19th INTERNATIONAL CONGRESS ON ACOUSTICS
MADRID, 2-7 SEPTEMBER 2007

A BASIC STUDY ON STAGE ACOUSTICS FOR AN ORCHESTRA CONDUCTOR TO ESTIMATE ACOUSTIC CONDITION OF AUDIENCE AREA

PACS: 43.55.Fw

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ABSTRACT
The purpose of this study is to acquire information of optimal stage acoustic design for orchestra music performance. According to a questionnaire survey for professional conductors, one of requirements for a good stage acoustic condition is that conductor can easily estimate or imagine acoustic condition of audience area. In this paper, it is assumed that conductor is estimating acoustic condition of audience area while conducting orchestra on the basis of time series information of stage acoustic condition and two experiments were carried out. One is to examine the influence of stage acoustic conditions and their parameters upon the conductor's "easiness of estimation" for acoustic conditions of audience area. Another is to understand the characteristics of the audience acoustic conditions estimated by conductors. The followings are found from the results of these experiments;
1. "Easiness of estimation" can be changed with Tsub (Reverberation Time) or the relation between Tsub and EDT (Early Decay Time).
2. Estimated acoustic condition of audience area is influenced by stage condition.
3. In actual case, it seems to be difficult for conductor to estimate from time series information of stage acoustic condition because difference of conditions cannot be distinguishable.

INTRODUCTION
Auditorium acoustics should be designed appropriately for either audience area or stage area so that musicians could perform with concentration and maximum potential. Previous works on stage acoustics for solo or ensemble performance has been studied by some researchers[1) 2)], but there are few works* as to orchestra performance because of its difficulty to model the orchestra as a sound source. On the other hand, orchestra conductor is the character who control all orchestra performers and acoustic output indirectly. It is possible to assume that offering optimal conditions to an orchestra is equivalent to offering it to the conductor.
And as to optimal stage acoustic condition for conductor, a questionnaire survey for professional conductors carried out by authors shows that it is possible to be a requirement for good performance that conductor on the stage can estimate the acoustic condition of audience area easily. In the survey, most conductors say that they estimate acoustic condition of audience area actually while conducting orchestra.
In this paper, it is assumed that conductor is estimating acoustic condition of audience area while conducting orchestra on the basis of information of stage acoustic condition and as the first step, the influence of time series component of stage acoustic condition upon conductor's "easiness of estimation" and the characteristics of the audience acoustic conditions estimated by conductor are examined.

PRELIMINARY EXPERIMENT
Antecedent to main experiments, a preliminarily experiment is examined. Preparatively, impulse responses are synthesized by means of CAD simulation for the conductor's position on stage and the representative position of audience area for 3 halls with different types. And 3 stimuli of

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*Meyer mentioned about the acoustic condition at the position of conductor on the stage[3)], and Gade carried out an interview survey for musicians include conductors.[4)]

music with simulated acoustic conditions at conductor's position of 3 halls are made by convolution of dry music sources and impulse responses. In the same way, 3 choices for audience area of 3 halls are made.
Each of subjects as an orchestra conductor firstly listens to a stimulus for conductor's position for one of 3 halls. And then he tries to estimate the acoustic condition of audience area corresponding to the same hall. Subjects have no information concerning to the specification of the 3 halls. They must estimate only by stimuli of music.
Next, the subject is asked to choose one between 3 choices for audience area, which is approximate to his estimation. He tries to estimate for all 3 halls and their choices are analyzed statistically.
If the subject selects the correct combination of acoustic condition of the same hall, it can be assumed that he can do proper estimation of acoustic condition of audience area.
A dry music source used for stimuli, is Mozart's The Marriage of Figaro, overture, KV492, bars 1-18 and period of stimulus presentation is about 15 seconds. 5 subjects participated in this preliminary experiment. The stimulus is presented through headphone monaurally and time series information of acoustic condition is dealt with in this experiment. Figure 1 shows plans and reflection diagrams of 3 halls (which is not informed to subjects). In the figure, S, C, A means the location of sound source, conductor's position and representative position of audience area in CAD simulation.

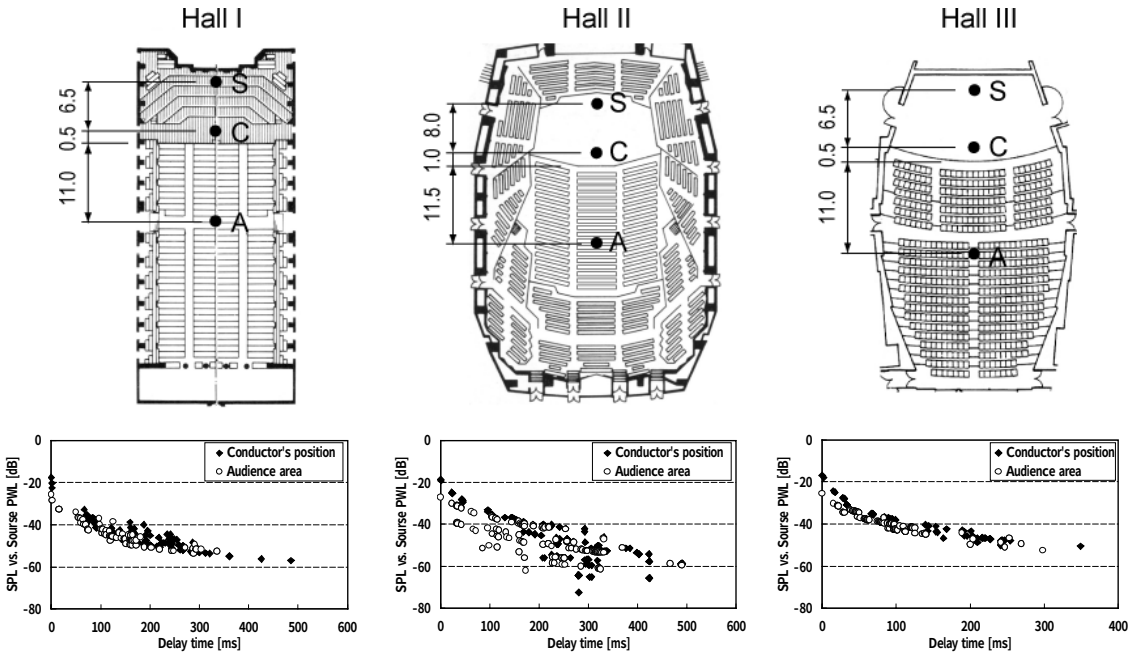

Figure 1.-Plans and reflect diagrams of 3 halls

Results and discussion

Table 1 shows the ratio of selection by subjects. For the hall II and III, most subjects selected correct choices that is corresponding to the stimulus of the same hall. In both acoustic conditions of stage and audience area of these halls, there are some similar acoustical characters in the decay property such as reverberation time, clarity, loudness, etc. It seems that subjects detect these acoustic characters in the stimuli and make a proper selection.

Table 1.- The ratio of selection

		Choices (acoustic condition of audience area)		
		I	II	III
stimuli (acoustic condition of conductor's position)	I	2/5	3/5	0/5
	II	0/5	4/5	1/5
	III	0/5	0/5	5/5

As a result, subjects could select correct choices with some probability, and it is possible that subjects acquire some information from stage acoustic condition, which is contributory to estimation of acoustic condition for audience area. In the following section, the results of two experiments (experiment1 and 2) are discussed.

EXPERIMENT 1

A subject as an orchestra conductor is firstly presented with a stimulus of impulse response (not convoluted music), which is simulated as an acoustic condition at the position of conductor on the stage of an auditorium. And then the subject estimates the acoustic condition of audience area from the stimulus and answers subjective evaluation about "easiness of estimation" in the scale of 7 categories (between -3 and +3). The subject also determines the estimated acoustic condition by adjustment method, in which subject directs operator who manipulates software on the PC to process the sound decay curve of impulse response about Loudness, Energy of Early Reflection, Length.

Table 2.- Presented acoustic conditions

No.	Tsub [s]	EDT [s]
1	0.736	0.624
2	0.731	1.139
3	0.690	1.566
4	1.243	0.594
5	1.222	1.080
6	1.201	1.638
7	1.702	0.601
8	1.706	1.072
9	1.700	1.640

Stimuli are 9 combinations of acoustic conditions Tsub and EDT, shown in Table 2. Initial delay gap is 20ms constant and "A" value (amplitude of sound) is between 1.0 and 1.1 in all cases. The stimulus is presented through the headphone monaurally. 3 subjects participated in this experiment.

Results and discussion

The results of statistical variance analysis (ANOVA) of subjective value "easiness of estimation" shows that Tsub is effective at 1% significant level and EDT is also effective at 5% significant level. Figure 2 shows the relationship of Tsub and "easiness of estimation", and Figure 3 shows that of EDT and the easiness. Value of the easiness has a tendency to increase near Tsub=1.2s, while the change of the easiness by EDT is smaller than Tsub.

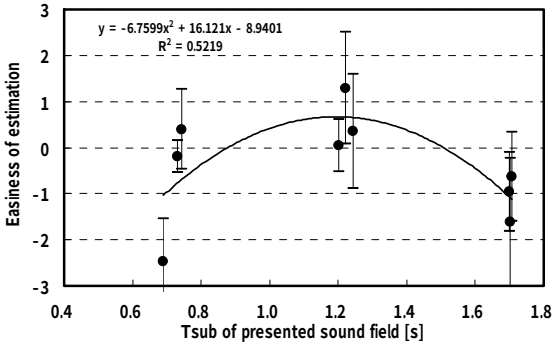

Figure 2.-Relation between Tsub and easiness

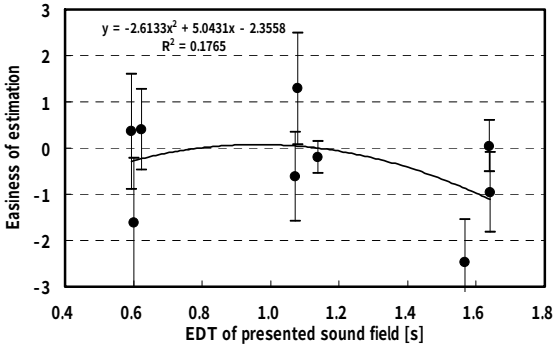

Figure 3.-Relation between EDT and easiness

Figure 4 shows that the easiness can be approximated by parabolic curve of the value calculated from Tsub-EDT (subtraction) and it reaches maximum value at Tsub=EDT. It is possible that conductor accept the equal condition of Tsub and EDT as a desired condition. The value calculated from Tsub/EDT (division) also fit parabolically but the coefficient of determination is smaller than Tsub-EDT.

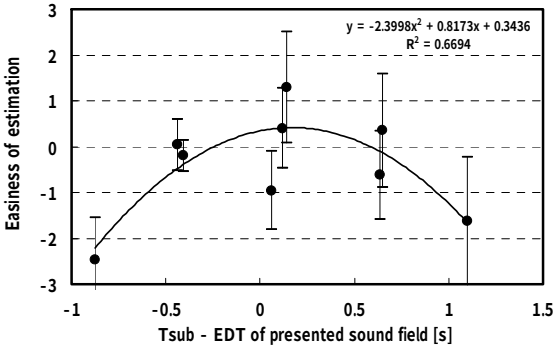

Figure 4. -Relation between Tsub-EDT and easiness

Subjects also answered about "degree of difference" (between 0 and 6) that is a subjective difference of acoustic condition between presented and determined sound field, namely, acoustic condition at a conductor's position and estimated audience area by subjects. A correlation coefficient between easiness of estimation and degree of difference is -0.478 with significance at 5% level. Figure 5 shows the relation between these subjective measurements. It is seemed that subjects feel the more difficulty about the estimation when they feel the more degree of difference.

Jordan suggested Inversion Index (II), which describes the difference of acoustic conditions between stage and audience area and it should be above 1.0 as a desired condition[5]. Figure 6 shows the relation between the easiness and Inversion Index concerning EDT (II_{EDT}) derived from presented (stage) and determined (audience) acoustic conditions. In figure 6, II_{EDT} are out of range between 1.0 and 2.0 when the easiness of estimation is low. It is assumed that when subjects feel the easiness lower, simultaneously they feel the more distance of acoustic condition between stage and audience area, and as a result, II_{EDT} becomes not realistic value.

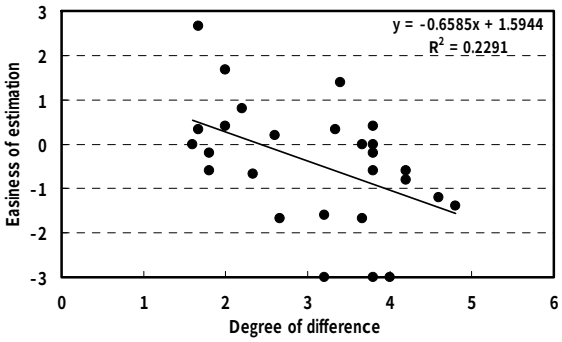

Figure 5. -Relation between degree of difference and easiness of estimation

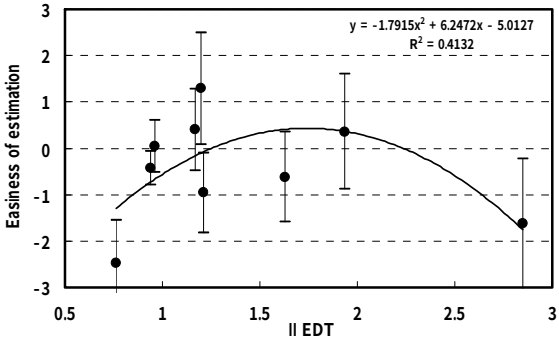

Figure 6. -Relation between II_{EDT} and easiness

Figure 7 shows the relation between Tsub of presented condition and determined sound field. It is supposed that subjects estimate a long reverberation at audience area for long Tsub at conductor's position empirically.

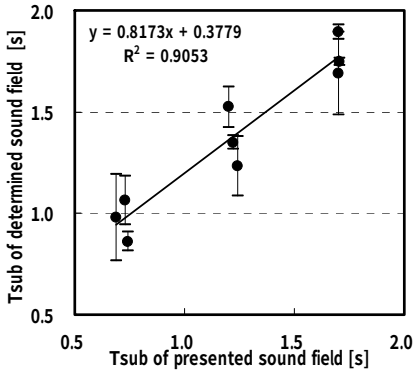

Figure 7.-Relation between presented and determined Tsub

EXPERIMENT 2

In experiment 2, a subject conducts an orchestra consisted of 2 musicians (keyboard and wind synthesizer player). They are asked to play music in the virtual stage acoustic conditions, in which played sound is effected by real-time convolution with impulse responses as stimuli. Impulse responses used as stimuli are the same as those of experiment 1. While conducting, the subject can switch between simulated stage acoustic condition and targeted audience condition, which he can edit by trial and error through operator. Then he evaluates about "easiness of estimation" and determines the acoustic condition of audience area in the same way as experiment 1. The music played is "Gavotte" composed by Gossec. Figure 8 shows the equipments and settings of experiment 2.

In the simulated acoustic condition at a conductor's position, orientation of direct sound to the subject from each player is controlled by panpot of mixer and reverberation sound is presented monaurally. On the other hand, to players, emitted direct sound by themselves is presented monaurally and sound of co-player comes from side like actual. Also, reverberation sound is presented monaurally in the same as conductor. 3 subjects participated in this experiment.

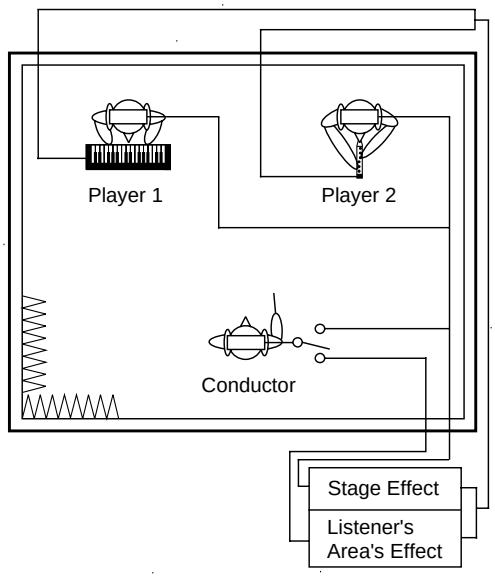

Figure 8.-Equipments of experiment 2

Results and discussion

The variance of the measured easiness of estimation is large and the change of easiness by Tsub and EDT are not significant in ANOVA. Figure 9 shows the relation between Tsub of presented sound field and the easiness of estimation. The parabolic approximation curve has a peak slightly at near the Tsub=1.2s and it has similar tendency to experiment 1. Figure 10 shows the relation between Tsub-EDT of presented sound field and the easiness. Though coefficient of determination is smaller than that of figure 4, the peak is near the zero and this tendency is similar to experiment 1.

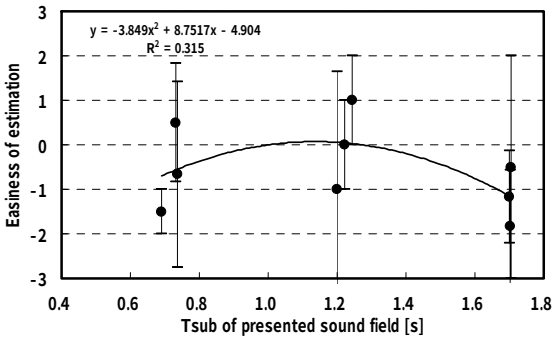

Figure 9. -Relation between Tsub and easiness

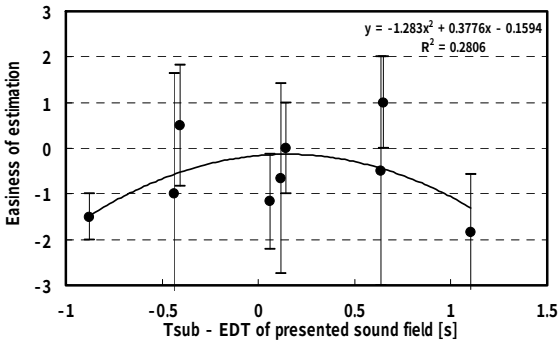

Figure 10. -Relation between Tsub-EDT and easiness

Figure 11 shows the relation between degree of difference and easiness of estimation. A correlation coefficient is -0.404 with significance at 5% level. The tendency that easiness of estimation decreases with increasing degree of difference is the same as experiment 1.

Figure 12 shows the relation between the easiness and II_{EDT} calculated from EDT of presented and determined sound field. The easiness does not change with II_{EDT}, and the change of the easiness by EDT of presented sound field is not significant in ANOVA.

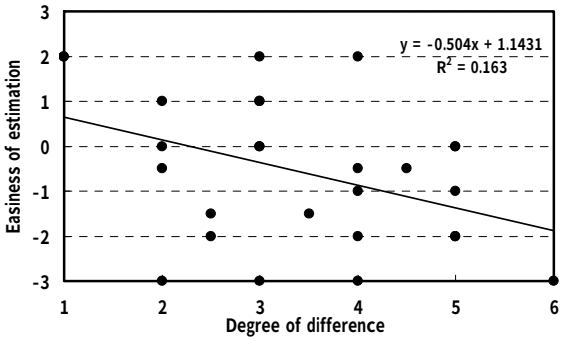

Figure 11.- Relation between degree of difference and easiness of estimation

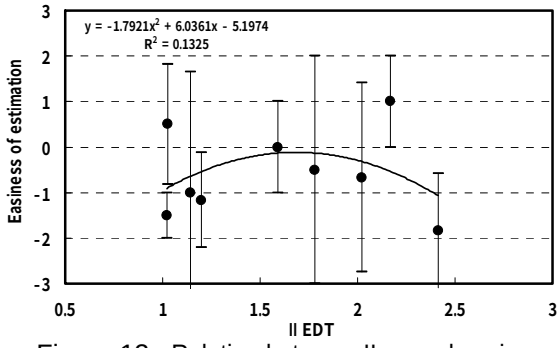

Figure 12. -Relation between II_{EDT} and easiness

Figure 13 shows the relation between Tsub of presented and determined sound filed. According to ANOVA, the change of Tsub of determined sound field is significant at 5% level (that of EDT is significant at 1% level). Tsub of presented sound field influences on Tsub of determined sound filed and it is similar tendency to experiment 1. But the regression coefficient is smaller than that of experiment 1. It is supposed that it is owing to the difference of presentation method of stimuli. When stimuli are presented through playing music, the resolution of subjects for difference between stimuli would get low and the weight of evaluation could diverge.

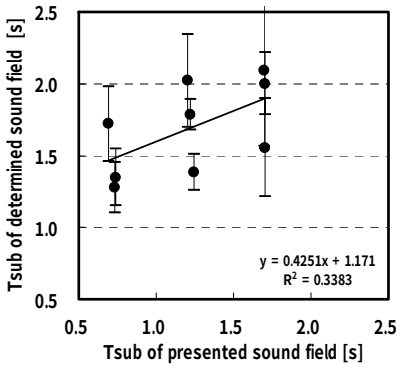

Figure 13.-Relation between presented and determined Tsub

In experiment 2, subjects also answered about "easiness of conduct" on stimuli. According to ANOVA, the change of the easiness of conduct by EDT of presented sound field is significant at 1% level but not significant by Tsub. Figure 14

shows the relation between EDT of presented sound field and the easiness of conduct. The easiness decreases with increasing EDT of presented sound field.
Figure 15 shows the relation between easiness of estimation and easiness of conduct. A correlation coefficient is 0.425 with significance at 5% level. Easiness of conduct increases with easiness of estimation.

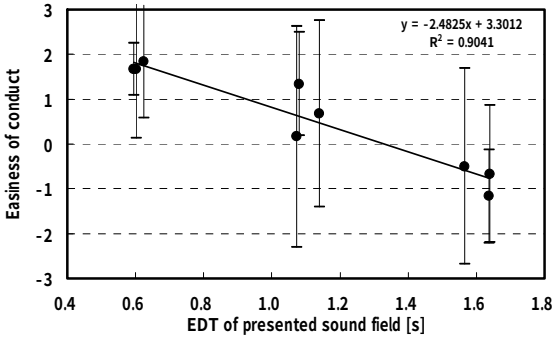

Figure 14. -Relation between EDT and easiness of conduct

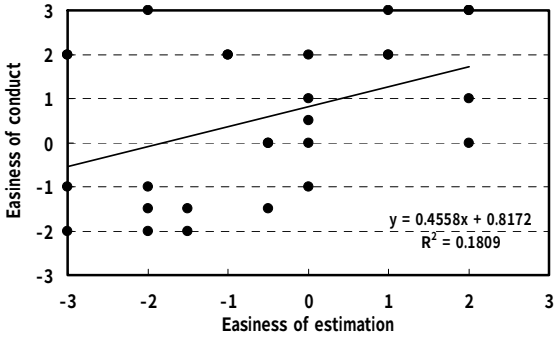

Figure 15.-Relation between easiness of estimation and easiness of conduct

Comparison between experiment 1 and 2
In the experiment 1, Tsub of presented sound fields influences on the easiness of estimation and it is able to express the easiness of estimation with Tsub-EDT. On the other hand in the experiment 2, the change of the easiness of estimation is not significant in all cases, because variance of subjective measurement is large, but the tendency similar to experiment1 still remains slightly. In the case of experiment 1 in which impulse responses are used as stimuli, subjects can detect differences between stimuli. In the case of experiment 2 in which stimuli are presented as convoluted music, the resolution of difference in the acoustic conditions by subjects become low, and the degree of conscious concentration on the estimation of subjects may go down. In the both experiments, a correlation coefficient between degree of difference and easiness of estimation is significant.

CONCLUSIONS
Though the enough examination about signification in the case of actual performance must be needed, the possibility is found that the acoustic conditions of conductor's position of a hall will have some information to contribute the estimation of acoustic condition of audience area. And it is supposed that subjective value related to easiness of estimation is effected by Tsub and EDT of the sound field in each. It is also found that easiness of estimation may be effected by the relation between Tsub and EDT, and when both are close values, easiness would become maximum.
Easiness of estimation is related to the subjective value of difference (distance) between presented stage sound field and estimated (determined) audience sound field, and the acoustic condition which makes conductor feel much difference (=distant), may be regarded difficult to estimate by conductor. Additionally easiness of estimation is also related to easiness of conduct, and the acoustic condition, which increases the easiness of estimation, would contribute to easiness of conduct and optimal stage acoustic design.

References:
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