WHAT IS THIS SOUND IN DECIBEL? － WE TRIED TO DETERMINE STUDENTS' COMPREHENSION OF SOUND LEVELS, ONLINE VER－

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ABSTRACT

To examine the appropriate information disclosure method of noise as the final goal, we firstly set the goal to grasp the degree of understanding of the dB values of the sound sources among people other than acoustic experts. In this paper, first, in order to measure the degree of understanding of the dB in university students without expert knowledge, we developed a loudness chart kit and evaluated the understanding of loudness in the classes. As a result, they commonly regarded the sound volumes of the rocket and the take-off of the airplanes as first or second loudest, but the subjective ranks of other sound sources were completely different among them. Some of the students who seem to have no knowledge at all about the sound source answered unreality values entirely. Furthermore, since the university class was brought online due to the influence of the new coronavirus, we developed an online version of this teaching material. In the future, we will measure the changes in the evaluated dBs after learning the dB values. Then, we also accumulate more data about the differences of the understanding degree in dB values among the individual characteristics including their university, nationality, and whether they are environmental officials, to discuss the diagnostic criteria of the volume of the sound. Moreover, we will discuss how to learn a sense of loudness and dB. This reports on the online version of the teaching materials developed as university class are now online due to the impact of the novel coronavirus.

KEYWORDS

Sound Level, Education in Acoustics, University Students, Teaching Materials for Acoustics, Online

1. INTRODUCTION

The needs for the disclosure of environmental information, including the conditions of noise as well as air pollution, are increasing in the world (Ueda, 2015). In response to the needs, Also, information on environmental noise is becoming progressively more available, as exemplified by the availability of noise maps related to an airplane, traffic, and construction site activity as well as the release by local governments of environmental noise maps (Bellucci, 2017). Particularly, the positive information disclosure of the Environmental Noise Directive (hereinafter, END) in the EU countries is one of the good examples (Maisonneuve, 2009). Also, in addition to the general index of noise level L_{Aeq}, such the cases of information disclosure increasingly display L_{den} (day-evening-night sound level) that weighted the noise level of nighttime (Directive 2002/49/EC).

In European countries, where information disclosure of environmental conditions is becoming ordinary, the current problem is how to provide environmental information, including noise level that anyone cannot understand. As an example of the current studies, there are examinations of indicators other than decibel (hereinafter, dB): a heat map of blue-to-red and size of icons corresponding to low-to-high volumes.

However, these cases did not mention the degree of the citizen's understanding of the sound level dB. To begin with, the degree of understanding remains unclear when the general public who does not specialize in acoustics, physics, environmental studies, and related academic area. How many decibels do people who are not experts feel sounds? Thus, in this paper, for proposing appropriate information disclosure method of noise conditions, the objective is to grasp the degree of understanding to the size of the sound in the persons except the experts of acoustics. In particular, as an attempt to measure the degree of understanding of the loudness of

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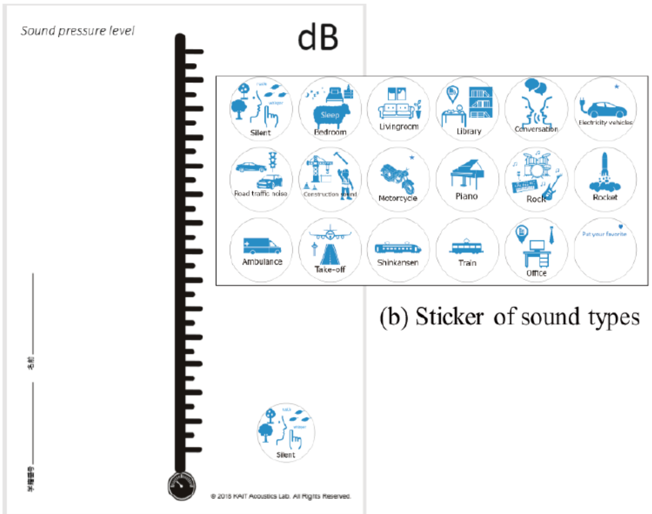
university students, we measured the degree of understanding using the loudness chart kit developed by ourselves in lecture courses. This reports on the online version of the teaching materials developed as university class are now online due to the impact of the novel coronavirus.

2. SOUND VOLUME CHART KIT: OFFLINE VERSION

2.1 Overview

In order to measure the degree of understanding of the dB, we developed a sound volume chart kit that is illustrated in Figure 1 (Ueda, 2019). This kit consists of a sheet with several grid lines without values (Figure 1 (a)), and 18 sound source stickers. In particular, the sound source stickers consist of 17 images of sound sources, as well as blank ones describing favorite sound sources. Participants are asked to paste the stickers on the board at the position of the scale that corresponds to the size of the sound they imagine.



(b) Sticker of sound types

(a) Sheet of sound level chart

Figure 1. Detail of the sound level chart kit. (a) Sheet and (b) sticker set of 18 sound types

2.2 Procedure

Using the kit, we evaluated the degree of understanding of the dB in university students. This evaluation was conducted in the classes of (a) Introduction to speech communication, which is an elective course at Kanagawa Institute of Technology, and (b) Applied acoustical engineering seminar, which is a compulsory elective course at the same institute. In total, fifty-one students, including forty-two sophomores (34 males and eight females) and nine juniors (9 males) participated in these classes.

In either class, to begin with, we explained the brief introduction about feeling the volume of the sound. First, the agenda of the class were outlined based on the syllabus, and then the participants were asked to judge the volume of each sound source using a kit as if they heard near the sound source. At this time, we also asked them to intuitively judge the volume without talking to each other and looking at any references. The working time was about 15 minutes, including the explanation.

2.3 Results

Figure 2 shows an example of the response to the kit. Since we did not specify how to describe the dB values of the sound sources, some people entered numerical values for all sound sources, but some also entered only the maximum and the minimum values.

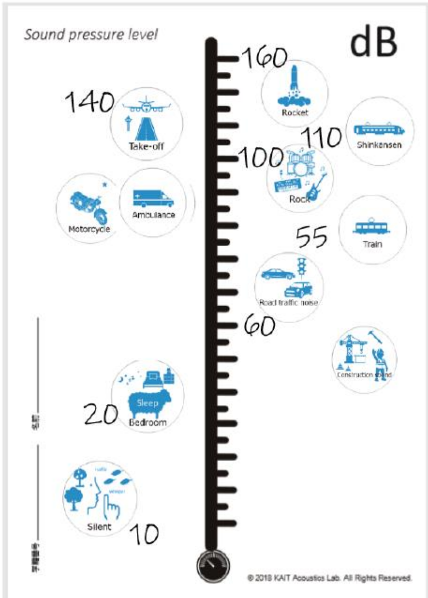


Figure 2. Detail of the sound level chart kit. (a) Sheet and (b) sticker set of 18 sound types

Figure 3 shows the confusion matrix of the actual order of the volumes of sound sources and the rank of the sound source volumes evaluated by the participants. The a—r on the x-axis indicates the type of sound source (r means the sound source freely answered by the individuals), and the y-axis indicated the actual descending order of dB values from 1 to 18. As the frequency is higher, the color of the cell becomes more reddish, and when the frequency was zero, the corresponding cell turns into green.

According to the students' responses, 96 % of the student regarded a. Rocket as the loudest in dB value among the sound sources. Next, 94 % of them answered b. A take-off of a plane as the second loudest. For other sound sources, the variation among individuals is considerable, which suggests that there are individual differences in how people feel the volume of the sound sources.

Table 1 shows the values of each sound source ±50 dB from the reference level (Bellucci, 2017), in addition to the mean, standard deviation, maximum and minimum values of the dB values judged by the students. Among the students who seemed to have no knowledge at all about the sound source, for example, those who answered the sound volume of the rocket as 3,000,000 dB, which was completely unreality. Therefore, the mean values and standard deviations in Table 1 are far from reality. On the other hand, those who answered relatively near realistic values (Reference levels ±50 dB) accounted for around 35~60% for each sound source.

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Sound types

(high) ↓ The order/ranks of the sound level ↓ (low)

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r
1	49	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
2	0	48	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
3	0	1	21	3	6	6	0	1	10	0	0	0	0	0	0	0	0	3
4	0	1	7	13	18	3	0	2	5	0	0	1	0	0	0	0	0	1
5	0	0	6	12	11	9	3	4	5	0	0	0	0	0	0	0	0	1
6	0	0	6	9	6	10	7	6	5	1	0	0	0	0	0	0	0	1
7	0	1	5	7	4	10	6	7	7	2	0	0	0	0	0	0	0	2
8	2	0	3	4	2	5	10	13	7	3	0	0	0	0	0	0	0	2
9	0	0	1	2	3	3	9	13	4	8	0	1	1	0	3	0	0	3
10	0	0	0	1	0	5	10	3	5	12	5	0	0	0	5	0	0	5
11	0	0	0	0	0	0	5	2	0	14	6	4	0	0	12	0	0	8
12	0	0	0	0	0	0	0	0	0	7	16	15	3	0	9	1	0	0
13	0	0	1	0	0	0	1	0	0	3	11	14	8	0	8	1	0	4
14	0	0	0	0	0	0	0	0	0	1	10	11	15	1	4	4	0	5
15	0	0	0	0	0	0	0	0	0	0	2	4	18	4	6	13	2	2
16	0	0	0	0	0	0	0	0	0	0	1	1	4	7	3	21	11	3
17	0	0	0	0	0	0	0	0	0	0	0	0	1	29	0	9	12	0
18	0	0	0	0	0	0	0	0	0	0	0	0	1	10	1	2	26	3

a rocket
b take-off
c shinkansen
d train
e construction
f ambulance
g road traffic noise
h motorcycle
i rock
j piano
k office
l conversation
m livingroom
n bedroom
o EV
p library
q silent
r put your favorite

Figure 3. Confusion matrix of the ranks of actual and subjective volumes of sound sources

Table 1. Experimental results by the participant

Sound types	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q
REF※	180	120	110	100	90	80	80	70	120	100	60	60	60	40	50	40	20
AVE	59778.4	61573.2	57827.3	53916.1	25232.3	24164	22834	23273	17973	163	139	102	91.9	62.2	62.1	40.8	23.1
SD	419952	390341	366929	343541	158077	153009	146555	144084	119228	371	318	244	239	188	138	94.6	50.1
MAX	3000000	2500000	2350000	2200000	1000000	980000	950000	900000	800000	2100	1800	1500	1500	1200	900	600	300
MIN	100	80	35	30	50	40	40	29	30	10	20	20	5	0	1	5	0
REF±50	43.1	35.3	45.1	47.1	49.0	41.2	47.1	37.3	39.2	37.3	35.3	54.9	39.2	52.9	47.1	51.0	60.8

3. SOUND VOLUME CHART KIT: WEB VERSION

3.1 Overview

We developed the online version of the teaching materials developed as university lessons are now online due to the impact of the novel coronavirus (db-spl, 2020).

As shown in Figure 4, this application consists of five screens: sign-in, explanation, face sheet, sound volume chart, and history. On the sign-in screen, the user can register the email address, name, and password in advance and sign in with that information or with the user's Google account. Next, after reading and understanding the explanations for this application on the explanation screen, the affiliation, name, age, gender, occupation, etc. is entered on the face sheet input screen. Filling out the face sheet allows one to create a sound volume chart.

In creating the sound volume chart, a chart is created using the screen in Figure 5. On the left side of the screen are sound source stickers representing 18 types of sound sources such as bedrooms, locks, bullet trains, and rockets, and on the right side are empty charts. The user first enters 1) four values on the scale of the chart. Then performs 2) drag and drop the sticker and place it where desired. The 18th sound source is designed so that the user can enter an arbitrary sound source in characters. The magnitude of the sound source is entered. The created chart is recorded every time, and the user can refer to the created chart at any time on the history screen.

Also, the instructor (administrator within the organization) can refer to the chart created by the user of the organization to which one belongs. Further, the administrator of this application can also acquire chart and face sheet data in CSV format.

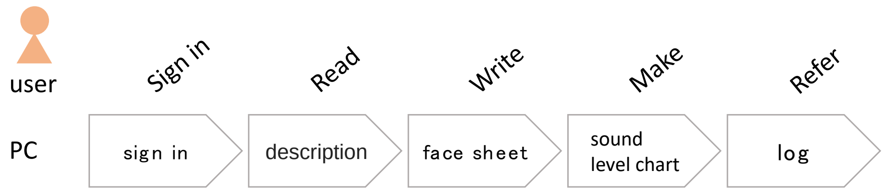

Figure 4. Application screen and flow of use

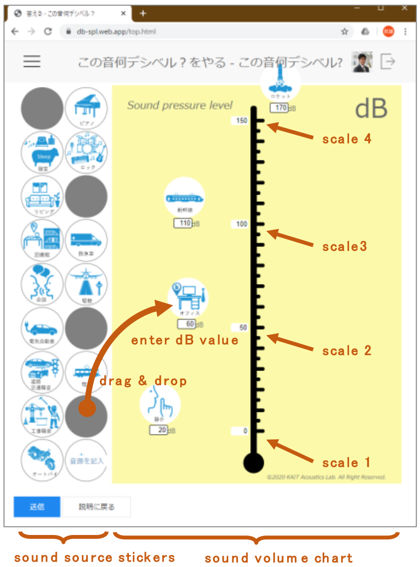

Figure 5. Online version of the sound level chart kit

3.2 Application Configuration

This application is implemented as a Web application, as shown in Figure 6. Firebase (Firebase) is used for server implementation. Firebase is a backend service (BaaS: Backend as a Service) for mobile and web applications offered by Google and consists of multiple product groups. Among them, the authentication service Firebase Authentication, NoSQL document-oriented database Cloud Firestore, and web hosting service Firebase Hosting are used. HTML, JavaScript, and CSS are used for implementation by the client, similar to general Web applications. In addition, Firebase SDK is used for accessing Firebase services and UIKit, a front-end framework (CSS and JavaScript library) widely used for web production. Further, HTML5 Drag&Drop API is used for dragging and dropping the sound source sticker, and the Web Storage API is used for temporarily storing data by the client.

The Cloud Firestore used in this application is a NoSQL document-oriented database. Contrary to relational databases, there are no tables or records, and data is stored in documents, which are organized into collections. Collections and documents correspond to tables and records in relational databases, respectively. Each document consists of multiple key/value pairs. The value can be a simple type, such as Boolean, number, string, or a map type (array or nested object). Maps allow one to structure the data in documents.

This application uses collection users, which stores user information, and answers, which stores information about the audio intensity chart (answer) created by the user. The structure (data model) of the document stored in users and answers. In the web application that uses Cloud Firestore, the database is accessed directly from the client (web browser). As the code of the client may be referenced or tampered with by a malicious user, user authentication/authorization is managed by rules stored on the server.

In this application, users are divided into three types: end-users, in-house administrators, and administrators, and the following rules are applied.

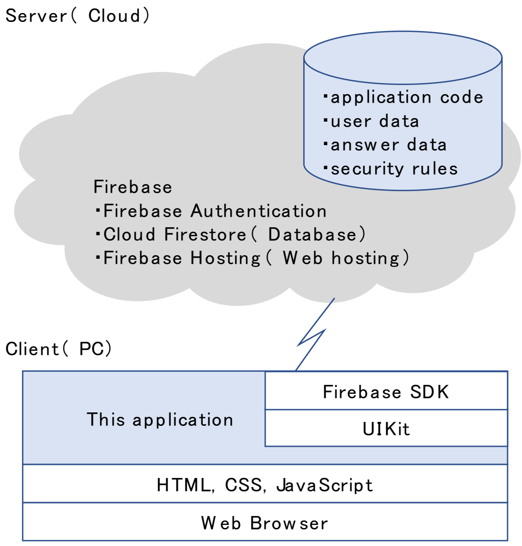

Figure 6. Application configurations

・The user can read/write own user data and answer data.

・The organization manager can read/write all user data and answer data of the organization to which one belongs.

・The administrator can read and write all user data and answer data.

3.3 Usability Evaluation of Application

3.3.1 Procedure

An experiment was conducted to measure the comprehension of sound volume chart using this application. The experiment was conducted with the students of the second class (May 19, 2020) of the Kanagawa Institute of Technology Faculty of Information Science second-year "Introduction to Acoustics" elective course as subjects. On the day of the experiment, which was held during an online lesson due to the novel coronavirus, the experiment and application were explained. If one could not register during the lesson, registration was to be performed within one week. As with the offline version, through the explanation screen and verbal directions, instructions were given to "not look at anything or speak with anyone, use your intuition," and "assume listening to each sound close to the sound source."

Of the 118 participants on the day of the experiment, 100 of them prepared and submitted answers. The respondents were students aged 19 to 23, with 86 males and 14 females. The task time of each respondent (the time from the beginning of preparing the sound volume chart to the registration) was about 10 minutes. More specifically, the average task time of 97 persons excluding three persons who discontinued preparation (appears chart preparation was discontinued when more than six hours was expended) was 588 seconds, the standard deviation was 389, and the median value was 464 seconds.

3.3.2 Results

Table 2 indicates the four values on the scale of the audio intensity chart. From the bottom of the axis, in the sequence of 1, 2, 3, and 4, the realistic values, average values, standard deviations, maximum values, minimum values, median values, and realistic values ±50 dB frequency, 200 dB and higher frequencies are listed.

A few students seemed to have no knowledge of the dB value, as they entered values higher than 200 on the four scales. For example, 18 students entered values higher than 200 dB on scale 3, and 25 students on scale 4. Along with this, the average value and standard deviation are also values that are not realistic. On the contrary, students who entered a value of ±50 dB consisted of more than 90% for scale 1 and 2, approximately 70% for scale 3 and 4, and the median value was realistic for all scales.

Figure 7 indicates the frequency distribution on the scale for the four values. Since dB itself is a unit of a logarithmic scale, it is not realistic to set the scale to logarithmic values such as 10, 100, 1000, 10000. However, as shown in Figure 7, 12 students entered the logarithmic scale or values close to the logarithmic scale. It appears that while students had a vague understanding that values were to be expressed in logarithm, those who did not fully understand responded in this way.

Figure 8 indicates the color map of the frequency of how many persons ranked the volume of the sound source filled in by the user. On the x-axis, a to q are sound sources, and on the y-axis, 1 to 17 are in sequence of increasing volume. The higher the frequency, the darker the color, and if lower than three, the color is white. The 18th sound source is the user's favorite sound source and is not included in the figure as it differs for each user.

Table 2. Outline of the experimental results by the participant

	scale1	scale2	scale3	scale4
standard value(ref)	0	50	100	150
ave	14.1	97.9	282.4	1403.0
sd	28.5	155.3	708.4	8078.3
max	250	1000	5000	80000
min	0	10	20	30
median	5	50	100	150
reference level ± 50	99	90	73	68
over 200 dB	1	7	18	25

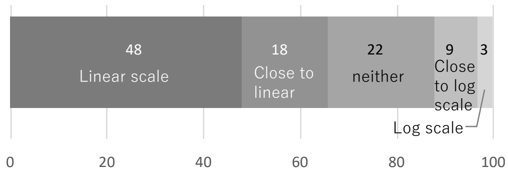

Figure 7. Frequency distribution of 4 scales

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q
1	99	6	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
2	1	83	6	3	0	0	7	3	0	1	0	0	0	0	0	0	0
3	0	6	12	40	11	0	21	6	5	7	0	0	0	0	0	0	0
4	0	2	9	16	28	0	20	16	7	8	0	0	0	0	0	0	0
5	0	1	6	12	15	2	19	20	10	12	0	0	0	1	0	0	0
6	0	2	18	9	16	2	15	18	15	14	0	0	1	1	0	0	0
7	0	0	13	4	16	4	8	16	15	15	0	0	0	1	0	0	0
8	0	0	12	4	5	9	3	10	21	19	0	0	0	1	0	0	0
9	0	1	16	6	3	14	2	6	16	16	1	0	1	5	0	0	0
10	0	0	3	4	3	26	1	1	6	4	13	3	1	28	0	1	0
11	0	0	0	0	1	26	0	0	0	0	12	10	10	30	1	0	0
12	0	0	2	1	0	6	0	1	1	1	27	21	25	12	0	2	0
13	0	0	1	0	0	3	0	0	0	0	18	27	26	6	5	0	0
14	0	0	0	0	0	1	0	0	0	1	13	18	22	4	13	2	1
15	0	0	0	0	1	0	1	0	2	1	5	8	2	1	53	17	14
16	0	0	1	1	2	0	0	2	1	1	0	1	0	0	13	38	31
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	25	39

a rocket
b take off
c rock
d shinkansen
e train
f piano
g construction sound
h ambulance
i road traffic noise
j motorcycle
k office
l livingroom
m conversation
n electricity vehicles
o library
p bedroom
q silent

Figure 8. Confusion matrix of the ranks of actual and subjective volumes of sound sources

The sound source a, the rocket, had the most responses from 99 students, and 83 students answered that b, the aircraft, which was second in frequency of responses. For other sound sources, it can be observed that there are significant variations among individuals, and there are differences in how one perceives the size of the sound source. Table 3 indicates the reference level(realistic value) of each sound source, the average of dB values entered by the user, the standard deviation, the maximum value, the minimum value, the median value, and the number of persons who responded with a value of reference level ±50 dB.

Some respondents entered unrealistic values, similar to the scale value, with the rocket sound of 50,000 dB. On the contrary, more than half of the users answered with a realistic value of ±50 dB as the reference value. Particularly for relatively low intensity sounds with a reference value of 60 dB or lower, more than 80% responded with realistic values.

Table 3. Experimental results by the participant

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q
	rocket	take off	rock	shin-kansen	train	piano	const-ruction sound	ambu-lance	road traffic noise	motor-cycle	office	living room	conver-sation	elect-ricity vehicle	library	bed room	silent
ref	180	120	120	110	100	100	90	80	80	70	60	60	60	50	40	40	20
ave	1104.3	590.3	173.9	265.1	195.6	83.0	237.2	190.2	132.3	192.8	48.3	41.1	48.8	77.1	26.9	18.3	11.8
sd	5135.3	1851.6	412.7	593.7	355.1	97.1	565.8	467.6	154.6	605.6	50.9	36.4	67.3	103.9	50.5	40.4	12.1
man	50000	15000	4000	5000	3000	800	5000	4500	900	6000	400	250	600	700	500	400	50
min	30	25	-1	18	19	5	17	11	10	15	3	-1	2	-1	-1	0	0
median	180	132.5	90	100	90	60	100	90	80	81.5	38	37.5	40	50	20	10	10
ref±50	50	61	59	67	70	66	69	77	80	78	86	86	89	86	98	99	100

4. CONCLUSION

To examine the appropriate information disclosure method of noise as the final goal, we firstly set the goal to grasp the degree of understanding of the dB values of the sound sources among people other than acoustic experts. In this paper, first, in order to measure the degree of understanding of the dB in university students without expert knowledge, we developed a loudness chart kit and evaluated the understanding of loudness in the classes. As a result, they commonly regarded the sound volumes of the rocket and the take-off of the airplanes as first or second loudest, but the subjective ranks of other sound sources were completely different among them. Some of the students who seem to have no knowledge at all about the sound source answered unreality values entirely.

Also, as university classes are now online due to the impact of the recent novel coronavirus, online versions of the teaching materials for about 100 students in the university lecture have been developed using web application with Firebase. The task was conducted using the app. As a result, the acoustic results, such as the dB value obtained, did not seem to be significantly different from the offline version of the kit. As comments from students from the minute paper session held in each class, students that experienced the offline version of the sticker noted: "I enjoyed pasting the stickers," "It was easy to do, and it was nice to be able to change the numbers and the position of the stickers," "For the implementer/administrator, the offline version requires additional work such as preparation for printing the sticker and data entry of the result, so I felt that the online version would be easier to implement once the application was created." Currently, the advantages and disadvantages of the offline and online versions of the teaching materials are being compared. After clarification, there is a plan to develop teaching materials that are further adapted to the individuality of students and the current social situation.

Furthermore, in the future, by measuring the changes in the evaluation results after learning of the dB value, and by further accumulating data (differences in universities and nationalities, whether an administrative officer involved in the environment is engaged or not), the volume of the sound, degree of understanding of dB is measured. Then, there is a plan to study how to more effectively understand the volume, dB of the sounds, perceptually and physically.

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