The Communication Method of Distance Education System and Sound Control Characteristics

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Summary
The present in used distance education system is based on audiovisual communications. So when a teacher gives lessons to many students who are dispersed in distant places, the teacher obtains input from students through image and sound information. The students can be visually distinguished by separately displaying an active picture and a non-active background. But it is hard to distinguish the students aurally when multiple sounds come from the same loudspeaker simultaneously. In a normal class, a teacher can usually obtain feedback from students and can respond to a question immediately. It is equally necessary to get student feedback through sound information in distance education. We examined how background sound affects the active sound in a practical distance education system, and studied how to main image interference. 2nd experiment, Next, we define the sound loudness as the sound pressure, perform AHP (Analytic Hierarchy Process) analysis for relation between the sound pressure and the sound image in this case, and elucidate the audibility characteristics. We define the time delay as the sound pressure, perform AHP analysis for relation between the time-difference and the sound image in this case, and elucidate the audibility characteristics.

Key words:
Auditory sense, Internet, Classroom design, Distance education, Multipoint communication, AHP(Analytic Hierarchy Process), Sound pressure, Time-difference

1. Introduction

Recently, communication technology is rapidly developing. Therefore, it becomes possible for schools and campuses which are physically separate to be connected by a digital transmission network and communication satellite. A joint class on real-time basis can be carried out [1]. We improve distance education system using a video teleconference system, and in this way joint class in the university and distance education for students who refuse to go to school were carried out [2][3][4]. Although, the distance education system has already entered the practical stage, but there seems to a problem with respect to the sound. The present distance education system is based on audiovisual communications. So when a teacher gives lessons to many students distant places, the teacher gets feedback from students through image and sound information. The students can be visually distinguished by separately displaying an active picture and a non-active background. But it is hard to distinguish the students aurally when multiple sounds come from the same loudspeaker simultaneously. In a normal class, a teacher can usually get feedback from students and respond to a question immediately. It is equally necessary to get student feedback through sound in distance education. The teacher always needs feedback from the aspect the pupil. We produced such a situation in the actual distance education system. We tested to what degree the background sound had on effect on the active sound [5]. As a result of this experiment, recognition rate was determined to be about 70% even with 70dB sound pressure background in case of the monaural presentation. Moreover, it was shown that even when the sound pressure of the background was 60dB, the presentation could not be easily understood. In stereo presentation however, sound pressure of the background does not affect the much active sound, even if it is 90dB[6]. Next, we define the sound loudness as the sound pressure, perform AHP (Analytic Hierarchy Process) analysis for relation between the sound pressure and the sound image in this case, and elucidate the audibility characteristics. We define the time delay as the sound pressure, perform AHP analysis for relation between the time-difference and the sound image in this case, and elucidate the audibility characteristics[7].

2. The Configuration of The Distance Education System

2.1 The Distance Education System

In this study, the video teleconference system used was "PictureTel System 2000 Model 30". Two systems were placed in adjoining classrooms, to create the distance education system were[5]. The main body of video

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teleconference systems placed in each the computer practice room by the Digital PBX at TBRI (Triple Basic Rate Interface). This allowed a maximum data transfer of 384kbps, and moving image of 30fps. The microphone for the collecting sonic reflection collects sound of a wider scope using "PowerMic (collecting sonic reflection range of 360 degrees, 100Hz-7kHz frequency range)".

2.2 Outline of AHP

The AHP is a tool for judgment or decision that has not yet been structuralized, and was proposed by T.L.Saaty[6]. It has also shown that this method can express human and physical sensations with a comparative correctness.
We calculated the importance ratio(weight) of alternative I and J based on an assessment criterion, and made a matrix of paired comparisons. Eigenvector components (the sum of components normalized as 1) belonging to the maximum eigenvector of this matrix were considered to be the weight (priority) of each alternative.
For example, assume that there are n assessment items of I_1, … and I_n, and their original weights are W_1, … and W_n. The paired comparison value a_{ij} of the importance of items I_i and I_j is given as $a_{ij} = W_i / W_j$. Matrix $A = \lfloor a_{ij} \rfloor$ of paired comparisons becomes.

$$A = \begin{bmatrix} W_1/W_1 & W_1/W_2 & \cdots & W_1/W_n \\ W_2/W_1 & W_2/W_2 & \cdots & W_2/W_n \\ \vdots & \vdots & \vdots & \vdots \\ W_n/W_1 & W_2/W_n & \cdots & W_n/W_n \end{bmatrix} \cdots\cdots(1)$$

Multiplying the vector of weight on the right side of A it will change to the following:

$$\begin{bmatrix} W_1/W_1 & W_1/W_2 & \cdots & W_1/W_n \\ W_2/W_1 & W_2/W_2 & \cdots & W_2/W_n \\ \vdots & \vdots & \vdots & \vdots \\ W_n/W_1 & W_2/W_n & \cdots & W_n/W_n \end{bmatrix} \begin{bmatrix} W_1 \\ W_2 \\ \vdots \\ W_n \end{bmatrix} = n \begin{bmatrix} W_1 \\ W_2 \\ \vdots \\ W_n \end{bmatrix} \cdots\cdots(2)$$

From this formula, it is clear that the weight vector is the eigenvector, n is the eigenvalue and the maximum one of matrix A. After finding the maximum eigenvalue and eigenvector of A, the eigenvector turns out to be the weight of each assessment item. If taking λ max as the maximum eigenvalue and ν as the eigenvector of a general matrix A of paired comparison, it becomes.

$$\nu = \begin{bmatrix} \nu_1 \\ \nu_2 \\ \vdots \\ \nu_n \end{bmatrix} \cdots\cdots(3)$$

From the relation of eigenvalue and eigenvector, a formula can be derived that

$$A\nu = \lambda \max \nu \quad \cdots\cdots(4)$$

In addition, the consistency index (C.I.) is used in the assessment of AHP results.

$$C.I. = (\lambda \max - n)/(n-1) \cdot\cdots\cdots(5)$$

C.I. is zero in matrix A with perfect consistency. The larger C.I., the higher the inconsistency. This means that the smaller C.I. is the better. The consistency scale is used as the consistency ratio (C.R.) and is judged to have consistency when C.R. is below 0.1.
The experiment was as follows.
Let us determine a priority scale in the following experiment. Let A, B, C, and D stand for listeners, arranged in a straight line, leading away from acoustic signal (sound pressure source). We develop a priority scale of relative loudness for the acoustic signal. Judgments will be obtained from an individual who stands by the acoustic signal source and is asked, for example, “How strongly louder is acoustic signal B than acoustic signal C ?” The subject will then give one number for comparison in the table and this will be entered in the matrix in position (B, C). By convention, the comparison of strength is always of an activity appearing in the column in the left against an activity appearing in the row on top. We then have the pairwise comparison matrix with four rows and four columns (a 4×4 matrix). (Table 1).

Table 1. Matrix of AHP(Example)

	A	B	C	D
A				
B				
C				
D				

The “agreed upon” numbers are the following, given elements A and B; if:
A and B are equally important, insert 1
A is weakly more important than B, insert 3
A is strongly more important than B, insert 5
A is demonstrably or very strongly more important than B, insert 7
A is absolutely more important than B, insert 9
in the position (A,B) where row A meets column B.
An element is equally important when compared with itself, so where row A and column A meet (A,A), insert 1. Thus, the main diagonal of a matrix must consist of 1s.
A meets row B, i.e., position (B,A) for the reverse comparison of B with A. The numbers 2, 4, 6, 8 and their reciprocals are used to facilitate compromise between slightly differing judgments. We also use rational numbers to from ratios from the above values when it is desired to force consistency on the entire matrix from a few judgments, i.e., a minimum of n-1.

3. Experimental

3.1 The presentation method of image and voice

Next consider methods used for presentation of image and voice from actual live class to the present remote education system. (1)The presentation by actual live class (Voice: Multi-channel, Image: Multi-channel). (2)The presentation of the stereo space (simulation space) using equipment (Voice: 2 channels, Image: 2 channels). (3)The presentation by the present distance education system (simulation space) (Voice: One channel, Image: One channel). We measured (2) and (3) as presentation methods for utilization in the distance education system.

3.2 The sentence intelligibility experiment using the present distance education system

This experiment used the above-mentioned distance education system. In the Local room, the presenter vocalized sound from the teacher’s desk, and it was collected by microphone. Simultaneously, background sound from the loudspeaker was also caught by the microphone (Figure.1).
At this time, the presenter vocalized sound at a constant sound pressure, while the background sound was varied. And, two types of noise as were used background sound: reading aloud and white noise. Each was made to vary over the following range: 60dB, 70dB, 80dB and 85dB. Active sound and background sound were presented from the four loudspeakers in the ceiling of the Remote room as part of the distance education system. 5 examinees were stationed in Remote (A,B,C,D, and E), and they heard the presentation from the loudspeakers(Figure.1).

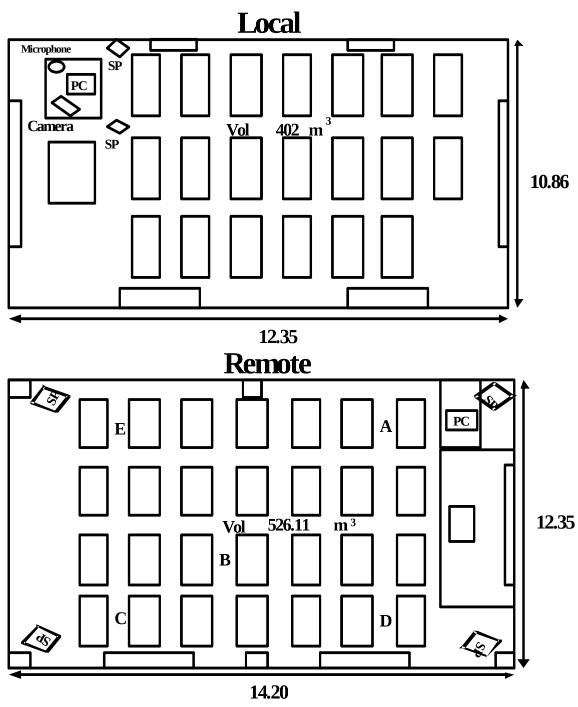

Figure 1 The classroom of Local and Remote

And, examinees observed the figure of presenter was captured by cameras in the Local room on sub-monitors installed in the Remote room. The sentence intelligibility the presenter’s question and subject’s answer was measured. The question was a short sentence which required only a general answer. 10 questions were used for each set of conditions.

3.3 The sentence intelligibility experiment with stereo equipment space (simulation space)

Separate voices (active sound and background sound) were presented by the right and left channels of stereo headphone. That is to say, the channel of one side presented the voice for the sentence intelligibility test, and the other channel presented the noise (reading aloud). The configuration of the experiment is shown in Figure.2. The background sound was made to change in the same range as the above-mentioned experiment: 60dB, 70dB, 80dB and 90dB. Simultaneously, the face of the presenter of the sentence intelligibility test and the face presenting the noise (reading aloud) were given on separate screens in order to synchronize the visual sense. The voice of the screen in the right would be presented from the right hannel of the headphone. It is also the same on the left side.

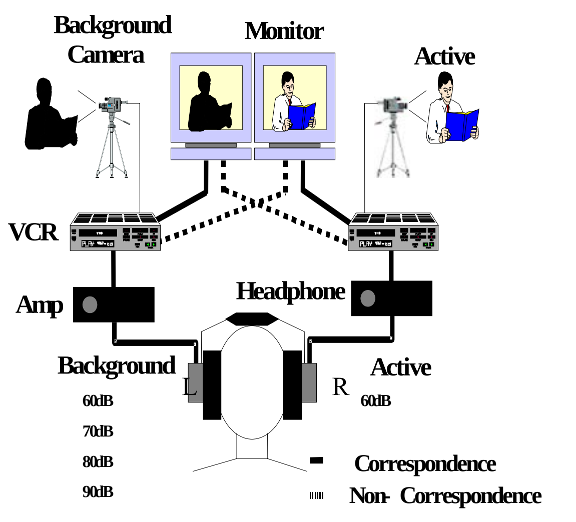

Figure 2 Experiment configuration of the stereo space by the equipment

Examinees were the 5 persons mentioned above. The sentence intelligibility test was carried out under the conditions exactly the same as the above-mentioned experiment. Then, synchronization was reversed. The importance of synchronous auditory sense and visual sense was evaluated by reversing voice and image between right and left channels.

3.4 Experimental of sound pressure level and time-differences

A schematic diagram of this experiment is illustrated in Figure 3.

As shown in the figure, we take a method to generate white-noise with a certain sound pressure or time-differences from a speaker at a point and to hear the sound at a position determined in advance. Because of a limitation of the measurement for individuals, we placed a noise meter at every position of individuals and measured the sound loudness with each noise meter. Then we recorded the sound with the same loudness as of this measured sound on a Computer and made a CD-ROM for sound pressure or time-differences stimulation.

The examinee listens to the sound pressure level or time-differences stimulation CD-ROM prepared in advance by using a headphone (MDR-CD350, SONY). The listeners were five healthy men. The age of the examinee is from 19 years old to 20 years old. (1) We make use of 0, 2, 4, 6, 8 and 10[dB] sound pressure level differences. (2) We make use of 0, 0.1, 0.25, 0.5, 0.75 and 1.0 [ms] sound time-differences. The subjects listen to white-noise signal using headphones. A person under test heard the white-noise through audio amplifier with a headphone. The output level of the person under test could hear the sounds most easily.

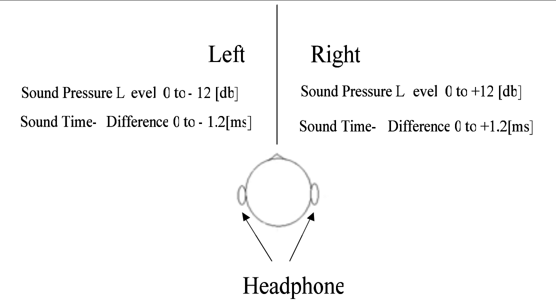

Figure 3 Illustration of Healing Experiment
(sound pressure level or time-differences stimulation)

4. Results and Discussion

4.1 In case of the presentation method of image and voice

First we will present the results of the experiment in the monaural experiment. Figure4 shows sentence intelligibility in the case when white noise plays the role of background noise and Figure 5, in the case when reading aloud plays the role of background noise. According to both Figure 4 and Figure 5, when the noise sound pressure is 70dB or less, the sentence intelligibility is more than 70 percent. Then the data can be partitioned grouped into two groups: 60-70dB and 80-85dB. Considering these results, there is a kind of threshold between 70dB and 80dB.

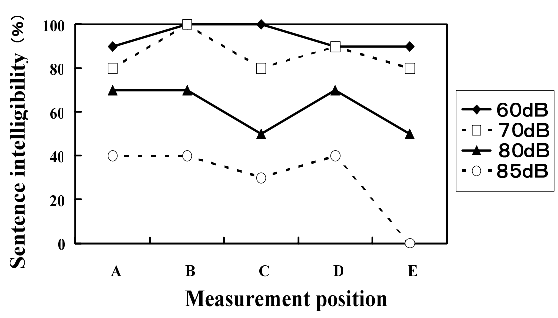

Figure 4 Sentence intangibility in the case that white noise plays the role of background noise

In the experiment using white noise, as in Figure 4, sentence intelligibility is almost 100 percent on the condition that the sound pressure is 60dB, while in the experiment using reading aloud, as in Figure 5, sentence intelligibility is low compared with that in Figure 4.
In the stereo experiment we used a method called dichotic listening, in which the subject listens to different sounds in each of his/her ears.

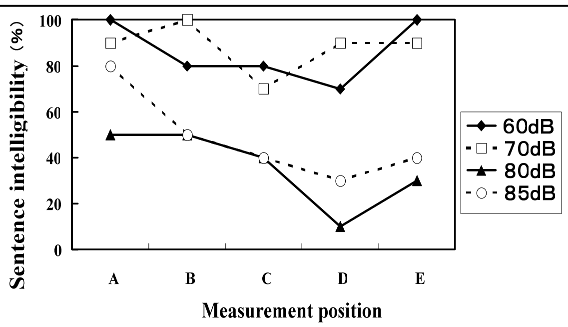

Figure 5 Sentence intangibility in the case that reading plays the role of background noise

On this basis we conducted two types of experiment. One (Correspondence Condition, henceforth CC) is when two images on the left corresponds to the sound in the left, and similarly for the right. But this does not bold for the other condition (Non-Correspondence Condition, henceforth Non-CC) is not. Figure 6 is sentence intelligibility in CC and Figure 7 is one in Non-CC.

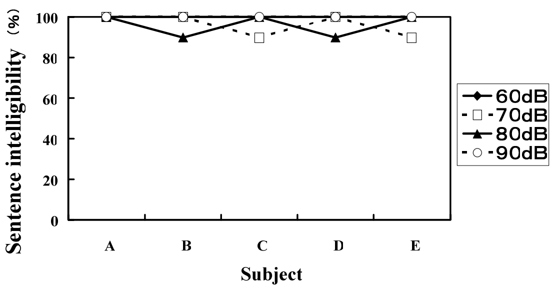

Figure 6 Sentence intangibility in the CC stereo experiment by reading

In contract to the monaural experiment, in the stereo experiment, even when the noise sound pressure is 90dB sentence intelligibility is almost 100 percent. Thus there is no difference in sentence intelligibility between CC and Non-CC. Unlike the monaural experiment, the subject can aurally distinguish the target from the noise in the stereo experiment. When two images are used, there is no difference between CC and Non-CC. Therefore the stereo effect is considered to be crucial.

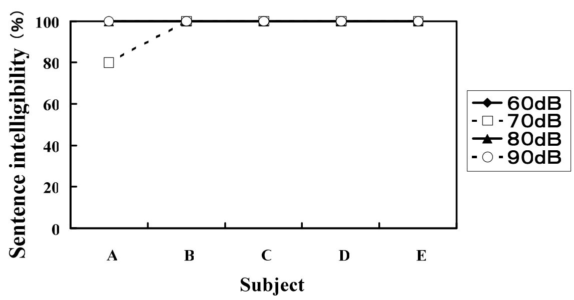

Figure 7 Sentence intangibility in the Non-CC stereo experiment by reading

4.2 In case of sound pressure level and time-differences

We made a paired comparisons among these sound pressure level or time-difference respectively and obtained the relation between the sound pressure level and the time-difference. In this experiment, the sound pressure level and the weight(ratio) appear to be in logarithmic relation. This is said almost applicable to the case of sound like a general relation between intensities of the physical stimulation and the resulted sensation, known as Weber-Fechner's law. It is shown in figure8. We made paired comparisons among these sound image respectively and obtained the relation between the sound image and the time-difference. As shown in the figure9, this can be regarded as almost linear characteristics.
We show a calculation result of consistency index (C.I.) for table 2. Besides, consistency index calculated for every examinee was below 0.15 throughout the experiment. In the AHP, criterion of acceptance (good) is defined as the consistency index being less than 0.15, so each examinee is regarded to have made consistent decisions in the present experiment.

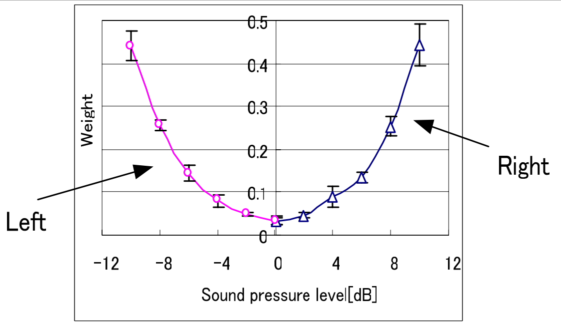

Figure 8 The relation between the sound pressure level and the sound image

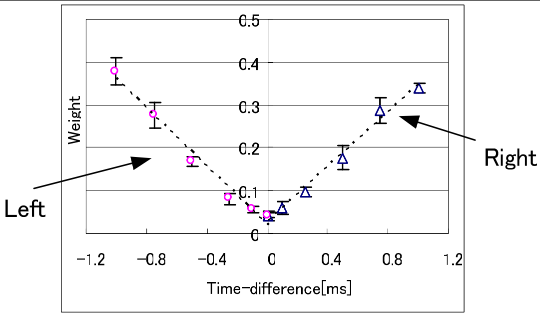

Figure 9 The relation between the Time-difference and the sound image

	Consistency Index			
	Sound pressure level		Time-difference	
	Left	Right	Left	Right
A	0.132	0.119	0.114	0.068
B	0.121	0.065	0.060	0.074
C	0.077	0.092	0.100	0.087
D	0.102	0.023	0.053	0.058
E	0.090	0.141	0.090	0.093
Avg.	0.104	0.088	0.083	0.076

5. Conclusions

When sound pressure was poor in the monaural presentation, the recognition rate was much lower for recitation background sound than for white noise. It may be that the questions were ignored because attention was paid to the background recitation. In the monaural presentation, the experiment used ceiling loudspeaker at the 4 corners in the classroom. It will be possible to raise the degree of recognition of the active sound, if the stereo loudspeaker are installed in individual machines. The presence of 3D sound allows for more accurate recognition of the active sound. However, the effect of reflected sound of the classroom and voice of other pupil nearby, etc. were significant factors in the test case. Therefore, though in addition, we need research in classroom design, on could also use stereo systems, 5.1 style stereo and virtual reality systems in combination with PC in the personal relations. This time, we conducted the experiment using headphones in order to present the ideal environment. The recognition rate of the stereo presentation was far higher than that of the monaural presentation. Therefore, this may be an effective way to achieve as a binaural system. Generally, in most of the current systems the images presentation a big screen, and the voice is monaural. Such distance education system has been introduced in great numbers. However, such environment should be changed allow for the voice to be stereo rather than monaural. The teacher could raise the recognition rate of the pupil, if this were done. In the case of multisite communication, the face of the pupils from the sites are displayed on the screen. In this case, the arrangement on this screen means being a simulated location. Therefore, it is necessary to present a sound image similar to the visual image. If the position of the window on the display is made to accord with the stereo image, then by using the coordination of the visual sense and the auditory sense, the degree of recognition of the active sound will rise. In short, a system which also moves stereo sound image when the window is moved on the display would be an effective tool for multisite communication.

Next experiment, the sound image and the weight(ratio) appear to be in logarithmic relation. And the time-difference and the weight(ratio) appear to be in linear relation. This is said almost applicable to the case of sound like a general relation between intensities of the physical stimulation and the resulted sensation, known as Weber-Fechner's law. Besides, consistency index calculated for every examinee was below 0.15 throughout the experiment. In the AHP, criterion of acceptance (good) is defined as the consistency index being less than 0.15, so each examinee is regarded to have made consistent decisions in the present experiment. It was found that there was a possibility of estimating the relation between the sound pressure level and the time-difference despite personal characteristics of each examinee.

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