SUBJECTIVE MEASURES TO EVALUATE SPEECH INTELLIGIBILITY, QUALITY AND DIFFICULTY IN ROOMS FOR YOUNG AND ELDERLY LISTENERS

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1. INTRODUCTION

Although many studies have evaluated speech transmission in rooms, they have used many different techniques making it difficult to compare their results. This paper presents an overview of several studies carried out by the author in Japan. They include relations between subjective measures to evaluate speech intelligibility (syllabic articulation, word recognition in sentences, sentence recognition) and objective acoustical measures. They also include consideration of different ideas for evaluating speech transmission quality in terms of easiness of speech perception (using paired comparison tests) and perceived difficulty of listening to speech. All experiments were carried out in simulated sound fields. These studies also compared the characteristics of elderly listeners and younger listeners for each measure.

2. SPEECH INTELLIGIBILITY TEST AND EASINESS OF SPEECH PERCEPTION

2.1 Speech intelligibility test

Figure 1 shows the results of speech intelligibility tests of young subjects in reverberant fields [1][2]. The experimental fields were reproduced in an anechoic chamber using an electro-acoustics system. Subjects were asked to write down what they heard for word intelligibility and syllabic articulation and were asked to write the response to questions and commands for sentence indelibility. Word intelligibility and syllabic articulation may not identify significant differences among sound fields even if subjects noticed the difference in conditions. Sentence intelligibility did decrease with reverberation time up to 3 s. Although the results suggest that sentence intelligibility seems to be good measure, it has the following problems : (1) to avoid learning effects, each sentence could be presented only once to each subject, (2) it is difficult to control the degree of difficulty of questions and commands, (3) subject's knowledge could affect the results. These problems cause large scatter in the results.

2.2 Easiness of Speech Perception

Figure 2 shows Easiness of speech perception with the paired comparison method[2][3]. After listening to a pair of sentences presented in different conditions, subjects rated the differences in 1 of 5 categories. The results can describe the significant differences of each pair of conditions and were highly correlated with Speech Transmission Index and some other physical indices. Easiness can identify differences among of each conditions for speech perception more precisely than speech intelligibility measures.

3. EASINESS IN AUDITORIUM AND MULTI DIMMENSIONAL SCALING ANALYSIS

To confirm Easiness can be applied to actual sound fields, Easiness was measured in simulated sound fields reproduced in an anechoic chamber with binaural impulse responses measured in 20 auditoriums with and without a sound reinforcement system [3][4]. Young subjects were used for this experiment. Figure 3 shows the relation between physical values of C50 obtained from impulse responses measured with an omni-directional microphone. Separate relationships are found for without-sound system and with system conditions. To find factors related to the systematic differences of each condition, Multi Dimensional Scaling (MDS) analyses were carried out and obtained a four-dimensional space for Easiness.. Figure 4 presents the plane of the first dimension (D1) and second dimension (D2) with the results of regression analyses of several

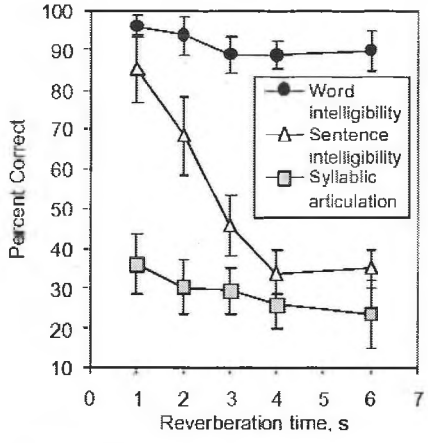

Figure1. Relation between reverberation time and speech intelligibility scores in reverberant fields. Error bar shows standard deviation.

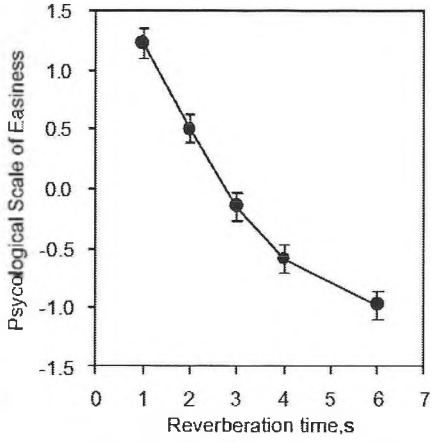

Figure2. Relation between Easiness of speech perception obtained by paired comparison method. Error bar presents yardstick ($p<0.05$).

acoustical indices with psycho-acoustical measure. It was found that STI and D1 were well correlated (R=0.90) but there aren't any indices describing other dimensions clearly. IACC and wD50 (frequency-weighed D50) show correlation but both of them are not enough to describe other factors. Binaural factors and frequency characteristics are expected to have some effects on Easiness. Another problem with Easiness is that Easiness can evaluate only relatively and cannot indicate how easy is good enough for speech communication in rooms. This is the reason why listening difficulty is presented with absolute numbers for rating the conditions.

4. RELATION BETWEEN SCORES OF YOUNG LISTENERS AND THOSE OF ELDERLY LISTERS

Several speech intelligibility tests were performed in noise and/or reverberation in experimental sound fields with young and elderly listeners[1][5]. Figure 5 shows the relation between speech intelligibility scores of young listeners and those of elderly listeners. It can be said that scores of elderly listeners are 25% lower than those of young listeners for all speech intelligibility measures.

Figure 6 shows the relation of listening difficulty between young and elderly listeners in reverberant fields. As the regression line shows, the variation of listening difficulty for elderly listeners is half that of the young listeners and even when no young listener feels difficulty, 50% of elderly listeners felt difficulty when they heard the speech.

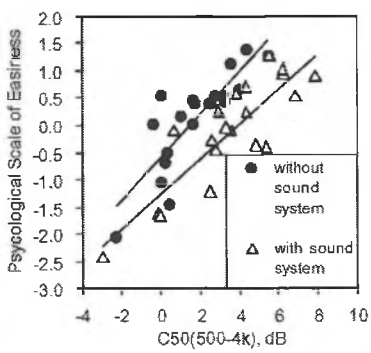

Figure 3. Relation between C50 and Easiness of speech perception in simulated sound fields of auditoriums.

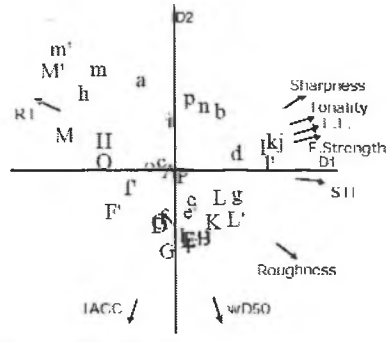

Figure 4. D1-D2 plane as a result of MDS analysis of Easiness. Results of regression analysis with psycho-acoustical measures and acoustical indices are also presented.

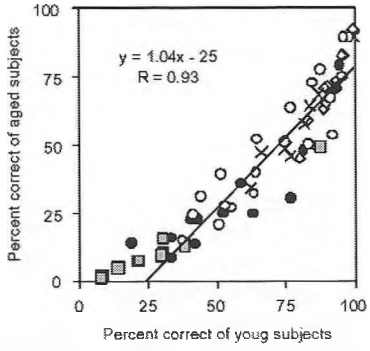

Figure 5. Relation between speech intelligibility scores of young and aged subjects in noise and/or reverberation. Different symbols present different measuring condition and measuring method.

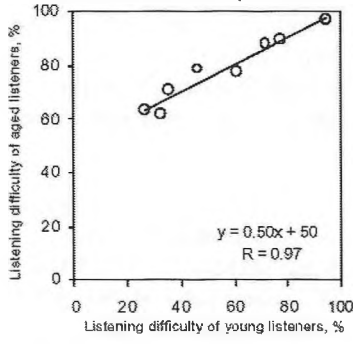

Figure 6. Relation between speech listening difficulty of young subjects and aged subjects in reverberation.

5. SUMMERY

Figure 7 illustrates how an ideal physical index would evaluate acoustical conditions for speech for the young and the aged. Speech intelligibility tests could be applied for zone (a) and listening difficulty used in zone (b) for young listeners. Signal-to-noise ratio works for conditions with ambient noise and without reflections. In terms of S/N, a 25% difference of scores between the young and the aged corresponds to 5dBA signal-to nois e ratio [1] in zone (a).

Although zone (c) is good enough for young listeners, conditions in this range will still be inadequate for aged listeners and listening difficulty of aged listeners should be investigated. Easiness is a good measure to study factors that have an effect on speech transmission even if it is relative rating. Each speech rating measure is useful over different specific limited ranges of physical measures. Thus each best describes different aspects of speech transmission conditions.

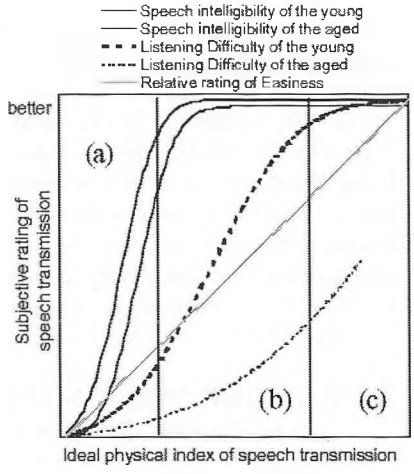

Figure 7. Illustration of relation between ideal physical index of speech transmission and subjective ratings of speech transmission.

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