A STUDY ON THE TONAL DISCRIMINATION TEST IN SENSORINEURAL DEAFNESS USING ABX PROCEDURE

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Introduction

Speech perception is the most important function of the human ear, and it involves complex perceptual processes that are concerned with amplitudes and frequencies of sound components. It is necessary for a good ear to have a minimum discriminative ability to sound intensity, which is considered as an acoustic measure to be related with loudness. The determination of the difference limen in intensity is one of the most important procedures to diagnose certain hearing impairments. Compared to intensity, pitch has been little studied for clinical purposes. In general, previous studies in pitch perception have been concerned with data of the difference limen in frequency (DLF) of pure tones obtained from normal subjects. It is said that the first investigation on DLF was performed by Delazenne in the last century, obviously without the advantage of the quantitative control and measurements by means of modern electronic techniques. An extensive study on DLF for normal subjects was performed by Shower and Biddulph in 1931. [1] It is well known that the relative DLF, in terms of the ratio of frequency increment to frequency, diminishes with an increase in frequency at first, but then it remains fairly constant from 1000 Hz upward. Studies on DLF for pathological ears had been seldom reported until recently. Also, the relation between pitch discrimination of pure tones and timbre discrimination seems to be little-known for pathological cases. In order to interpret impairments in speech sound perception, it seems desirable to obtain data on timbre perception rather than pure tone DLF, particularly in a relatively low frequency region; the sensory mechanisms involved in the two cases may be essentially different from each other. In this study, rather than vowel-like periodic sounds, random noise through a resonant circuit was used in order to avoid complication due to effects of the harmonic structure on

the timbre judgment.

Procedure

1. Subjects

There were five groups of subjects who participated in this experiment. Group 1 were patients who were diagnosed clinically as suffering from the endorgan (cochlear) deafness. Their audiograms were flat or gradually tapered upward indicating some additional high frequency loss. To avoid possible audiological changes caused by aging, patients under forty years of age were used. Group 2 were patients who showed sensorineural deafness for low tones. This group was characterized by increased thresholds for both air and bone conductions in the lower frequencies, the thresholds in the higher frequencies being almost normal. In this group, also, only patients under forty years of age were tested. Group 3 were patients of neural deafness suffering from acoustic tumor or cerebello-pontine angle tumor as determined clinically or surgically. Group 4 were persons over sixty years old who had no complaints of hearing impairments. Their pure tone audiograms were mostly normal within 10 dB in high frequencies. Subjects in this group were either identified or suspected as suffering from the presbycusis in a limited sense, having lesions in the central nervous system, and were separated from the normal subjects in our score analyses. Group 5 were young persons under twenty-five years of age showing normal hearing.

The sensorineural deafness may be grossly subclassified into endorgan and retrocochlear deafnesses, and has been generally considered to be caused by damages at various locations in the cochlea or the retrocochlear pathway. The retrocochlear deafness in previous studies has been identified anatomically as a peripheral nerve deafness which is caused by some lesion in the VIIIth nerve as in the case of our Group 3 or the central nerve deafness which is caused by lesions in the region from the brain stem to the auditory cortex (Group 4). The presbycusis in a limited sense was assumed to be the central nerve deafness because it showed some psychoacoustic phenomena which did not indicate endorgan deafness or peripheral

nerve deafness.

2. Tests

The following kinds of stimuli were used for evaluating the subjects' hearing abilities.

i. Pure tone audiometry

The pure tone thresholds were determined in all subjects by the conventional method of audiometry. The test was performed in the sound-treated room using standard audiological equipment.

ii. Speech discrimination test

Speech discrimination was examined in an identification test by use of unfiltered speech stimuli. A standard recording of utterances was copied onto magnetic tape and the sound stimuli were given to each subject through a high quality receiver headset using an attenuator for level adjustments. The test was performed at 80 dB SL for the normal subjects (Group 5) and at the most comfortable level between 80 and 100 dB SL for each of the hearing impaired subjects (i. e., Groups 1, 2, 3 and 4).

iii. Distorted speech discrimination test (1200 Hz Low Pass)

Distorted speech signals carry less redundant information than normal speech, and discrimination tests using such test materials have been developed by some investigators for diagnosing the retro-cochlear lesions.[2, 3, 4, 5] The distorted speech discrimination test as developed by Shitara[5] was employed in this study. The test stimuli, a set of selected Japanese monosyllables, were distorted through a low pass filter with a cut-off frequency of 1200 Hz, and subjects identified each item.

iv. Tonal dsicrimination test

(a) Stimuli: White noise signals were generated within a computer (PDP-9) and fed through a hardware simple-resonance circuit (single formant circuit) for generating the stimuli in this experiment. In all cases, Q of the resonance was held constant; the 3 dB-down frequencies were off the resonance frequency by

±10%. The test was performed in three different frequency ranges, viz., by use of three different filter conditions with the resonance frequencies at one of 500 Hz (low frequency), 1500 Hz (middle), and 3000 Hz (high).

(b) Experimental method: An ABX test procedure was employed, where the subjects were asked to judge whether the third stimulus was the same as the first or the second, with the knowledge that either A or B was the same as X. Stimulus durations were all 1.5 sec, including two 1/4 sec long portions with a tapered amplitude on both ends. The inter-stimulus intervals were 0.8 sec within each ABX, and the time assigned for judgments and marking was 5.2 sec. The intensity of sound stimuli was kept at the most comfortable level, which turned out to be between 70 to 100 dB in sensation level.

Results

1. Correlation between the pure tone threshold and speech discrimination scores

1.1 Pure tone vs. unfiltered speech

In Figure 1, the hearing acuity of each subject is shown by the abscissa and the undistorted speech discrimination score by the ordinate. It is shown that in Group 1, all patients having hearing losses within 30 dB have good discrimination scores of over 70% even though there is seen some negative correlation between the speech discrimination score and the pure tone threshold. Group 2 shows similar results, but some patients having good hearing acuity show poor discrimination scores. In Group 3, it was observed that six ears out of 13 whose hearing had losses within 30 dB showed markedly deteriorated discrimination scores. All subjects in Group 4 show more or less deteriorated discrimination in spite of no complaints about hearing impairments. The normal subjects in Group 5 show scores above 80% in the discrimination.

1.2 Pure tone threshold and filtered speech discrimination score:

The correlation between the pure tone threshold and the 1200 Hz low-

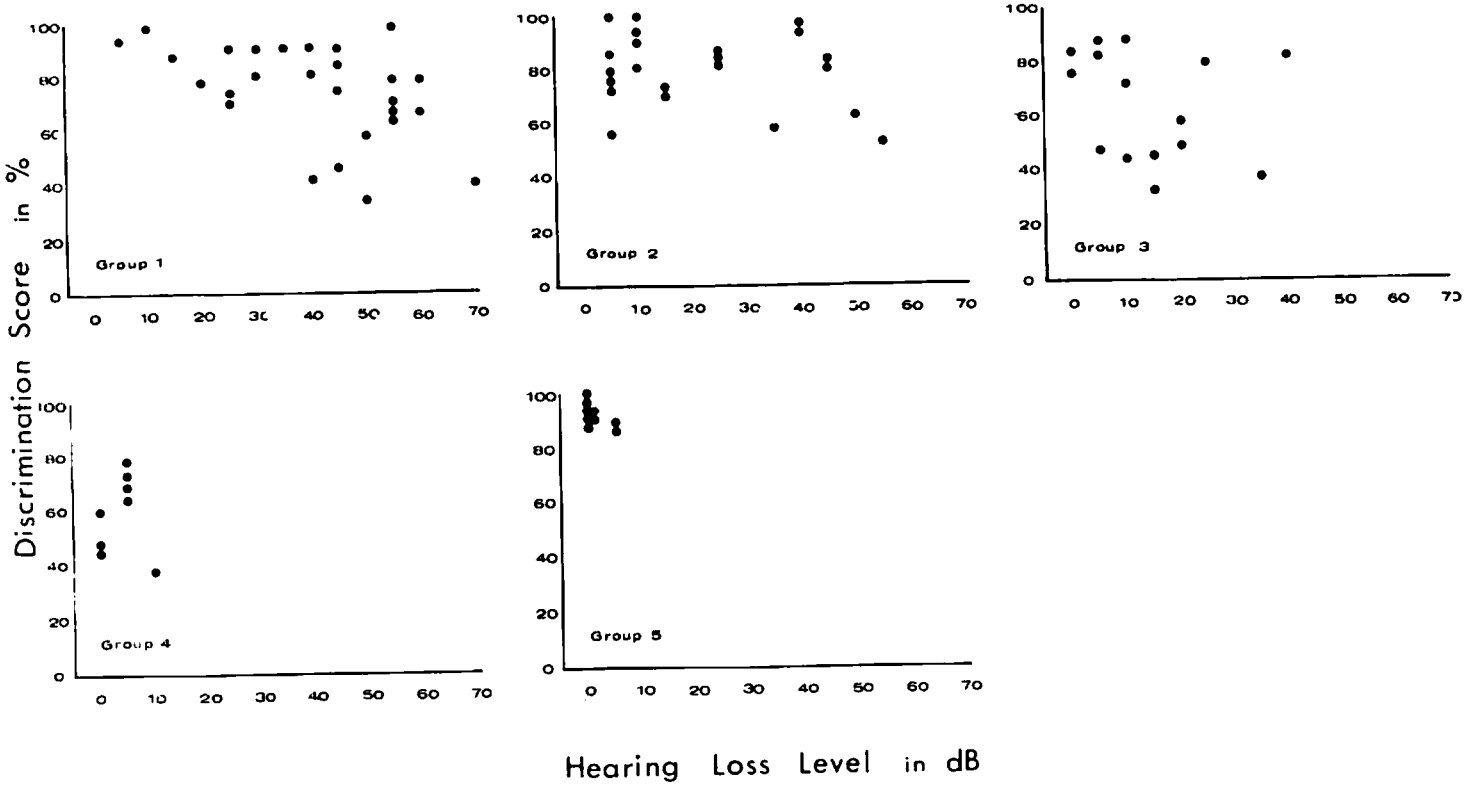

Fig. 1. Pure-tone hearing threshold and unfiltered speech discrimination.

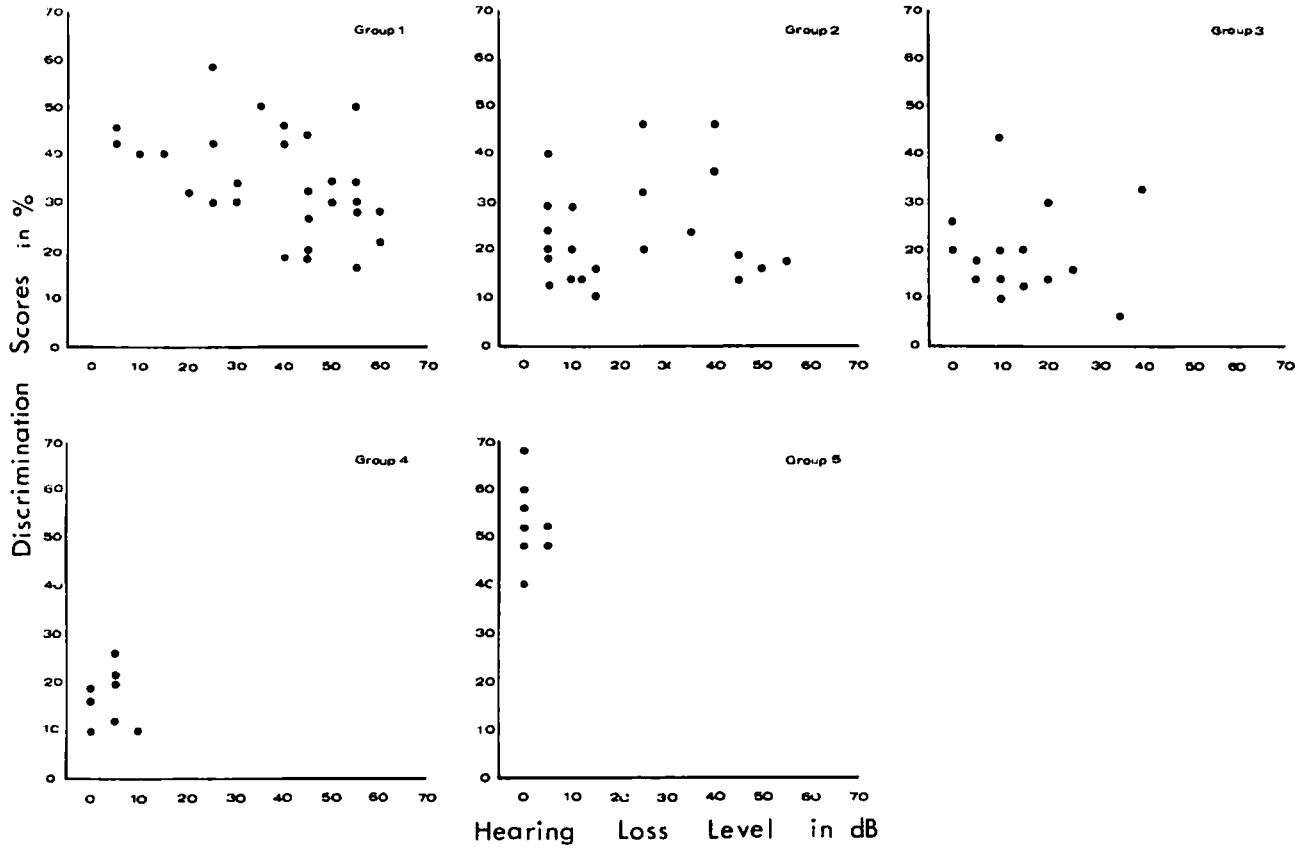

Fig. 2. Pure-tone hearing threshold and filtered speech discrimination (1200 Hz low pass).

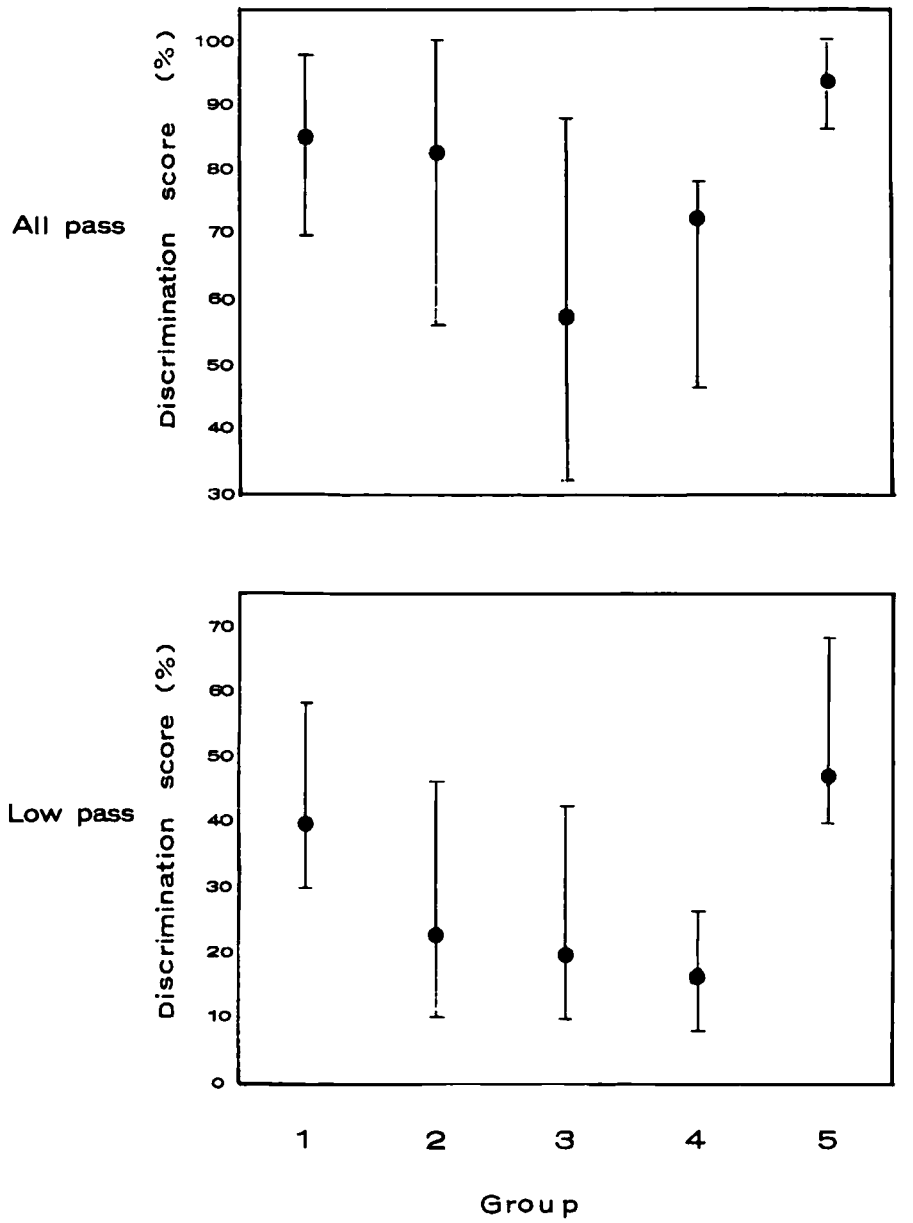

Fig. 3. The range and mean of discrimination scores for unfiltered and filtered speech for the subjects having losses within 30 dB.

passed filtered speech discrimination is shown in Figure 2. The speech discrimination scores of filtered speech were poor in the cases of the retrocochlear lesions, i. e. in Group 3 and Group 4 and it was also poor in Group 2. In these groups even the patient whose hearing thresholds were within 30 dB had discriminations of generally lower than 30%. The result of Group 1 shows in contrast a general correlation between speech discrimination and pure tone hearing. It can be seen, over all the different groups, that where there is a severe hearing loss, then speech discrimination is also limited. The correlation between speech discrimination and pure tone hearing in those subjects whose audiograms showed fair hearings with losses within 30 dB is shown in Figure 3. In this figure the range of variation is shown by the vertical line and segments and dots indicate the mean value. The speech discrimination scores appear to be heavily dependent upon the location of damage. The dependence is particularly distinct in the filtered speech discrimination test, in which subjects of Group 4 showed the poorest discrimination score regardless of their hearing loss level.

2. Tonal discrimination test

2. 1. Tonal discrimination score

The tonal discrimination scores for all subjects whose correct responses showed 75% (18 our of 24 test stimuli) or more are shown in Figure 4. In this figure, the discrimination score is shown by the ordinate and the resonance frequencies of the test stimuli by the abscissa.

Group 1, in general, shows good discrimination, nearly as good as in Group 5, in spite of the widely distributed hearing thresholds. The retrocochlear deafness, Groups 3 and 4, indicates considerably lower tonal discrimination scores and Group 2 is located between the cochlear deafness and the retrocochlear deafness. It seems that the tonal discrimination becomes generally worse as the frequency increases.

The number (in percentage) of the ears in each group that responded correctly to 18 or more out of 24 test stimuli is shown in Table 1 for each frequency range. In Group 1, 28 ears out of 29 in the low frequency range, 27 ears out of 29 in the middle frequency range and 21 ears out of 25 in the

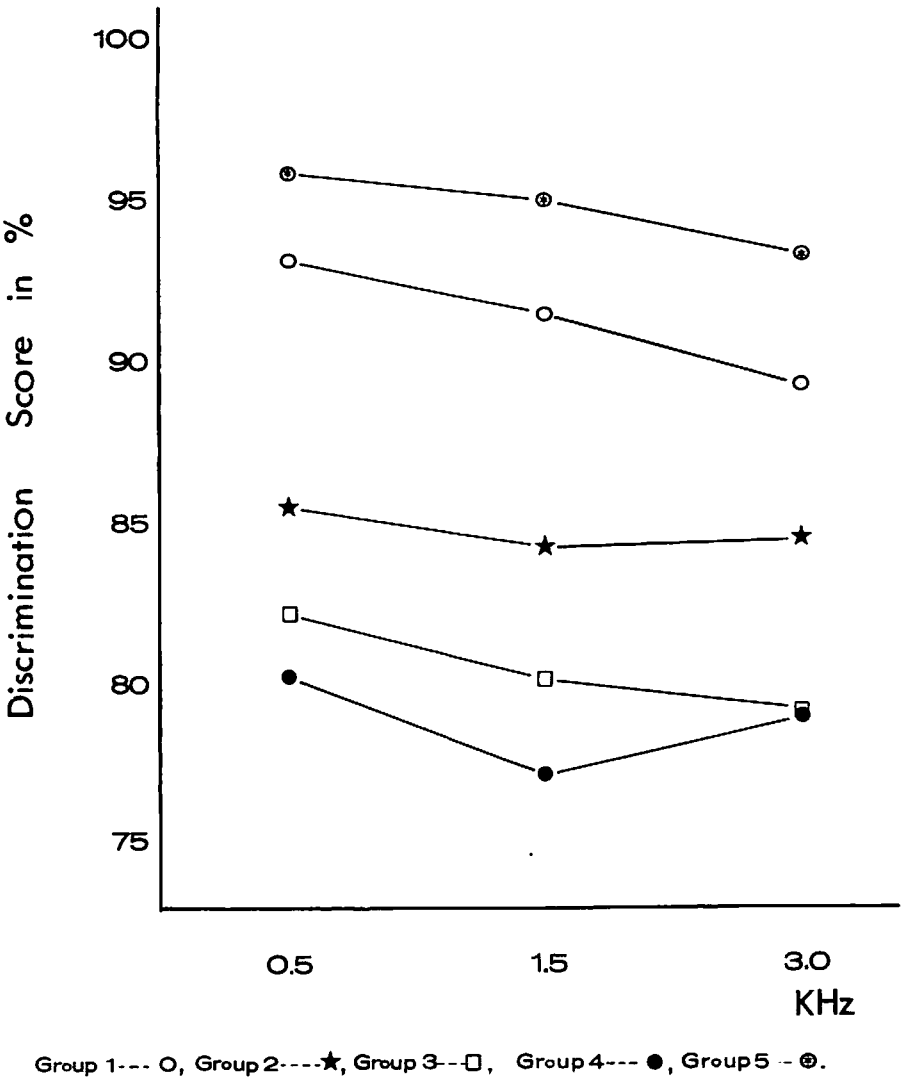

Fig. 4. Tonal discrimination score.

high frequency range showed 75% or more correct responses. But in Groups 2, 3 and 4, the number of the ears which showed 75% or more correct responses was considerably lower in percentage than in Group 1. Group 5 showed 75% or more correct responses in all tested ears.

In order to measure the correlation between tonal discrimination and pure tone threshold, subjects in each of the five groups were subdivided into three subgroups according to the severity of their hearing loss.

Table 1. The number, in percent, of ears that gave better tonal discrimination scores (18/24 or more correct).

	500 Hz	1500 Hz	3000 Hz
Group 1	96.6	93.1	84.0
Group 2	54.5	68.1	54.5
Group 3	66.7	33.3	20.0
Group 4	50.0	25.0	12.5
Group 5	100.0	100.0	100.0

In order to measure the correlation between tonal discrimination and pure tone threshold, subjects in each of the five groups were subdivided into three subgroups according to the severity of their hearing loss. Table 2 shows the tonal discrimination scores of subclasses of subjects with varying degrees of hearing impairment (for different frequencies of the test stimuli). As the pure tone threshold at 1500 Hz in this table, the mean value of the thresholds at 1000 Hz and 2000 Hz is given and the threshold at 3000 Hz is the mean of those at 2000 Hz and 4000 Hz. Within Group 1, the tonal discrimination may be slightly worse when the hearing loss is higher, but generally, the subjects of this class seem to maintain a good discriminative ability. In Group 2, the tonal discrimination scores of the subgroup with hearing loss above 40 dB appear even better than the 15 dB group.

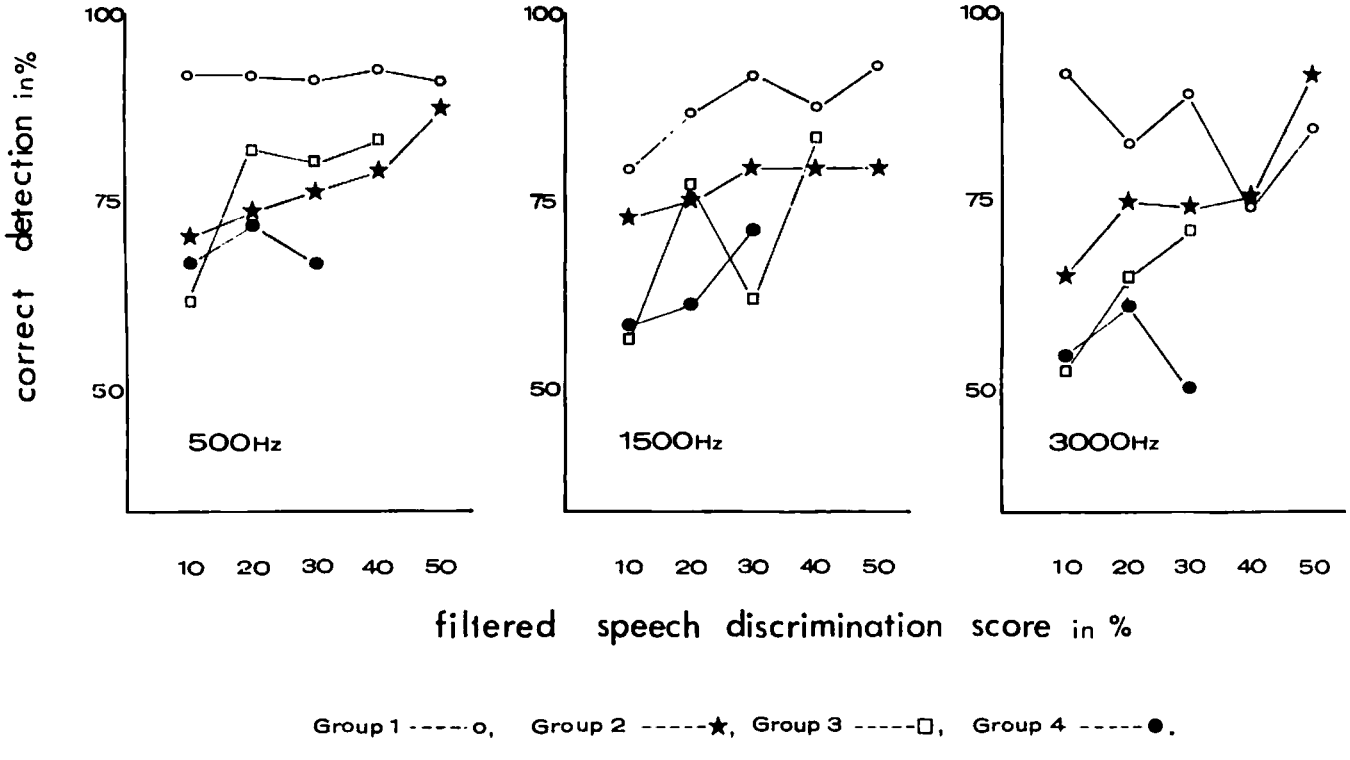

Fig. 5. Tonal discrimination and filtered speech discrimination (1200 Hz low pass)

Table 2. Tonal discrimination scores of patients subclassified in terms of pure tone thresholds.

	500 Hz			1500 Hz			3000 Hz		
hearing loss in dB	0-15	20-35	40-	0-15	20-35	40-	0-15	20-35	40-
Group 1	97.1	95.0	88.3	88.3	91.3	89.6	95.8	80.3	83.3
Group 2	54.2	75.0	78.8	73.8	76.7	77.1	72.5	66.7	85.4
Group 3	75.8	73.3		71.3	60.4	41.7	58.8		70.8
Group 4	55.8			64.2			57.9		

The correlation between filtered speech discrimination and tonal discrimination is shown in Fig. 5. It seems that the tonal discrimination scores of Group 2 and Group 3 become worse as the filtered speech discrimination score becomes poorer.

Discussion

It is well known that the higher the hearing threshold the lower the speech discrimination score generally is, and that the score of discrimination tests of filtered speech is particularly poor in the case of retrocochlear lesions.[5] As shown in Figures 1, 2 and 3, it has been revealed in this experiment, too, that the ability of speech perception is related to the location of the damage which caused the hearing impairment, to a large extent regardless of the hearing threshold. In this study, furthermore, subjects suffering from sensorineural deafness have been found to have peculiarly poor tonal discrimination scores. It can be compared with the results of DLF measurements by many previous authors[6, 7, 8, 9, 10, 11] who reported that the DLF of the sensorineural deafness is generally worse than the normal subjects. On the endorgan deafness, our result on tonal discrimination does not conform with Meurmann's,[6] who stated that Meniere's disease, one of the endorgan deafnesses, showed higher than normal DLF values in low frequencies but was within normal limits

in high frequencies. On the other hand, Azzi[12] has reported that the DLF of the endorgan deafness is smaller than that of the VIIIth nerve tumor. The tonal discrimination score of the endorgan deafness has been appraised in the present study to be better than retrocochlear deafness, and similar to that of normal subject.

In this study the retrocochlear deafness was sub-classified into a) the peripheral nerve deafness, viz., the VIIIth nerve tumor (Group 3) and; b) the central nerve deafness, viz., the presbycusis in a limited sense (Group 4). The hearing impairments of our Groups 3 were not so severe but the tonal discrimination scores were poor. This data agrees again with Azzi[12] and also several other authors[13, 14] who studied on experimental animals.

It is well known that the histopathological changes of presbycusis are seen in both the inner ear and the retrocochlear pathway.[15, 16, 17, 18, 19] But we regarded Group 4 as the presbycusis in a limited sense, namely that the pathological changes were mainly in the retrocochlear pathway. As Kirikae et al.[15] reported, it seems that these senile changes in the retrocochlear pathway especially in the central nervous system bring important consequences to the auditory function. It has been reported that the DLF becomes poorer in advanced ages.[20, 21, 22] In our study the subjects of Group 4 showed the poorest tonal discrimination score among the five of our groups in spite of their normal hearing thresholds. We may assume that this is caused by a hypo-function of the central nervous system which serves as a frequency analyzer.

The sensorineural hearing loss for low tones, on the other hand, could be considered to be mainly caused by an inner ear lesion. However, there are cases, as is well known, that suggest through a battery of audiometric tests[23] the existence of retrocochlear lesions. It may be noted that in this study sensorineural hearing loss for low tones has shown an extensive variation in tonal discrimination scores and the mean value was located between those for endorgan deafness and retrocochlear deafness. It seems to suggest that low tone deafness is associated with wide-spread lesions covering the region from the cochlea to the retrocochlear pathway.

Summary

Subjects with different kinds and degrees of hearing impairments have been examined in terms of pure tone thresholds, all-passed and low-passed speech stimulus identifications, and timbre discrimination tests with use of random noise fed through a simple-resonance circuit with different resonance conditions. Endorgan deafness showed relatively better tonal discrimination scores than the cases of retrocochlear deafness and aged subjects (presbycusis in a limited sense). It seems that in the endorgan deafness, if most of the neural elements in the auditory pathway maintain normal functions, the discriminative abilities of tonal timbre are kept to a good extent even when the hearing threshold is considerably high. For the sensorineural deafness for low tones, both the cochlea and the retrocochlear pathways have been speculated as the locations of lesions. The range of variation of correct responses in the cases of sensorineural deafness for low tones is larger than the other groups, and this seems to indicate an extensive range of locations of lesions for this subcategory.

The tonal discrimination scores were poorer in the case of retrocochlear lesions than for the cochlear lesions regardless of the hearing threshold values. It seems that poor (low-pass-filtered) speech discrimination scores are always associated with poor tonal discrimination scores.

The discriminative ability of timbre thus seems to be related with the location of the malfunctioning organ rather than with the hearing threshold.

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