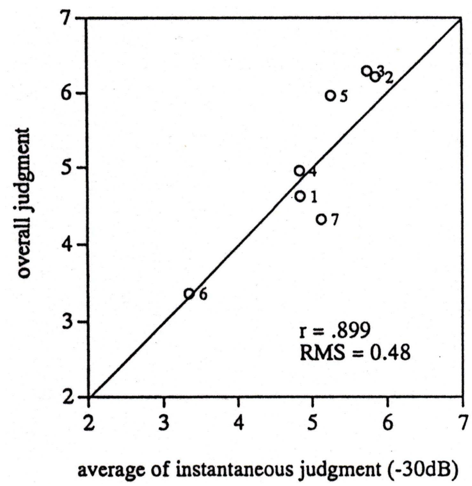


Figure 12.

3.3 - Relation between overall judgment of sound with mixed sources and judgment of each sound source

We are surrounded with various kinds of sound in our daily life. We have the overall impression of our sound environment with mixed sources as well as the impression of each sound source independently. It would be important to examine by which mechanism the overall impression of sounds with mixed sources is determined in order to improve our sound environment. Various models have been proposed for predicting the overall impression of the sound with mixed sources [38-42]. It is indicated that L_{Aeq}, i.e. simple average of energy, usually shows fairly good correlation with subjective impression, but it is not always the best.

In our former study [43] subjects were asked to recall and write the names of sound sources which they memorized and rate their loudness in the questionnaire conducted after listening to the sounds of 15 min. The number and kind of sound sources they recalled were different among subjects. The sound sources they recalled may be impressive and prominent sounds to the subject. The judgments to these sounds were averaged for each subject and the averages of six subjects were calculated. The contribution of a dominant source to the determination of the overall impression may be greater than the other sound sources.

In the questionnaire, subjects were also asked what was the loudest sound. The judgments of the loudest sounds of all the subjects were averaged and added to the average of all the constituent sounds except for the loudest sound. This average is plotted against the overall impression in Fig. 13. Good correspondence was found between them except for the stimulus No. 12, which included a signal of the ambulance and this sound seemed not to be accepted as a part of the environmental sound by most of the subjects. This result suggests that different weighting may be added to the constituent sounds when overall impression of long-term sounds is judged.

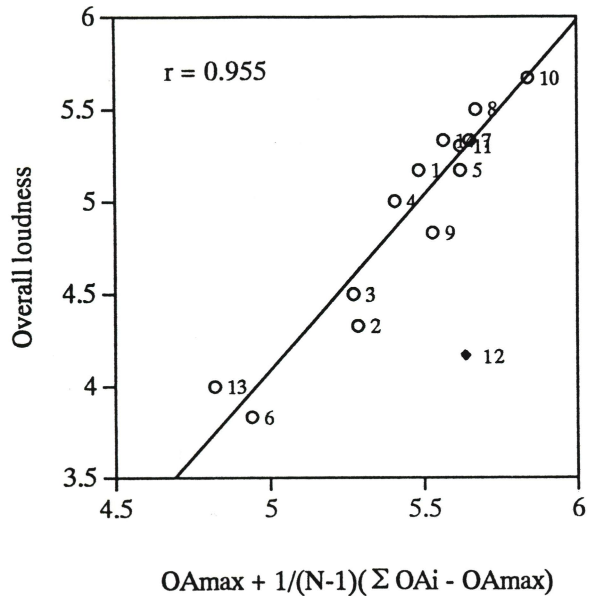


Figure 13.

4 - FINAL REMARKS

The frame of reference has an important effect on the evaluation of environmental noise. In this paper the effect of frame of reference was discussed focusing on the temporal aspects. Noise is defined as "unwanted sound". Any sounds may possibly become noise if it is perceived as being annoying or disturbing by people. Therefore noise problems must be considered in reference to subjective impression. Psychology can offer tools to measure subjective impression. Many methods have been proposed [44] and if there is no appropriate method, new methods have to be developed. It is important to select an optimal method according to the purpose of the measurement in relation to temporal aspects of the sounds.

As the first approximation, it was suggested that the impression of loudness is determined by L_{AE} in perceptual moment, by L_{Aeq} in perceptual present and by weighted average in the judgment based on memory. The weighting is not simple and may differ depending on cognitive, social and cultural factors as well as temporal factors. Further investigation is needed in order to find appropriate weighting.

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REFERENCES

1. **S. Namba and S. Kuwano**, "The validity of scaling and subjective assessment of noise in relation to frame of references", in A. Schick et al. (Eds.), *Contributions to Psychological Acoustics*, (BIS Oldenburg, 1999), pp.15-38

2. **H. Helson**, *Adaptation Level Theory*, (Harper & Row, 1964)

3. **A. Parducci**, "Context effects: A range-frequency analysis", in E. C. Carterette and M. P. Friedman (Eds.), *Handbook of Perception Vol.II, Psychophysical Judgment and Measurement*, (Academic Press, 1974), pp.127-142

4. **A. Eddins and D. M. Green**, "Temporal integration and temporal resolution", in B. C. J. Moore (Ed.), *Hearing*, (Academic Press, 1995), pp.207-242

5. **R. Teranishi**, "Temporal aspects of hearing", in S. Namba (Ed.), *Handbook of Hearing*, (Nakanishiya-Shuppan, Kyoto, 1984), pp.276-319

6. **R. M. Warren**, *Auditory Perception*, (2nd Ed.), (Cambridge University Press, 1999)

7. **H. Haas**, "Über den Einfluss eines Eubfachechos an die Hörsamkeit von Sprache", *Acustica*, 1, 49-58 (1851)

8. **H. Woodrow**, "Time perception", in S. S. Stevens (Ed.) *Handbook of Experimental Psychology*, (New York: John Wiley & Sons, 1951), pp.1124-1236.

9. **P. Fraisse**, *Psychology du Temps*, (Press University, 1957), (Japanese translation by Y. Hara, revised by K. Sato)

10. **J. A. Michon**, "The making of the present: A tutorial review", in J. Requin (Ed.), Attention and Performance VII, (LEA, 1978)

11. **R. G. Crowder**, "Auditory memory", in S. McAdams and E. Bigand (Eds.), *Thinking in Sound*, (Oxford University Press, 1993), pp.113-145

12. **L. M. Ward**, "Memory for psychophysical scaling judgments", Psychonomic-Bulletin-and-Review, 6, 472-478 (1999)

13. **S. Namba, K. Ohta, S. Kuwano and K. Namba**, "The effect of envelope pattern on subjective duration in relation to perception of rhythm", J. Music Perception and Cognition, 4, 71-80 (1998)

14. **S. Namba, S. Kuwano, T. Yamasaki and K. Nishiyama**, "Relation between dynamic characteristics of hearing and 'legato' in music performance", Studies in the Humanities and Social Sciences, Faculty of General Education, Osaka University, 41, 17-35 (1993)

15. **S. Kuwano, S. Namba and S. Kato**, "Loudness of impulsive sound", J. Acoust. Soc. Jpn., 34, 316-317

16. **S. Kuwano and S. Namba**, "On the dynamic characteristics of hearing and the loudness of impulsive sounds", Trans. Noise, Acoust. Soc. Jpn., N-8303-13, 79-84 (1983)

17. **S. Kuwano, S. Namba, H. Miura and H. Tachibana**, "Evaluation of the loudness of impulsive sounds using sound exposure level based on the results of a round robin test in Japan", J. Acoust. Soc. Jpn. (E), 8, 241-247 (1987)

18. **T. Sone, Y. Suzuki, M. Kumagai and T. Takahashi**, "Loudness of a single burst of impact sound: Results of round robin tests in Japan (I)", J. Acoust. Soc. Jpn. (E), 7, 173-182 (1986)

19. **G. von Bismarck**, "Sharpness as an attribute of the timbre of steady sounds", Acustica, 30, 159-172 (1974)

20. **S. Kuwano, S. Namba, K. Ohta, H. Takeda, K. Sato and Y. Tsuji**, "Relation between envelope pattern and sound quality of impulsive sounds", J. Acoust. Soc. Jpn. (E), 20, 153-155 (1999)

21. **S. Namba, S. Kuwano and T. Kato**, "The loudness of sound with intensity increment", Jpn. Psychol. Rev., 18, 63-72 (1976)

22. **H. Fastl**, "Subjective duration and temporal masking patterns of broadband noise impulses", J. Acoust. Soc. Am., 61, 162-168 (1977)

23. **S. Namba, T. Hashimoto and C. G. Rice**, "The loudness of decaying impulsive sounds", J. Sound Vib., 116, 491-507 (1987)

24. **S. Namba and S. Kuwano**, "The relation between overall noisiness and instantaneous judgment of noise and the effect of background noise level on noisiness", J. Acoust. Soc. Jpn. (E), 1, 99-106 (1980)

25. **S. Kuwano and S. Namba**, "Continuous judgment of level-fluctuating sounds and the relationship between overall loudness and instantaneous loudness", Psychol. Res., 47, 27-37 (1985)

26. **S. Kuwano**, "Continuous judgment of temporally fluctuating sounds", in H. Fastl, S. Kuwano and A. Schick (Eds.), Recent Trends in Hearing Research, (BIS, Oldenburg, 1996), pp.193-214

27. **E. Pöppel**, "Time perception", in R. Held, H. W. Leibowitz and H. -L. Teuber (Eds.), Handbook of Sensory Physiology, vol.III, Perception, (Springer Verlag, 1978), pp.713-729

28. **S. Namba, S. Kuwano and T. Kato**, "On the investigation of Leq, L10 and L50 in relation to loudness", J. Acoust. Soc. Am., S58 (1978)

29. **S. Namba and S. Kuwano**, "Psychological study on Leq as a measure of loudness of various kinds of noises", J. Acoust. Soc. Jpn. (E), 5, 135-148 (1984)

30. **S. Kuwano, S. Namba and H. Fastl**, "On the judgment of loudness, noisiness, and annoyance with actual and artificial noises", J. Sound Vib., 127, 457-465 (1988)

31. **H. Fastl, S. Kuwano and S. Namba**, "Assessing the railway bonus in laboratory studies", J. Acoust. Soc. Japan (E), 17, 139-148 (1996)

32. **S. Namba and S. Kuwano**, "Measurement of habituation to noise using the method of continuous judgment by category", J. Sound Vib., 127, 507-511 (1988)

33. **S. Namba, S. Kuwano, A. Kinoshita and Y. Hayakawa**, "Psychological evaluation of noise in passenger cars - The effect of visual monitoring and the measurement of habituation", J. Sound Vib., 205, 427-434 (1997)

34. **S. Kuwano, S. Namba, T. Yamasaki and K. Nishiyama**, "Impression of smoothness of a sound stream in relation to legato in musical performance", Perception & Psychophysics, 56, 173-182 (1994)

35. **S. Namba and S. Kuwano**, "Effects of temporal structure of masker on temporal masking. Appendix: Measurement of simultaneous masking using PSCS II", Trans. Hearing, Acoust. Soc. Jpn., H-84-1, 1-6 (1984)

36. **T. Abe**, "Generation mechanisms of car noise and its control on the basis of subjective evaluation", Dissertation in Osaka University, (1995)

37. **J. Hochberg**, "Organization and the Gestalt tradition", in E. C. Carterette and M. P. Friedman (Eds.), Handbook of Perception, vol.1, (Academic Press, 1974), pp.179-210

38. **S. Namba and S. Kuwano**, "Psychological effects of noise - evaluation of noise with mixed sources", J. Industrial Pollution Protection Organization, 19, 282-287 (1983)

39. **S. M. Taylor**, "A comparison of models to predict annoyance reactions to noise from mixed sources" J. Sound Vib., 81, 123-138 (1982)

40. **T. Gjestland**, "Assessment of noise impact in a multisource environment", Proceedings of Inter-noise 97, 1033-1036 (1997)

41. **B. Berglund and M. E. Nilsson**, "Empirical issues concerning annoyance models for combined community noises", Proceedings of Inter-noise 97, 1053-1058 (1997)

42. **J. Kaku, T. Kato, S. Kuwano and S. Namba**, "Predicting overall reaction to multiple noise source", J. Acoust. Soc. Am., 105, 1005 (1999)

43. **S. Kuwano, J. Kaku, T. Kato and S. Namba**, "Psychological evaluation of sound environment with mixed sources", Proceedings of International Congress on Acoustics, 1131-1132 (1998)

44. **S. Namba and S. Kuwano**, Method of Psychological Measurement for Hearing Research, (Corona Publisher, 1998).