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A SIMPLE TEST OF FREQUENCY SELECTIVITY

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INTRODUCTION

Pure-tone thresholds are at present the most important audiological characteristic of a hearing loss, both for the purposes of diagnosis, rehabilitation (e.g. hearing aid fitting), and quantification of auditory handicap. While the threshold adequately quantifies a conductive hearing loss, it has long been recognized that it is inadequate to describe a sensorineural hearing loss. Particularly for mild and moderate sensorineural hearing losses it appears that the accompanying inability to discriminate speech sounds in noise constitutes a greater handicap than the inaudibility of weak sounds. While the latter can be compensated by a hearing aid, the loss of discrimination will persist, and poor discrimination in noise appears to be the largest single problem that hearing aid users at present must endure.

Speech audiometry in noise has been used to assess discrimination, but suffers from a number of disadvantages (Lyregaard et al., 1976). The objective of the present study was to develop a simple and efficient substitute, particularly suited for clinical work.

Neurophysiological studies have shown that cochlear disorders lead to fairly flat primary neuron tuning curves, and corresponding results have been obtained in human psychophysical experiments. It was therefore hypothesized that loss of frequency selectivity might partly or wholly be responsible for poor discrimination in noise.

METHOD

Various methods of quantifying frequency selectivity have been developed, including psychophysical tuning curves (Zwicker and Schorn, 1978), masking curves (Leshowitz and Lindstrom, 1979; Florentine et al., 1980), loudness summation (Bonding, 1981), and gap detection in combfiltered noise (Pick et al., 1977). Based on a preliminary investigation it was decided here to use the critical ratio paradigm (Fletcher, 1953), entailing measurements of masked pure-tone threshold in a broad-band noise masker.

Measurements were made with a Madsen OB70 audiometer, using the broad-band masking noise as a masker. Two different masker levels were utilized, corresponding to a power spectrum density of 35 and 59 dB SPL/Hz as measured with the TDH 39 earphones on a 6 cc coupler. The masker was left on continuously and the threshold for ipsilateral pulsed pure-tones was determined using an ascending procedure in 2 dB steps. Pure-tone frequencies were 500,1000,2000, and 4000 Hz.

56 test subjects were selected, among these 10 with normal hearing, the remaining with a variety of hearing losses, predominantly sensorineural. Measurements were performed on both ears, and since all hearing losses were substan-

tially symmetrical, no contralateral masking was required.

All measurement results for which the masked threshold was less than 10 dB from the unmasked threshold were eliminated, in order to avoid that critical ratios were confounded by the hearing loss per se. Particularly at the low masking level a large number of results from the hearing impaired group were thus eliminated.

RESULTS

The critical ratio (CR) is defined as the ratio between the SPL of the masked threshold of a pure tone and the power spectrum density of the masking noise.

Mean results for the normal group are shown on fig. 1 for both masker levels, and are in good agreement with Fletcher (1953). A small but consistent difference of approximately 2 dB was observed between results for low and high masker level (which differed by 24 dB). The precision of the CR measurement was found to correspond to a standard deviation of approximately 3 dB.

For the entire group the linear regression on hearing loss for the 59 dB SPL/Hz masker are shown in table 1.

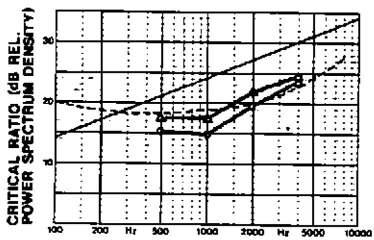

Fig. 1: Mean critical ratios for normal group (20 ears). Triangles correspond to 35 dB SPL/Hz masker, circles to 59 dB SPL/Hz masker. Full line is 1/3 octave band SPL for masker. Results by Fletcher (1953) are shown for comparison (dashed).

FREQUENCY (Hz)	INTERCEPT (dB)	SLOPE	CORRELATION COEFFICIENT	NUMBER OF RESULTS
500	15	0.20	0.67	93
1000	15	0.20	0.76	84
2000	19	0.17	0.72	81
4000	23	0.19	0.81	72
Average	18	0.21	0.82	56

Table 1: Linear regressions of CR on corresponding pure-tone hearing loss (dB HL).

These results suggest a degradation of CR by approximately 10 dB for a 50 dB hearing loss, which is broadly in agreement with results obtained by Pick et al. (1977) using a gap detection method. Individual CR data averaged over the four frequencies are shown on fig. 2, as a function of the corresponding average hearing loss.

RELATION TO SPEECH INTELLIGIBILITY

The same subjects as employed above were also given a test of speech intelligibility in noise. The test material was nonsense CVCs in sentences, presented at a level set by the test subject, and the noise was speech spectrum shaped random noise. Following initial training, each test subject was given two lists of 25 words each, presented at signal-to-noise ratios of +12 and +4 dB (for subjects with normal hearing +6 respectively -2 dB). Subjects wrote down the responses, which were scored phonemically. The signal-to-noise ratio corresponding to 50% intelligibility was, for each individual, found by a least squares fit for the arctangent transformed speech score, with a fixed slope of 5% per dB.

Fig. 3 shows the individual signal-to-noise ratios as a function of CR averaged over 4 frequencies. There appears to be a 1:1 relation between CR and signal-to-noise ratio for speech, strongly suggesting that the impoverished frequency selectivity, as measured by the CR, is a major factor in speech intelligibility in noise. The other point to note is that the diagnostic categories roughly are ordered in the anticipated sequence.

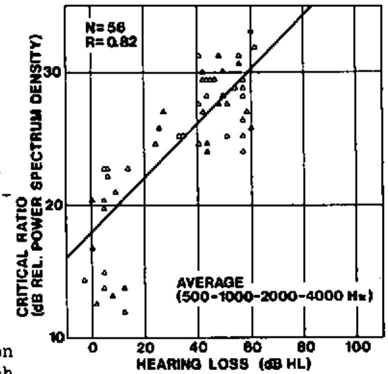

Fig. 2: Scattergram of CR versus hearing loss, both averaged over frequencies (500-1000-2000-4000Hz)

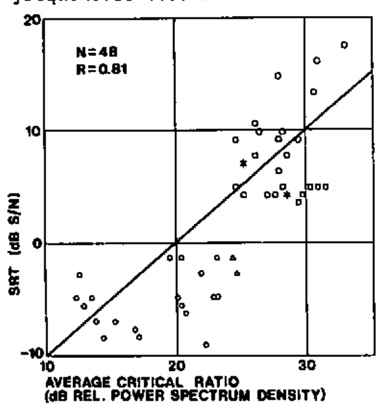

Fig. 3: SRT (signal-to-noise ratio corresponding to 50% phoneme intelligibility) as a function of critical ratio averaged over frequencies. Symbols denote diagnostic groups, as follows: 0*-normal,* Δ*-conductive,* **-mixed,* □*-sensorineural.*

DISCUSSION

The study has demonstrated that the critical ratio, averaged over speech frequencies, provides a good measure of the perceived signal-to-noise ratio as found in speech intelligibility in noise. For clinical purposes the CR test has a number of advantages compared to speech tests:

1. CR is approximately independent of masking level.

2. To a first approximation CR does not depend on individual variations of SPL under earphones.

3. CR can be measured with a standard clinical audiometer, and results directly plotted in the audiogram (fig. 4).

4. The test is quick, involving only four threshold determinations per ear.

5. It is easily understood by the test subject, and does not depend on linguistic proficiency.

6. It is amenable to International Standardization.

7. It is not affected by even substantial ambient noise levels in the test environment.

One might speculate that the CR test, in view of the advantages stated above, could prove a viable alternative to pure-tone thresholds in industrial audiometry. Anecdotal evidence suggests that the true handicap experienced by persons with mild noise-induced hearing loss is underestimated by pure-tone thresholds, perhaps because the handicap may be more related to frequency selectivity than to pure-tone threshold shift. Evidently further investigations of this aspect are required.

The assistance provided by Mrs. K. Fabiansen, who performed most of the measurements, is gratefully acknowledged.

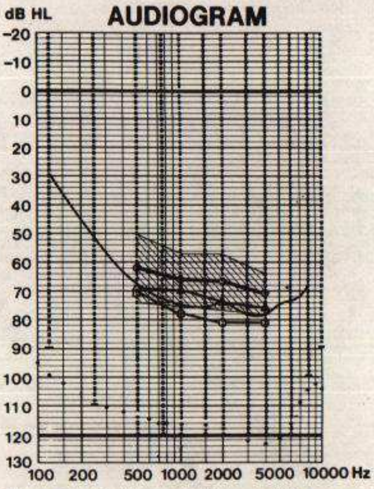

Fig. 4: Audiogram form with normal CR values (open circles) and 95% confidence limits (hatched). Full line shows 1/3 octave band SPL of noise (dB HL), and results for two subjects with approximately similar hearing losses are shown (Δ-conductive; □-sensorineural).

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