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On the psychological measurement of loudness, noisiness and annoyance: A review

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Following topics were discussed from the psychological viewpoint of noise assessment :
1) The distinction among loudness, noisiness and annoyance. 2) Validity of the sone scale

,

and the methods of calculating loudness. 3) Physical descriptors of non-steady state sounds. 4) Psychological methods to evaluate the effects of noise on man.

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1. INTRODUCTION

Noise can be defined as "unwanted sound." Re-search on the effects of noise can enable us to predict noise problems in daily life and help to solve them. To do this, it is necessary to know the relationship between subjective attributes and physical charac-teristics of noise.
The basic attribute of sound is loudness. When

sound is very loud, it easily becomes unwanted, noisy and annoying, disturbs conversation and causes temporary threshold shift (TTS). If sound is not loud, it usually has no serious effect on most people. For example, in a hotel, if noise is sufficiently at-tenuated, guests can be comfortable even in a room which is located in front of a busy road or a railroad station. When the noise from the air-conditioner

ducts in a concert hall is attenuated enough, the audi-ence can enjoy the "pianississimo" part of a music performance.
Loudness is defined as the subjective intensity of sound, independent of any meaning the sound might have (Kryter, 1985,1) p. 112). Since loudness is a subjective attribute, it is unobservable. We can only conjucture listener's the perceptual world from rela-tions between stimuli presented to the listener and the overt responses (judgments) made by the listener to the stimuli. Findings in psychophysical experi-ments may be affected by the methods of judgments (categorical judgment, magnitude estimation, etc.)

and by the kinds of stimuli (pure tones, complex sounds, artificial sounds, actual sounds, etc.).
There have been many studies concerning the rela-tion between loudness and sound pressure level of tones at various frequencies. It has been found that there is a good relation between them, in a statistical sense. This means that loudness can be predicted from the physical measurements of sounds, with some deviations (errors).
When the loudness of two sounds with the same

frequency is compared, judgment is easy and the loudness is determined by intensity alone.2) On the other hand, it is difficult to compare the loudness of two sounds with different frequencies. Deviation between judgments becomes larger, because loudness is affected by frequency as well as intensity. In actual situations, there are many sound sources which contain various frequency components. In this case, the prediction of loudness is not at all simple. To predict the loudness of sounds with different fre-quencies, several methods of calculating loudness from physical measurements have been proposed. We will discuss this problem in Sect. 2.
If the duration of sounds is different, even though they are of equal loudness, the effect of noise can be different. When sounds are unacceptable, and their durations are different, sounds of longer duration may be more undesirable.
According to Kryter, the duration of noise usually has much to do with its acceptability, unwantedness,

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or noisiness. The critical duration of the temporal summation of loudness is less than 1 s, while the critical duration of noisiness seems to be longer. Kryter (1985,1) p. 122) says that "While loudness and perceived noisiness may be similarly related to sound spectra at a moment in time, they are not similarly related to certain important temporal variables in sounds or noises." Therefore, temporal variables have an important role in the differentiation of noisi-ness from loudness. We will discuss the role of tem-

poral variables in loudness and noisiness judgments in Sect. 3.

Aircraft noises around an airport are usually loud and noisy for inhabitants under the flight-path, but these noises might be enjoyable for a jet-plane fanat-ic. Sounds of music are pleasant for music listeners, but the sounds may cause severe nuisance for a

person who wants to sleep. This nuisance aspect of noise is annoyance.
Berglund et al.3,4) have defined annoyance as the nuisance aspect of noise experienced in an particular situation, giving this as an example : "After a hard day's work, you have just been comfortably seated in your chair and intend to read your newspaper."

By reference to the terms "noisiness" and "an-noyance" alone, it is not easy to discriminate the two concepts. The connotative meanings of "noisiness" and "annoyance" are quite similar in Japanese and English, as is shown in Figs. 1 and 2.5) In German and English, the connotative meanings of "loudness" and "annoyance" are quite similar, as is shown in Figs. 2 and 3. We need some explanation or work-ing definitions of the concepts.
The definition of noisiness proposed by Kryter (1985,1-) p. 126) is "the subjective impression of the unwantedness of a not unexpected sound that does not provoke pain or fear is defined as perceived noisiness, or more simply, noisiness." Further to this, Kryter adds that, "Noisiness is obviously synon-

ymous with what is often implied by the word `annoyance.' However, annoyance commonly signi-
fies one's reaction to sound based both on its physical nature and its emotional content and novelty (which are excluded from perceived noisiness)."
The following is a part of the instructions for the method of paired comparison for the judgments of noisiness (Kryter, 1970,6) p. 272). "You will hear one sound followed immediately by a second sound. You

Fig. 1 Semantic profiles of "noisiness." The profiles of English and Japanese "noisiness" show good agreement in the

two countries. There is no term equivalent
to "noisiness" in German.5)

Fig. 2 Semantic profiles of "annoyance." The profiles of "annoyance" show good agreement in the three countries.5)

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Fig. 3 Semantic profiles of "loudness."
The profiles of "loudness' show good
agreement in German and English. Japa-
nese "loudness" is quite neutral, but both
German and English "loudness" have
negative connotation.5)

are to judge which of the two sounds you think would be the most disturbing or unacceptable if heard regularly, as a matter of course 20 or 30 times per

day in your home. Remember, your job is to judge the second of each pair of sounds with respect to the first sound of that pair. You may think that neither of the two sounds is objectionable or that both are objectionable; what we would like you to do is to judge whether the second sound would be more dis-turbing or less disturbing than the first sound if heard in your home periodically 20 to 30 times during the day and night." Interestingly, Kryter explained the concept of "noisiness" without using the term "noisiness."

Izumi7) has proposed a working definition of loud-ness, noisiness, and annoyance (Table 1). Moline has described the factors that affect individual an-

noyance by noise (Table 2).
Annoyance due to noise is strongly affected by non-acoustic as well as acoustic factors. It is not

easy to measure annoyance in a laboratory situation. Social surveys have been used to measure annoyance in actual life, and recently it has become common to recreate ordinary living conditions in the laboratory for the measurement of annoyance in a laboratory situation. In a social survey it is not easy to find the relation between physical parameters and subjective responses. When living conditions are simulated in the laboratory, the control of physical parameters is much easier. It is, however, probable that the at-titude of respondents is quite different under simu-lated conditions. It is not sufficient to measure the

effect of noise on man only by the methods of tradi-

Table 1 Factors affecting three attributes.7)

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Table 2 Factors that affect individual an-
noyance to noise.8)

tional psychophysics. The measurement of the effects of noise will be discussed in Sect. 4.

2. LOUDNESS SCALING AND
FREQUENCY CORRECTION

There have been many studies concerning the loudness of pure tones, and the relation between loudness and physical characteristics is defined in the International Standard by the ISO (International Organization for Standardization). For example, equal loudness contours at different sound pressure levels are defined in ISO R/226-1961.9)
A pure tone of 1,000 Hz is used for the standard, and loudness level in phons is defined as the sound pressure level of a 1,000 Hz pure tone which is perceived as being equal in loudness to a given sound. The loudness level in phons is an ordinal scale. However, while it is true that a sound with a larger number in phons is perceived as being louder, the two-fold value of phons does not necessarily mean two-fold loudness.

How does loudness grow with intensity? Concern-ing this problem, Stevens10-13) did many experi-ments, and has proposed the sone scale on the basis of results of his own and those of other re-searchers. Loudness in sones is defined in ISO 532-

197514) as "Numerical designation of the strength of a sound which is proportional to its subjective

magnitude as estimated by normal observers. One sone is a sound whose loudness is 40 phons." Loud-ness function in sone is standardized in ISO 131-

1979,15) "Expression of physical and subjective magnitude of sound or noise in air."
It is desirable that the loudness of any sound can be predicted from the equal loudness contours and the sone scale. Hindering the achievement of this, how-ever, are several problems in the equal loudness contours and the sone scale.

2.1 The Validity of Equal Loudness Contours
The equal loudness contours and the sone scale are International Standards (IS). They seem to be very valid and reliable. But they are based on empiri-cal data, which depend on experimental conditions and usually show some variance. The curves in the figures of the IS are obtained by averaging individual data and being smoothed.
When the frequencies of two sounds are close to each other, comparison of their loudness is easy and reliable, and the magnitude of phons may be a good index of loudness. However, if the frequencies are widely separated, adjustments of equal loudness may show standard deviations of about 6 or 10 dB (Green,16) p. 282). A practical purpose of the equal loudness contours is to compare the loudness of sounds at different frequencies. For this purpose, the reliability or variance of contours should be equal in any frequency separation between sounds. Re-cently, the loudness of low frequency sounds, such as explosive noises, has become a problem.17-19) We need more precise data for the low frequency region. Now reexamination of equal loudness contours is going on in ISO TC-43. Errors due to psychophysical methods should be decreased by devising a good ex-perimental design. However, when the frequencies are widely separated, what is termed the point of subjective equality (PSE) cannot be a point, but has some range. We have to know this "equivalency range" of sounds at different frequencies. This in-formation about variance is necessary for predicting loudness from physical measurements in a statistical
terms.

2.2 The Validity of the Sone Scale
In the sone scale, a two-fold change in loudness is produced by a 10 dB increase in the sound pressure level. When we are concerned with the judgment of length, we can easily understand the meaning of two-

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Fig. 4 Individual loudness functions ad-
justed for differences in Zero point.21)

fold. We can also, perhaps, understand the meaning of "two-fold" in the perception of the area or the volume of an object. However, the meaning of "two-fold" in the case of loudness or noisiness cannot be

so clearly understood as with spatial attributes such as length, area, and volume.") As shown in Fig. 4, individual loudness functions") are very different from each other. If the slope of the function is different, the level which produces two-fold loudness is different.

As Trisman22) and Attneave23) have objected, only when there is a linear relation between sensation and

magnitude estimation, can the judgments of subjects indicate the magnitude of sensation. But it is difficult to verify a linear relation between them. To avoid the problem in using numerals, Stevens24) has invent-ed cross-modality matching. For example, in cross-modality matching between brightness and loudness, subjects match brightness directly to loudness, and loudness directly to brightness. Stevens assumed that in the first sense modality the sensation VI is related

to its stimulus di by a power function with the ex-
ponent m

Likewise, in the second sense modality, we assume

a similar equation, but with a different exponent, n

Now ifƒµ1 is matched to ƒµ2 at several different values
over a range of stimuli, then for the equated values

Ψ1andΨ2 we can substitute the stimulus values,
so that

Then by taking the logarithm of each side of the
equation we can write

or

This last equation represents a straight line, provided
the values are plotted in log•\log coordinates. The
slope of the line is n/m, the ratio of the two original
exponents.
The slope obtained by the cross-modality match-
ing is the same as the ratio of the two original ex-
ponents obtained by using magnitude estimation.
Stevens said that "the procedures that involve num-
ber matching•\magnitude estimation and magnitude
production•\are merely special cases of cross-
modality matching. In other words, the number
continuum serves as just another kind of stimulus
continuum." He added that, "Cross-modality match-
ing provides the foundation for the sensory power
law."
As Triesman22) and Aiba25) pointed out, the cross-
modality matching does not prove the validity of
the power law. For example, if we assume that
sensation is related to its stimulus by the logarithmic
law (Fechner's law), we can get the same relation as
by the power law, as shown in the following equation.

If ƒµ1 is equated to ƒµ2, then,

We cannot decide the propriety of the logarithmic law or the power law using cross-modality matching. Therefore, the validity of calculating loudness based on the sone scale is not ascertained.
Many methods of calculating loudness using the psychophysical scaling have been proposed. In the

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following we would like to discuss the propriety of these methods.

Among them, Stevens' method (LLs) and Zwick-er's method (LLz) have been adopted in ISO 53214) as methods for calculating the loudness level of broad-band steady state sounds. With both methods, it is necessary to analyze sounds using 1/1 or 1/3 octave band filters, and then each band level is con-verted into loudness on the sone scale. The total

loudness of the complex sound is calculated by add-ing the sone values of each band, taking mutual inhibition (masking) between bands into considera-tion.

Kryter6) has proposed a method of calculating noisiness using the same formula as Stevens' method but with different contours (noy curves).
Howes26) has proposed a "power summation" method for calculating loudness. In his method, "the overall loudness of broad-band noise is not

determined by loudness summation, but rather power (more specifically, average power) summation over bandwidths equal to the critical bands defined by Zwicker."
To evaluate noise, there are several methods based on physical measurement rather than the sone scale.

A-weighting is widely adopted for regulations con-cerning noise and methods for the measurement of noise, as, for example, in JIS Z8731-1983.27) The A-weighting is the reversed function (approximately) of the equal loudness contour of 40 phons. There are no theoretical reasons for using the A-weighting, regardless of the sound level.
Noise criteria (NC) and noise rating (NR)28,29) have been proposed for evaluating the internal en-vironment of buildings. Different curves are adopted in these measures, but the methods for determining the values are similar. The octave-band levels of a

given noise are plotted on the curves of NC or NR and the NC- or NR-value is decided as the highest value that the plotted levels exceed. For NC and NR, the level of a single octave band determines the rating.
Tachibana et al.30-32) have proposed a new method, L(63-4k) or L(125-4k), employing the arithmetic

mean of octave-band sound pressure levels. L(63-4k)
is the arithmetic mean of octave-band sound pres-sure levels whose center frequencies are 63 Hz•` 4 kHz, and L(125-4k) is the arithmetic mean of those of 125 Hz N 4 kHz. This method has no theoretical basis, as with other methods such as SIL, NC, NR

Fig. 5 The correspondence between a standard stimulus and comparison stimuli with different physical descriptors of noise.30)

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and the A-weighted sound pressure level. LLs and LLz have some theoretical foundation. Especially, LLz is a kind of a simulation of the basilar membrane

of the inner ear. But they are simplified models for engineering purposes. Also, there are some objec-tions to their assumptions, especially concerning the validity of the sone scale and loudness summation on the sone scale.
For practical purposes, it is important to know which methods can predict the loudness of various kinds of noise correctly and easily. Simplicity is as important in practical situations as accuracy. Tachibana et al."-") have done several experi-ments to examine the relation between judged loud-ness and predicted loudness, using several rating methods. The stimuli are electrically simulated sounds transmitted through various types of walls. An example of the results is shown in Fig. 5. It can be seen that L(63-4k) has better correspondence with loudness than LLs, PL (Stevens' Mark VII), NC and dBA (LA). In their series of experiments it was found that LA, (dBA) and L(63-4k) or L(125-4k) have almost equally good correspondence with loudness, but that NC shows poorer corre-spondence than the other rating methods mentioned above.

Using the data from Corlise and Winzer (1965), Howes26) asserted that his power summation method showed better correspondence with loudness than the methods based on loudness summation, such as LLs and LLz.
Namba and Kuwano33) have done experiments concerning the loudness of various kinds of non-steady state noise and compared the propriety of LAeq, LLs and LLz. LLs and LLz showed better correspondence with loudness than LAeq, but the difference in their correspondence with loudness is very small.
It may be concluded that psychophysical methods based on loudness summation are not always better than the methods based on physical summation or averaging of sounds, such as LAeq, L(63-4k), etc. The latter methods are very simple, whereas the former methods, especially LLz, require very com-plicated calculations. For theoretical purposes, it would be necessary to understand exactly the mechanism of hearing and the processing of the loud-ness of complex sounds. The questions of loudness scaling, masking pattern, partial masking, recruit-ment in the low frequency region, critical bandwidth

and the dynamic characteristics of hearing would need to be considered.
For practical purposes simpler methods are desirable. When sounds do not contain peculiar frequency components, the differences among rating methods such as LAeq,L(63-4k), LLs, LLz, etc. are small.
However, when sounds have prominent compo-nents in some frequency regions, dBA may not be a good measure of loudness. For example, Tempest") has shown that loudness and annoyance (noisiness) due to low frequency sounds do not have good cor-respondence with dBA. Further examination is needed in order to evaluate specific noises, such as explosive sound, helicopter noise, and noise trans-mitted from a long distance.

3. EVALUATION OF NON-STEADY
STATE SOUNDS

In daily life there are various kinds of non-steady state sound, such as road traffic noise, aircraft noise, train noise, construction noise, music, and speech. It is important to decide on a representative value for the overall level-fluctuations. The Japanese Industri-al Standard, JIS Z 8731,27) and ISO 2204-1973 (E)34) define several kinds of level-fluctuation.

According to ISO 2204, non-steady noise is a higher concept which includes fluctuating noise, intermittent noise, and impulsive noise. Impulsive noise is a higher concept which includes quasi-steady impulsive noise and isolated bursts of sound energy. JIS Z 8731 recommends LAeq,T (equivalent con-tinuous A-weighted sound pressure level in decibels) as well as Lx (percentile levels) for the measurement of fluctuating noise. Namba and Kuwano33) have investigated the advantages of Leg as a measure of the loudness of various kinds of non-steady state sound in comparison with Lx. Fujimoto and Sakata35) have also examined the propriety of Leg as a measure of the noisiness of randomly fluctuating sounds. According to Hiramatsu et al.,36) when the duration of noise varies (30 ms N 90 s), the total energy of noise is a good measure of noisiness. Kuwano et al.37) have examined the relation between the noisiness of intermittent noise and the number of

times of repetition. They found that noisiness is determined by both the Leq of intermittent noise, including the period of ambient noise, and the num-ber of times of repetition.
For impulsive sounds, Kuwano et al.38) have con-

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firmed the propriety of sound exposure level (LAE). Tachibana et al.39) have recommended LpE (sound exposure level without A-weighting) as a measure of the loudness of impulsive sounds with exponential decay.
Izumi") has investigated the startling effect of impulsive noise, and proposed the necessity of a penalty for the evaluation of impulsive sound. Some kind of penalty for impulsive sounds may be neces-sary, but to decide the value of the penalty further examination of the question is necessary. ISO/ R199641) proposed a 5 dB penalty for impulsive sounds. But the round robin test on impulsive sounds conducted by ISO,42) as well as other research, has thrown doubt on the validity of the 5 dB penalty and this penalty is no longer adopted in ISO 1996/ 1.43)
Kumagai et a/.44-48) have proposed a maximum value by using a CR-circuit with several values of time-constants. There have been many experiments concerning the time constants of the auditory system,49) but many questions remain unanswered. According to Buus and Florentine,50) there is a possibility that the auditory system has different time-constants according to conditions. If this is so, it is difficult to decide on time-constants which can be used in the measurement of the loudness of all

kinds of impulsive sound. In my opinion, a value based on the energy of sounds should be adopted as a basic quantity. And to decide permissible levels of noise, we must take such factors into account as physical, physiological, psychological and social con-ditions. There is a limit to our ability to predict the effect of noise on man by physical measurement alone, and we must consider these other factors.
It is important that physical measurement should be done on a physical basis. Leq and LAE are very simple, based as they are on physical value of energy.

4. PSYCHOLOGICAL METHODS
OF NOISE EVALUATION

The present author's survey of methods of noise evaluation has appeared in the Journal of the Acoustical Society of Japan (J) (Vol. 42, No. 10).51)

4.1 Category Rating Scale
Various approaches have been suggested for determining the permissible limits of noise and the subjective effects of noise. In many of these, cate-gorical scaling is used, where the category scale is

based on ordinal scale. To calculate the interval

scale from the data obtained by using the category scale, a number of methods have been employed : the law of Categorical Judgment ; Likert's method; and Hayashi's quantification theory.
To give some examples. Kuno et al.52-54) measured Leq every ten minutes over a 24 h period using Leq-meters, and asked respondents to judge the loudness of noise, the annoyance due to noise, and the degree of sleep disturbance, using the rating-scale method. They then calculated the relationship between Leq1/6 (10 min) and the subjective responses were analyzed by reference to Hayashi's quantification theory. They also analyzed the relation between subjective variables using the quantification theory. Nishinomiya") and Kondo et al.") used the same quantification theory in their study on transportation noises. Schomer57) used the rating-scale method to measure annoyance due to aircraft noise around an airport, and investigated the relation between Ldn and reported annoyance. Fidell et al.58) also used the rating-scale for the measurement of annoyance due to aircraft noise.

Rice") has proposed the SSV (subjective scale values) method, which consists of 10 categories (from "not at all annoying" to "extremely annoying")

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He used SSV to measure reported annoyance caused by impulsive noise and compared the results with reported annoyance caused by transportation noises. This was in EC countries (U.K., Italy, the Nether-lands, and Denmark). In Japan, Izumi60) used SSV to measure annoyance caused by transportation noises in a simulated living room. Vos and Smooren-burg61) also used SSV to investigate annoyance caused by impulsive sounds and road traffic noises.

4.2 Psychophysical Methods
Where the purpose is to find physical descriptors of loudness or noisiness, traditional psychophysical methods are suitable. The following are examples. Kumagai et a/.44-48) has used the method of constant stimuli to measure the loudness of impact sounds, and it has been used in the Japanese round robin tests of impulsive sounds.62)
Namba et al.63) used the method of adjustment to measure the loudness of road traffic noise.

Stevens has proposed magnitude estimation for ratio scaling. As discussed in Sect. 1, it is not easy to check the validity of power law. On the other hand, it seems reasonable to assume that the same

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numerical indication of magnitude estimation indi-cates the same sensory magnitude. Marks") says, "Subjects could square or cube all of their numerical

responses, could take logarithms, could exponential, could add a constant, without changing the fact that
to the same sensory magnitude they would always assign the same number, at least on the average. Thus, sensory-physical laws, laws which relate phys-ical variables to one another in order to describe

sensory invariances, would be totally unaffected." If this approach is accepted, we can measure points of subjective equality (PSE) using magnitude estimation. Several researchers have measured

PSE's among various kinds of stimuli. For example, Hiramatsu et al.65,66) have done several experiments using magnitude estimation, and investigated the relationship between Leq and the loudness or noisi-ness of several kinds of non-steady state sounds. This resulted in their proposed formula, ESL (effec-tive sound level). Using magnitude estimation, Namba and Kuwano33) have examined the validity of L, as a measure of several kinds of non-steady state sound (road traffic noise, aircraft noise, rail-road noise, bullet train noise, speech, music and artificial level fluctuating noise). Fujimoto and Sakata") have also examined the validity of Leq as a measure of the noisiness of several kinds of sound

sources.

4.3 Newly Developed Methods
Some other methods have been developed recently. Kado") has investigated the loudness of artificial non-steady state sounds using the sequential search-ing method, which is a kind of adaptive method. Namba and Kuwano68) and Kuwano and Nam-ba69) have developed "the method of continuous judgment by category." With this method, subjects judge the instantaneous loudness of level-fluctuating sounds continuously using key boards. Each key is labeled by category (i.e. "very loud," "loud," "in-different," "soft," "very soft," etc.). Durations of stimuli are 10 min, 30 min or even 3 h. They ex-amined the relationship between instantaneous judg-ments and overall judgments of stimuli. With this method, subjects can respond freely to any change in loudness, and do not need to concentrate on specific changes in stimuli. It is, therefore, possible to examine the trade-off effects of several factors

(ratio of specific signals to ambient noise, sound level and number of events, etc.). The method was

adopted for the evaluation of the noisiness of air-craft noise,68) noise from loudspeakers,70) and road traffic noise.69,71)
Molino72) has devised the method of "acoustic menu." With this method, subjects can change one noise source for another at will. The number of avoidances of a noise source is, therefore, a good measure of annoyance. With this method, behavior is the index of annoyance. This is one of the advan-tages of "acoustic menu," since verbal definition of annoyance is not clear.

5. SUMMARY AND
FURTHER REMARKS

Typical psychophysical studies are useful for evaluating and predicting the effects of noise from physical measurements. Actually, many basic ap-proaches of psycho-acoustics have been applied to the research on noise descriptors. From study of noise descriptors, we can learn the relation between psychological attributes and physical characteristics. Typical research of this type is the study of methods of calculating loudness. However, we cannot decide the permissible level of noise from these types of study.
To show the degree of the effect of noise, verbal categories, such as "noisy," "very noisy," or "a little annoyed," "highly annoyed," have been used. In social surveys on noise problems, verbal catego-ries are usually used, and the relation between physical descriptors and subjective responses on the category rating scale is examined. It is not easy to correlate subjective response and physical measure-ments of noise in social surveys. Kono et al.73) and Kuno et al.52-54) have measured Leq every 10 min during 24 h using portable Leq-meters, and compared. Leq to subjective responses obtained by question-naires. They found an interesting relation between physical descriptors and subjective responses in daily life. This method may be ideal for finding the rela-tion, though many L,-meters are necessary.
The use of a simulated living-room is also helpful for finding the relation between descriptors and responses. The success of this method depends on the degree of similarity between the simulation and real life situations. Izumin has conducted a question-naire survey in a real situation, and done experiments in a simulated living room using the noises recorded in the place where he did the survey. He found similar results from actual and simulated situations.

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Tamura74) has adopted techniques of experimental social psychology in order to examine the effect of human relationships on the evaluation of noise in laboratory situations. For example, he has found the evaluation of noise is affected by whether other persons show a friendly attitude or a hostile attitude to the subjects.
Leq-meters, simulated living rooms, and the tech-niques of experimental social psychology are useful for measuring and analyzing the annoyance due to noise.

When we use verbal categories, however, one of the problems is to decide which category corresponds to the limit of noise exposure. In some surveys "an indifferent point" is adopted as the limit, and in other surveys, "highly annoyed" is adopted. If the degree of annoyance exceeds the limit of tolerance, inhabitants may protest against the noise source. This behavior may be an overt index of the limit of tolerance in noise problems. "Acoustic menu" de-veloped by Molino72) is very interesting from the behavioral point of view, because the number of times there is avoidance behavior can be an index of

annoyance.

In daily life, there are many sound sources which have various frequency components, intensities, durations, temporal patterns, frequencies of occur-rence and spatial positions. The subjective mean-ing of sound sources may also differ from one another. Some sound sources are accepted by in-habitants, while others are not. A model for evaluat-ing sounds from mixed sound sources may be needed. Perhaps, "Acoustic menu" may be useful for finding unacceptable sound sources, using avoidance be-havior as an index.

Many physical descriptors of noise are used only for a single noise source. There is a need for further examination of how physical descriptors can be ap-plied to complex noise sources. Energy based de-scriptors such as Leq have the advantage that all the sound sources in a given environment can be integ-rated on an energy basis. But such simple integration may be inadequate when the subjective meaning of each sound is different, or when people are habitu-ated to sounds in different degrees. The situation is complex. Several models have been proposed,") but there are big differences among them. Perhaps, the aim or the purpose of each model is different. We have to make clear the limits of their application, or we have to make an approach to a new model for

evaluating complex noise sources.

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