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# Laboratory studies of annoyance

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## ABSTRACT

It is said that in the concept of annoyance of noise, non-acoustic factors are involved as well as physical factors of sounds. Annoyance is often investigated in social surveys at the places where the respondents spend their daily lives. Since many factors may have effects on annoyance responses, it is difficult to find the effect of each factor in social surveys. Though laboratory situation is different from daily life, laboratory studies have merits that various parameters are precisely controlled. In order to study annoyance of noise in laboratory experiments, it is important to create new ideas. The authors and their colleagues tried various laboratory studies of annoyance of noise by developing new methods and controlling the experimental procedure. The study of annoyance of noise in laboratory experiments will be introduced in this paper.

Keywords: Annoyance, Laboratory study

## 1. INTRODUCTION

Loudness, noisiness and annoyance are the terms often used in the research into the subjective impression of noise. The definition of these three terms has been often discussed, but the discussion has not reached the final decision of the definition. In this paper, the authors would like to follow mainly the definition described in the Dictionary of Acoustics (1). The loudness is an attribute of sensation related to the intensity of sound. Noisiness is the term to express the unpleasant impression related to physical properties of sound itself. Annoyance is affected by non-acoustic factors such as human relationship and fear that the sounds may bring, e.g. traffic accidents, as well as physical properties of the sounds. Therefore, annoyance is not always related to sound level. Even low level sounds that are scarcely audible may cause annoyance.

There are many social surveys where annoyance caused by noise is examined (e.g. 2-4). Social surveys have a merit that the feeling of residents can be obtained in their daily life situations. However, many factors are involved in the responses and they cannot be estimated or predicted. Also there is a possibility in questionnaire surveys that the respondents may answer the questions on the basis of the ideal or false attitude due to self-defense mechanism and that it may be difficult to obtain their true intention. On the other hand, many factors can be precisely controlled in the laboratory experiments. However, even if the experiments are conducted in a laboratory that is simulated to a living room or a bed room at home as much as possible, they are different from the place where they spend every day. Therefore, it is necessary to design the experiments carefully, for example, developing new methods and preparing new stimulus

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conditions in order to examine annoyance in laboratory experiment. In this paper, trials of the laboratory experiments conducted by the present authors with their colleagues to examine annoyance are introduced and reviewed to make clear the properties caused by sounds.

## 2. LABORATORY EXPERIMENT OF LOUDNESS, NOISINESS AND ANNOYANCE USING ACTUAL AND SIMULATED SOUNDS

When actual sounds are used in the experiment, cognition of the sound sources may have an effect on judgment. In this experiment, actual sounds and sounds whose level-fluctuating patterns were simulated to actual sounds were used in order to examine the effect of cognitive meanings of sounds on the judgment (5).

### 2.1 Procedure

Nine kinds of environmental noise were used. They were aircraft noise, super-express train noise, ordinary train noise, road traffic noise, speech, music, impulsive noise, artificial level-fluctuating noise and pink noise. Four levels of each sound source were used. Therefore, in total 36 sounds were used as stimuli. These are actual sounds recorded in various places in Osaka, Japan and the participants could identify what were the sound sources. The duration of these sounds were about 10 s except for impulsive sounds whose duration was about 1 s. In another session, pink noise was used as carrier and the level patterns were simulated to the 36 actual sound sources using Programmable Sound Control System II in Osaka University. Therefore, the participants could not identify the sound sources.

Magnitude estimation was used in the experiment. There were two sessions. In session 1, actual sounds were used and the participants were asked to judge loudness, noisiness and annoyance of each sound. In session 2, simulated 36 sounds were used and as in session 1, participants were asked to judge loudness, noisiness and annoyance. All six kinds of judgment were conducted on different days. No special explanation was given about the terms of loudness, noisiness and annoyance. The 36 sounds were presented in random order.

Eight Japanese participants aged between 18 and 21 joined in the experiments conducted in Osaka University, Japan. Eight German participants aged between 25 and 41 joined in the experiments conducted in Technical University of Munich in Germany. All had normal hearing ability.

Additional supplementary survey was conducted in Japan.

### 2.2 Results

Examples of the results are shown in Figures 1 and 2. There were differences in the judgments of loudness, noisiness and annoyance in session 1 where actual sounds were used. Clear differences can be seen among the judgements of loudness, noisiness and annoyance. This may be due to the cognitive effect. This was confirmed by the result of supplementary survey. On the other hand, in session 2, where the sound sources could not be identified, there were little differences among the judgment of loudness, noisiness and annoyance except for the judgment of impulsive sounds whose duration were short and underestimated compared with the other sound sources. These results suggest that identification of the sound sources have an effect on the impression of the sounds, especially strong effect on annoyance. Similar results were obtained with German participants except for a little overestimation of level fluctuation by German participants.

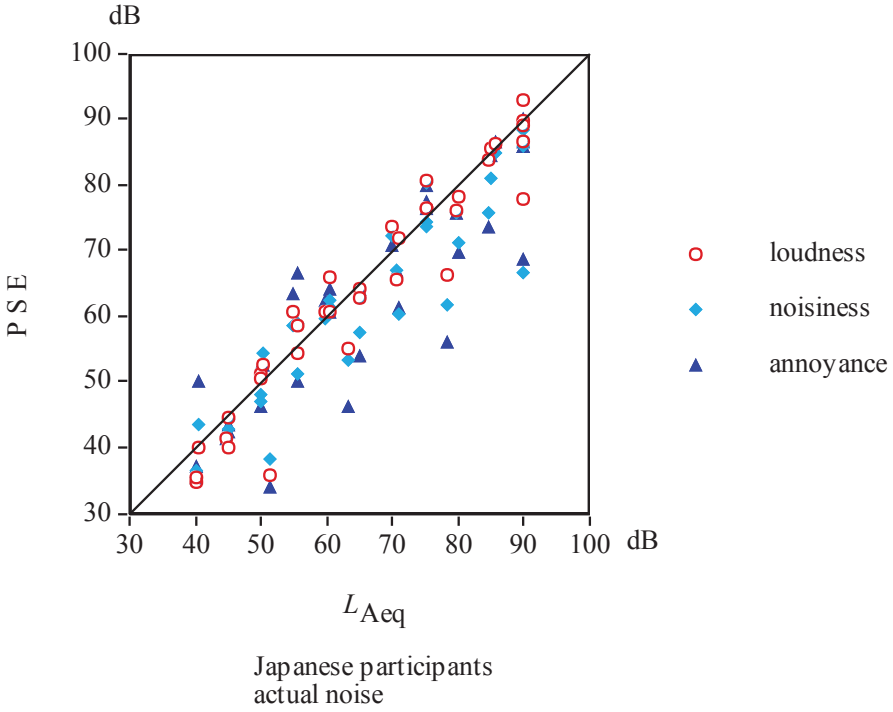


Figure 1. The results of loudness, noisiness and annoyance judgments with Japanese participants using actual sounds (5).

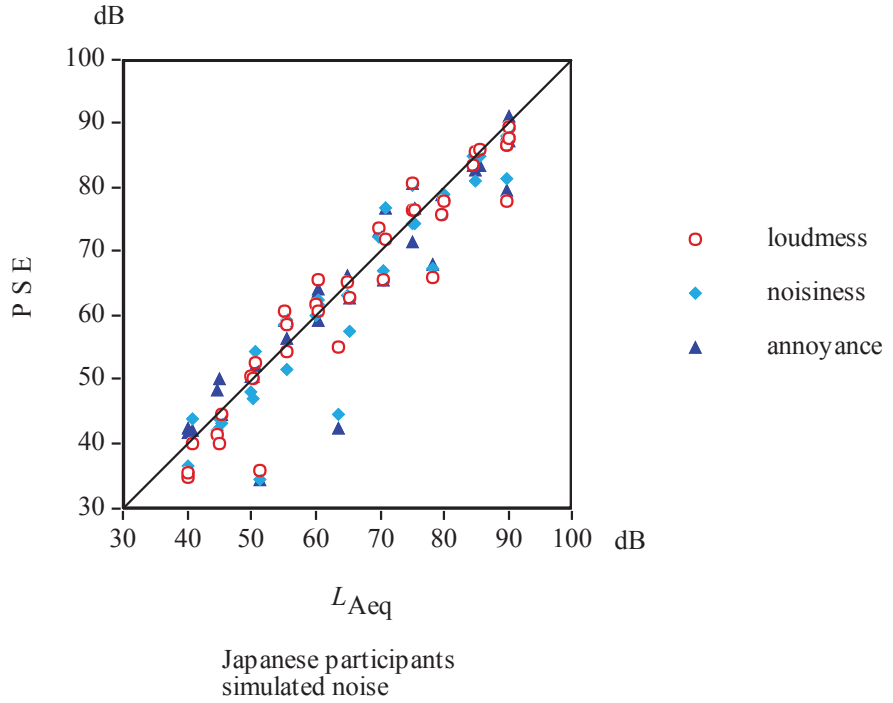


Figure 2. The results of loudness, noisiness and annoyance judgments with Japanese participants using simulated sounds. There were little differences among the three judgments except for impulsive noises (5).

### 2.3 Summary

The result suggests that the judgments of loudness, noisiness and annoyance are affected whether the sound sources are identified or not. Especially it was found that cognitive effect is great on annoyance judgment. This suggests that annoyance response cannot be estimated by physical parameters alone.

## 3. EXPERIMENT USING THE METHOD OF SUBJECT-INTERRUPTED NOISE SOURCE

When people are severely annoyed by noise, they may possibly escape from it or claim the person who makes noise. “The method of subject-interrupted noise source” is the method that has been developed by the authors with their colleagues so that annoyance responses as escape behavior from the sound source can be examined in the laboratory experiment by simulating situation to that of real life (6).

### 3.1 Procedure

A mental task was imposed on participants during the experiments. The task was to mark cards for the analysis of a social survey in session 1 and to check the cards marked by other participants in session 2. Since the marking was checked by others, the participants were motivated to do the task carefully. Four participants joined the experiment at a time, but conversation was prohibited. In total 52 females aged between 30 and 45, participated in the experiment.

Various sounds audible in daily life were presented during the experiments. While performing the mental task, the participants were asked to judge the instantaneous noisiness, using the method of continuous judgment by category (7, 8). A response box for the continuous judgment was placed at the side of each participant.

The participants were also instructed that they could interrupt the noise when it became very disturbing by pressing another, separate button, which was located close to the experimenter. In order to press this button, the participant had to walk to the place where the button was placed and press a button on which her name was indicated. This made the participants to hesitate to press the button. The action of pushing the button suggests that the sound could not be tolerated. A record was kept of when the button was pressed. In session 1, after the noise had been interrupted, it was not presented again, whereas in session 2, it was presented again, at a low level, five minutes after the button had been pressed. Noise problems tend to become serious when a person continues to make noise in spite of the claim from his/her neighbor. This situation was simulated in the session 2. A questionnaire survey was conducted with the participants in order to examine the relation between the results of the experiment and their sensitivity to noise, attitudes towards noise, etc. The duration of session 1 was 90 m and that of session 2 was 80 m. The experiment was conducted in a sound proof room and sounds were presented through loudspeakers located behind the screens.

### 3.2 Results

(1) Relation between interruption of noise and instantaneous noisiness.

The average evaluation of the category in instantaneous noisiness was 6.7 on the seven-point scale just before the interruption of noise. This indicates that participants perceived the noise as being very noisy when they took action to interrupt it.

(2) Relation between interruption of noise and accomplishment of task.

Not all the participants pressed the button to interrupt the noise. In the group who pressed the button

(abbreviated “off-group”) the amount of cards marked was on average 195 cards, on the other hand, in the group who did not press the button (abbreviated “not-off-group”) the average was 254 cards. This fact suggest that the “off-group” were disturbed by the noise more seriously that the “not-off-group”.

(3) Relation between interruption of noise and questionnaire survey.

A cross-sorting was conducted between “off-group” and “not-off-group”. As a whole, it was found that the “off-group” were more sensitive to, and more critical of, noise than the “not-off-group“. For example, the “off-group” showed a higher percentage of affirmative answers to the following questions than the “not-off-group” (Figure 3). (Q1) Have you ever been annoyed by various noises in your neighborhood? (Q2) Are there any noises produced in your house that may possibly annoy your neighbors? (Q4) Have you ever complained directly to your neighbors about noise? The questionnaire also indicated that the “off-group” found it more difficult to tolerate and to get used to noise (Q10, 15).

### 3.3 Summary

The method of subject-interrupted noise source is designed to estimate the degree of annoyance by noise as it is indicated by behavior, without using verbal responses. Therefore it has the advantage that it is objective and free from the ambiguity of verbal responses. The results of the experiment suggest that the reaction of interrupting noise by pressing a button is a good index of annoyance and can review individual differences in the degree of annoyance. It would be possible using this method to explore various aspects: (a) simulation of various social situations, (b) manipulation of human relationships among group members, (c) examination of the trade-off effect among noise sources, etc.

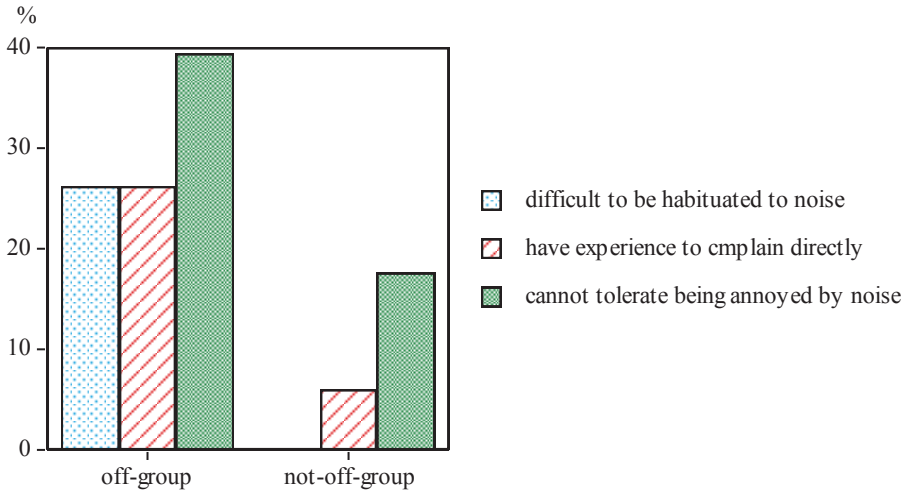


Figure 3 Comparison between off-group and not-off-group (6)

## 4. EFFECT OF NOISE ON SLEEP

Electroencephalography (EEG) is the most effective measure to find the stage of sleep and EEG is often used to examine the effect of noise on sleep. However, participants do not feel easy to sleep with many electrodes on his/her head. Rylander with his colleagues used the body movement during sleep as an index of sleep stage (9). Recently, instead of attaching a sensor of movement to the bad, a wrist watch called actiwatch is used to estimate the sleep stage by body movement. In these cases, noise is presented whole

night. This may become stressful to the participants. Also participants cannot always sleep well in a laboratory.

In order to avoid these problems the authors with their colleagues tried to examine the effect of noise on sleep. The behavior of stopping the noise source was used as an index of the effect of noise on sleep (10).

### 4.1 Procedure

The participants could sleep in his/her own bedroom at home and noises were presented there with a mini-disk player that had an automatic reverse function. The participants were allowed to stop the noise one hour after they tried to sleep if the noise was disturbing and they could not fall asleep. If they did not stop the noise, the noise was presented until the next morning. Whether they stopped the noise one hour after they tried to sleep was used as an index of the effect of noise on sleep. Road traffic noise, simulated air-conditioner noise, Karaoke songs and people's talk were used as stimuli. Four females and 14 males aged between 19 and 38 participated in the experiment.

### 4.2 Results

The result is shown in Figure 4. It was found that the percentage of stopping behavior becomes higher as the $L_{Aeq}$ values become higher. Also the meaning full noises are disturbing even if the sound level is low.

The results suggest that annoyance of noise can be examined by the behavior whether they stop the noise one hour after they try to sleep. This method has a merit that the participants do not need to be exposed to noise whole night. Using this method, it would be possible to examine what kinds of noises are disturbing to sleep and that sound level is not the only factor of sleep disturbance.

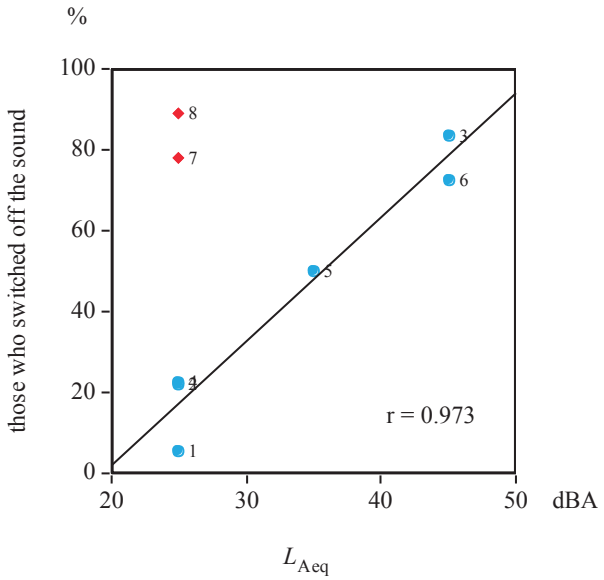


Figure 4. Relation between $L_{Aeq}$ and the percentage of participants who switched off the sound one hour after they tried to fall asleep (10). Blue circles indicate road traffic noise and simulated air-conditioner noise. Red diamonds indicate Karaoke songs and people's talk. The meaningful sounds had a great effect on sleep regardless of the sound level. Coefficient of correlation was calculated excluding these two sounds.

## 5. FINAL REMARKS

Annoyance is related various non-acoustic factors as well as physical acoustic factors. Therefore, it is not easy to examine annoyance using verbal response in laboratory experiments. However, it is possible to estimate annoyance by designing experimental conditions carefully. In this paper, the following results were introduced.

(1) The effect of cognition of sound sources on annoyance was made clear by eliminating cognitive factors with simulated noises.

(2) Annoyance can be estimated through behavior of participants by stopping the noise. This method can simulate the situation to claim or protest behavior to the person who generates noise. Estimation by behavior can avoid the ambiguity of verbal responses. Also when the effect of noise on sleep is examined, the participants are not always exposed to the noise whole night. This is desirable from ethical viewpoint of experiments using human participants.

Laboratory experiments have a merit that experimental conditions can be controlled precisely. It can be estimated what factor may affect annoyance. The findings of these examples under experimental situations agree with the results of many social surveys.

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