Priority of subjective attribute in discrimination between sound fields of architectural spaces

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ABSTRACT

We can realize and discriminate the difference between sound fields of different spaces by some clue. It seems that discrimination between sound fields is due to the difference in some subjective attributes. We hypothesize that the subjective attribute, which is the ground of judgment in discrimination of sound field, is determined according to subjective weight/priority, and are discussing about modeling of mechanism in discrimination. The purpose of this study is to model the discrimination process between sound fields in architectural spaces, and that of this paper is to clarify the weight/priority of subjective attributes in discrimination judgment. Subjective experiments were carried out by using stimuli of impulse responses from existing concert halls and music data, which is made from convolution of impulse responses and dry sources. In these experiments, subjects are asked to evaluate the impression of each stimulus, and to judge the difference among stimuli in pared comparison. The results of these experiments were analyzed and the weight of each subjective attribute was estimated. It seems that for pulsing signal of sound source, the attribute related to Reverberance is dominant in discrimination, but for continuous signal, Clarity is dominant, in the case of monaural presentation of stimuli.

Keywords: Sound Field, Discrimination, Priority I-INCE Classification of Subjects Number(s): 51.1

1. INTRODUCTION

In recent years, many objective criteria by attenuation property of room acoustic energy have been suggested, and relationships with subjective attributes have been clarified. Difference limens, for such as reverberation time, Clarity, the center time, Lateral energy fraction or inter-aural cross-correlation were clarified (3~6) and there are many studies about subjective impression for sound field in concert hall and construction of assessment system for sound field. But the detail of discrimination mechanism among sound fields is not clarified. We have been studying on the factor in discrimination among sound fields and trying to clarify the weighting or priority of acoustical parameter, which discrimination is dependent on. Then it has been found that one could use subjective impression “Reverberance” or “Clarity” as a clue to one-dimensional (monaural) sound field discrimination according to the continuity of the sound signal, impulsive or continuous (1~2). When signal is impulsive like impulse response or pizzicato, discrimination seems to be done by judgment of difference in “Reverberance”, while in case of continuous signal like music discrimination seems to be due to difference in “Clarity”.

The purpose of this study is to model the discrimination mechanism for subjective difference in sound fields. In this report, in order to clarify the detail of the priority of acoustical parameters especially in case of musical signal, subjective experiments for discrimination among sound fields with various EDT and C_{80} were carried out by using stimuli, that are parts of music data made by convoluting impulse responses and dry source computationally. Results of experiments that were subjective evaluation experiment and paired comparison are statistically summarized and analyzed. Lastly the factors of subjective judgment of sound field discrimination are examined and the relationship of answer ratio of discrimination and difference of physical quantities of acoustic parameters are discussed.

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2. EXPERIMENT

The experiments were consisted of subjective evaluation for each stimulus and paired comparison between stimuli. Stimuli were 15 kinds of sound fields, with various attenuation properties and presented to subjects as a part of music "Water Music (Handel)" made from convolution of dry source with impulse response. Impulse responses were made by processing on PC from existing concert hall original, so that EDT of them could be changed at 3 levels (Group I: EDT is around 1.5s/ II: 1.8s / III: 1.2s), C_{80MID} at 0.5~1dB interval, and L_{Aeq} constant at around 79dB. TABLE 1 shows the acoustic property of stimuli. All experiments were conducted in anechoic chamber, and all stimuli were presented to subjects through a monophonic loudspeaker i.e. all stimuli are one-dimensional sound fields.

TABLE 1 – Acoustic Property of Stimuli

Gr	No	EDT[s] (500Hz)	$C_{80\ MID}$ [dB]	Tsub [s] (500Hz)	BR	Ts [s] (All Pass)	L_{Aeq} [dB]
I	**1**	1.68	2.9	1.74	0.84	0.04	79.1
	2	1.59	3.4	1.67	0.84	0.04	78.9
	3	1.57	4.2	1.71	0.86	0.03	79.0
	4	1.58	5.3	1.73	0.83	0.03	78.8
	5	1.55	6.2	1.68	0.85	0.02	79.0
	6	1.51	6.9	1.84	0.85	0.02	79.2
II	**7**	1.89	2.2	1.92	0.86	0.05	78.9
	8	1.93	3.5	1.78	0.87	0.03	78.9
	9	1.84	4.1	1.39	0.92	0.03	79.0
	10	1.88	5.1	1.64	0.93	0.03	79.2
	11	1.81	5.7	1.52	0.93	0.03	79.1
III	**12**	1.23	2.6	1.60	0.84	0.07	78.9
	13	1.20	4.2	1.67	0.83	0.05	78.9
	14	1.19	5.0	1.61	0.84	0.03	78.9
	15	1.20	5.9	1.51	0.89	0.03	78.9

TABLE 2– Adjective Pairs of Subjective Evaluation

Impression item	Adjective pair	
Clarity	Clear	Unclear
Distinctness	Distinct	Ambiguous
Sharpness	Sharp	Dull
Thickness	Thick	Thin
Liveness	Wet	Dry
Reverberance	Long	Short
Sense of Distance	Near	Far
Spaciousness	Spatial	Flat
Extent of space	Large	Small

For the first of experiment, subjective evaluation for each stimulus was performed. Subjects answered their responses to stimuli presented at random order, in adjective pair of the subjective impression, 7 step category scales, shown in TABLE 2.

For the next of experiment, paired comparison was conducted for round robin of stimuli. Subjects were presented with each stimuli pairs one after another, and asked about whether the same impression or different among each pair. Additionally if subjects answer as different, they also have to answer the degree of difference in each impression item shown in TABLE 2. Each subject performed comparative judgments for total 105 pairs of 15 stimuli. Eight subjects who understand acoustic properties and subjective attributes participated in each experiment.

In this experiment, stimulus is presented as a monaural signal, and "Spaciousness"=Apparent Source Width or Envelopment cannot be evaluated exactly.

TABLE 3 – Results of Factor Analysis

Factor	All	Group I	Group II	Group III
1st	Clarity Distinctness Sharpness	Clarity Distinctness Sharpness	Clarity Distinctness Sharpness	Clarity Distinctness Sharpness
2nd	Spaciousness Thickness Liveness	Spaciousness Thickness Extent of Space Liveness	Spaciousness Thickness Extent of Space	Spaciousness Thickness
3rd	Sense of Distance	Sense of Distance	Reverberance	Sense of Distance Extent of Space
4th	Reverberance	Reverberance Liveness	Sense of Distance	Liveness
-	Extent of Space	-	Liveness	Reverberance

3. RESULTS AND DISCUSSION

3.1 Factor Analysis

Table 3 shows the results of factor analyses for experiments. In every mode of analysis, it is found that items relating ”Clarity” are derived as the first factor, and items relating “Reverberance" are derived as lower factors. This is consistent with experimental conditions in which C_{80} is varied and EDT is constant at each mode except “All”. And the result of “All” mode means that discrimination of subjects is mainly due to “Clarity”. But “Spaciousness” or ”Thickness” is derived as the second factor and the relationship with physical quantity cannot be realized.

3.2 Difference of Physical Quantity and Answer Ratio

Figure 1~4 show the results of comparing the difference of physical quantity between stimuli. Horizontal axis means answer ratio of “different” in subjective total judgment of discrimination for sound fields. In these figures, ”Ts” is shown in 10 times original value, and stimulus with large C_{80MID} value are ranked high among stimuli with the same answer ratio.

In Figure 1~3, the lower answer ratio becomes, the larger the difference of C_{80MID} becomes. On the other hand, even if the difference of C_{80MID} is large, answer ratio sometimes can be high. It seems to be due to the difference of other parameter than C_{80} or EDT. In Figure 4, the lower the answer ratio becomes, the smaller the difference of C_{80MID} between stimuli becomes. And in stimuli pairs with higher answer ratio (>=63%), there is a tendency that difference of EDT is large when the difference of C_{80MID} is small. In stimuli pairs with lower answer ratio (<=50%), there is a tendency that the difference of C_{80MID} and T_s is small but EDT is comparatively large.

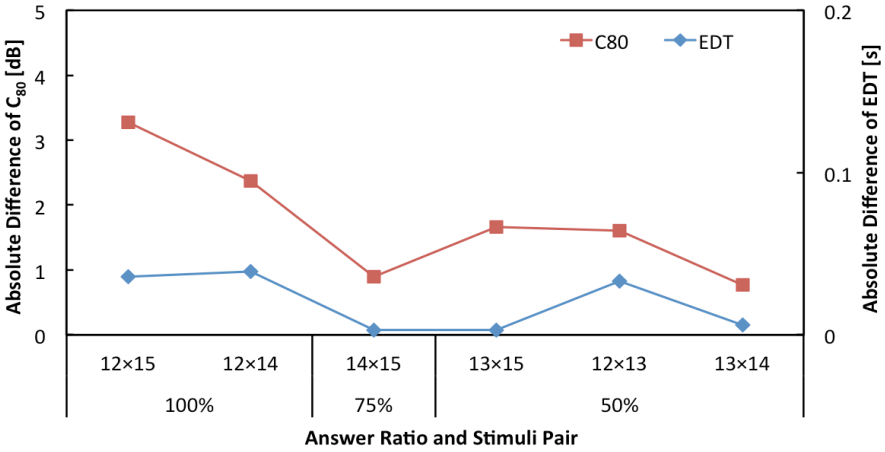

Figure 1 – Difference of C_{80}/EDT and Answer Ratio (Stimulus Group I)

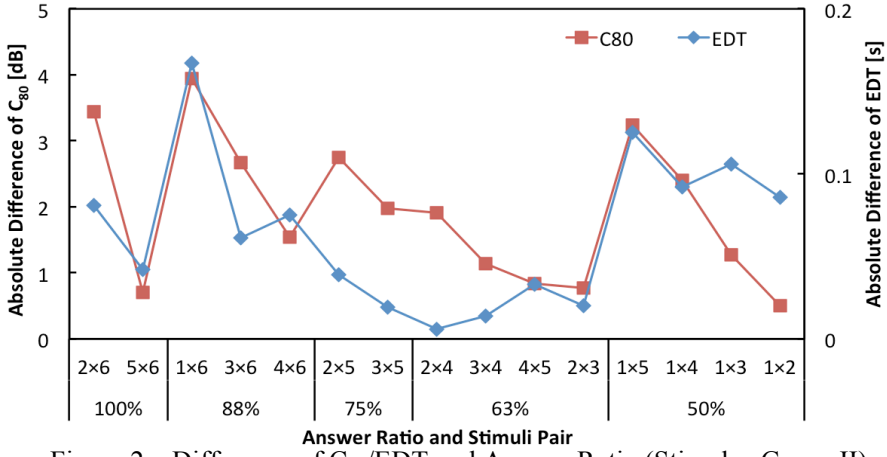

Figure 2 – Difference of C_{80}/EDT and Answer Ratio (Stimulus Group II)

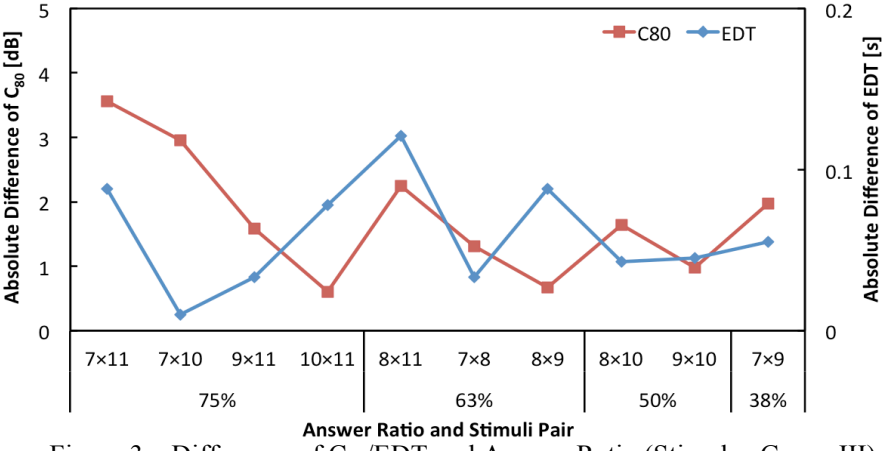

Figure 3 – Difference of C_{80}/EDT and Answer Ratio (Stimulus Group III)

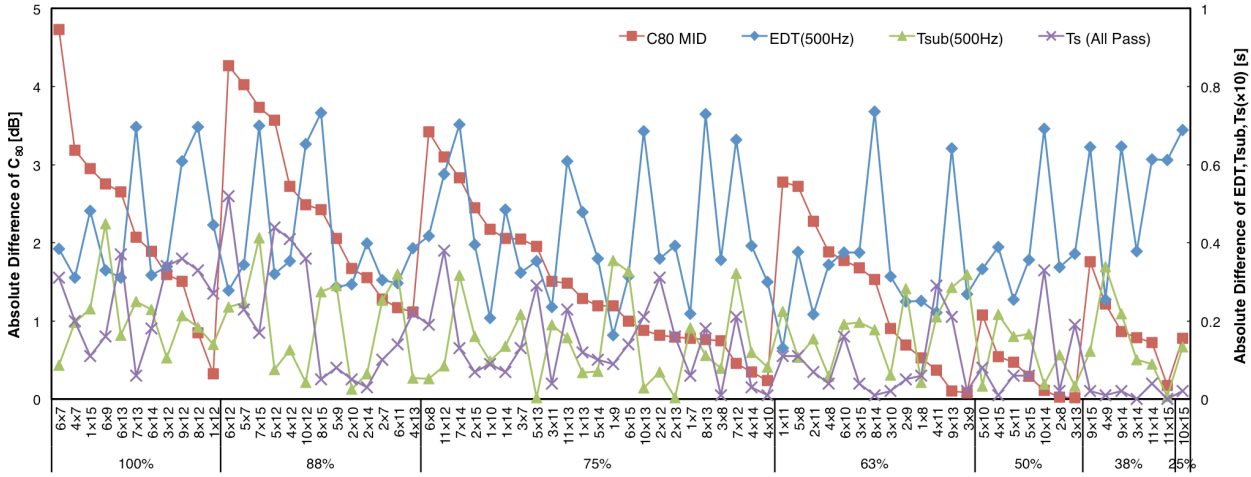

Figure 4 – Difference of Physical Quantity (vertical axis) and Answer Ratio (horizontal axis)

3.3 Physical Quantity and Scores in Paired Comparison

Figure 5~8 shows the scores from the results of paired comparison by multiple regression analysis. In Figure 5~7 for stimuli with each EDT level, the ranking of each stimulus mostly corresponds to physical quantity related to each subjective impression. In Figure 6, stimuli belonging to Group II (EDT is around 1.8s) have smaller distribution than Group I or III. On the other hand, in Figure 8 for all stimuli, scores for stimuli belonging to Group I (EDT~1.5s) seem to be further away from Group II (EDT~1.8) than Group III (EDT~1.2s). And order of score distribution is not always due to EDT values (II>I>III).

Figure 9~11 shows the analysis on relationships between score ranking and physical quantities. In each figure, horizontal axis means stimulus placed in the score ranking order. In Figure 9, in term of "Reverberance", the score ranking of stimuli has relationships with the value of C_{80MID} (coefficient of determination R^2=0.71). In Figure 10, about "Clarity", there is relationship of score ranking with C_{80MID} (R^2=0.65) and T_s (R^2=0.75). In Figure 11, about "Spaciousness", it seems that dependence of C_{80MID} or T_s becomes lower.

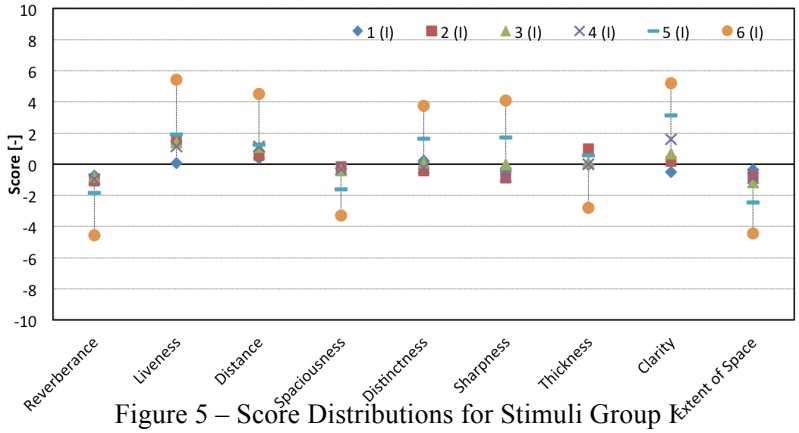

Figure 5 – Score Distributions for Stimuli Group I

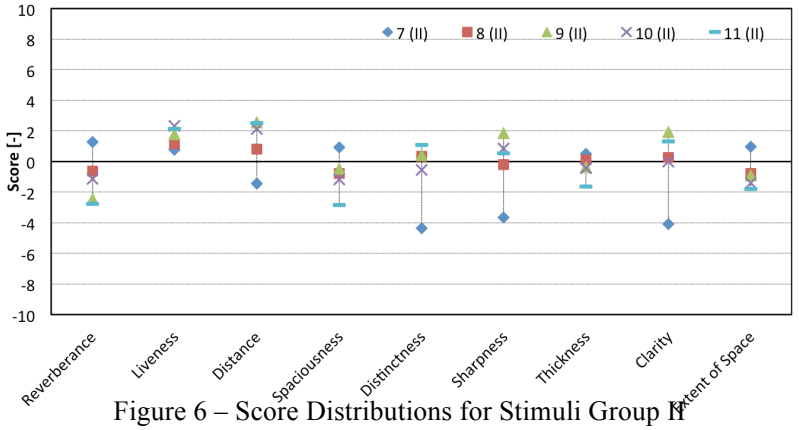

Figure 6 – Score Distributions for Stimuli Group II

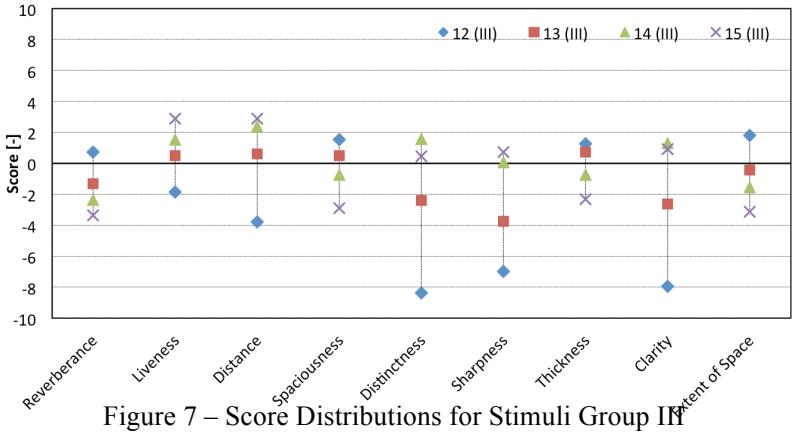

Figure 7 – Score Distributions for Stimuli Group III

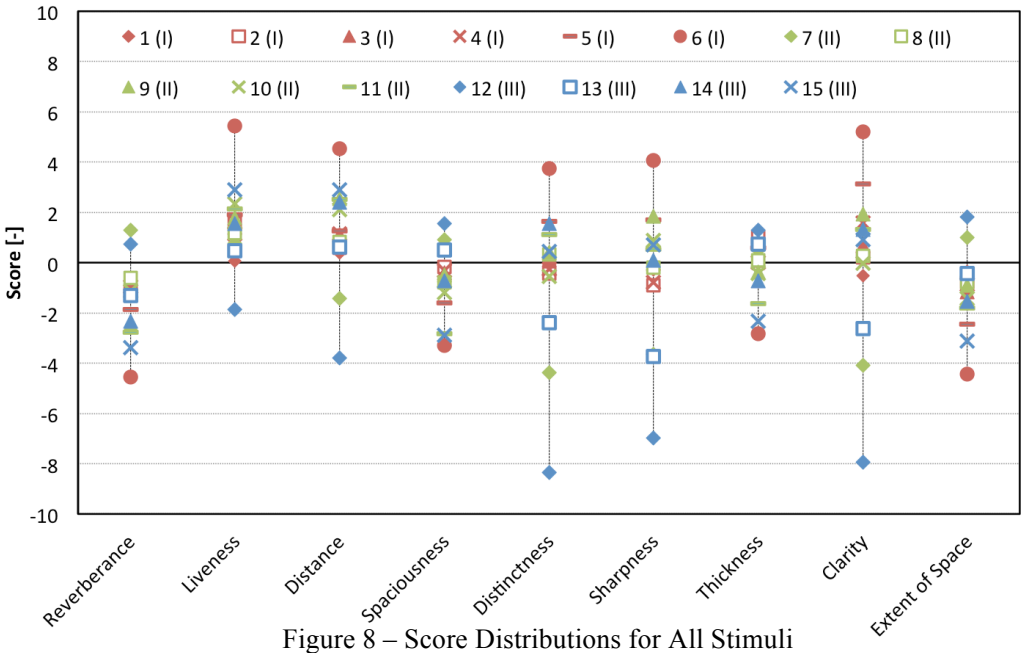

Figure 8 – Score Distributions for All Stimuli

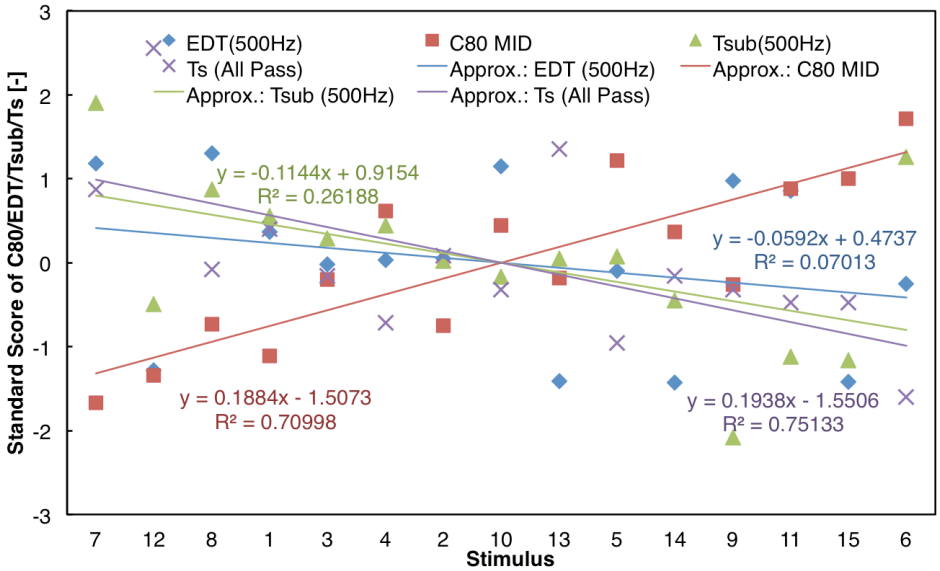

Figure 9 – Score Ranking of "Reverberance" and Physical Quantity

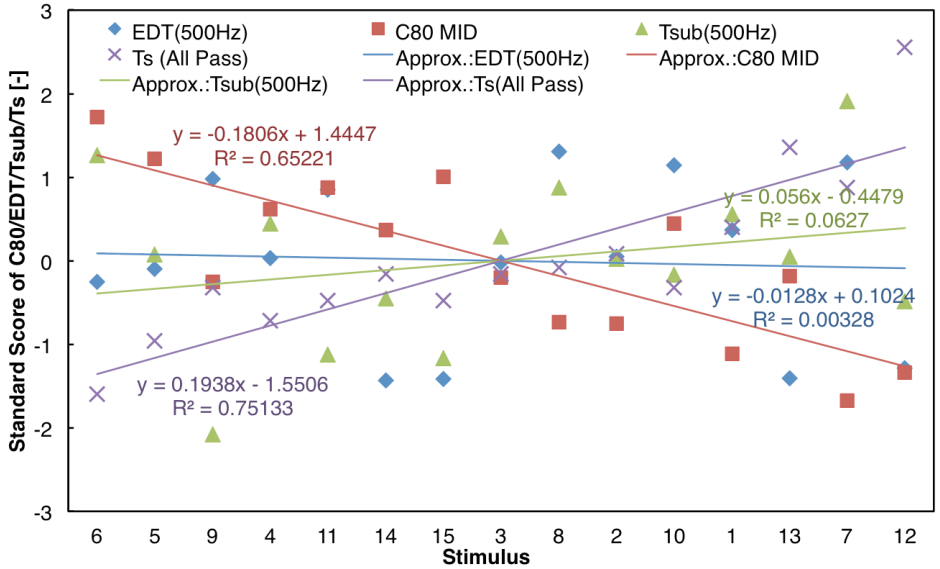

Figure 10 – Score Ranking of "Clarity" and Physical Quantity

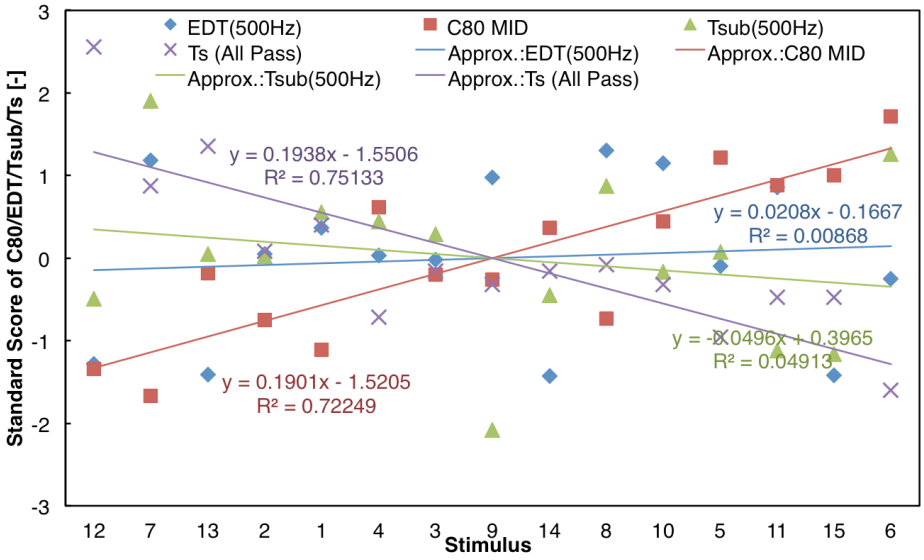

Figure 11 – Score Ranking of "Spaciousness" and Physical Quantity

4. CONCLUSIONS

The following knowledge is obtained in this paper

- Determinant of discrimination can be changed according to continuity of sound signal. In this paper, continuous signal: music is dealt with.
- Experiment of subjective evaluation and paired comparison were carried out by using stimuli of sound fields, with 3 levels of EDT and some distance of C_{80}.
- Result of factor analysis on subjective evaluation shows "Clarity" as the first factor.
- Result of paired comparison shows that answer ratio of "different" in discrimination among sound fields becomes higher, when the difference of C_{80} values would be larger between sound fields.
- Score calculated from paired comparison shows that most aspects of subjective impression are relatively related with C_{80}.
- In case of continuous signal, "Clarity" seems to be the most dominant and dependent factor in discrimination among sound fields. And it seems that if sound fields of "Clarity" are equal, discrimination among them could be done by the next factor "Reverberance".

As future works, experiments by using stimuli of 3-dimensional (binaural) sound fields will be carried out and priority of "Spaciousness" will be examined in sound field discrimination.

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