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OFFICE of SCIENTIFIC RESEARCH and DEVELOPMENT
NATIONAL DEFENSE RESEARCH COMMITTEE
DIVISION 17 SECTION 17.3

Contract OEMsr—1201

OSRD Report No. 6303

31 July 1946

TOLERANCE FOR PURE TONES AND SPEECH IN NORMAL AND HARD-OF-HEARING EARS

RESEARCH LABORATORY
CENTRAL INSTITUTE FOR THE DEAF
ST. LOUIS, MISSOURI

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I. PREFACE

The NDRC Aural Rehabilitation Project

The NDRC project (17.3-19), operating under Directive AN-10, has been broadly concerned with all electro-acoustic instruments and methods relevant to the rehabilitation of aural casualties. A major part of the general program has been an experimental study of hearing aids, both as physical instruments and as aids to hearing. Their electro-acoustic properties have been studied at Electro-Acoustic Laboratory, Harvard University. These studies have included an examination of the electrical circuits and the component parts of the instruments, their overall frequency response, input-output characteristics for pure tones, amplitude distortion, battery drain, the acoustic properties of individual earmolds, microphone pickup pattern, and the body-baffle effect. The Psycho-Acoustic Laboratory has been concerned with studies involving the transmission of speech by hearing aids, the limitations they impose upon intelligibility, and the quality of their transmission. This laboratory has also developed several auditory tests that are useful for research on problems of impaired hearing, for the clinical diagnosis of hearing loss, and for the selection of hearing aids.

Another section of the project has been concerned with the development and validation of diagnostic methods appropriate to impaired hearing. The Central Institute for the Deaf at St. Louis has developed apparatus and methods of this type.

The work of these various laboratories has been closely coordinated with the Aural Rehabilitation Services of the Army and the Navy. In particular, the NDRC project has endeavored to provide practical assistance in the design and procurement of acoustic facilities and equipment for several of the hospitals where the Aural Rehabilitation Services are located; and, through the Psycho-Acoustic Laboratory, the project has engaged in research programs which utilize the laboratory facilities at one of the Army hospitals. Through this association the special problems of military aural casualties and their rehabilitation have been studied; and the results of laboratory research at Psycho-Acoustic Laboratory, at Electro-Acoustic Laboratory, and at Central Institute for the Deaf, have been validated and applied.

II. INTRODUCTION

Scope and Objectives

The traditional approach to measurement of impairment of auditory function has, in the main, involved measurements of threshold of acuity for either pure tones or speech. The former approach has particularly characterized clinical practise and procedures. It has been demonstrated, however, through the study of loudness well above threshold that the threshold audiogram alone is not an adequate measure of the impairment of auditory function.[1] Furthermore, the impairment of understanding of speech is more closely related to the overall loudness loss at the intensity level at which speech is heard than to the threshold audiogram.[1] It is, therefore, difficult to predict from a threshold of acuity measure how the impaired ear will function in an above-threshold acoustic environment.

The need for accurate information concerning responses well above the threshold of acuity in order adequately to appraise auditory function has consequently focused attention upon the concept of the *auditory area* or auditory "map." The auditory area is properly described by equal-loudness contours[2] and is bounded at its lower border by the threshold of acuity and at its upper border by the thresholds of tolerance. The auditory area might be likened to a building with the foundation represented by the threshold of acuity, the in-between stories corresponding to levels of equal loudness, and the roof represented by tolerance limits.

The investigation described in this report represents a systematic study of the *quantitative and qualitative nature of the tolerance limits for speech and pure tones of normal and deafened human ears.* With reference to the Aural Rehabilitation Programs of the Armed Forces, it was hoped to attain the following significant objectives:

1. To yield data pertinent to the *design characteristics of future hearing aids.* The maximum acoustic output of present day hearing aids, either by intent or accident, is such that presumably it protects the wearer from acoustic stimuli that would exceed his tolerance limits. If it could be demonstrated that the tolerance limits are higher than heretofore supposed, the instrument could be designed with a higher level of maximum undistorted acoustic output and thereby the auditory range of usefulness could be increased materially.

2. To provide information which could guide procedures in *the clinical selection of hearing aids.*

[1] CMR report, Temporary Deafness Following Exposure to Loud Tones and Noise, 30 September 1943, OEMcmr-161.

[2] Stevens, S. S. and Davis, H., Hearing: Its Psychology and Physiology, New York, John Wiley & Sons, Inc., 1938.

Tolerance

Previous studies [4] indicate a relatively vague conception of the qualitative nature of the threshold of pure tone tolerance. This threshold has at times been termed the threshold of "pain," and more frequently has been called the threshold of "feeling." From the psycho-physical standpoint the "pain" response is most readily identifiable but the "feeling" response is vague. The subject is at a loss to know when "hearing" ceases and "feeling" begins. Furthermore, these last two sensations can, and do, occur simultaneously as the clinician who practises bone conduction audiometry can testify.

In the experimental approach to the determination of pure tone tolerances, the present investigators, therefore, postulated *several qualitatively different tolerance thresholds* which could be established in terms of separately identifiable sensations. It was felt, in other words, if the analogy of the auditory area and the building is carried out, that the "roof" of the auditory area might be *multilayered* in character. Looking upwards the roof of the building might be comprised of a plaster ceiling, supporting beams, and an external roof. It was supposed that the responses of the subject to high intensity stimuli might reflect a pattern of multiple layers varying with the qualitative nature of the response to be elicited.

Exploratory experimentation suggested that *three* specific pure tone tolerance threshold layers could be established as a function of frequency and intensity. It was determined further that the same thresholds could be used to establish specific levels for speech tolerance.

Three clearly distinguishable thresholds proved to be

1. *Discomfort threshold*, defined as the point at which the subject feels that he would cease to care to listen because the stimulus was uncomfortable. (The precise instructions to the subject are given later in the report.)
2. *Tickle threshold*, defined as the point at which the subject experiences a definite tickling sensation deep in the ear.
3. *Pain threshold*, defined as the point at which the subject experiences a definite sensation of sharp pain, as opposed to mere discomfort deep in the ear.

Organization of Experiments

The experiments were organized in the following general manner: (Details of procedure are given later.)

1. *Pure tone tolerance* - - The subjects were divided into two groups, normal hearing * and hard-of-hearing. There were sixteen ears in each group exposed to the complete experimental procedure. At each ex-

[4] Wegel, R. L., "Physical Data and Physiology of Excitation of the Auditory Nerve," Ann. Otol., Rhinol., and Laryngol., 1932, 41, 740-779.

* The "normal hearing" group will subsequently be referred to as "normals."

perimental session the thresholds on each ear for discomfort, tickle, and pain were determined for given frequencies and then repeated. In other words the thresholds were determined for the right ear then the left ear, followed by a repeat series of measurements on the right ear and the left ear. Except in a few instances there were six consecutive sessions one week apart for each subject. In most cases thresholds of acuity were determined before and after testing for tolerance thresholds. This latter procedure was introduced in the course of the experiment to determine what effect exposure to high intensity stimuli might have on the threshold of acuity.

2. *Speech tolerance*- There were 30 normal ears and 30 hard-of-hearing ears exposed to the complete experimental procedure. These subjects were subdivided into three groups (1, 2, and 3) of 10 normal and 10 hard-of-hearing ears each. The basis of division between groups 1 and 2 was the order of testing of ears with the time interval between sessions remaining constant. Groups 1 and 3 differed in the time interval between sessions with the order of testing of ears remaining constant. An experimental session consisted of determination of thresholds of acuity for speech, and discomfort, tickle, and pain thresholds four times for each ear. All subjects were exposed to four sessions of speech tolerance testing as contrasted with six sessions for pure tone tolerance. The fact that the speech tolerance threshold curves were reaching asymptotes as a function of experience determined the number of sessions.

3. *Study of change of toleronce*

a) *Change with experience:* The change of tolerance (which subsequently proved to be upward) for pure tones and speech as a function of number of consecutive testing sessions was studied.

b) *Retention of tolerance:* The retention of tolerance for speech as a function of given time intervals from date of last test was investigated.

c) *Contralateral tolerance:* The effect of tolerance tests for speech and pure tones of one ear on the opposite ear was studied. This phenomenon is defined as contralateral tolerance.

d) *Transfer tolerance:* The effect on tolerance for pure tones as a result of exposure to speech tolerance procedure was investigated. This phenomenon is defined as transfer tolerance.

e) *Methods of elevating tolerance:* When it was noted that the testing procedure, per se, elevated tolerance, it was decided to make a deliberate experimental attempt to increase tolerance in hard-of-hearing ears through exposure of the subject to two different levels of high intensity speech. Therefore, a third group of 10 hard-of-hearing subjects was exposed at four weekly experimental sessions. The right ears of this group were exposed to one level of stimulation and the left ears to another level.

III. SUBJECTS

Equal numbers of normal and hard-of-hearing subjects were chosen for the experiments on pure tone and speech tolerance. There were 16 ears in each group for pure tone tolerance and 30 ears in each group for speech tolerance. In the study of experimental elevation of tolerance, 20 hard-of-hearing ears were involved. Thus, a grand total of 46 normal ears and 66 hard-of-hearing ears were employed throughout the entire series of experiments. These figures do not include a few subjects (noted later) who dropped out, for one reason or another, during the course of experimentation.

An even distribution of subjects according to sex was approximated. The age range of the subjects was from 16 to 42 years which are normal military limits.

Audiometry

Air and bone conduction audiograms for each ear were obtained on a Maico D-5 Audiometer in a room of approximately 45 db residual noise as

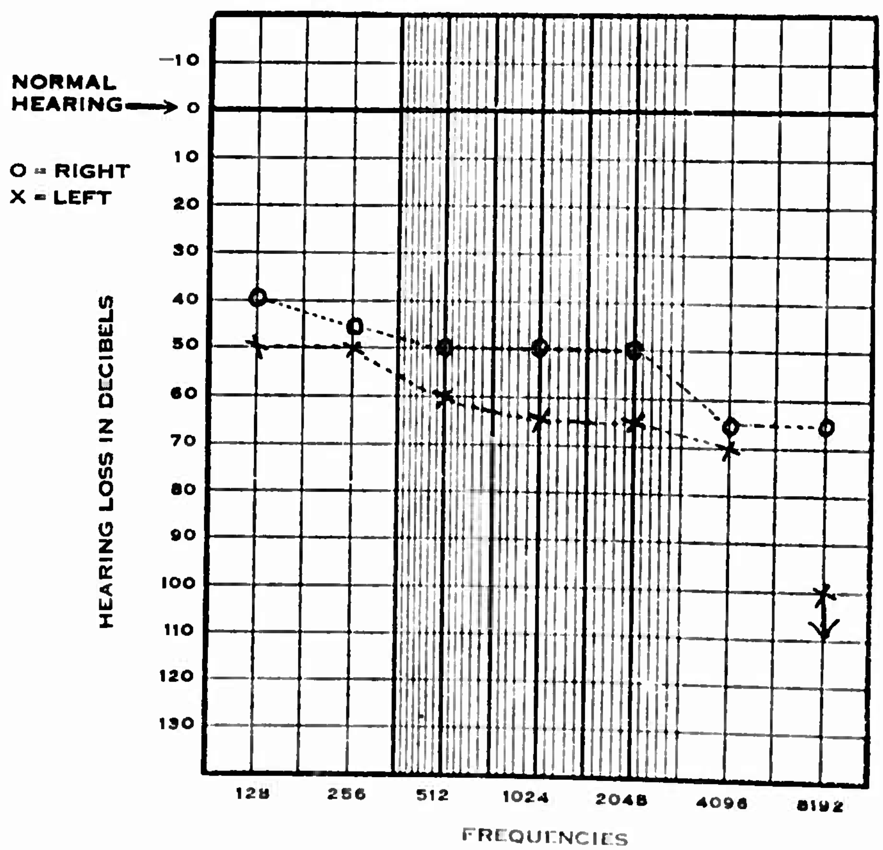

Fig. 1. Sample Audiogram.

measured by a Western Electric RA-330 sound level meter. For convenience of presentation the audiograms in the tabular portions of the reports are recorded numerically instead of graphically. Each digit represents the hearing loss in bels with a dash below indicating loss of an additional half bel. In other words, the figure 2 would indicate a loss of 2 bels or 20 decibels; the figure $\underline{2}$ would indicate a loss of 2½ bels or 25 decibels. The letter "x" signifies no response for the indicated frequency. The figures, reading from left to right, represent the loss at the following frequencies: 128, 256, 512, 1024, 2048, 4096, and 8192 cycles per second. The audiogram in Fig. 1 would therefore be recorded as follows:

Right	-	4	$\underline{4}$	5	5	5	$\underline{6}$	$\underline{6}$
Left	-	5	5	6	$\underline{6}$	$\underline{6}$	7	x

Clinical Classification

The classification of subjects into the following clinical types of deafness was established after thorough otological examination. The criteria are also given:

1. *High frequency nerve deafness* -- abrupt loss in hearing for air and bone conduction, beginning at 1000 cycles.

2. *Nerve deafness* --- marked reduction in hearing for air and bone conduction.

3. *Conduction deafness* --- normal hearing or slight decrease in hearing for bone conduction with greater loss for air conduction. (These cases usually show a negative Rinne and a normal or retracted tympanic membrane. The pathology involved is usually early otosclerosis or hyperplastic otitis media.)

4. *Mixed deafness* --- bone conduction slightly better than or equal to air conduction. (The pathology is usually a combination of early nerve lesion and middle ear disease.)

The hard-of-hearing subjects represent a fairly well balanced distribution of clinical types. Detailed information concerning the subjects in each group is given in appropriate sections of the report.

IV. APPARATUS

The apparatus was capable of reproducing known sound pressure levels under an earphone from 0 db to approximately 145 db r.m.s. (re: 0.0002 dynes/cm^2) at 1000 cps. The acoustic output could be varied in any combination of 1, 2, or 10 db steps over the entire 145 db intensity range. Figs. 2 and 3 are block diagrams of the systems used for pure tones and speech respectively. The laboratory in which the equipment was housed consists of a large room containing a dead room and an adjacent control room. The dead room has an absorption coefficient of .83 as calculated by the Sabine formula. The ambient noise level is 35 db sound pressure level as measured on the R-330 sound level meter with selector set to "flat." The meter had been checked for accuracy by the Bureau of Standards.

The subject was seated comfortably in the dead room and listened to the test tones or speech through a single PDR-10 earphone mounted on a double headband. A 6B cushion and dummy headphone (provided by Psycho-Acoustic Laboratory) covered the ear which was not being tested. The PDR-10 earphone was fed through an appropriately matched 110 db Hewlett-Packard attenuator. A talkback microphone was suspended from the ceiling of the dead room. An instruction microphone was available to the experimenter for communication with the subject through the earphone. This arrangement assured convenient and accurate rapport even with the hard-of-hearing subjects.

The remainder of the apparatus was mounted in the cabinet convenient to a window between the dead room and the control room. A resistance-tuned audio-oscillator was used as the source for the pure tones. This unit was connected through a matching attenuator to a power amplifier capable of delivering up to 60 watts of undistorted audio power. The source for the speech tolerance tests was an electrical transcription turntable. A calibrated attenuator was inserted between the power amplifier and the matching transformer ahead of the earphone. Attenuation of the output, therefore, reduced the amplifier hum, tube noises, etc., equally with the signal and maintained a constant signal-to-noise ratio of about 55 db.

Calibration

Fig. 4 shows the pressure response into a 6cc coupler of one of the Permoflux PDR-10 earphones used in the experiment. This calibration was carried out at the Electro-Acoustic Laboratory,[1] using a W.E. 640A condenser microphone. The pressure response shown in Fig. 4 is typical of all the earphones used in this experiment, except that the sensitivity of one of the earphones was 4 to 5 db lower than the rest of the lot.[2] At the Electro-Acoustic Laboratory, it was also found that the PDR-10 earphones were capable of delivering instan-

[1] OSRD Report No. 3105, "Response Characteristics of Interphone Equipment IV." 1 January 1944, OEMsr-658.

[2] Several earphones were burned out in the preliminary experiments with pure tones, and it became necessary to limit the sound pressure level of the tests to 145 db for pure tones and to 140 db for speech. The earphones proved capable of handling these power levels without alteration of their frequency response or sensitivity.

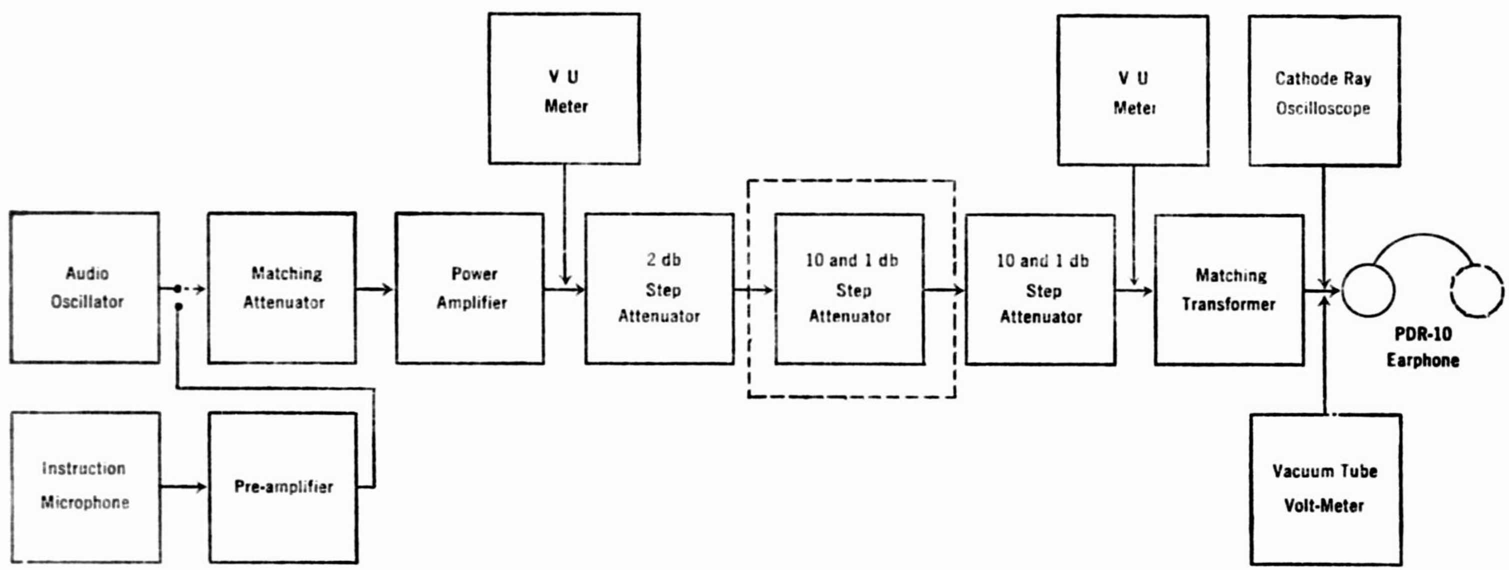

Fig. 2. Block diagram of apparatus for pure tone tolerance tests.

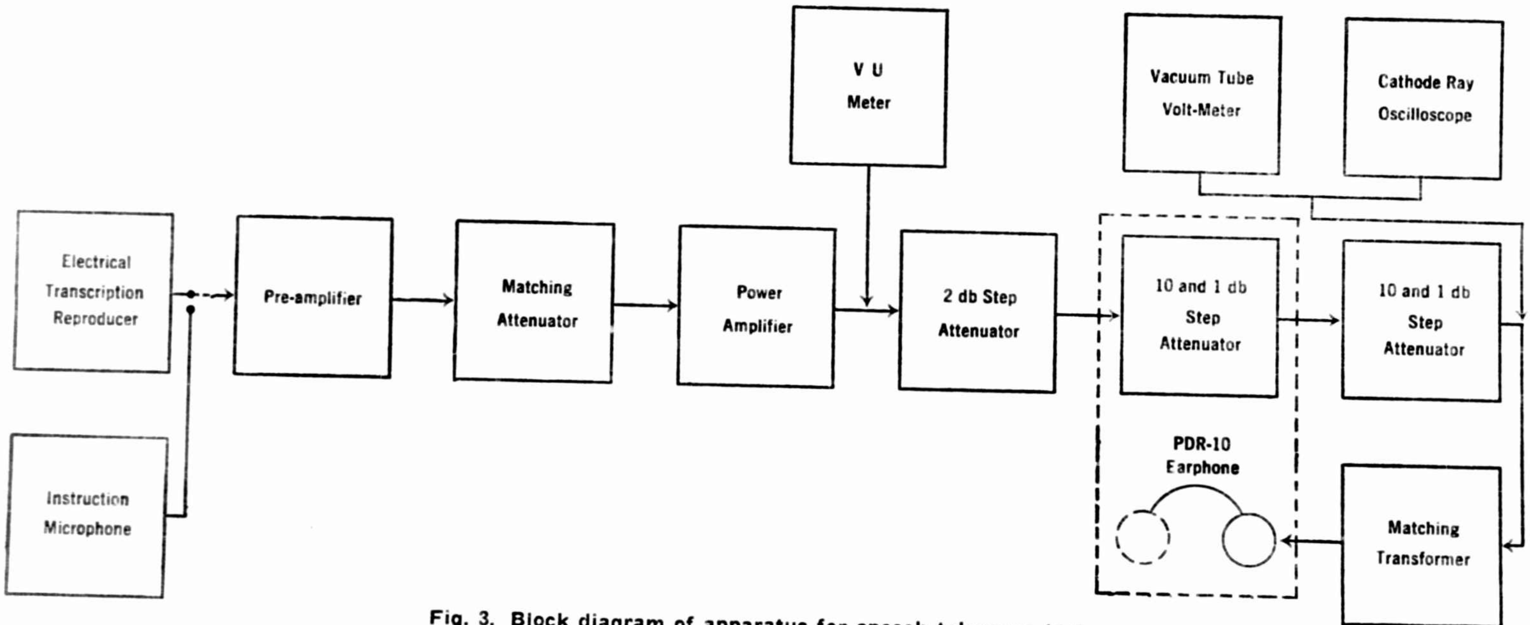

Fig. 3. Block diagram of apparatus for speech tolerance tests.

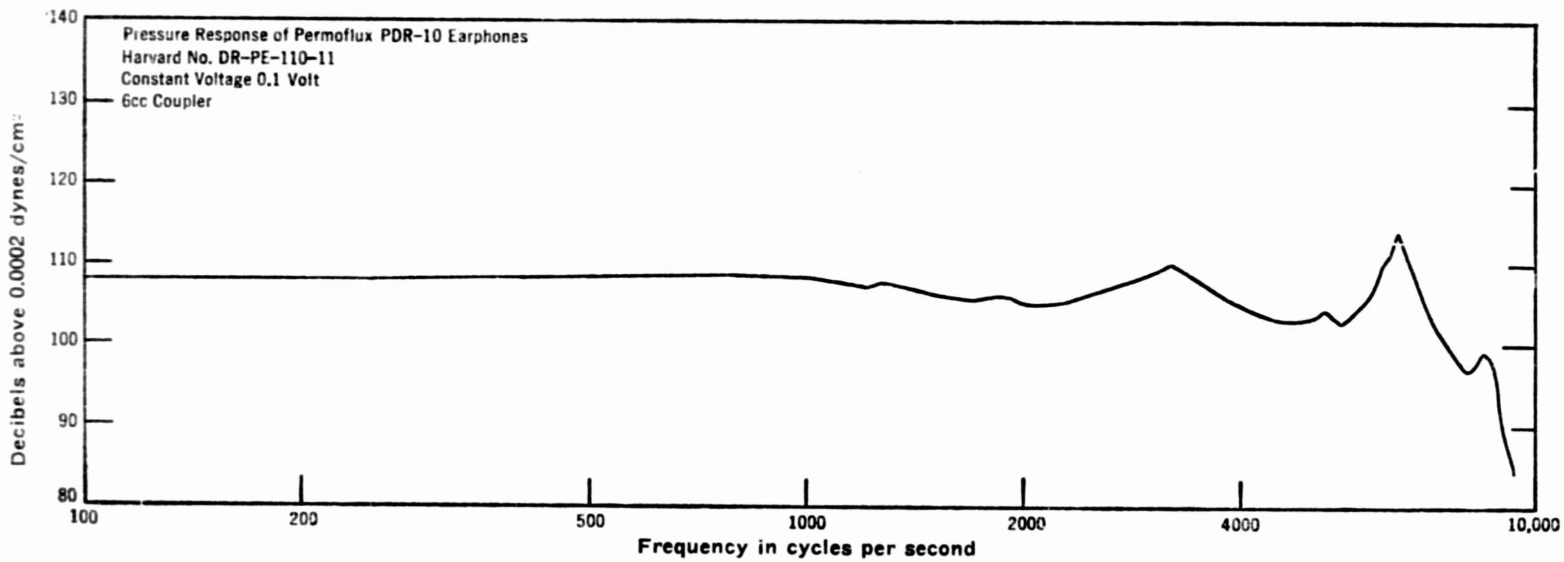

Fig. 4. Pressure response of sample PDR-10 earphone.

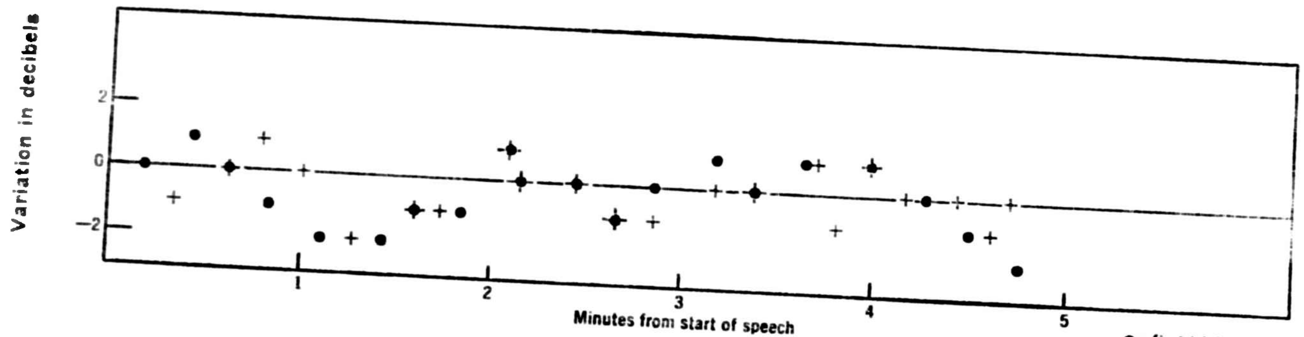

Fig. 5. Relative evenness of speech samples for intelligibility threshold.

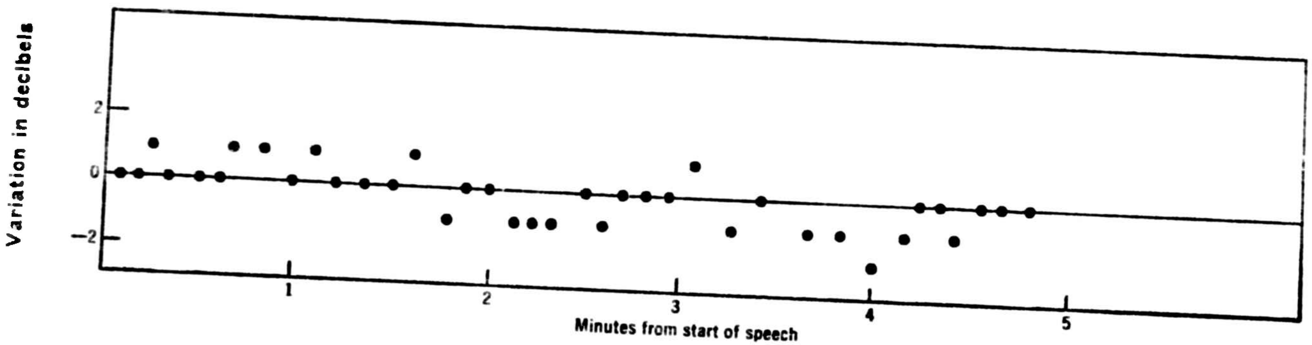

Fig. 6. Relative evenness of speech sample for tickle threshold.

taneous peaks of pressure, such as occur in speech, at levels of at least 155 db instantaneous sound pressure (re: 0.0002 dynes/cm ^{2}) into the 6cc coupler. The power required for such sound pressure was about 6 watts.

Speech Sample

A newscast by Fulton Lewis, Jr. transcribed from the network lines was selected as a speech sample for the tests of speech tolerance. This sample was chosen because of its evenness of level. Four minutes and forty-five seconds of the original 15 minute disc was re-recorded by The Technisonic Laboratories of Central Institute. A calibrating tone of 1000 cps was recorded on the same disc. This original transcription was then processed and a number of vinylite pressings made. The average speech level as measured by the VU meter throughout the four minutes and forty-five seconds playing time lay within 2 db of the level of the calibrating tone.

The evenness of the speech level was further verified by an experienced observer with respect to his threshold of intelligibility and also with respect to his threshold of tickle. In the first test the observer adjusted the attenuator (1 db steps) from time to time as required to keep the speech just intelligible to him. The test was then repeated to insure reliability. Fig. 5 shows the changes of attenuation required in order to keep the speech just at the threshold of intelligibility. All of the settings of both tests lie within a total range of 3 db. In another test the observer adjusted the attenuator to maintain a definite and consistent tickle in his ear on nearly all of the stressed syllables. Fig. 6 shows that all 37 settings lie within a total range of 3 db.

It will be recognized that the test of intelligibility is a test of the evenness of the general level of speech and that the test of tickle is a test of the evenness of the peaks of speech. The evenness of the sample is equally good according to both criteria.

A cathode ray oscilloscope was connected across the terminals of the earphone beyond the matching transformer. The level reached by the instantaneous peaks of speech was found to be 12 db above the general (r.m.s.) level of speech (and calibrating tone) as measured by a VU meter. It is evident, therefore, that at the speech level of 140 db (re: 0.0002 dynes/cm ^{2}), the maximum level employed in the test, the instantaneous pressure of the peaks of speech was 152 db (re: 0.0002 dynes/cm ^{2}). The earphones had been shown by their calibration to be capable of delivering such pressures without distortion, and the oscilloscope showed that up to this level no peak clipping or other apparent distortion was introduced by the reproducing system or the power amplifier. It will be recalled that the power amplifier could deliver at least 60 watts in undistorted audio output, which would produce an r.m.s. sound pressure level of 155 db under a PDR-10 earphone. We may, therefore, be confident that at the highest output levels employed the acoustic output was free from serious distortion.

V. PURE TONE TOLERANCE

Procedure

Instructions to subjects: The subject was seated in a comfortable chair situated within the sound chamber. Instructions were communicated directly except in cases of severe deafness, when the instruction microphone was used to insure accurate understanding of directions. The precise instructions for the three thresholds were as follows:

1. *Discomfort:* "You will hear a tone which will get louder and louder. Tell me when you reach the point where the tone is uncomfortable, that is, when you would no longer care to listen or when you feel like removing the earphone from your ear. When the uncomfortable point is reached say, 'uncomfortable,' and I will shut off the tone. We shall then repeat the procedure with another tone. Are you ready?"

2. *Tickle:* "You will hear a tone which will get louder and louder. Tell me when you reach the point where you feel a tickling sensation deep in the ear as though a broom straw were tickling it. Be alert only for the tickling sensation. When the tickle point is reached say 'tickle' and I will shut off the tone. We shall then repeat the procedure with another tone. Are you ready?"

3. *Pain:* "You will hear a tone which will get louder and louder. Tell me when you reach the point where you feel a sharp pain deep in the ear. Be alert only for the pain sensation. When the pain point is reached say 'pain' and I will shut off the tone. Are you ready?"

In cases where the subject failed initially to comprehend the meaning of the instructions, they were repeated or elaborated with the basic point in mind that the type of response desired was not altered. Obviously, as the subject became more sophisticated the necessity for repetition and elaboration of instructions decreased.

Frequencies tested: The following frequencies were tested: 250, 500, 1000, 1400, 2000, 2800, 4000, and 5600 cps. These frequencies were chosen because they involve an adequate sample of the speech range and because they include the frequency range of all hearing aids. Also these frequencies were best suited to the frequency response of the PDR-10 earphone which has a fairly flat response throughout the spectrum chosen for testing. Exploratory tests showed that because of the downward slope of the frequency response of the PDR-10 earphone beyond 5600 cps, tolerance limits could not very often be reached in that area. Furthermore, below 250 cps the seal of the earphone against the ear is critical. A slight leak may introduce a large error.

Duration of exposures and stepwise increases of intensity: The subject was exposed at each frequency, starting at a level of 100 db above 0.0002 dynes/cm ^{2}. Each exposure lasted for 1.5 seconds and then the intensity was increased in 2 db steps without interrupting the tone. The step intervals of 2 db were maintained up to 130 db. If the subject had not yet reached his tolerance, the step intervals were reduced to 1 db. The duration of each step was maintained at 1.5 seconds. The tolerance limits of some subjects exceeded the limitations of the apparatus (approximately 145 db r.m.s. at 1000 cps). The technique of determining tolerance limits by a method of gradually increasing intensities appeared to be appropriate since we wished to avoid the complications introduced by the sudden onset of a high intensity stimulus. A level of 100 db above 0.0002 dynes/cm ^{2} was adopted as a convenient starting point. Only a few subjects (on early tests) reported discomfort below 100 db.

Sequence of observations: The following sequence of frequencies was used: 1000, 1400, 2000, 2800, 4000, 5600, 500, 250 cps. The sequence is arbitrary but follows orthodox audiometric technique in commencing with the portion of the frequency spectrum to which the ear is most sensitive. The discomfort thresholds were first determined at the various frequencies, then the tickle thresholds, and finally the pain thresholds.

Thresholds of acuity: Beginning about midway in the experiment the thresholds of acuity at each frequency were determined before and after the tolerance tests. In other words, the thresholds of acuity from 250 to 5600 cps were obtained (using the same apparatus), then the threshold for discomfort, tickle, and pain, followed immediately by another determination of the thresholds of acuity.

Order of ears tested: The right ear was always tested first followed *immediately* by the left ear.

Testing timetables: Each testing session consisted of a complete series of tolerance tests on each ear (test A), followed after a ten minute rest period by a repetition of the complete series on each ear (test B).* An experimental session lasted from 105 to 120 minutes. These sessions were repeated at weekly intervals for six weeks. This schedule allowed a comparison of the effects of brief as well as the much longer (one week) intervals between tests.

Subjects: There were 9 normal and 10 hard-of-hearing subjects in the pure-tone tolerance experiment. However, the 9 normal subjects represented only 16 ears since only one ear of each of two subjects was used. Midway in the experiment two hard-of-hearing subjects dropped out, leaving a total of 8 subjects (16 ears) who completed the experiment. Tables 1 and 2 contain pertinent information concerning normal and hard-of-hearing subjects respectively.

* A few subjects had only A tests at the outset of the experiment. In a few cases, the weekly sequence was interrupted for approximately three months after the third session before experimentation was resumed. These irregularities are indicated in the data.

Table 1 — Normal Subjects For Pure Tone Tolerance

Subject	Age	Sex
U.B.	18	M
H.T.	22	F
M.R.	29	M
L.S.	33	F
J.D.	36	M
C.H.*	38	M
A.M.	38	F
H.L.*	39	F
F.S.	42	F

* one ear used

Table 2 — Hard-of-Hearing Subjects for Pure Tone Tolerance

Subject	Age	Sex		Air Conduction Audiogram*	Type of Deafness**	Age of Onset of Deafness	Loss for Speech	Use of Hearing Aid
V.B.	32	M	R.	2 1 2 1 6 8 5	HFN	30	R. 12	
			L.	2 1 2 2 6 8 6			L. 14	—
L.M.	19	M	R.	1 3 4 5 5 8 7	HFN	14	R. 53	
			L.	0 1 3 3 3 5 7			L. 38	—
C.B.	41	M	R.	x 8 8 7 8 9 x	N	?	R. 73	
			L.	x 8 7 7 7 8 x			L. 71	R
C.G.***	26	F	R.	5 5 5 5 7 7 6	N	?	R. —	
			L.	6 5 6 6 8 7 7			L. —	—
A.P.	38	F	R.	5 6 6 7 4 5 3	C	20	R. 51	
			L.	4 4 5 5 5 4 3			L. 53	L
M.S.	36	F	R.	6 6 6 5 5 5 3	C	26	R. 55	
			L.	6 6 7 6 5 4 5			L. 53	—
A.C.	35	M	R.	5 6 6 6 4 5 5	C	3	R. 59	
			L.	4 5 5 5 4 3 5			L. 51	R
H.J.	37	M	R.	4 5 6 6 5 4 4	M	11	R. 43	
			L.	6 7 8 8 9 9 6			L. 85	R
I.K.	26	M	R.	4 3 3 3 1 1 5	M	16	R. 44	
			L.	4 4 3 2 1 3 5			L. 30	—
A.S.***	24	M	R.	2 2 3 3 3 4 5	M	?	R. —	
			L.	5 5 6 5 3 4 5			L. —	L

*See page 7 for explanation of figures.
**HFN—High Frequency Nerve. N—Nerve. C—Conductive. M—Mixed.
***Did not complete all tests.

Results — Normals

The pure tone thresholds for discomfort, tickle, and pain were tabulated for all subjects as a function of frequency.

Measure of central tendency: The *median* was chosen as a measure of central tendency for two reasons:

1. The thresholds of some subjects exceeded the intensity limitations of the apparatus. An alternative measure of central tendency, *the mean*, could not, therefore, be calculated correctly. As long as not more than half of the thresholds exceeded the limitations, the *median* could be found with complete accuracy.

2. Extreme individual differences would have affected the average disproportionately and perhaps erratically.

Derivation of threshold contours: The three threshold contours were derived separately because frequently in the case of the tickle threshold and more frequently in the case of pain, the values lay beyond the range of the apparatus. It was, therefore, necessary to resort to different statistical treatment to arrive at either a true or postulated contour.

In order to arrive at the ultimate composite contour for each of the three thresholds as a function of frequency, it was first necessary to calculate for each frequency the median values of A and B tests for all six sessions. Using these values, contours were plotted at various stages in the experiment and were also plotted for the overall experiment. The contours were then examined for irregularities and significant changes in shape. Since the irregularities were neither constant nor significant, the curves were superimposed graphically to yield the final contour for each threshold.

Derivation of discomfort contour: The following calculations were performed:

1. The mean of all medians for each frequency was computed.

2. The mean of the median values for each frequency for sessions I and II was calculated. The values for these particular sessions were chosen because the subjects had not begun to show a marked elevation of tolerance as a result of exposure to the test procedure.

3. The mean of the medians for sessions III, IV, V, and VI was determined. In these last four sessions the asymptote for elevation of tolerance was being approached.

The mean of the medians for A and B tests on transfer tolerance was computed. These subjects were those who had been exposed to the speech tolerance procedure. This step added additional subjects to strengthen the validity of the final results.

The median values on the initial test (IA) were then plotted as a function of frequency. (Fig. 7) This figure represented the discomfort contours of the subjects in their most naive state. The median values on the final test (VIB) were similarly plotted to represent the discomfort contours of the subjects in their most sophisticated state.

Table 3 and Fig. 7 show that irregularities in the contours are neither constant nor significant. The shape of the discomfort threshold contour as a function of frequency was therefore derived by superimposing graphically the curves in Fig. 7 and weighting the curves according to the number of responses they represent. It is clear from Fig. 7 that the curves representing the greatest number of responses (sessions I-VI and sessions III-VI) are most constant and regular. The most irregular curve (IA) represents the least number of responses when the subjects were most naive.

The discomfort contour shown in Fig. 8 reveals a long shallow minimum from 1400 to 4000 cps which is approximately 6 db below the high points at 250 and 5600 cps, the lowest and highest frequencies tested. This curve represents only the ***shape*** of the discomfort threshold contour and not its absolute intensity.

Derivation of tickle contour: The tickle contour was derived in precisely the same manner as the discomfort contour although more difficulties were involved in the treatment of the data because some subjects did not report tickle at some frequencies in any test. Furthermore, in later sessions, many subjects failed to report tickle at some frequencies and a few subjects failed to report tickle at any frequency. Fig. 9 shows that generally as the curves are more heavily weighted in terms of number of responses they tend to become more horizontal up to 2000 cps. *It seems reasonable, therefore, to represent the shape of the tickle threshold contour as a horizontal line up to 2000 cps with a rise of 4 db to 2800 cps and a continued rise as the higher frequencies are approached.* (Fig. 10)

Derivation of pain contour: In deriving the pain contour statistical difficulties ruled out the use of the same sequence of steps employed to determine the discomfort and tickle contours. Since a majority of subjects did not report pain at some frequencies in any session and since a few subjects failed to report pain at any frequency in later sessions, it was necessary to base the shape of the pain contour on the mean of the medians for sessions I and IIA only. Although the data in Table 3 and Fig. 11 are relatively meagre *it is probable that the pain threshold contour is a horizontal line.*

Shift of tolerance thresholds with experience: The data involving repeated sessions were studied to observe the effect of repeated exposure to the testing procedure. Figs. 7 and 9 show that the discomfort and tickle thresholds are systematically elevated as a function of number of sessions. The thresholds weighted with responses of later sessions are consistently higher. Although the systematic elevation of the pain threshold is not as dramatically evident, Fig. 11

TABLE 3 — PURE TONE TOLERANCE — NORMALS

Mean of Medians of All Responses in Sessions Designated

Sessions	No. of Ears	No. of Stimuli	250	500	1000	1400	2000	2800	4000	5600
			Cycles per Second							
Thresholds of Discomfort in decibels above 0.0002 dynes/cm²										
I-VI inc.	16	184	119.9	117.2	116.3	113.7	113.7	113.5	113.3	118.8
I-II	16	46	114.9	110.9	113.6	109.5	111.3	112.5	109.8	115.7
III-VI inc.	16	128	122.4	120.4	117.6	115.8	115.1	114.1	115.1	120.4
IA*	16	16	113.0	109.5	111.0	109.0	108.0	111.0	105.0	113.0
VIB*	16	16	124.5	129.0	122.0	121.0	119.0	117.0	120.0	128.0
Transfer Group*	30	60	124.0	122.0	122.0	120.0	117.0	120.0	118.0	120.0
Thresholds of Tickle in decibels above 0.0002 dynes/cm²										
I-VI inc.	16	184	139.2	139.6	138.1	136.2	136.2	140.1	—	—
I-II	16	46	137.0	136.5	133.0	133.5	133.0	137.0	—	—
II-VI inc.	16	128	142.9	143.5	143.5	—	—	—	—	—
IA*	16	16	136.0	134.0	129.0	128.0	128.0	130.5	—	—
VIB*	16	16	—	—	—	—	—	—	—	—
Transfer Group*	30	60	144.0	144.5	—	—	—	—	—	—
Thresholds of Pain in decibels above 0.0002 dynes/cm²										
I-IIA	16	39	142.2	140.7	142.1	141.5	140.3	—	—	—
IA*	16	16	142.5	138.5	139.0	139.5	137.5	—	—	—
Transfer Group	30	60	—	—	—	—	—	—	—	—

*medians only.

—over 50% of responses exceeded limit of apparatus.

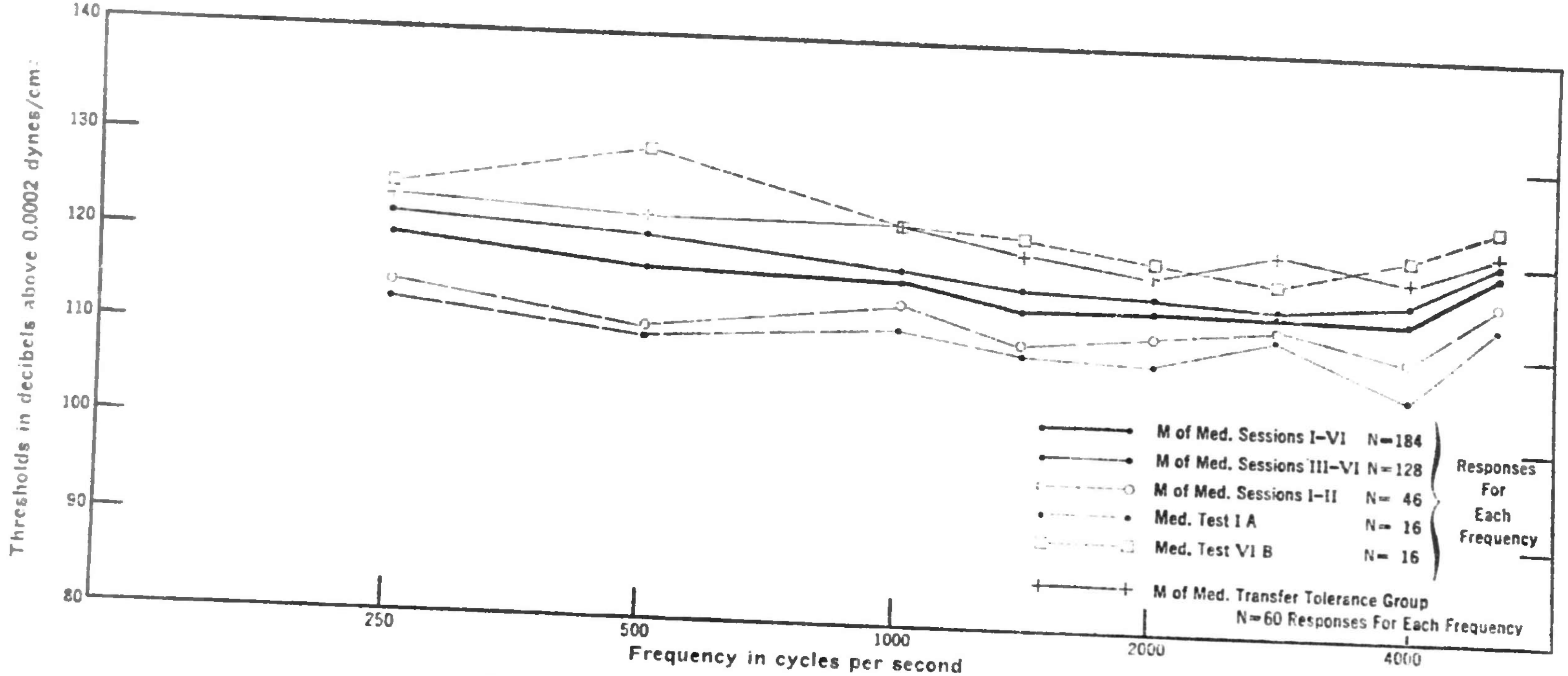

Fig. 7. Thresholds of discomfort for pure tones—Normals.

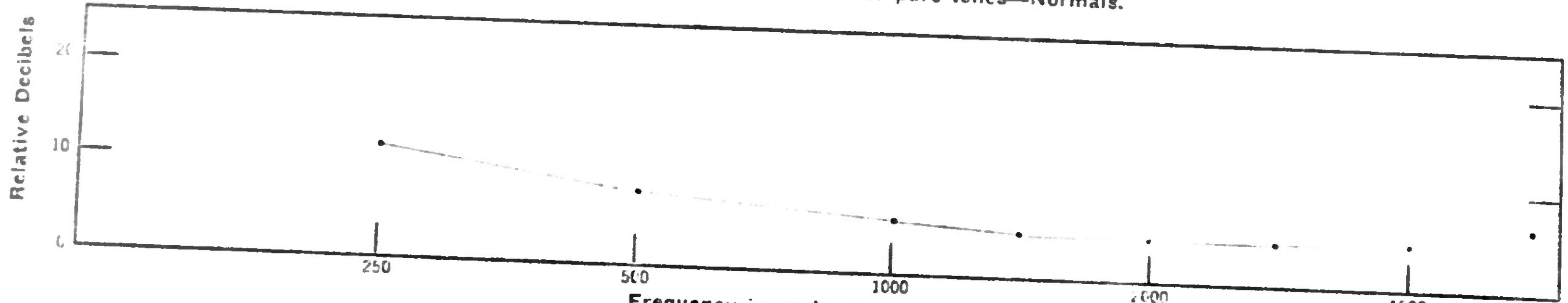

Fig. 8. Discomfort contour for pure tones—Normals.

Frequency in cycles per second

Fig. 8. Discomfort contour for pure tones—Normals.

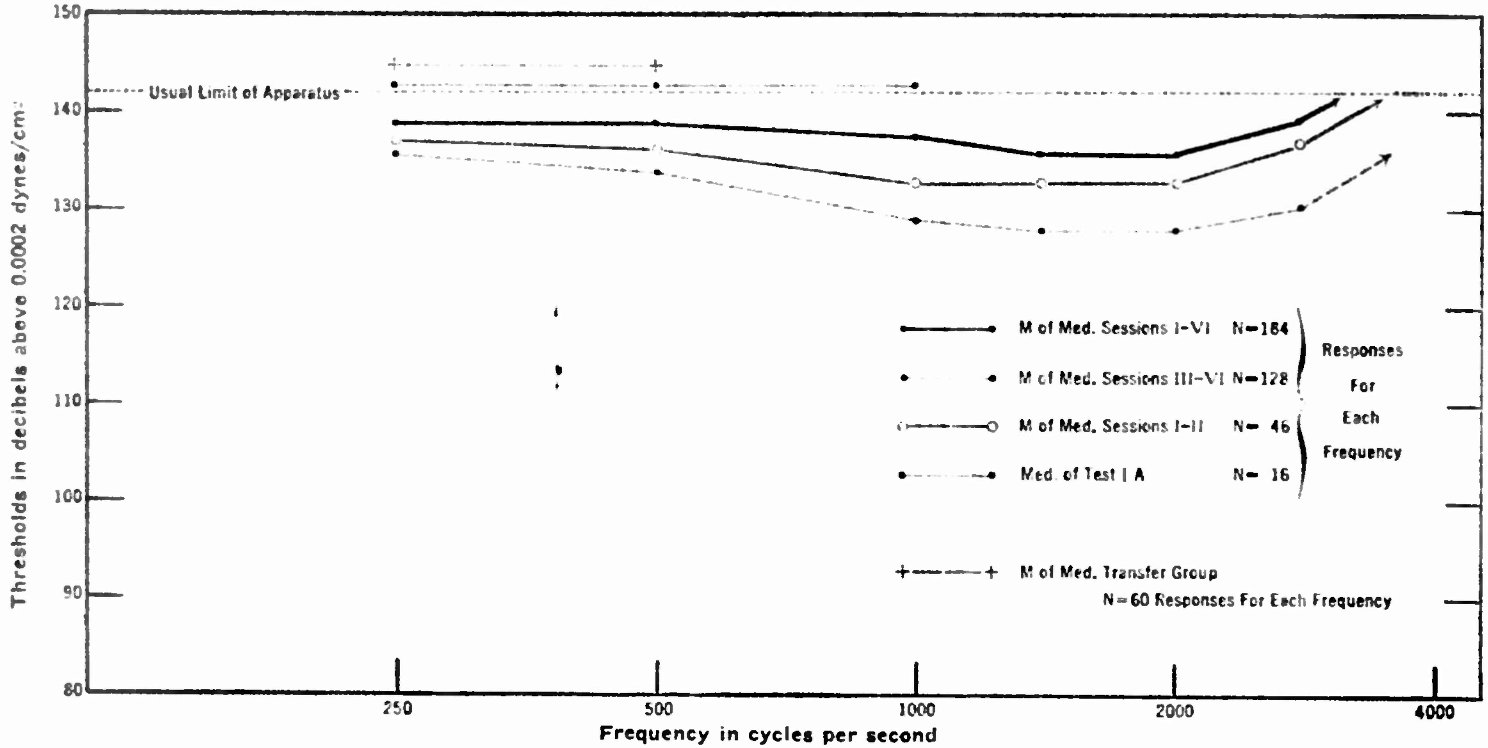

Fig. 9. Thresholds of tickle for pure tone—Normals.

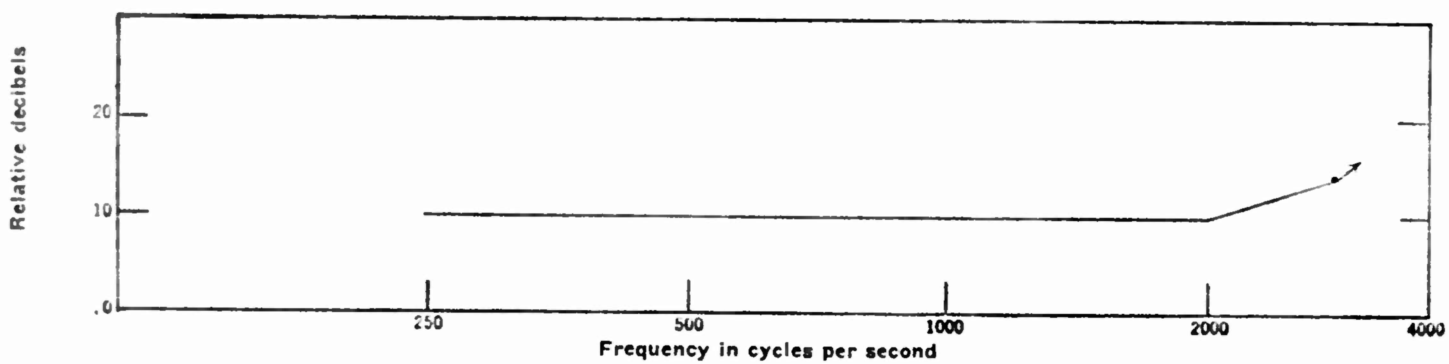

Fig. 10. Tickle contour for pure tones—Normals.

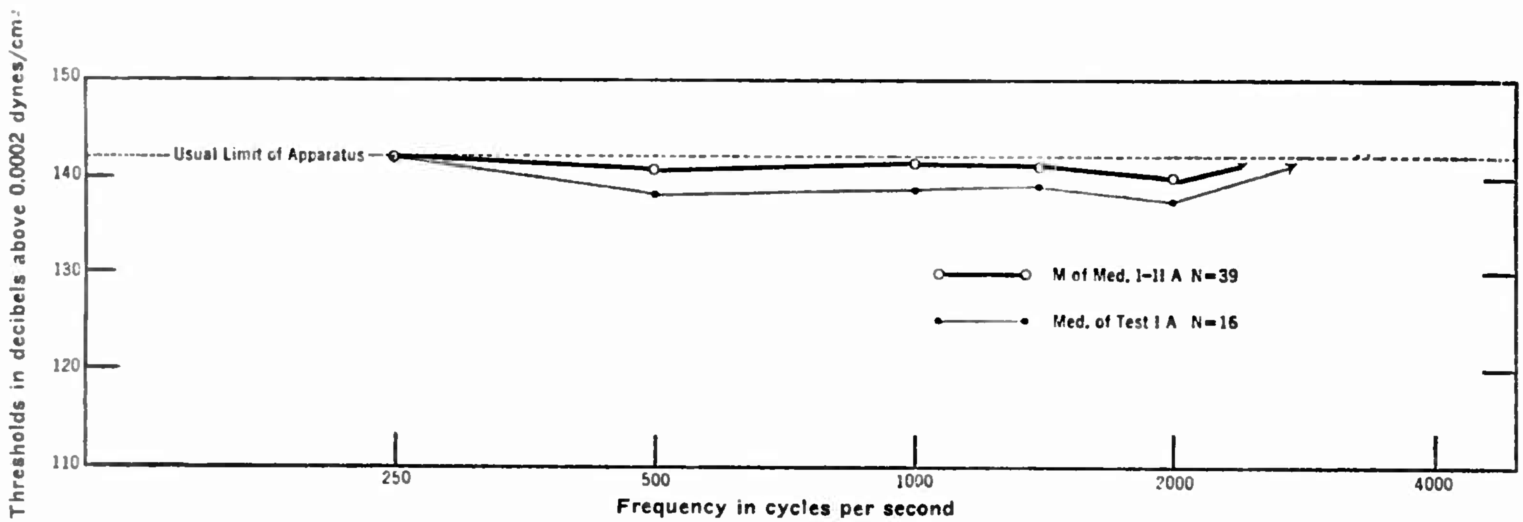

Fig. 11. Thresholds of pain for pure tones—Normals.

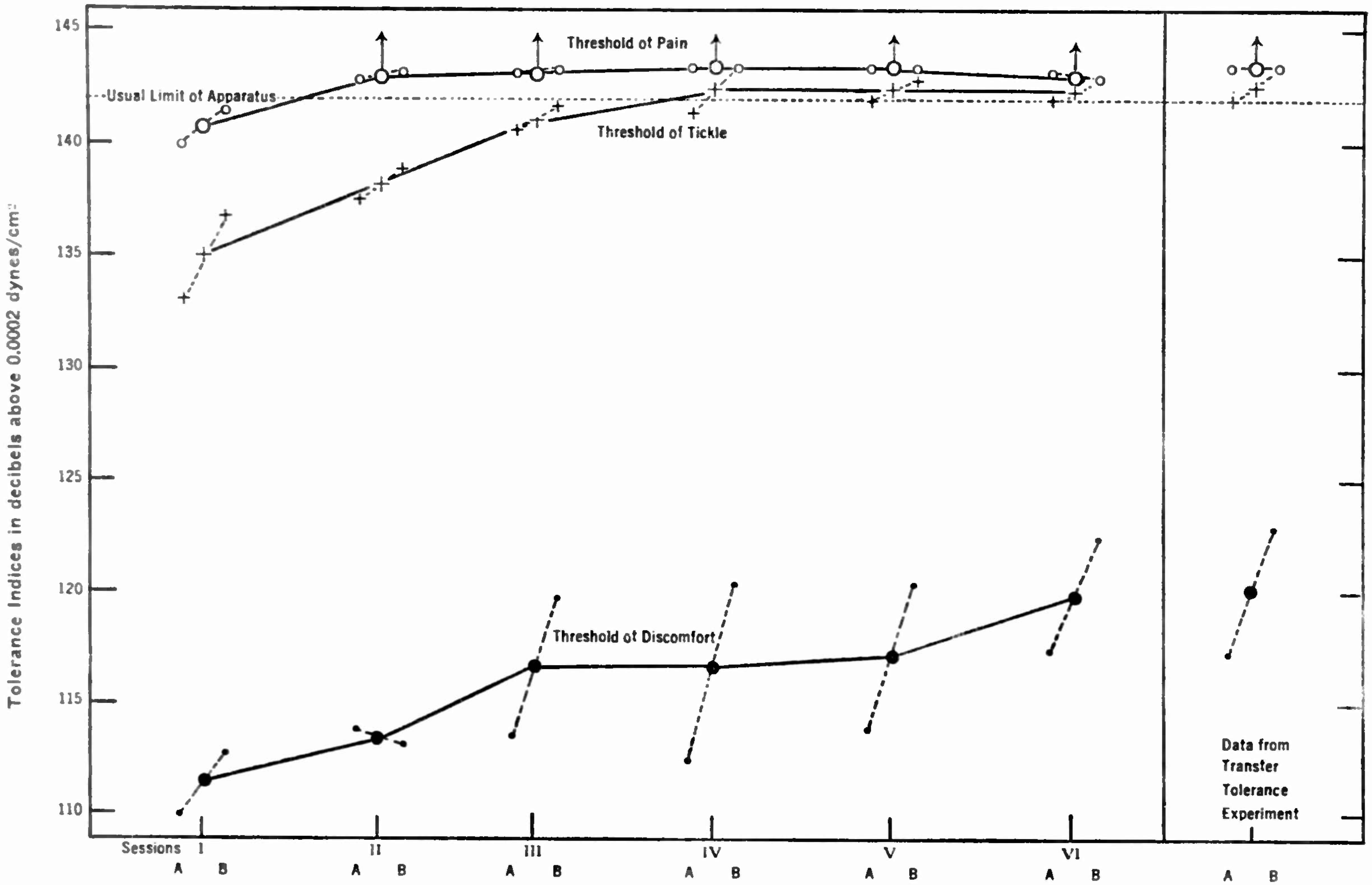

Fig. 12. Elevation of tolerance indices for pure tones—Normals.
Inter-session shift indicated by solid line; intra-session shift by dotted line.

does indicate a rise from session I to IIA. The fact that the median thresholds in subsequent tests lie above the limits of the apparatus justifies the conclusion that *the pain threshold also is elevated as a function of number of sessions.*

Single index of tolerance: In order to study further the phenomenon of shift of thresholds with successive exposures and also subsequently to arrive at a single quantitative measure for each threshold, the medians of all individual values for each frequency were computed and the mean of these medians was used to represent the tolerance level for each threshold. This calculation was made for sessions I, II, III, IV, V, and VI. It will be noted in Table 4 that values lying beyond the limit of the apparatus (figures in italics) entered into the calculation of the mean for tickle and pain. Therefore, the means given are only approximate and *the true mean must lie consistently above the values indicated.* Table 4 shows further that as the number of sessions increased more values beyond the limitations of the apparatus had to be used to determine the approximate means. The limits of the apparatus depended on the characteristics of the earphones; and, since it was necessary to change earphones during the experiment and since the earphones varied slightly in their characteristics, it was impossible to use a constant limiting value for statistical treatment. But, as the shape of each of the three contours was fairly constant from session to session, the use of the mean as a single index of tolerance was justifiable to study elevation of threshold as a function of experience.

Shift of tolerance indices with experience: It is evident from Table 4 and Fig. 12 that the three thresholds are systematically elevated as a function of number of sessions. The amount of elevation for the discomfort threshold was 10.1 db from session IA to VI. However, it is impossible to know the amount of elevation of the tickle and pain thresholds because the limits of the apparatus were reached prior to session VI. The elevation of the tickle threshold from session IA to IVA was 8.8 db and for the pain threshold it was 1.4 db from Test IA to IB. It is obvious, therefore, that the amount of elevation for tickle and pain is greater than these values.

Shift of tolerance indices within a given session: In addition to the shift of tolerance from session to session, there was a systematic elevation within a given session, reflected in the upward shift from tests A to tests B, as shown in Table 4 and in the dotted lines in Fig. 12. For the discomfort threshold the mean elevation (session I-VI) was 4.4 db.

Shift of discomfort threshold and dispersion: In order to demonstrate further the elevation of tolerance with experience, all of the discomfort responses for each of three sessions (I, IV, VI) were tabulated in a frequency distribution. Sessions I, IV, and VI were chosen because they represent, respectively, the initial session, the first session after an approximate break of three months in the experiment for 9 ears, and the final session. This distribution (Fig. 13) disregards the frequency of the stimulating tone. Fig. 13 clearly indicates the upward shift of the discomfort threshold. Session I reveals the greatest dispersion ranging from 88 db to greater than 140 db. The number of responses indicating no

Table 4 — Pure Tone Tolerance — Normals

Median Values — N = 16 ears

Thresholds of Discomfort in decibels above 0.0002 dynes/cm²

Cycles per Second	Sessions I A	I B	II A	II B	III A	III B	IV A	IV B	V A	V B	VI A	VI B
250	113.0	114.0	116.5	116.0	118.0	127.5	117.0	123.5	122.5	129.0	117.5	124.5
500	109.5	108.0	114.0	112.0	112.0	121.0	114.0	123.0	116.0	128.0	120.0	129.0
1000	111.0	115.0	114.5	114.0	116.0	116.0	114.0	120.0	114.0	120.0	119.0	122.0
1400	109.0	108.0	109.0	112.0	111.0	116.5	111.0	118.5	115.0	116.5	117.0	121.0
2000	108.0	110.0	114.0	113.0	113.0	114.5	111.0	117.0	112.0	117.0	117.0	119.0
2800	111.0	114.0	111.0	114.0	109.0	118.5	113.0	117.0	111.0	114.0	113.0	117.0
4000	105.0	115.0	110.0	109.0	113.0	117.5	111.5	120.0	109.0	116.0	114.0	120.0
5600	113.0	115.0	120.0	115.0	118.0	126.0	114.0	122.5	111.5	121.0	122.0	123.0
Mean of Test	109.9	112.4	113.6	113.1	113.8	119.7	113.2	120.2	113.9	120.2	117.4	122.6
Mean of Session	111.2		113.4		116.8		116.7		117.1		120.0	
Mean of All Sessions	115.83											

Thresholds of Tickle in decibels above 0.0002 dynes/cm²

Cycles per Second	I A	I B	II A	II B	III A	III B	IV A	IV B	V A	V B	VI A	VI B
250	130.0	134.0	138.0	145.0	141.5	145.0	140.0	144.0	144.0	144.0	141.0	144.0
500	134.0	136.0	139.0	138.0	140.0	145.0	142.5	145.0	142.5	144.5	145.0	145.0
1000	129.0	132.0	133.5	135.0	141.0	141.0	144.5	145.0	142.5	144.0	145.0	145.0
1400	128.0	136.0	135.5	136.0	141.0	140.5	144.0	144.0	144.0	144.0	144.0	144.0
2000	128.0	136.0	137.0	135.0	140.5	140.5	142.0	142.0	142.0	142.0	142.0	142.0
2800	130.5	139.0	139.0	138.0	140.0	140.0	140.5	144.0	139.0	143.0	143.5	144.5
4000	140.0	140.0	139.5	140.0	140.0	140.0	140.5	141.0	140.0	140.5	140.0	140.0
5600	140.0	140.0	140.0	140.0	140.5	140.0	141.0	141.0	140.0	141.0	139.0	139.0
Mean of Test	133.1	136.6	137.7	138.4	140.6	141.5	141.9	143.2	141.8	142.9	142.4	142.9
Mean of Session	134.9		138.1		141.1		142.6		142.4		142.7	
Mean of All Sessions	140.25											

Thresholds of Pain in decibels above 0.0002 dynes/cm²

Cycles per Second	I A	I B	II A	II B	III A	III B	IV A	IV B	V A	V B	VI A	VI B
250	142.5	139.0	145.0	145.0	145.0	145.0	145.0	145.0	144.5	145.0	144.0	144.0
500	138.5	139.0	144.5	145.0	145.0	145.0	145.0	145.0	145.0	145.0	145.0	145.0
1000	139.0	145.0	142.5	142.0	145.0	145.0	145.0	145.0	145.0	145.0	145.0	145.0
1400	139.5	143.0	143.5	145.0	144.0	144.0	144.0	144.0	144.0	144.0	144.0	144.0
2000	137.5	141.0	143.0	143.0	142.0	142.0	142.0	142.0	142.0	142.0	142.0	142.0
2800	144.0	145.0	145.0	145.0	145.0	145.0	145.0	145.0	145.0	145.0	145.0	145.0
4000	140.0	140.0	140.0	140.0	140.0	140.0	141.0	141.0	140.5	141.0	140.0	140.0
5600	140.0	140.0	140.0	140.0	140.5	140.0	141.0	141.0	141.0	141.0	139.0	139.0
Mean of Test	140.1	141.5	142.9	143.1	143.3	143.2	143.5	143.5	143.4	143.4	143.0	143.0
Mean of Session	140.8		143.0		143.2		143.5		143.4		143.0	
Mean of All Sessions	142.82											

Figures in italics indicate values above limit of apparatus.

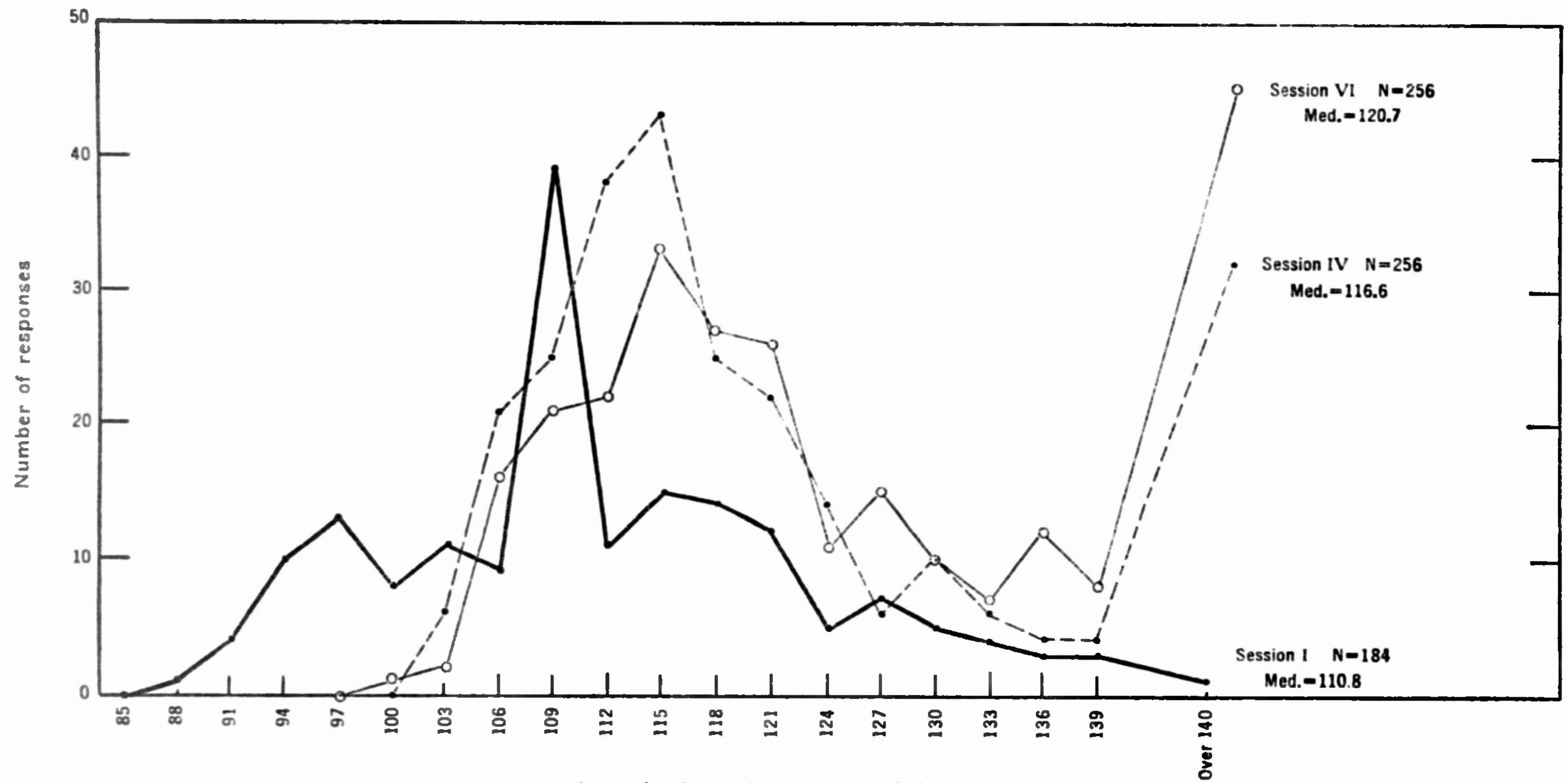

Fig. 13. Frequency distribution of thresholds of discomfort for pure tones—Normals.

discomfort increased with the number of sessions. The large number of thresholds that lay above the limits of the apparatus made it impossible to compute the dispersion statistically.

A similar distribution for tickle and pain is not very informative because of the relatively large number of thresholds which lay beyond the range of the apparatus. Table 5 reveals the number of these thresholds and further indicates the progressive elevation of tolerance.

TABLE 5 — NUMBER OF THRESHOLDS SURPASSING THE LIMITS OF THE APPARATUS

Session	Discomfort	Tickle	Pain
I	1	41	75
IV	29	143	221
VI	42	149	238

Auditory Map — Normals

The ultimate threshold levels of tolerance for discomfort, tickle, and pain are represented by the asymptotes of the three curves in Fig. 12, showing the means of each session. By fitting the shapes of the curves previously derived to the nearest asymptotic values, the final tolerance thresholds can now be represented by the curves in Fig. 14.

It should be recalled that the discomfort level is represented by the mean of a curve having a long shallow minimum from 1400 to 4000 cps which is approximately 3 db below the mean for all frequencies. Using the mean points for each session to determine the asymptote *the mean value for the ultimate discomfort level is 120 db.*

From Fig. 12 it is clear that the ultimate tickle threshold cannot be established precisely because the approximate mean value for later tests lies beyond the limits of the apparatus and, therefore, the asymptote is indefinite. *All that can be said is that the tickle threshold is greater than 141.9 db which represents the last approximate mean lying below the range of the apparatus.*

The asymptote of the pain threshold in Fig. 12 is undoubtedly an artefact since the approximate mean as early as Session IIA lies beyond the apparatus limitations. *It is certain, however, that the mean threshold is greater than 141.5 db.*

Fig. 15 represents the auditory map using the data of Sivian and White [1] for the threshold of acuity. For purposes of comparison Wegel's [2] points for the threshold of "feeling" and an equal loudness contour at the 100 db level [3] are included. The uppermost curve labelled "threshold of pain" actually indicates the limit of the apparatus, and the vertical arrows indicate that the actual threshold of pain lies somewhere slightly *above* this line. The map suggests the following comments:

1. *The final levels, never before approached because of inadequacy of equipment, are surprisingly high.*

[1] Fletcher, Harvey, Speech and Hearing, New York, D. Van Nostrand Company, Inc., 1929.
[2] Wegel, op. cit.
[3] Stevens and Davis, op. cit.

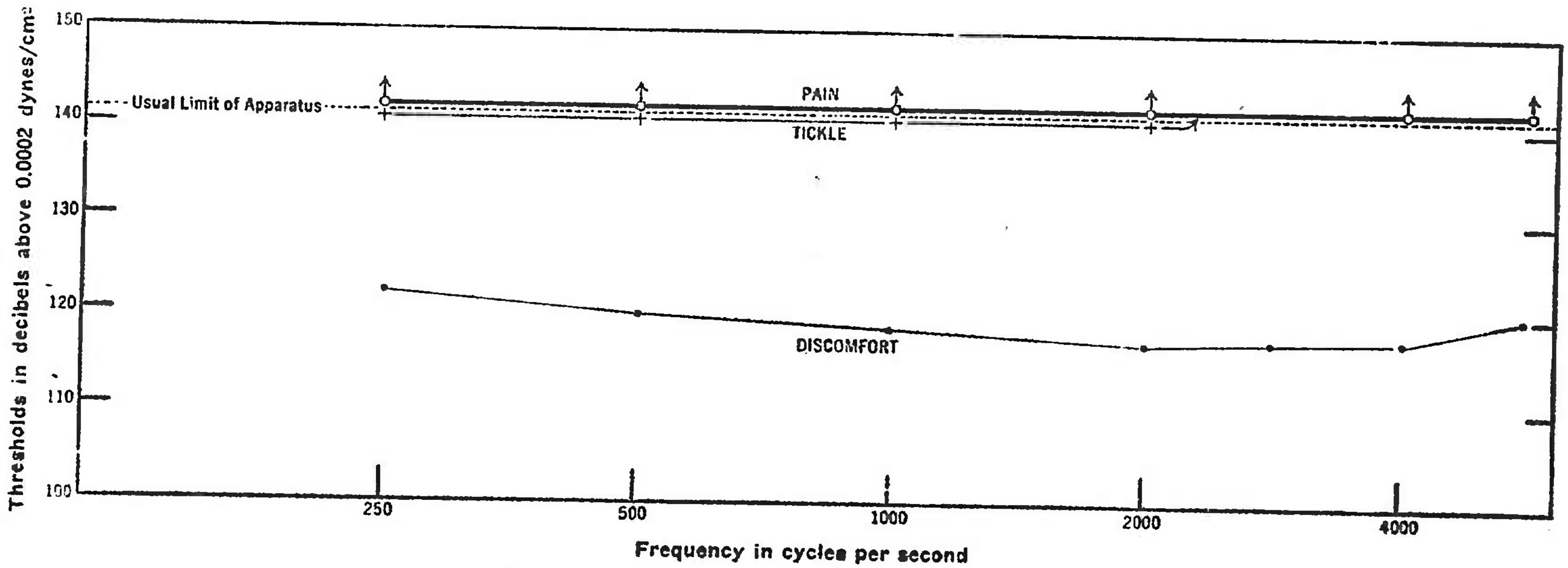

Fig. 14. Ultimate thresholds for pure tones—Normals.

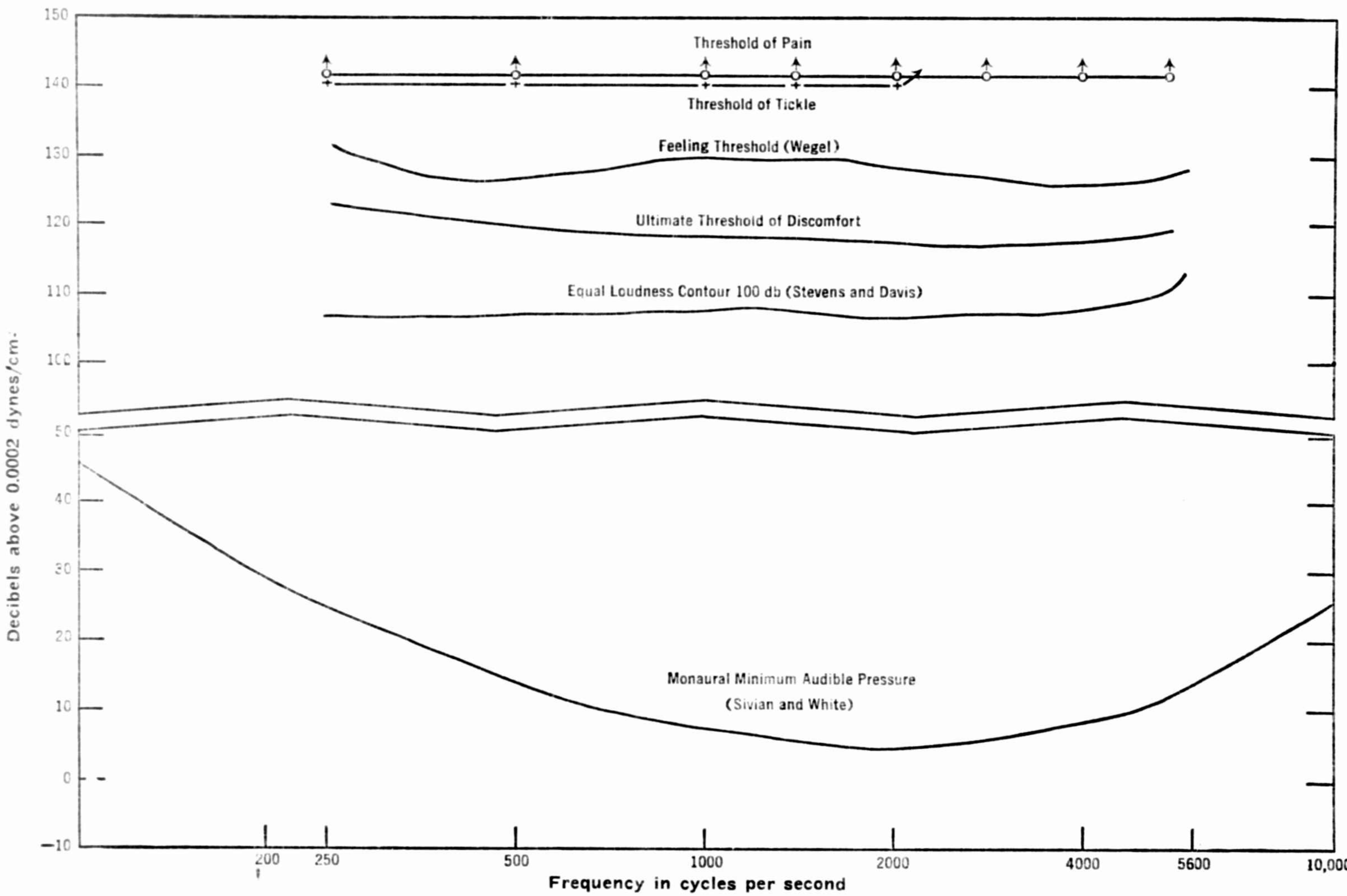

Fig. 15. Auditory map for pure tones—Normals.

The curves in the upper half of the figure represent pressures measured under the receiver by means of a coupler. The lower curve for minimum audible pressure has been corrected to give the pressure at the ear drum. It is therefore approximately but not precisely comparable with the upper curves.

2. *The shape of the discomfort contour is supported by Wegel's data.* The levels suggest that Wegel's threshold was the beginning of the tickle sensation. This inference is supported by Wegel's description of his instructions to subjects.[2]

3. *The shape of the discomfort contour strongly suggests that it is a high-intensity equal-loudness contour.*

4. *There is no support for the theory that high pitched tones are more painful as has been suggested by Fletcher's curve.*[1] Although because of limitations of apparatus it was impossible to obtain data for the area around 8000 cps, there is no suggestion of a downward trend in the higher frequencies. The reports that higher frequencies are more painful are probably the result of semantic confusion with such sensations as "sharp," "piercing," and "annoying."

Individual Differences

In order to study individual differences, the subjects were ranked from "tenderness" to "toughness." The mean of the initial scores of each subject for the eight frequencies was computed for discomfort, tickle, and pain. Since the objective was to rank the individuals with respect to tenderness, it appeared logical to base the rank on the mean of the combined data of both ears (where available) and all three thresholds. Table 6.

Relationship of ears: The rank order correlation between the two ears on initial discomfort was .86. This high correlation indicates that *if an individual was tender in one ear he was likely to be equally tender in the other ear.*

Relationship of initial and final thresholds: Omitting three ears which did not experience final discomfort, shown in Table 6, the rank order correlation between the initial and final discomfort measure on each ear was .16. (The low correlation is probably due to the crowding of final values.) *All individuals tend to approach the final values plotted on the auditory map.*

Age and sex factors: The data suggest no relationship between tenderness and age. The only true data obtainable were the mean initial discomfort thresholds for male and female which were 113.5 db and 111.4 db, respectively, suggesting no relationship between sex and tenderness.

Stability and Threshold of Acuity

Before and after each A test the thresholds of acuity for each frequency were determined. This procedure was introduced midway in the experiment, but sufficient data are available to indicate the trend. Fig. 16 shows the temporary

[1] Fletcher, Harvey, Speech and Hearing. New York, D. Van Nostrand Company, Inc., 1929.
[2] Wegel, op. cit.

TABLE 6 — PURE TONE TOLERANCE — NORMALS

Mean of all frequencies in decibels above 0.0002 dynes/cm^2

Individual Threshold Indices

Subject	Ear	Discomfort Initial	Discomfort Final	Tickle Initial	Tickle Final	Pain Initial	Pain Final	Discomfort Threshold Shift	Mean Hearing Loss Temporary
H.L.	R	106.2	135.2	120.8	*143.4*	135.6	*145.0*	29.0	13.4
H.T.	R	95.8	121.0	133.6	*143.0*	133.7	*143.0*	25.2	8.6
	L	98.8	119.8	132.8	*143.0*	135.9	143.0	20.7	6.6
C.H.	R	107.0	118.2	124.8	129.9	141.2	135.6	11.2	16.2
J.D.	R	108.1	115.4	131.4	*143.1*	140.2	*143.4*	7.3	7.2
	L	107.8	118.1	130.6	*143.4*	138.5	*143.4*	10.3	9.7
M.R.	R	109.8	132.8	125.5	*143.4*	139.6	*143.5*	23.0	7.8
	L	112.0	134.4	135.6	*143.5*	141.1	*143.5*	22.4	6.5
A.M.	R	114.1	*137.1*	126.0	141.0	142.8	*143.0*	—	19.5
	L	112.1	134.9	131.2	142.0	*144.0*	*143.0*	22.8	20.7
L.S.	R	114.5	113.5	141.2	141.9	138.5	*143.8*	-1.0	2.4
	L	109.8	113.0	137.6	*142.5*	141.2	*143.8*	3.2	5.7
F.S.	R	124.6	*143.0*	*136.9*	*142.5*	135.9	*143.0*	—	6.6
	L	127.0	*142.1*	132.8	*143.0*	133.2	*143.0*	—	5.8
U.B.	R	126.9	117.5	140.8	141.1	*143.5*	*143.5*	-9.4	5.1
	L	122.9	116.5	139.8	142.0	*143.5*	*143.5*	-6.4	7.7
									Mean = 9.3
									S.D. = 5.13

Figures in italics indicate values above limit of apparatus.

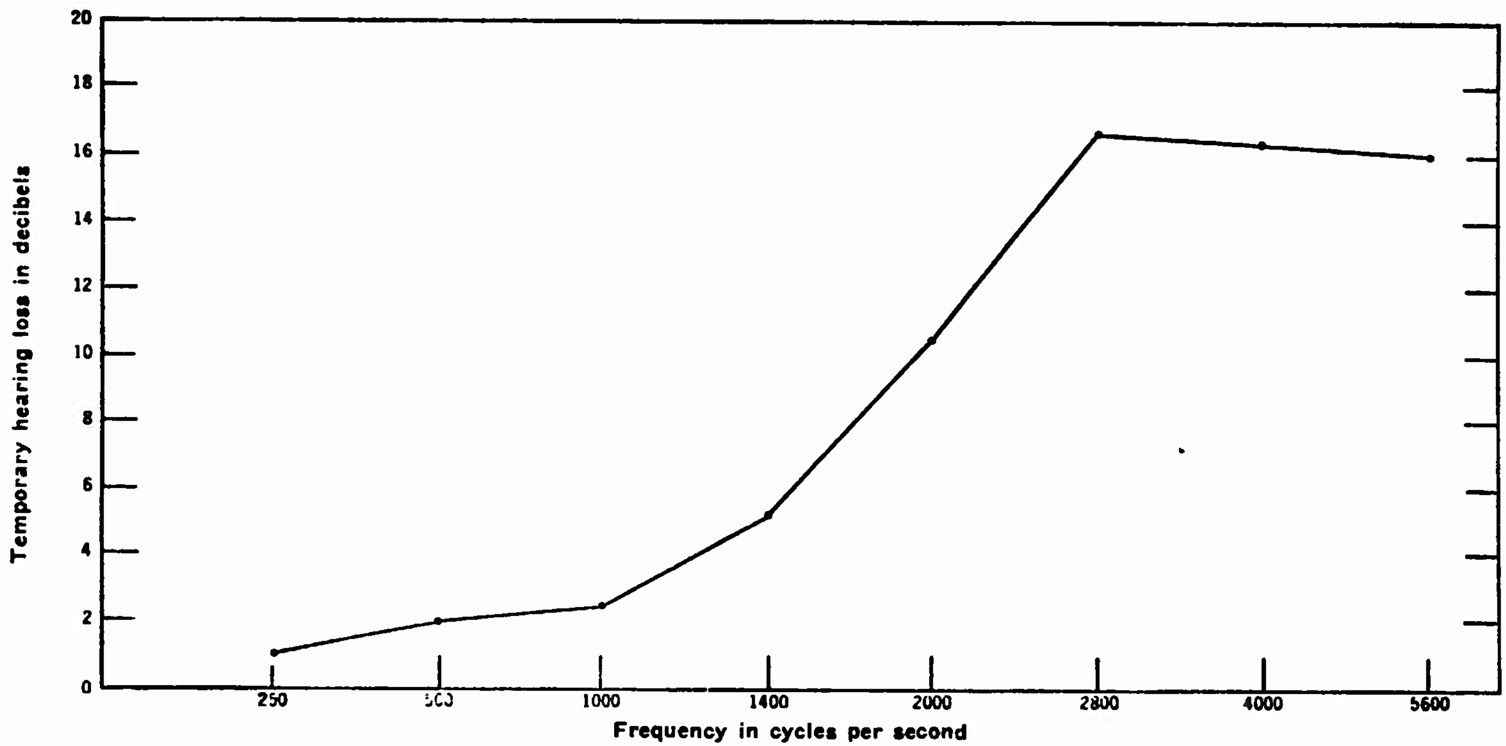

Fig. 16. Temporary hearing loss immediately after pure tone tolerance tests—Normals. 16 ears: 77 responses for each frequency.

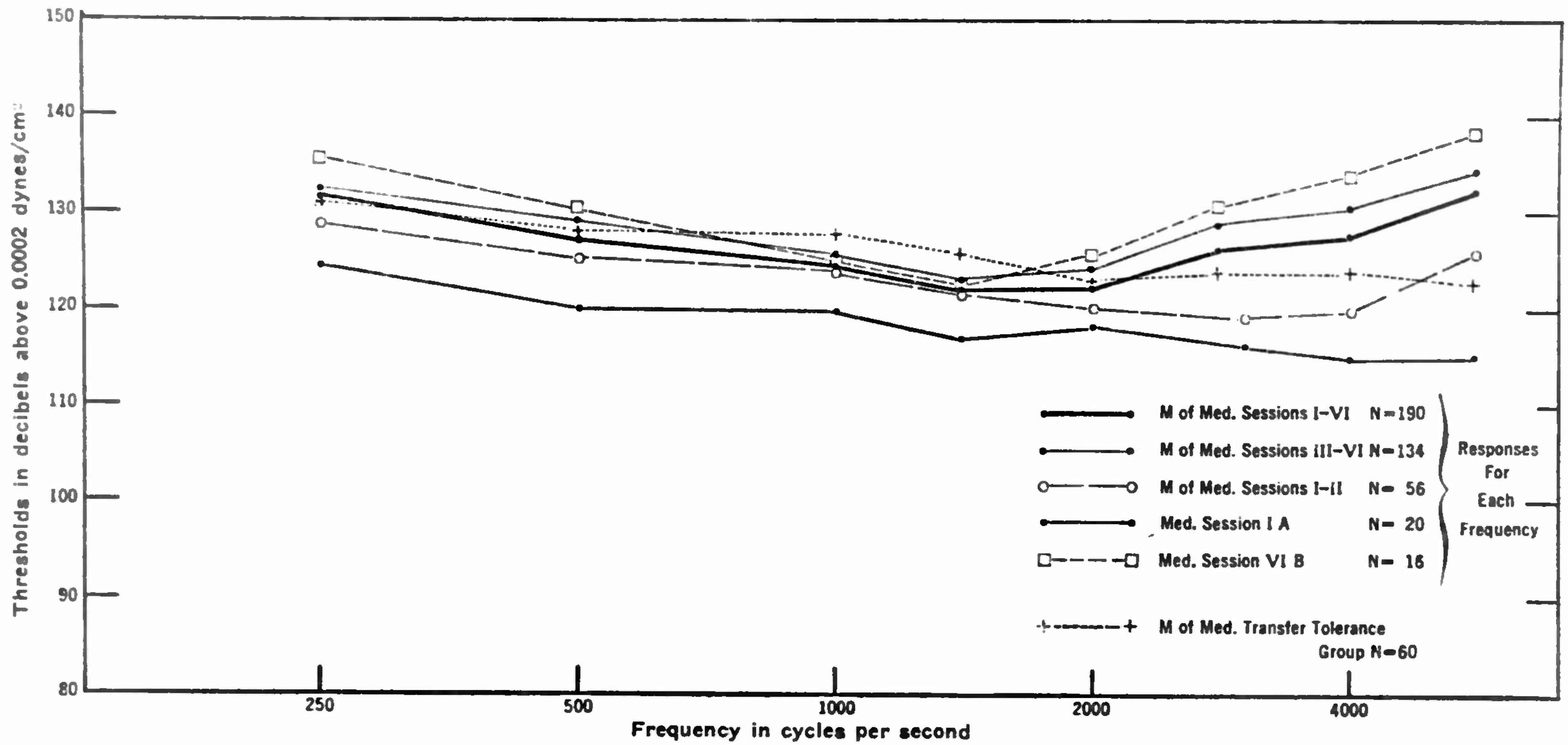

Fig. 17. Thresholds of discomfort for pure tones—Hard-of-Hearing.

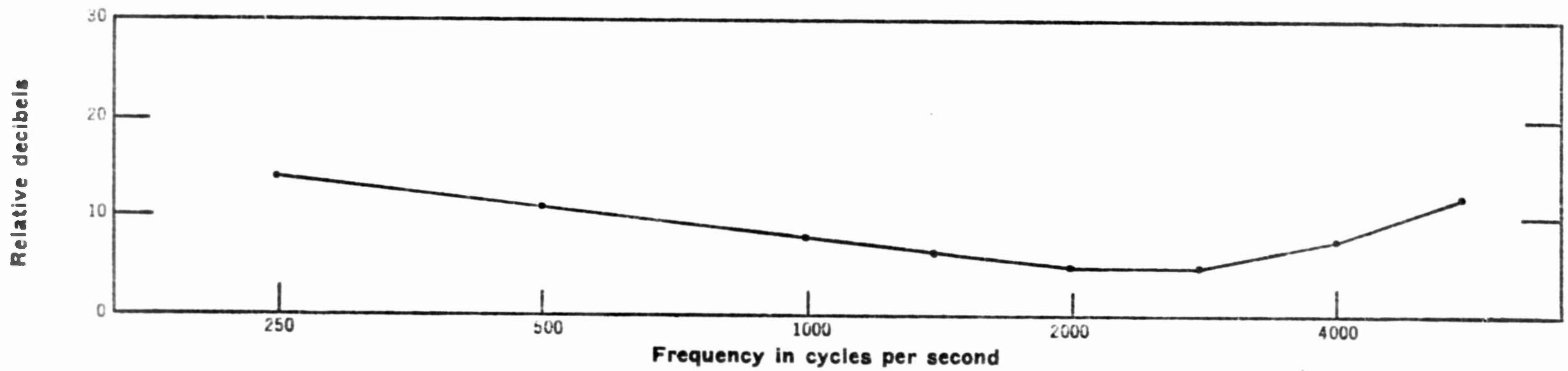

Fig. 18. Discomfort contour for pure tones—Hard-of-Hearing.

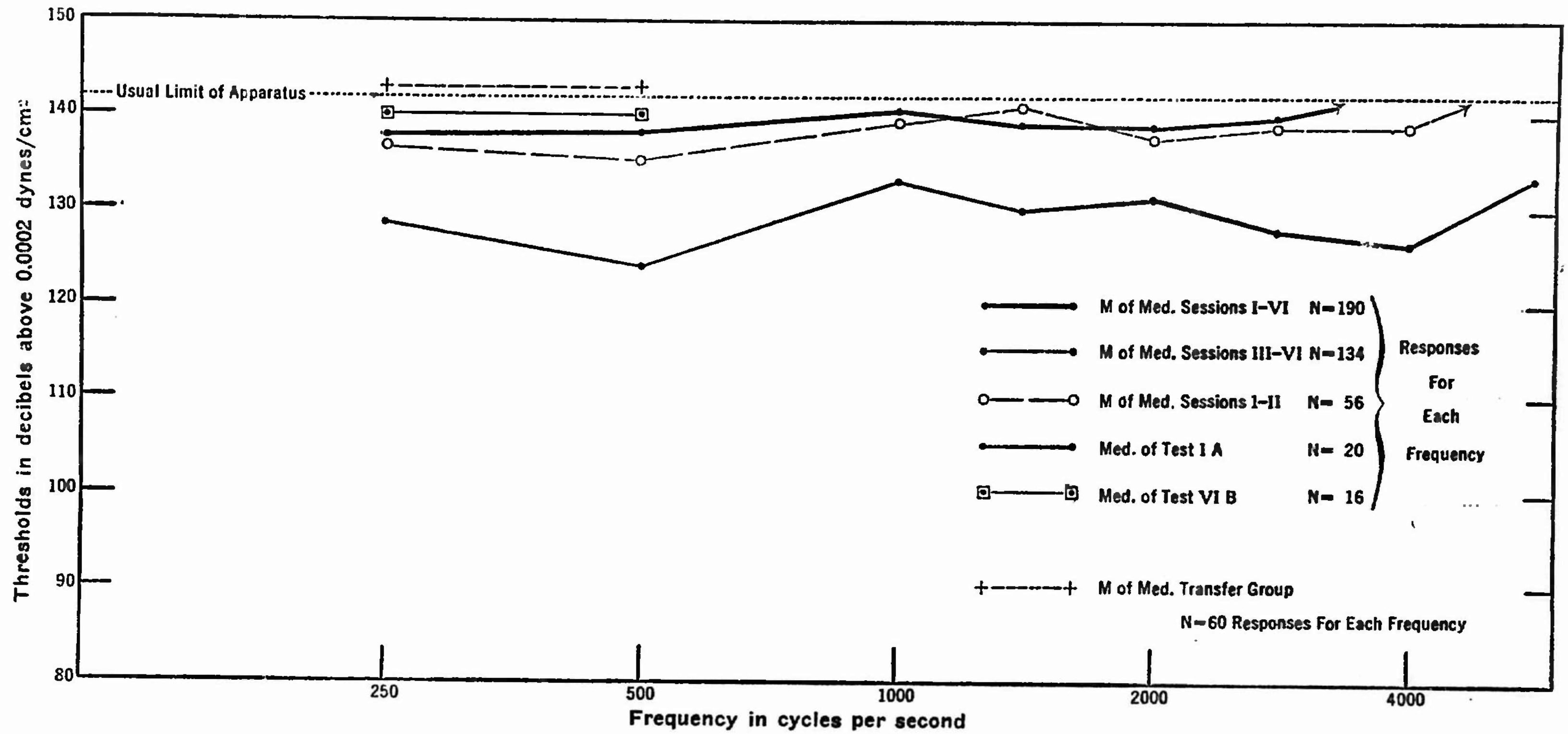

Fig. 19. Thresholds of tickle for pure tones—Hard-of-Hearing.

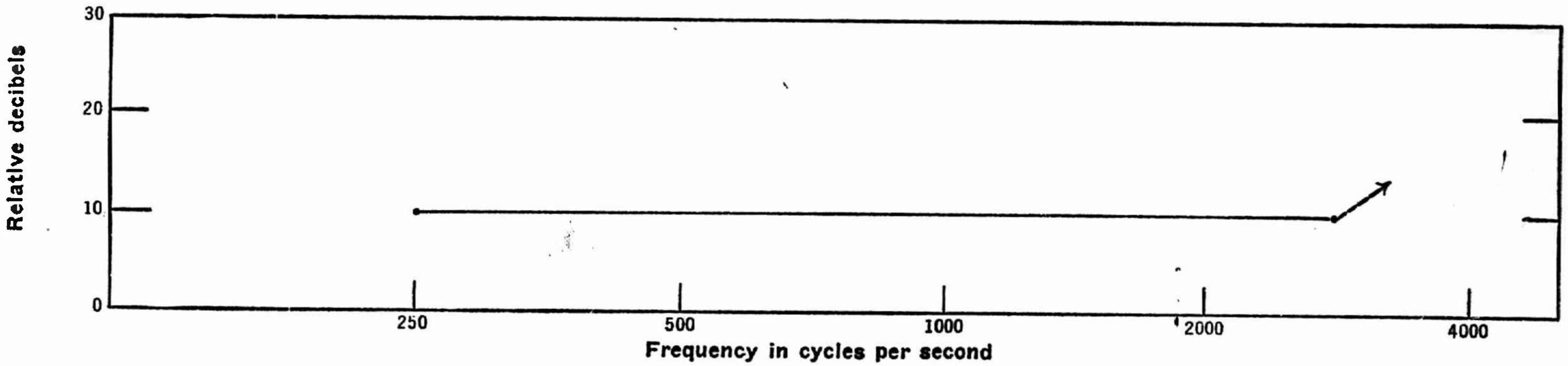

Fig. 20. Tickle contour for pure tones—Hard-of-Hearing.

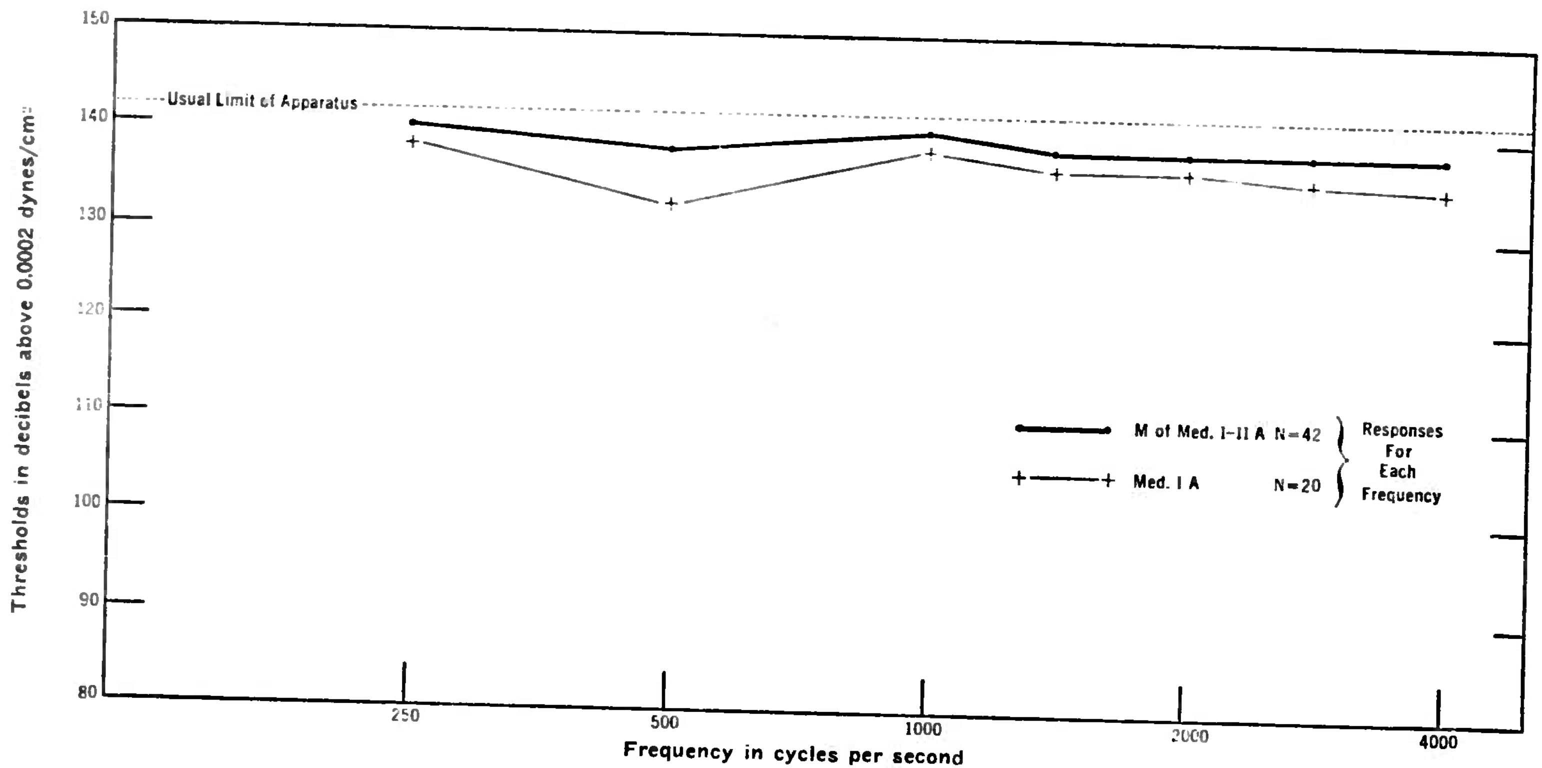

Fig. 21. Thresholds of pain for pure tones—Hard-of-Hearing.

Table 7 — Pure Tone Tolerance — Hard-of-Hearing

Mean of Medians of All Responses in Sessions Designated

Sessions	No. of Ears	No. of Stimuli	Cycles per Second 250	500	1000	1400	2000	2800	4000	5600
Thresholds of Discomfort in decibels above 0.0002 dynes/cm²										
I-VI inc.	20	190	131.2	127.5	124.4	122.3	122.8	126.3	127.8	132.5
I-II	20	56	129.0	125.5	124.5	122.0	120.5	119.5	120.0	126.0
III-IV inc.	16	134	132.0	129.3	125.8	123.2	124.8	129.0	130.8	134.8
IA*	20	20	124.5	120.0	120.0	117.0	118.5	116.5	115.0	115.5
VIB*	16	16	133.5	130.5	126.0	125.0	125.5	131.0	134.0	138.5
Transfer Group*	30	60	131.0	128.0	128.0	126.0	123.0	124.0	124.0	123.0
Thresholds of Tickle in decibels above 0.0002 dynes/cm²										
I-VI inc.	20	190	137.4	138.0	140.7	139.1	138.8	139.8	—	—
I-II	56	56	137.0	135.0	140.0	141.0	138.0	139.0	139.0	—
III-VI inc.	16	134	140.0	140.0	—	—	—	—	—	—
IA*	20	20	128.5	124.0	133.0	130.0	131.5	128.0	126.5	133.5
VIB*	16	16	140.0	140.0	—	—	—	—	—	—
Transfer Group*	30	60	142.5	143.0	—	—	—	—	—	—
Thresholds of Pain in decibels above 0.0002 dynes/cm²										
I-IIA	20	42	140.5	138.0	140.5	138.5	138.3	138.7	138.3	—
IA*	20	20	138.5	132.5	138.5	136.5	136.5	135.5	135.0	—
Transfer Group*	30	60	—	—	—	—	—	—	—	—

*medians only.
–over 50% of responses exceeded limit of apparatus.

loss in acuity as a function of frequency. There is an elevation of threshold for frequencies above 1000 cps which amounts to 16 db at 2800, 4000, and 5600 cps.

Threshold measurements taken at the beginning of each session were also compared with similar measures taken before and after the A test of the previous session. The hearing losses indicated in Fig. 16 and Table 6 were definitely temporary. The mean shift in threshold for the group was 9.3 db with an SD of 5.13 db which indicates a wide spread among the shifts.

Results — Hard-of-Hearing

The logic and procedure in deriving threshold contours for the hard-of-hearing was identical with the step by step development followed for the normal group. The data are presented in Table 7 and Fig. 17.

Discomfort contour: The discomfort contour shown in Fig. 18 reveals a shallow minimum from 1400 to 3000 cps which is approximately 7 db below the high points at 250 and 5600 cps, the highest and lowest frequencies tested.

Tickle contour: Fig. 19 shows that the contour based on the greatest number of tests (I-VI) is roughly a horizontal line up to 2800 cps with a rise from that point with frequency. The magnitude of the rise is indeterminate because of the limitations of the apparatus. It seems reasonable to represent the tickle threshold contour for the hard-of-hearing by the curve in Fig. 20.

Pain contour: Because of statistical difficulties similar to those encountered in the derivation of the pain contour for normals, the pain contour for the hard-of-hearing had to be based on the mean of the median of tests I and IIA. *The data in Table 7 and Fig. 21 point to the probability that the pain threshold contour is a horizontal line.*

Shift of tolerance thresholds with experience: It is clear from Figs. 17 and 19 that the discomfort and tickle thresholds are systematically elevated as a function of number of sessions, since the curves weighted with responses of later sessions are consistently higher. Fig. 19 illustrates a rise in the pain threshold from session I to IIA; and, since curves containing values of later sessions would lie beyond the limits of the apparatus, *it is reasonable to conclude that the pain threshold is also elevated by successive exposures.*

Shift of tolerance indices with experience: Using the single index of tolerance (mean of medians for all frequencies) and keeping in mind the limitations of the statistical treatment described for the normals on p. 24. the systematic elevation of threshold as a function of number of sessions is again shown in Fig. 22. The dip at session IV reflects a time break of approximately 3 months for all but one subject. The ultimate elevation of the discomfort threshold was 10.7 db. The elevation for the tickle threshold from session I-IVB was 11.7 db and for pain from session I-IIA 5 db; and the ultimate elevations must have been still greater.

Table 8 — Pure Tone Tolerance — Hard-of-Hearing

Median Values — N = 20 ears (sessions I, II, III)
16 ears (sessions IV, V, VI)

Cycles per Second	Sessions: I	II		III		IV		V		VI	
		A	B	A	B	A	B	A	B	A	B
Thresholds of Discomfort in decibels above 0.0002 dynes/cm²											
250	124.5	130.0	129.0	132.0	134.0	130.0	133.5	130.0	133.0	130.0	135.5
500	120.0	127.0	128.0	128.5	133.0	124.0	130.0	127.0	129.0	125.0	130.5
1000	120.0	124.5	126.5	125.0	128.0	122.0	124.0	122.0	127.0	122.0	126.0
1400	117.0	123.0	123.0	123.5	124.0	119.0	121.0	121.0	126.0	123.0	125.0
2000	118.5	120.0	120.5	121.0	128.0	120.5	124.0	122.0	129.0	119.5	125.5
2800	116.5	112.5	120.0	126.0	127.0	127.5	128.5	129.5	130.0	130.0	131.0
4000	115.0	123.0	123.5	132.0	133.0	122.5	132.0	126.5	135.0	129.5	134.0
5600	115.5	130.0	132.0	134.0	137.0	129.0	132.0	129.5	140.0	136.0	138.5
Mean of Test	118.4	125.0	125.3	127.8	130.5	124.3	128.1	125.9	131.1	126.9	130.8
Mean of Session	118.4	125.2		129.1		126.2		128.5		128.9	
Mean of All Sessions	126.73										
Thresholds of Tickle in decibels above 0.0002 dynes/cm²											
250	128.5	135.0	138.0	139.0	140.0	137.0	139.5	135.0	140.0	140.0	140.0
500	124.0	135.0	138.5	139.0	140.0	139.5	139.5	138.5	141.5	141.0	140.0
1000	133.0	139.0	141.5	141.5	142.0	141.5	*143.5*	143.5	*145.0*	*145.0*	*145.0*
1400	130.0	139.0	141.5	*143.0*	*142.0*	*143.0*	*143.5*	*143.5*	*143.5*	*143.5*	*143.5*
2000	131.5	137.0	139.5	140.0	140.0	139.0	*142.0*	*141.0*	*141.5*	*141.5*	*141.5*
2800	128.0	139.0	139.0	*145.0*	*145.0*	*142.0*	*141.0*	*145.0*	*145.0*	*145.0*	*145.0*
4000	126.5	*139.0*	*139.0*	*139.5*	*139.0*	*139.5*	*139.5*	*140.0*	*140.0*	*140.0*	*140.0*
5600	133.5	*139.0*	*139.5*	*140.0*	*140.0*	*140.0*	*140.0*	*140.0*	*140.0*	*140.0*	*140.0*
Mean of Test	129.4	*137.8*	*140.9*	*140.9*	*141.0*	*140.2*	*141.1*	*140.8*	*142.1*	*142.0*	*141.9*
Mean of Session	129.4	*139.4*		*141.0*		*140.7*		*141.5*		*142.0*	
Mean of All Sessions	*139.83*										
Thresholds of Pain in decibels above 0.0002 dynes/cm²											
250	138.5	143.0	143.0	*144.0*	*146.0*	*145.0*	*145.0*	*145.0*	*145.0*	*145.0*	*145.0*
500	132.5	142.0	144.5	*143.0*	*144.0*	*145.0*	*145.0*	*145.0*	*145.0*	*145.0*	*145.0*
1000	138.5	143.0	146.0	*145.0*	*145.5*	*145.0*	*145.0*	*145.0*	*145.0*	*145.0*	*145.0*
1400	136.5	*140.5*	*144.5*	*144.0*	*144.0*	*144.0*	*143.5*	*143.5*	*143.5*	*143.0*	*143.5*
2000	136.5	140.0	142.5	143.0	*142.0*	*142.0*	*142.0*	*141.5*	*141.5*	*141.5*	*141.0*
2800	135.5	143.5	143.5	*145.0*	*144.0*	*145.0*	*145.0*	*144.5*	*145.0*	*144.5*	*145.0*
4000	*135.0*	*140.0*	*140.0*	*141.0*	*141.0*	*140.0*	*140.0*	*140.0*	*140.0*	*140.0*	*140.0*
5600	*137.0*	*138.5*	*139.0*	*140.0*	*140.0*	*140.0*	*140.0*	*140.0*	*140.0*	*140.0*	*140.0*
Mean of Test	*136.3*	*141.3*	*142.9*	*143.1*	*143.3*	*143.2*	*143.2*	*143.1*	*143.1*	*143.0*	*143.1*
Mean of Session	*136 3*	*142.1*		*143.2*		*143.2*		*143.1*		*143.1*	
Mean of All Sessions	*142.26*										

Figures in italics indicate values above limit of apparatus.

Shift of tolerance indices within a given session: Table 8 and Fig. 22 show an upward shift in each session. At the outset of the experiment for the hard-of-hearing, session I involved only an A test, hence the graph cannot indicate the shift at this point. The mean elevation (session I-VI) for the discomfort threshold within a given session was 3.2 db.

Shift of discomfort threshold and dispersion: The distribution in Fig. 23, derived in the same manner as Fig. 12, further shows the upward shift of the discomfort threshold with experience. Session I shows a range from 92 to greater than 140 db. The number of subjects who indicated no discomfort increased with the number of sessions. Table 9 shows the number of thresholds which lay beyond the limits of the apparatus and further demonstrates the systematic elevation of tolerance.

TABLE 9 — NUMBER OF THRESHOLDS SURPASSING THE LIMITS OF THE APPARATUS

Session	Discomfort	Tickle	Pain
I	19	50	46
IV	27	126	181
VI	47	140	175

Auditory Map — Hard-of-Hearing

The ultimate threshold levels of tolerance for discomfort, tickle, and pain are the asymptotes of the three curves (showing the means of each session) in Fig. 22. By locating the shapes of curves previously derived at the appropriate mean levels, the final tolerance thresholds are represented by the curves in Fig. 24. *The ultimate discomfort level is 129.1 db.* The ultimate tickle threshold cannot be established precisely because the approximate mean value for later tests lies beyond the limits of the apparatus; and, therefore, the asymptote is indefinite. All that can be said is that the *tickle threshold is greater than 141.1* which represents the last approximate mean lying below the range of the apparatus. *The pain threshold is greater than 141.3 db.*

The high level of the tickle and pain thresholds suggests that there is an approachable and potentially useful portion of the auditory area beyond the range of present audiometry. Consequently, some individuals who have heretofore been termed "totally deaf" as a result of audiometric tests might be reached by auditory stimulation through properly designed apparatus.

Individual Differences

The subjects were ranked according to tenderness, using the method already described for obtaining the indices. Table 10.

Relationship of ears: The rank order correlation between the two ears on initial discomfort was .81. These data again indicate a strong positive relationship with respect to tenderness between the two ears of a given subject.

TABLE 10 — PURE TONE TOLERANCE — HARD-OF-HEARING

Mean of all frequencies in decibels above 0.0002 dynes/cm²

Individual Threshold Indices

Subject	Ear	Discomfort Initial	Discomfort Final	Tickle Initial	Tickle Final	Pain Initial	Pain Final	Discomfort Threshold Shift	Mean Hearing Loss Temporary
I.K.	R	108.4	128.0	116.0	134.8	117.8	137.5	19.6	4.9
	L	112.8	129.8	118.9	139.5	120.0	138.6	17.0	2.3
L.M.	R	118.9	119.0	117.5	128.8	134.1	132.2	.1	1.4
	L	106.1	112.0	124.5	127.5	129.6	134.4	5.9	2.5
V.B.	R	102.1	128.2	134.3	*143.2*	136.1	*143.4*	26.1	6.8
	L	105.1	134.4	131.4	*143.2*	136.9	*143.4*	29.3	6.5
M.S.	R	117.4	138.6	124.1	139.5	136.2	*142.9*	21.2	.9
	L	123.0	140.9	122.8	140.4	132.4	*143.0*	17.9	.5
H.J.	R	111.4	129.9	118.5	*142.2*	131.6	*143.0*	18.5	3.4
	L	118.9	*143.0*	137.0	*143.0*	139.2	*143.0*	24.1	1.4
A.C.	R	132.8	126.4	*142.2*	*142.2*	142.2	*142.4*	−6.4	1.5
	L	121.8	124.1	*142.2*	*142.2*	141.0	*142.8*	2.3	−.3
C.B	R	135.9	142.6	*138.6*	*143.4*	*137.6*	*143.5*	6.7	.6
	L	132.2	139.8	*141.0*	*142.1*	*143.5*	*143.5*	7.6	.7
A.P.	R	*143.0*	125.9	*143.1*	*143.0*	*140.0*	*143.5*	−17.1	6.4
	L	*141.2*	123.8	*143.1*	*143.5*	*140.0*	*143.5*	−17.6	−2.3

Figures in italics indicate values above limit of apparatus.
Notice should be taken of the failure of subject A.P. to report initial discomfort. It is probable that she misunderstood the instructions.

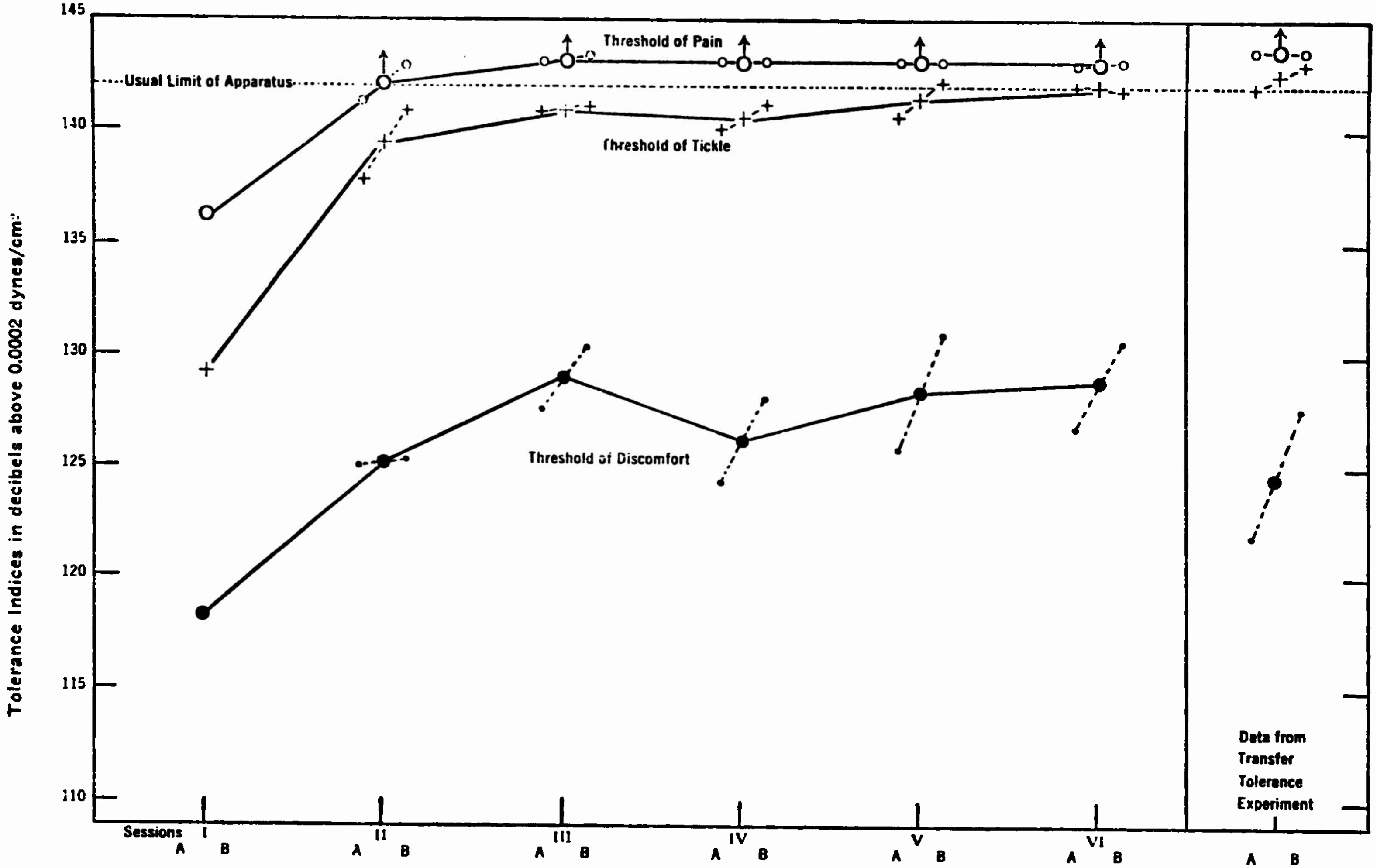

Fig. 22. Elevation of tolerance indices for pure tones—Hard-of-Hearing.
Inter-session shift indicated by solid line; intra-session shift by dotted line.

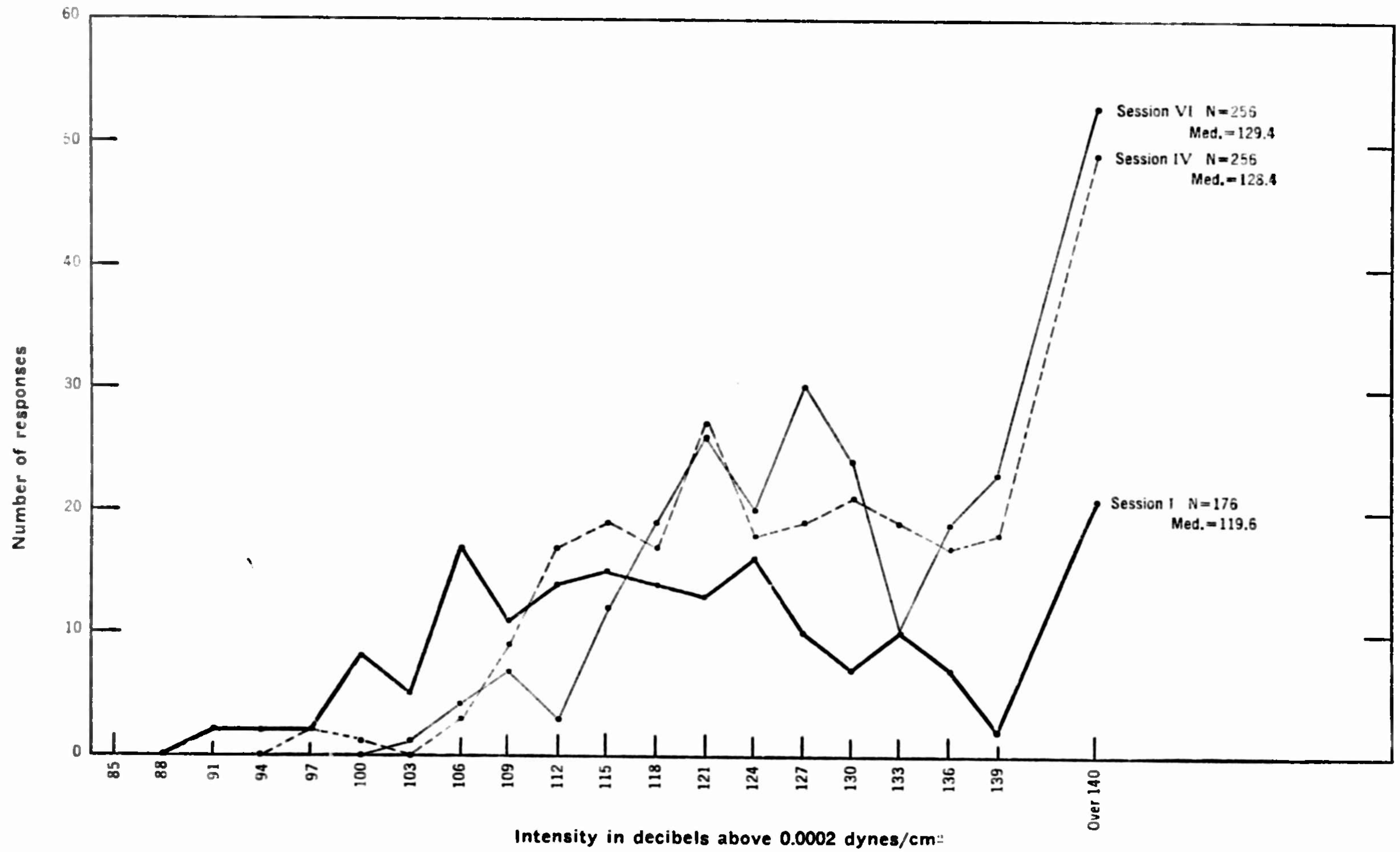

Fig. 23. Frequency distribution of thresholds of discomfort for pure tones—Hard-of-Hearing.

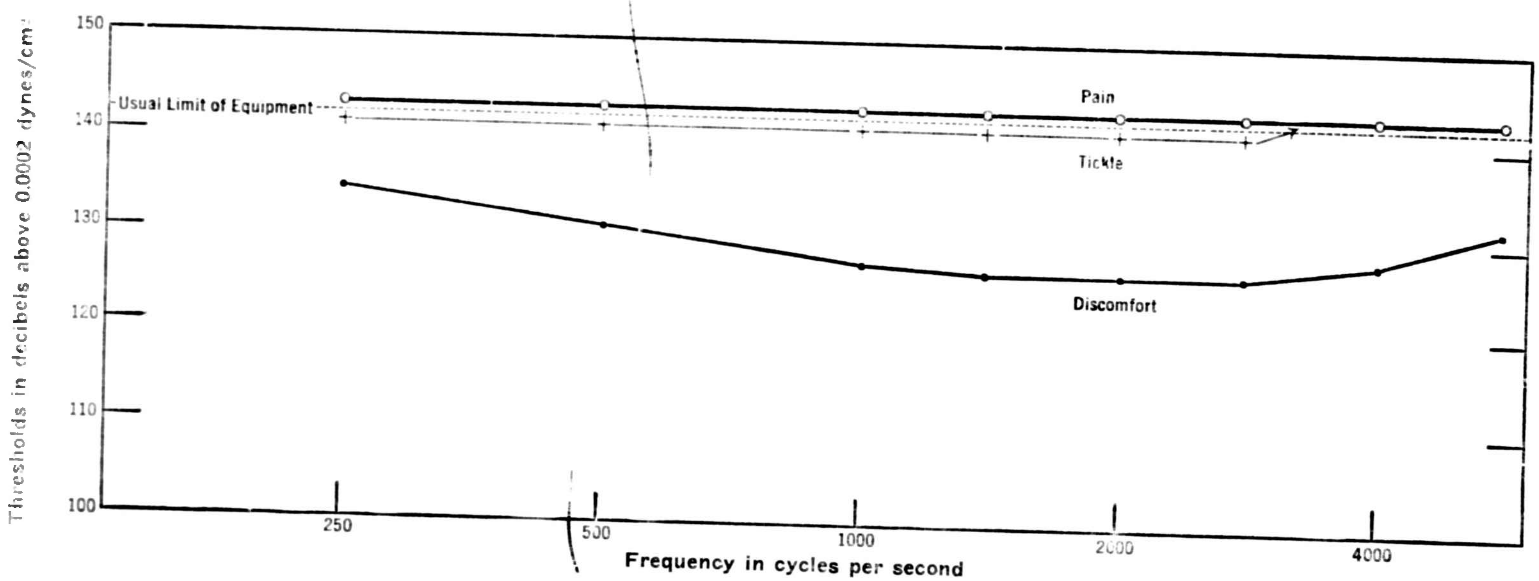

Fig. 24. Ultimate thresholds for pure tones—Hard-of-Hearing.

Relationship of initial and final thresholds: The rank order correlation between the initial and final discomfort measure was .03. As with the hearing group, *all individuals tend to approach the final values plotted on the auditory map.*

Age and sex factors: The data suggest no significant relationship between tenderness and age. The mean for males was 118.5 db and for females 115.4 db, but only four female ears entered into the calculation. The tenderest individual on initial discomfort was a male.

Relationship of hearing loss (512-2048 cps) to tenderness: There appears to be no strong positive relationship between hearing loss and the initial discomfort threshold. A few cases of low threshold of acuity seem to have a low initial discomfort threshold, but because of the relatively few cases included in a scatter diagram this mild concentration may be due to chance factors. However, in two subjects (L.M. and M.S.) where two ears differ substantially in hearing loss, greater hearing loss is related positively to higher initial tolerance. The relationship of tolerance to clinical types of deafness will be discussed in connection with speech tolerance.

Relationship to use of hearing aid: The data are too meagre to allow any comment as to the possible effect on tolerance of habitual use of a hearing aid.

Stability of Threshold of Acuity

There was no significant mean increase of hearing loss (Fig. 25) nor were there any cases of extreme shift even of temporary character. Observed changes in threshold were generally within the ± 5 db limit usually expected from test to test in clinical audiometric measurements.

Comparisons between Normal and Hard-of-Hearing

Comparisons between normal and hard-of-hearing subjects can be drawn on the bases of shape of contours, shift of tolerance thresholds, level of thresholds, and the effect of the testing procedure on the threshold of acuity.

Shape of contours: For the discomfort threshold the hard-of-hearing show a greater upward trend in the high frequencies beginning at approximately 3000 cps. It was thought that, perhaps, the difference might be due to weighting, introduced by a particular type of deafness, but examination of individual contours revealed no consistent relationship between clinical types and shape of contour. The difference may be due to chance or some factor not observable from the data. Limitations of apparatus made it impossible to treat dispersion statistically. The tickle contours for the two groups show the same general horizontal character with a rise at 2800 cps for the hard-of-hearing and a rise at 2000 cps for the normals. It is statistically impossible to know whether this slight difference is real. The pain contour for both groups is probably horizontal. At least, it is difficult to prove otherwise.

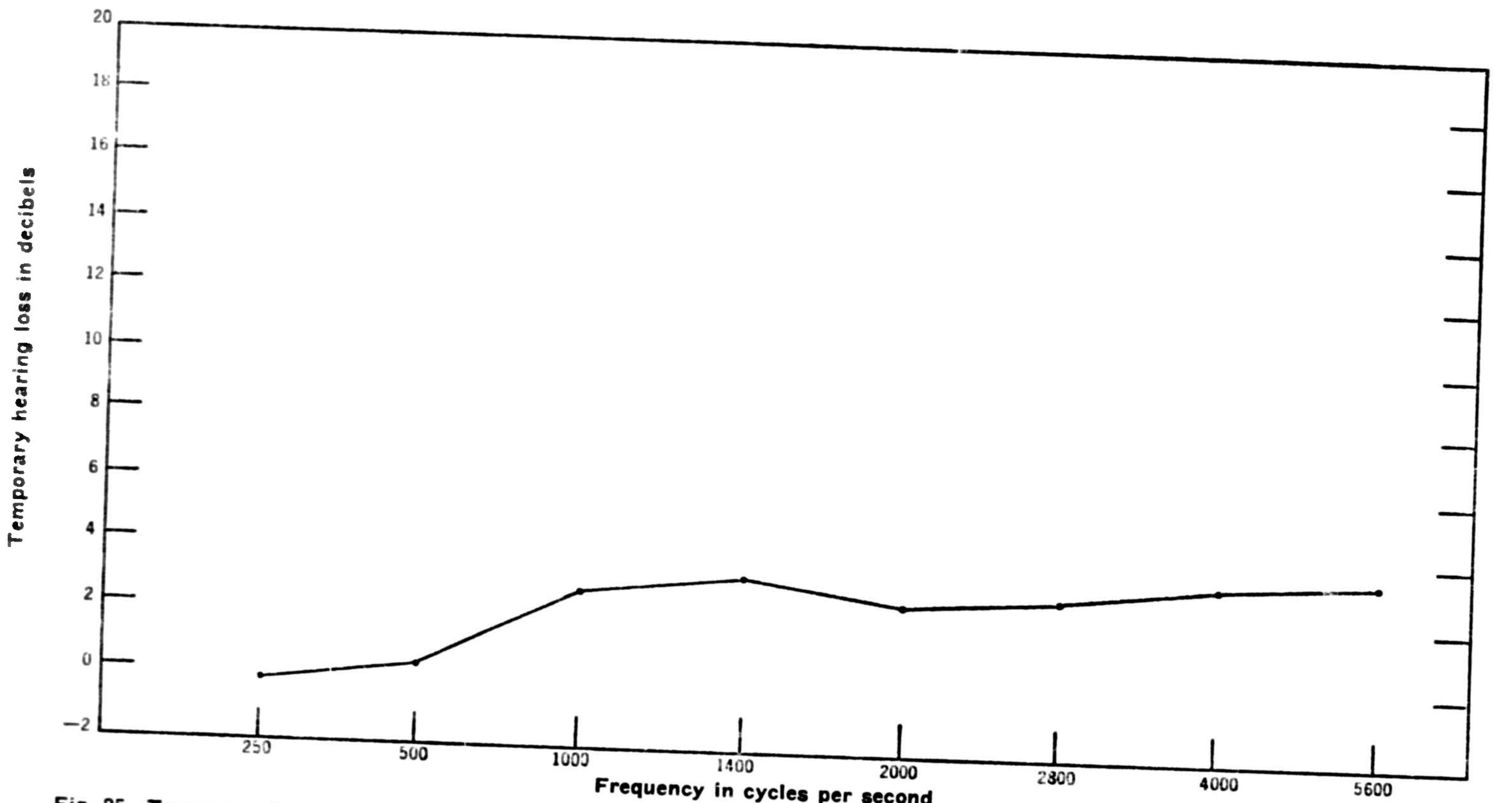

Fig. 25. Temporary hearing loss immediately after pure tone tolerance tests—Hard-of-Hearing. 16 ears: 36 responses for each frequency

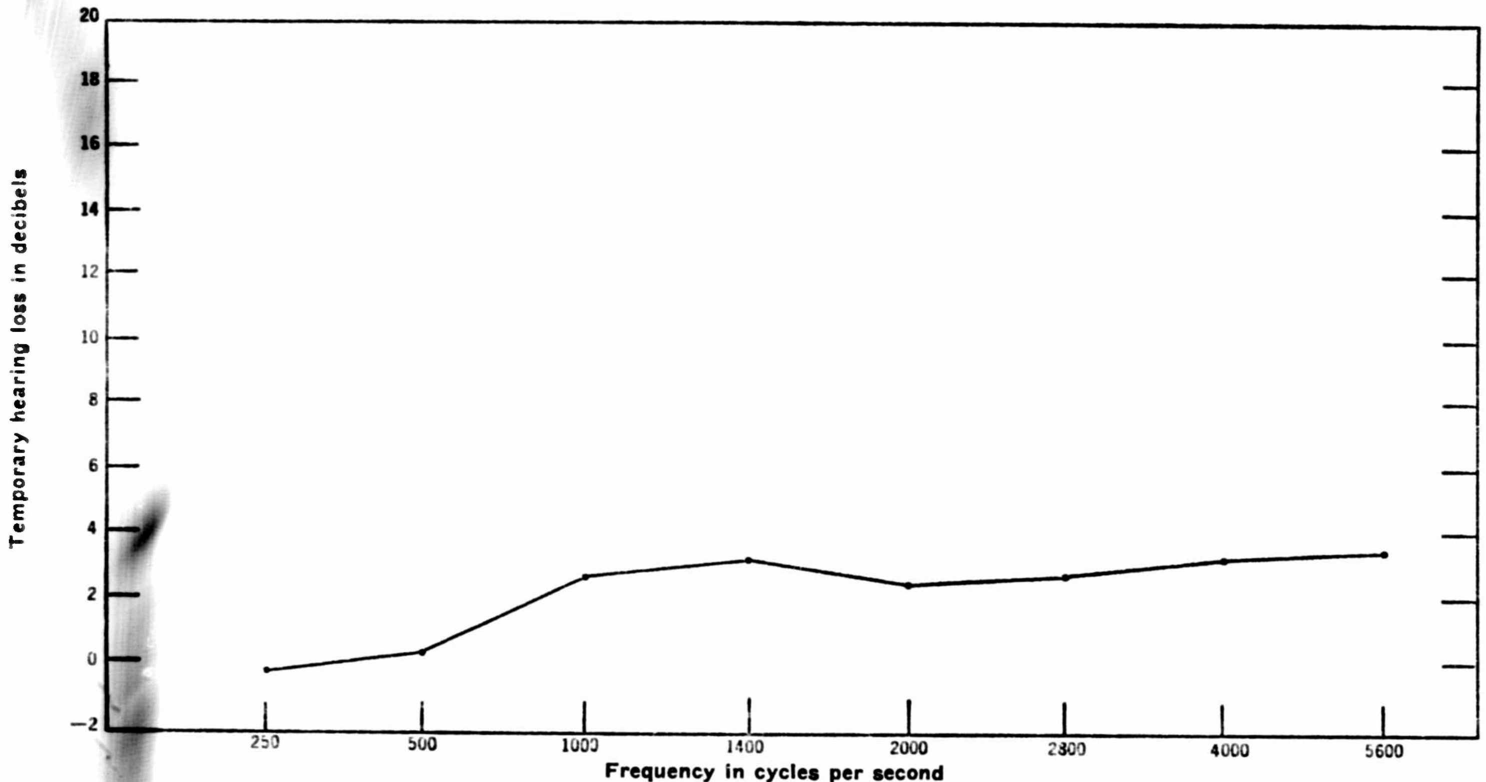

Fig. 25. Temporary hearing loss immediately after pure tone tolerance tests—Hard-of-Hearing. 16 ears: 36 responses for each frequency

Shift of tolerance thresholds with experience: Table 11, containing the means of the medians for each session, shows the systematic elevation of discomfort thresholds for both groups. The upward shift of tolerance within a given session (Figs. 12 and 22) is generally the same for both groups

TABLE 11 — SHIFT OF THRESHOLDS OF DISCOMFORT WITH SESSIONS FOR NORMAL AND HARD-OF-HEARING SUBJECTS

Tolerance Indices in decibels above 0.0002 dynes/cm [2]

Session	I	II	III	IV	V	VI
Hearing	111.2	113.4	116.8	116.7	117.1	120.0
Hard-of-Hearing	118.4	125.2	129.1	126.2	128.5	128.9

Level of thresholds: The hard-of-hearing show a higher final threshold of discomfort by 9.1 db (129.1 db for hard-of-hearing at session VIB; 120 db for normals). The significance of this difference is questionable since the normal and the hard-of-hearing speech tolerance groups reach approximately the same level. The difference might be due to sampling of either group. Differences in tickle and pain thresholds are not known because of limitations of the apparatus.

Shift of thresholds of acuity: The normal group showed a greater temporary loss of hearing (in tones above 1000 cps) as a result of exposure to testing procedure. The possibility that this difference was due to the presence of high-tone deafness in the hard-of-hearing group was examined and it was found that the resistance to the development of temporary hearing loss was shared by all of the hard-of-hearing subjects.

VI. SPEECH TOLERANCE

Procedure

Instructions to subjects: The same precautions, as in the previous experiment, were taken to insure accurate understanding of instructions. The precise instructions for the three thresholds were as follows:

1. *Discomfort:* "You will hear a man talking and his speech will get louder and louder. Tell me when you reach the point where the speech is uncomfortable; that is, when you would no longer care to listen or when you feel like removing the earphone from your ear. When the uncomfortable point is reached say 'uncomfortable' and I will shut off the speech. You are not required to remember the content of the talk. Are you ready?"
2. *Tickle:* "You will hear a man talking and his speech will get louder and louder. Tell me when you reach the point where you feel a tickling sensation deep in the ear as though a broom straw were tickling it. Be alert only for the tickling sensation. When the tickle point is reached say 'tickle' and I will shut off the speech. You are not required to remember the content of the talk. Are you ready?"
3. *Pain:* "You will hear a man talking and his speech will get louder and louder. Tell me when you reach the point where you feel a sharp pain deep in the ear. Be alert only for the pain sensation. When the pain point is reached say 'pain' and I will shut off the speech. You are not required to remember the content of the talk. Are you ready?"

Speech material: The speech material consisted of a recorded sample of connected discourse from a news broadcast by Fulton Lewis, Jr. The content of the material concerned a progressive private housing project; and, although it was uniformly interesting, it did not evoke any violent emotional reaction. Of course, after repeated tests the material became boring; but, since the subject was instructed to disregard the content, this factor could have no bearing on the results. It is standard practice to discard vinylite discs after 50 reproductions because of wear, but the experimental discs were discarded after only 12 reproductions in order to eliminate any possible error from this source.

Duration of exposures and stepwise increases of intensity: The duration of exposures and stepwise increases of intensity were exactly the same as were used in the pure tone experiment. The test material was started at 100 db above 0.0002 dynes/cm ^{2} and increased in 2 db steps every 1.5 seconds up to 130 db. Above 130 db the intensity steps were reduced to 1 db. Because of the limitations of the apparatus and the necessity for avoiding peak clipping at high intensity levels, the highest intensity used was 140 db (by VU meter) above 0.0002 dynes/cm ^{2}.

Sequence of observations and scheduling: The speech tolerance subjects were divided into three groups according to the sequence of ears tested and time intervals between sessions.

For *Speech Tolerance Group 1* the order of sequence of tests was as follows:

TEST A

RIGHT EAR

Acuity	Threshold of detectability for speech
Discomfort	Threshold
Tickle	Threshold
Pain	Threshold
Acuity	Threshold of detectability for speech

LEFT EAR

Acuity	Threshold of detectability for speech
Discomfort	Threshold
Tickle	Threshold
Pain	Threshold
Acuity	Threshold of detectability for speech

Five minute rest

TEST B

RIGHT EAR

Discomfort	Threshold
Tickle	Threshold
Pain	Threshold
Acuity	Threshold of detectability for speech

LEFT EAR

Discomfort	Threshold
Tickle	Threshold
Pain	Threshold
Acuity	Threshold of detectability for speech

Five minute rest

TEST C

RIGHT EAR

Discomfort	Threshold
Tickle	Threshold
Pain	Threshold
Acuity	Threshold of detectability for speech

LEFT EAR

Discomfort	Threshold
Tickle	Threshold
Pain	Threshold
Acuity	Threshold of detectability for speech

Five minute rest

TEST D — RIGHT EAR

Discomfort	Threshold
Tickle	Threshold
Pain	Threshold
Acuity	Threshold of detectability for speech

LEFT EAR

Discomfort	Threshold
Tickle	Threshold
Pain	Threshold
Acuity	Threshold of detectability for speech

In Speech Tolerance Group 1, therefore, there were four tests on each ear per session administered in the pattern RLRLRLRL. Group 1 was exposed to four sessions (I to IV) of testing at weekly intervals. Thus test IIA indicates the first test of the second session.

For *Speech Tolerance Group 2* the sequence of tests was as follows:

TEST A — RIGHT EAR

Acuity	Threshold of detectability for speech
Discomfort	Threshold
Tickle	Threshold
Pain	Threshold
Acuity	Threshold of detectability for speech

TEST B — RIGHT EAR

Discomfort	Threshold
Tickle	Threshold
Pain	Threshold
Acuity	Threshold of detectability for speech

Five minute rest

TEST C — RIGHT EAR

Discomfort	Threshold
Tickle	Threshold
Pain	Threshold
Acuity	Threshold of detectability for speech

TEST D — RIGHT EAR

Discomfort	Threshold
Tickle	Threshold
Pain	Threshold
Acuity	Threshold of detectability for speech

TEST A	LEFT EAR
Acuity	Threshold of detectability for speech
Discomfort	Threshold
Tickle	Threshold
Pain	Threshold
Acuity	Threshold of detectability for speech

TEST B	LEFT EAR
Discomfort	Threshold
Tickle	Threshold
Pain	Threshold
Acuity	Threshold of detectability for speech

Five minute rest

TEST C	LEFT EAR
Discomfort	Threshold
Tickle	Threshold
Pain	Threshold
Acuity	Threshold of detectability for speech

TEST D	LEFT EAR
Discomfort	Threshold
Tickle	Threshold
Pain	Threshold
Acuity	Threshold of detectability for speech

In Speech Tolerance Group 2, therefore, there were four tests on each ear per session administered in the pattern RRRRLLLL. Group 2 was exposed to four sessions (I to IV) of testing at weekly intervals.

The difference in sequence between Groups 1 and 2 was introduced to detect the development of a "contralateral tolerance." It seemed possible that a tolerance test performed on one ear might affect the tolerance of the opposite ear by making the subject accustomed to very loud sounds, but no such general effect was detected.

For *Speech Tolerance Group 3* the sequence of tests was exactly the same as for Group 1: i.e., RLRLRLRL. However, the time interval between sessions was 24 hours instead of one week. The difference in time interval between Groups 1 and 2 on the one hand and Group 3 on the other was introduced to study the persistence of after-effects of the tests of tolerance as a function of the interval between sessions.

The time consumed in an experimental session of speech tolerance generally ranged from 55 to 70 minutes.

Thresholds of Acuity were determined at the beginning of each session and immediately following each discomfort-tickle-pain series. This was done to determine what effect the exposure to high-intensity speech might have on the threshold of detectability for speech. The threshold of detectability is the point at which the subject just hears the sound of speech without regard for intelligibity.

Subjects: There were 5 normal and 5 hard-of-hearing subjects in each speech tolerance group. There were thus 10 normal and 10 hard-of-hearing ears in each group or a total of 30 normal and 30 hard-of-hearing ears in the speech tolerance experiment. Tables 12 and 13 give pertinent information for the normal and hard-of-hearing subjects respectively.

TABLE 12 — NORMAL SUBJECTS FOR SPEECH TOLERANCE

	Subject	Age	Sex
Group 1	W.M.	17	M
	A.F.	21	F
	R.S.	24	M
	F.L.	25	F
	F.S.	32	M
Group 2	D.M.	21	M
	A.R.	21	F
	V.F.	24	M
	T.K.	24	M
	E.S.	28	F
Group 3	A.K.	20	F
	V.H.	23	F
	J.M.	26	F
	E.M.	31	M
	C.D.	41	M

Results — Normals

In computing thresholds for speech tolerance, as for pure tones, the median was used as the measure of central tendency. The medians for 16 tests on each threshold were chosen as the measures of tolerance for each group (1, 2, 3). The reasons for this statistical treatment, elaborated in the section on pure tone tolerance, were dictated by the upper intensity limits of the apparatus.

Thresholds for each group, including shift with experience: Thresholds for discomfort, tickle, and pain for groups 1, 2, and 3 are given in Table 14 and Figs. 26, 27, and 28, respectively.

Table 13 — Hard-of-Hearing Subjects for Speech Tolerance

Subject	Age	Sex		Air Conduction Audiogram*	Type of Deafness**	Age of Onset of Deafness	Loss for Speech	Use of Hearing Aid
Group 1								
J.D.	17	M	R.	5 5 5 6 3 2 2	C	14	R.	
			L.	5 5 5 5 3 3 6			L.	—
F.H.	33	M	R.	3 4 4 3 2 3 3	M	29	R. 43	
			L.	5 5 5 4 6 4 4			L. 39	R
R.M.	20	M	R.	3 4 4 3 3 1 2	M	10	R. 47	
			L.	3 3 3 2 3 4 1			L. 45	—
E.D.	32	F	R.	5 5 5 5 6 4 6	M	22	R. 59	
			L.	4 4 4 5 4 4 4			L. 49	R
J.M.	33	F	R.	5 5 5 5 5 3 3	M	23	R. 47	
			L.	5 6 6 6 5 5 5			L. 53	R
Group 2								
S.C.	24	M	R.	5 5 5 6 9 9 x	N	2	R. 69	
			L.	5 5 6 6 9 x x			L. 70	R
E.L.	34	F	R.	5 7 7 8 9 x x	N	8	R. 83	
			L.	5 6 8 8 8 9 x			L. 83	L
B.M.	36	F	R.	5 6 6 4 3 3 3	C	31	R. 52	
			L.	4 4 3 3 3 2 2			L. 41	—
V.C.	38	M	R.	5 6 6 6 5 8 6	M	28	R. 56	
			L.	4 4 5 6 4 6 5			L. 61	R
R.E.	37	M	R.	5 5 6 5 5 7 6	M	2	R. 52	
			L.	5 5 5 4 4 6 6			L. 53	—
Group 3								
H.E.	22	M	R.	x 7 7 7 6 6 5	N	?	R. 57	
			L.	x x 9 9 9 x x			L. 101	R
C.S.	28	F	R.	4 4 4 5 6 7 6	N	?	R. 65	
			L.	4 4 5 5 7 7 6			L. 61	L
B.S.	22	M	R.	5 5 5 5 5 3 2	C	18	R. 44	
			L.	5 5 5 5 5 3 2			L. 48	R
A.C.	29	M	R.	5 6 6 6 6 5 2	C	18	R. 52	
			L.	4 4 5 5 5 5 3			L. 52	L
M.N.	23	M	R.	5 5 6 6 5 5 5	M	17	R. 52	
			L.	4 5 5 5 4 5 4			L. 51	—

*See page 7 for explanation of figures.
**N—Nerve. C—Conductive. M—Mixed.

Table 14 — Speech Tolerance — Normals

N = 30 ears

Sessions	I				II				III				IV			
Tests	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Thresholds of Discomfort in decibels above 0.0002 dynes/cm²																
Speech Tolerance																
Group 1	118.0	118.0	123.0	126.0	127.0	127.0	128.0	128.0	124.0	125.0	128.0	130.0	128.0	130.0	133.0	133.5
Group 2	113.0	117.0	119.0	121.0	121.5	126.0	124.0	128.0	125.0	129.0	127.0	130.0	125.0	128.0	130.0	130.0
Group 3	120.0	124.0	125.0	126.0	122.0	123.0	126.0	128.0	126.0	127.0	130.0	130.0	126.0	130.0	130.5	130.0
Mean of Test	117.0	119.7	122.3	124.3	123.5	125.3	126.0	128.0	125.0	127.0	128.3	130.0	126.3	129.3	131.2	131.2
Mean of Session	120.8				125.7				127.6				129.5			
Thresholds of Tickle in decibels above 0.0002 dynes/cm²																
Group 1	126.0	128.0	128.0	131.5	133.0	132.5	133.5	132.5	131.5	130.0	130.5	134.5	135.5	134.5	136.5	137.0
Group 2	128.0	130.0	130.5	131.5	130.5	131.0	132.5	133.0	133.0	133.5	133.5	134.5	134.5	134.0	134.5	133.5
Group 3	131.0	131.0	132.0	132.5	131.0	131.5	132.0	131.5	132.0	133.0	133.5	134.0	133.5	134.0	134.5	133.5
Mean of Test	128.3	129.7	130.2	131.8	131.5	131.7	132.7	132.3	132.2	132.2	132.5	134.3	134.5	134.2	135.2	134.3
Mean of Session	130.0				132.1				132.8				134.6			
Thresholds of Pain in decibels above 0.0002 dynes/cm²																
Group 1	136.0	135.5	137.5	*140.0*	*140.0*	*140.0*	*140.0*	*140.0*	140.0	139.5	*140.0*	*140.0*	*140.0*	*140.0*	140.0	*140.0*
Group 2	136.0	138.0	140.0	139.0	140.0	140.0	*140.0*	*140.0*	*140.0*	*140.0*	*140.0*	*140.0*	*140.0*	*140.0*	*140.0*	*140.0*
Group 3	138.5	137.0	138.5	138.5	136.5	136.0	137.0	138.0	135.5	138.0	139.0	138.5	140.0	140.0	139.5	139.5
Mean of Test	136.8	136.8	138.7	*139.2*	*138.8*	*138.7*	*139.0*	*139.3*	*138.5*	*139.2*	*139.7*	*139.5*	140.0	*140.0*	139.8	139.8
Mean of Session	*137.9*				*139.0*				*139.2*				*139.9*			

Figures in italics indicate values above limit of apparatus.

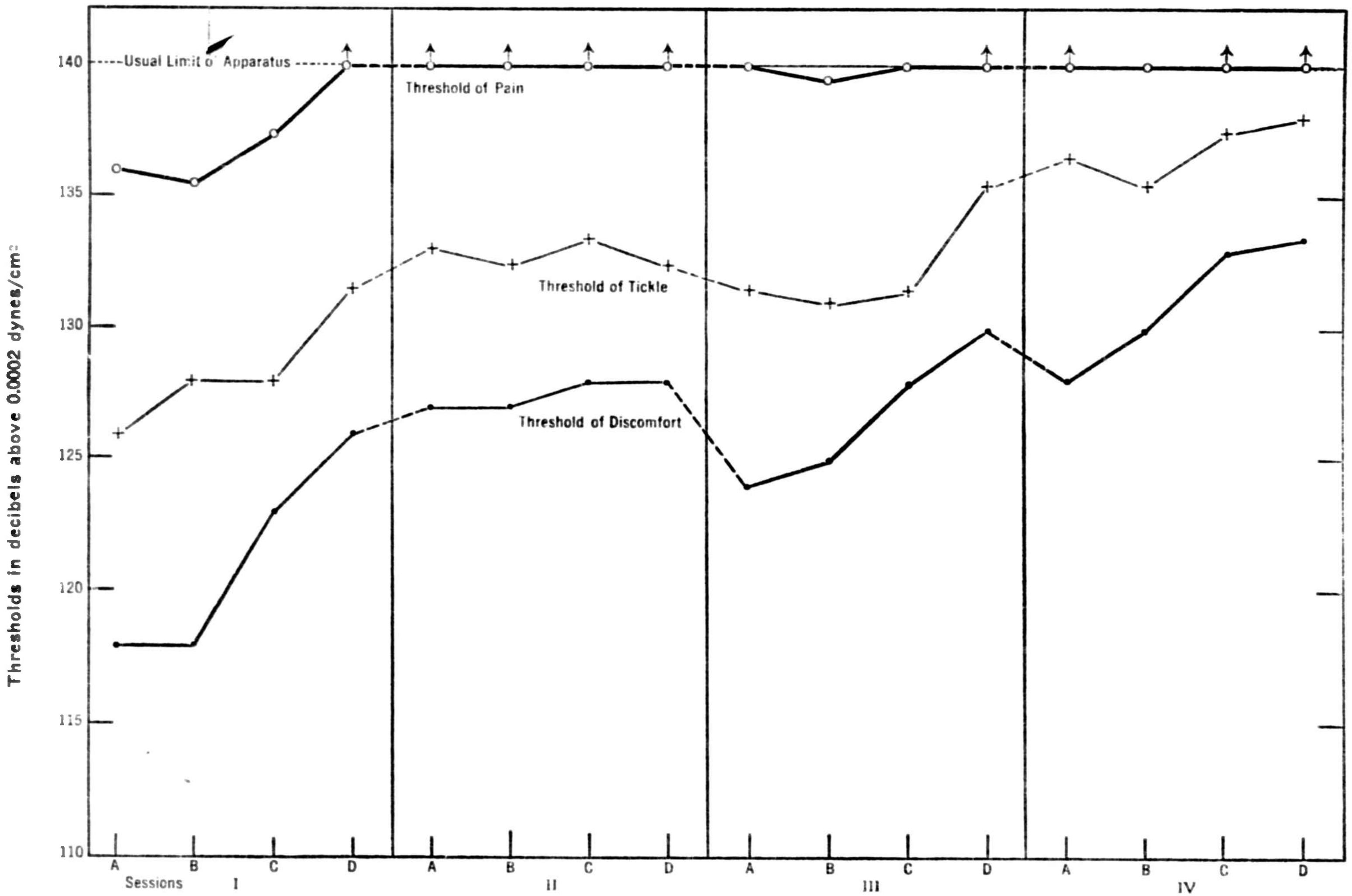

Fig. 26. Elevation of tolerance for speech—Normals. Group 1. Median values for 10 ears.

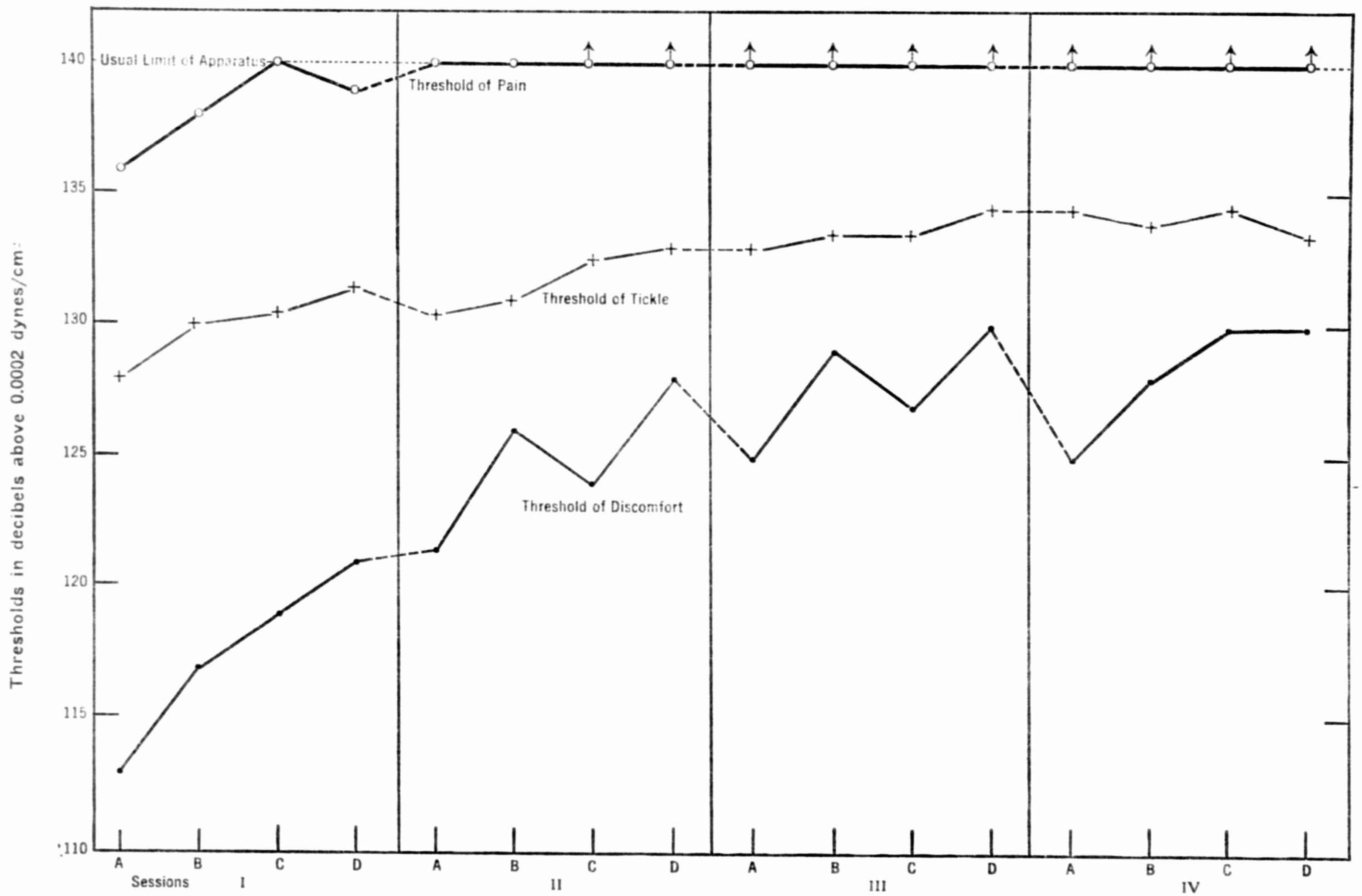

Fig. 27. Elevation of tolerance for speech—Normals.. Group-2. Median values for 10 ears.

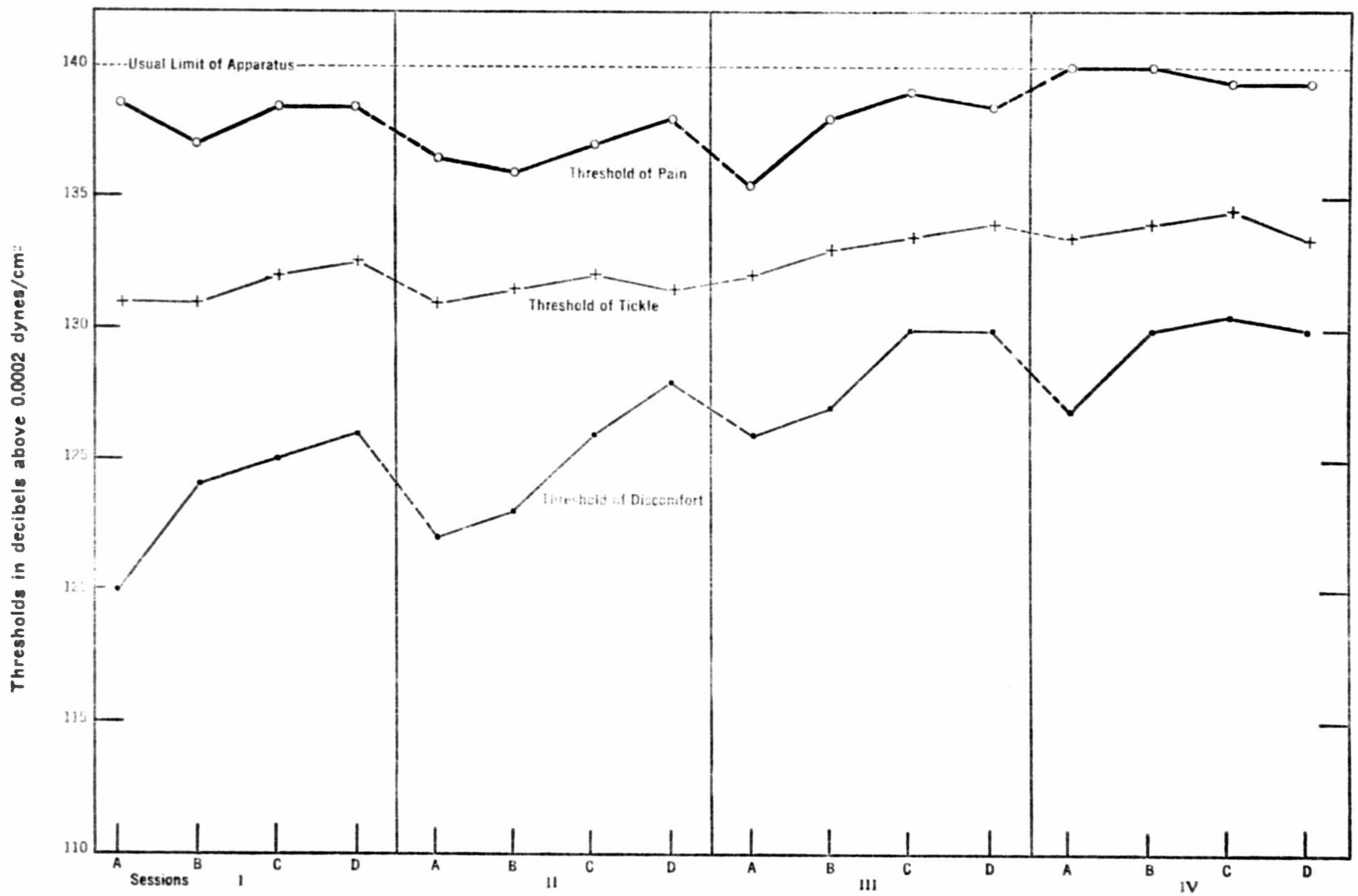

Fig. 28. Elevation of tolerance for speech—Normals. Group 3. Median values for 10 ears.

Comparison of the different sequences of exposure: The means (for all tests IA, IB....IVC, IVD) of the medians for each test for each of the three procedures are shown in Table 15. The values for groups 1, 2, and 3 are nearly identical. It is clear, therefore, that the *tolerance levels are not significantly influenced by the the sequence of exposure of the ears.* Figs. 26, 27, and 28 show, however, that there is a progressive increase in tolerance with experience. The effect is exactly similar to that already described for pure tone tolerance.

TABLE 15 — COMPARISON OF SPEECH TOLERANCE GROUPS 1, 2, 3, — NORMALS

Means of Medians in decibels above 0.0002 dynes/cm ^{2}

	Group 1	Group 2	Group 3
Discomfort	126.7	124.6	126.5
Tickle	132.3	132.4	132.5
Pain	>139.3	>139.6	>138.1

The discomfort thresholds were further examined for any indication of the development of "contralateral tolerance." The first step was the calculation of the mean of the differences between Tests A on the right ear and tests A on the left ear in group 1 (RL......). Then the mean of the differences between tests A and B on the right ear of group 2 (RR..LL...) was computed. These means were 2.35 db and 3.45 db for groups 1 and 2 respectively. Statistical treatment * showed that the probability was 85 chances in 100 that the difference in favor of group 2 was significant.

Although the difference in the means of the two groups appears to be slight, indicating the possibility of a small amount of contralateral tolerance, the fact that the hard-of-hearing group shows a wider difference between groups 1 and 2 supports the observation that, in general, contralateral tolerance does not take place.

In other words two successive exposures of the same ear were likely to produce a real elevation of tolerance as detected by the second test in that ear, while exposure of one ear followed immediately by exposure of the other ear was not likely to produce an elevation of tolerance in the latter ear.

Since there was no significant difference among the thresholds related to the sequence of or the interval between exposures, the data for all three groups were combined. The means of the medians of all tests are plotted in Fig. 29.

Dispersion and shift of thresholds: In Fig. 30 are plotted the frequency distributions of the thresholds of discomfort of the entire group on the first (IA) and on the last (IVD) tests. The upward shift of the threshold as a group is clearly indicated.

* By the formula $\frac{DM_2M_1}{P.E._{DIFF}}$

Comparison of the different sequences of exposure: The means (for all tests IA, IB....IVC, IVD) of the medians for each test for each of the three procedures are shown in Table 15. The values for groups 1, 2, and 3 are nearly identical. It is clear, therefore, that the *tolerance levels are not significantly influenced by the the sequence of exposure of the ears.* Figs. 26, 27, and 28 show, however, that there is a progressive increase in tolerance with experience. The effect is exactly similar to that already described for pure tone tolerance.

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Although the difference in the means of the two groups appears to be slight, indicating the possibility of a small amount of contralateral tolerance, the fact that the hard-of-hearing group shows a wider difference between groups 1 and 2 supports the observation that, in general, contralateral tolerance does not take place.

In other words two successive exposures of the same ear were likely to produce a real elevation of tolerance as detected by the second test in that ear, while exposure of one ear followed immediately by exposure of the other ear was not likely to produce an elevation of tolerance in the latter ear.

Since there was no significant difference among the thresholds related to the sequence of or the interval between exposures, the data for all three groups were combined. The means of the medians of all tests are plotted in Fig. 29.

Dispersion and shift of thresholds: In Fig. 30 are plotted the frequency distributions of the thresholds of discomfort of the entire group on the first (IA) and on the last (IVD) tests. The upward shift of the threshold as a group is clearly indicated.

* By the formula $\frac{DM_2M_1}{P.E._{DIFF}}$

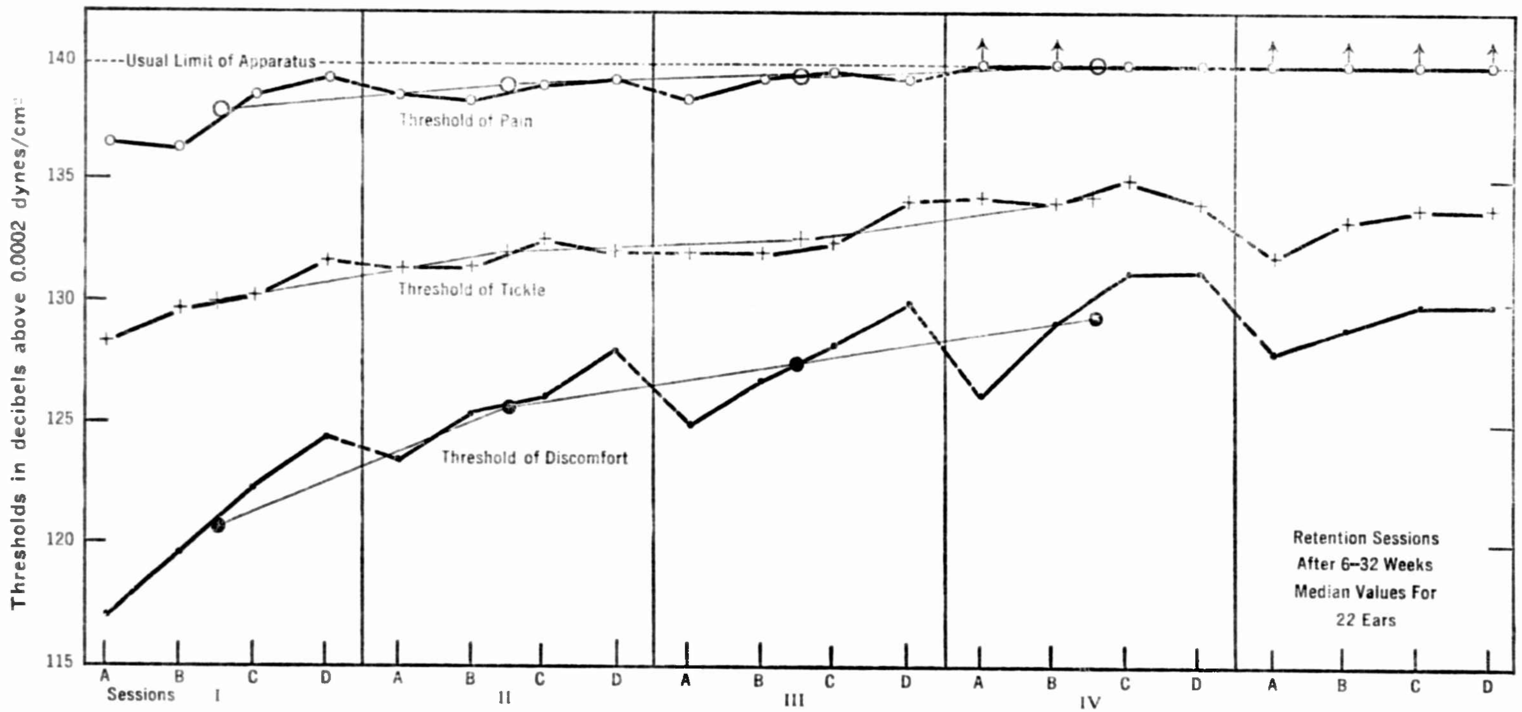

Fig. 29. Elevation of tolerance for speech—Normals. All groups: Mean of median values for 30 ears.

Heavy lines indicate means of median for each test: light lines indicate means for each session.

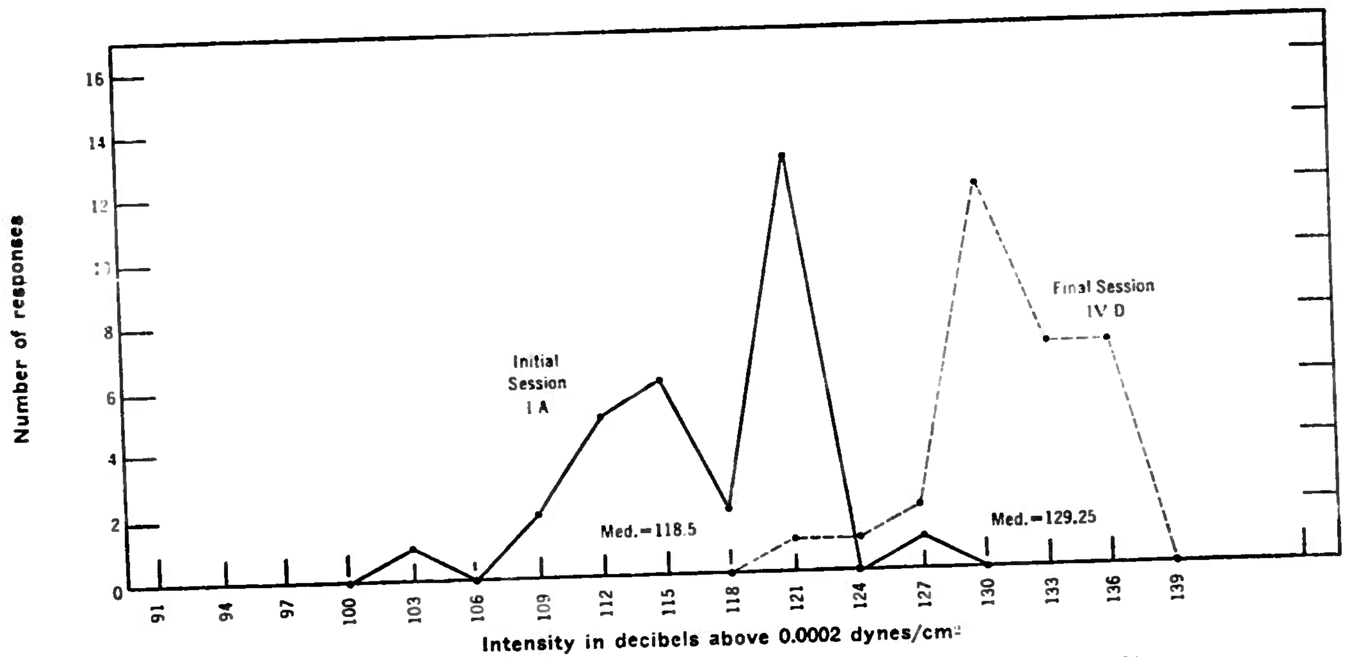

Fig. 30. Frequency distribution of thresholds of discomfort for speech—Normals. 30 ears.

Fig. 31 indicates a similar trend for the tickle threshold. Most subjects on the final test approached a level between 129 and 140 db.

The initial distribution for pain (IA) in Fig. 32 shows a range from 127 to greater than 140 db with the values of eight responses lying above the limits of the apparatus. The curve for the final test (IVD) clearly shows the upward shift of the pain threshold. On the final test, 18 responses lay beyond the limits of the apparatus.

Ultimate thresholds of tolerance: The ultimate level for each threshold was derived from the asymptotes of the curves in Fig. 29 which represent the means for each session. *These values were 129.5, 134.6, and greater than 139.2 db for discomfort, tickle, and pain, respectively.* In addition, the means for each test are plotted in Fig. 29 to show in greater detail the elevation of thresholds with experience.

Exact values for both sets of data are given in Table 14.

Threshold shift: The amounts of elevation of tolerance from test IA to the highest values of the curves in Fig. 29 are given in Table 16.

TABLE 16 — ELEVATION OF TOLERANCE FOR SPEECH IN DECIBELS — NORMALS

	Mean of Medians Test IA *	Highest Value of Mean for Individual Test *	Elevation
Discomfort	117.0	131.2	14.2
Tickle	128.3	135.2	6.9
Pain	137.9	>138.7	> 1.9

* decibels above 0.0002 dynes/cm²

It is further evident from Table 14 and Fig. 29 *that there is a constant pattern of elevation within a given session with test A usually the low point and test D the high point.* As the number of sessions increases the amount of elevation within a given session decreases. For the discomfort threshold the elevation within session I was 7.3 db while it was 4.9 within session IV. A similar comparison for the tickle threshold shows a shift of 3.5 db within session I and 1 db within session IV.

Comparison of the final threshold of discomfort for speech with the analogous threshold for pure tones shows that the speech threshold is higher by 9.5 db. The thresholds of tickle and pain for speech fall below similar thresholds for pure tones. The limitations of such comparisons must be borne in mind, however, because it was probably the peaks of speech, concentrated in a limited portion of the frequency spectrum (700 to 1000 cps), which determined the thresholds for speech; whereas, the range from 250 to 5600 cps was involved in final determination of thresholds for pure tones.

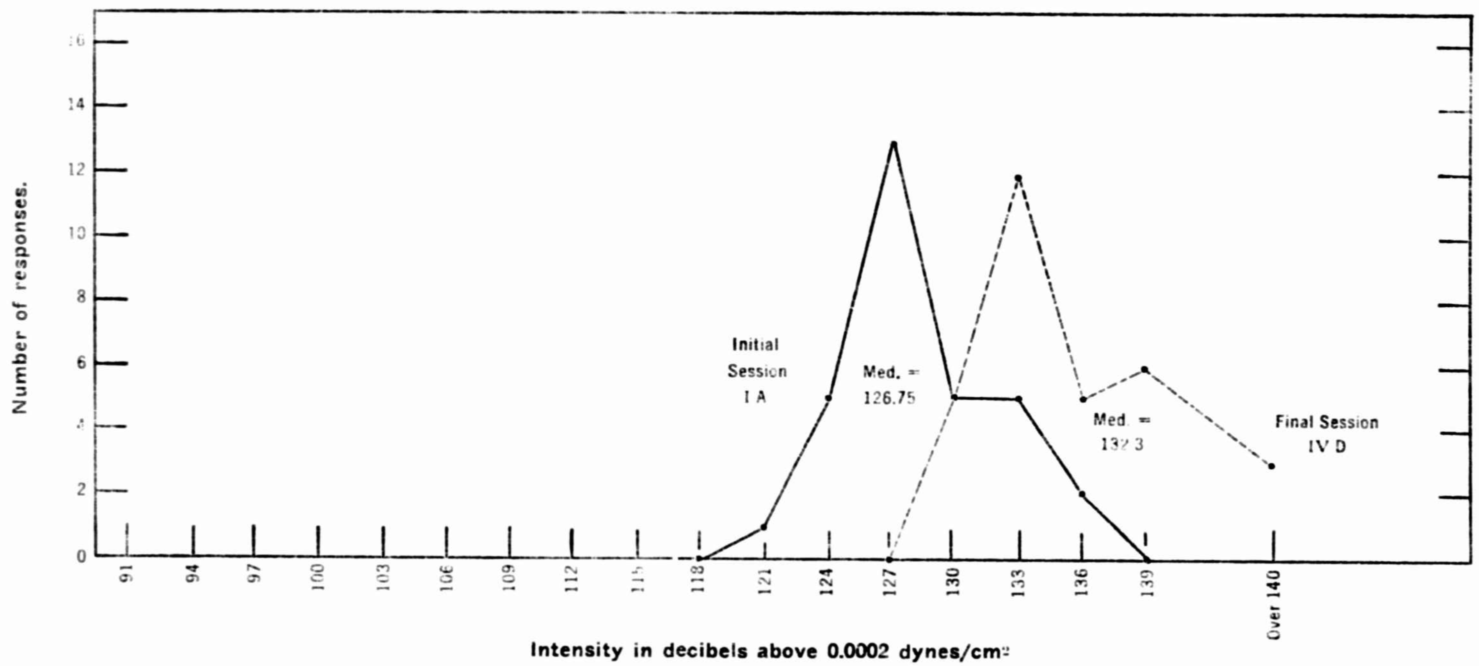

Fig. 31. Frequency distribution of thresholds of tickle for speech—Normals. 30 ears.

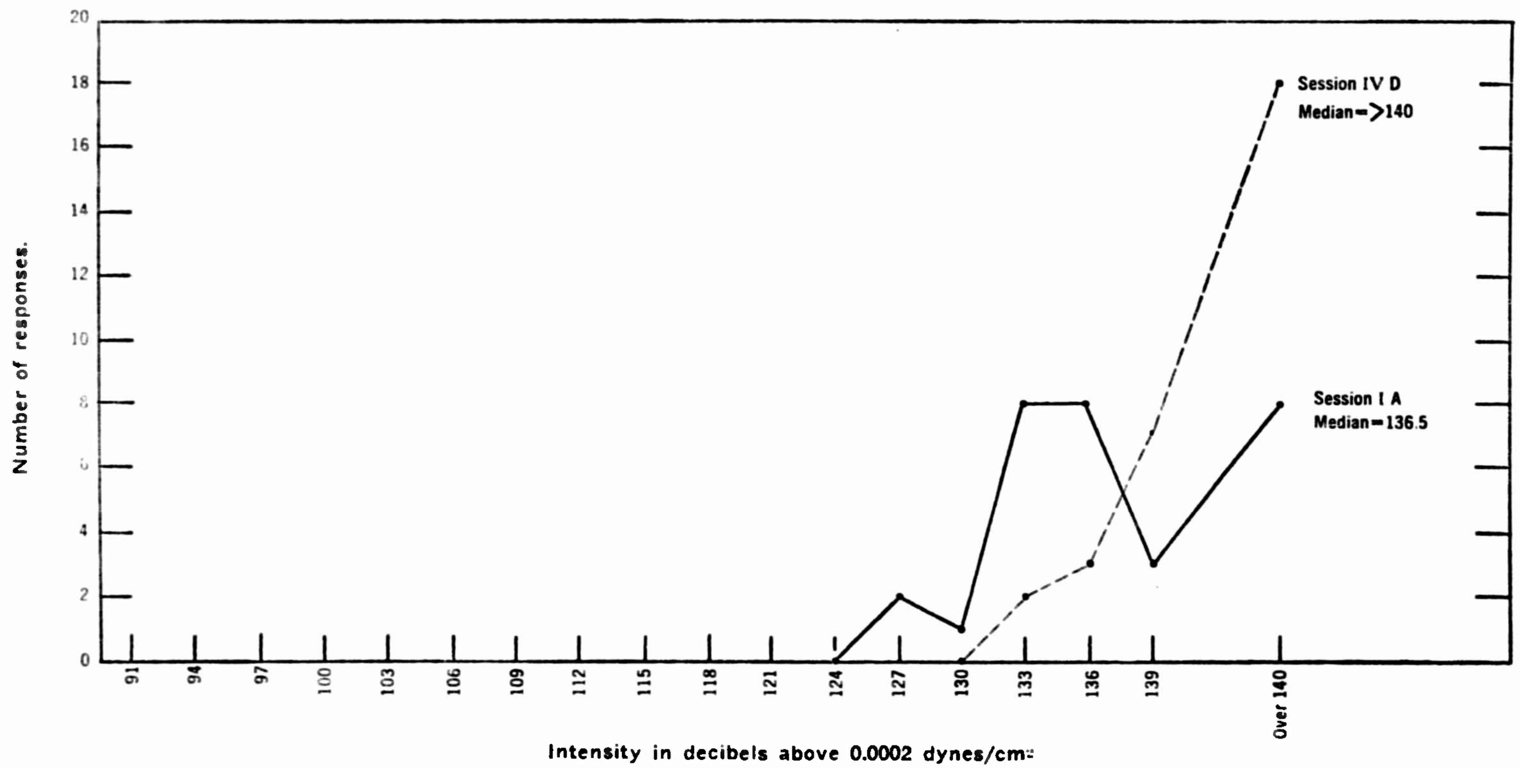

Fig. 32. Frequency distribution of thresholds of pain for speech—Normals. 30 ears.

Table 17 — Speech Tolerance — Normals

Individual Threshold Indices in decibels above 0.0002 dynes/cm^2

Subject	Ear	Discomfort		Tickle		Pain		Threshold Shift		Mean Hearing Loss
		Initial	Final	Initial	Final	Initial	Final	Discomfort	Tickle	Temporary
F.L.	R	110	137	122	140	136	*140*	27	18	3.3
	L	114	134	126	*140*	137	*140*	20	14	−.3
A.R.	R	104	122	124	130	*140*	*140*	18	6	.3
	L	114	129	130	131	*140*	*140*	15	1	−1.0
J.M.	R	112	130	128	131	133	139	18	3	0
	L	112	130	128	133	134	140	18	5	− .5
A.F.	R	120	135	126	131	128	136	15	5	0
	L	122	133	126	132	126	134	11	6	5.5
T.K.	R	112	133	124	135	133	*140*	21	11	.3
	L	114	136	130	138	136	*140*	22	8	−1.5
E.S.	R	108	130	124	139	135	*140*	22	15	− .5
	L	121	130	128	137	134	*140*	9	9	0
W.M.	R	114	137	128	138	136	*140*	23	10	.5
	L	118	137	126	137	130	140	19	11	− .3
V.F.	R	112	131	133	133	140	140	19	0	.5
	L	112	131	128	132	136	*140*	19	4	.5
R.S.	R	120	132	124	134	*140*	*140*	12	10	.3
	L	122	132	124	134	133	*140*	10	10	2.0
D.M.	R	116	124	128	132	132	134	8	4	.8
	L	120	130	130	134	137	137	10	4	0
C.D.	R	120	128	132	131	137	137	8	− 1	1.0
	L	120	130	128	133	132	138	10	5	1.0
A.K.	R	122	130	130	134	140	139	8	4	1.0
	L	120	130	128	132	132	139	10	4	− .3
F.S.	R	118	128	135	138	*140*	*140*	10	3	1.3
	L	116	130	130	137	*140*	*140*	14	7	−2.0
E.M.	R	120	135	134	*140*	*140*	*140*	15	>6	− .3
	L	122	137	133	*140*	*140*	*140*	15	>7	0
V.H.	R	120	134	132	135	140	*140*	14	3	1.0
	L	128	133	135	138	*140*	*140*	5	3	.5

Figures in italics indicate values above limit of apparatus.

Subjective reports from the subjects of both experimental groups revealed that for the speech tolerance group the tickle sensation was much more definite than for the pure tone group. For the former group there seemed to be little question as to the point at which tickle was experienced. There seemed to be some doubt on this point in the mind of the pure tone tolerance group. The tickle threshold was lower for speech than for pure tones, rarely exceeding 140 db.

Individual Differences

In order to study individual differences the subjects were ranked from tenderness to toughness. Rank order was determined by calculating the mean of the six measures representing initial thresholds of discomfort, tickle, and pain for both ears. The rank order of subjects is shown in Table 17. In a relatively few instances one or two of these six values lay beyond the limit of the apparatus. An approximate mean was computed and the rank of the subject was determined.

Relationship of ears: The rank order correlation on initial discomfort between the two ears was .71 and on final discomfort, .93. If an individual was tender in one ear he was likely to be equally tender in the other ear.

Relationship of initial and final thresholds; age and sex: The rank order correlation between the initial and final discomfort measure on each ear was .16. The low correlation is probably due to the crowding of final values which are approached by most individuals. The data suggest no relationship between tenderness and age. Table 18, comparing the sexes for initial and final discomfort and initial tickle values, suggests no appreciable differences with respect to tenderness.

TABLE 18 — THRESHOLDS OF TOLERANCE FOR SPEECH — NORMALS

Mean of Values, as in Table 17, in decibels above 0.0002 dynes/cm²

Sex	Discomfort Initial	Discomfort Final	Tickle Initial
Male	117.2	131.9	129.2
Female	116.2	131.2	127.6

Stability of Threshold of Acuity

The mean hearing loss resulting from exposure to one test was only 0.4 db. This small shift is not statistically significant, although the SD of 1.36 db suggests a relatively wide spread of the individual values. The latter are given in Table 18. The ineffectiveness of high-intensity speech in producing even a temporary hearing loss is probably due to the brevity of the intense peaks and the fact that the energy of speech depends primarily on tones below 1000 cps. Fig. 16 shows that acuity for these low tones was only slightly affected in the pure tone tolerance tests.

TABLE 19 — SPEECH TOLERANCE — HARD-OF-HEARING

N = 30 ears

Sessions	I				II				III				IV			
Tests	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Thresholds of Discomfort in decibels above 0.0002 dynes/cm²																
Speech Tolerance																
Group 1	115.0	120.0	122.0	124.0	121.0	124.0	125.0	126.0	122.0	125.0	127.0	129.0	125.0	128.0	130.5	130.0
Group 2	127.0	130.0	132.5	133.0	126.0	130.0	131.0	131.0	128.0	131.0	133.0	134.0	130.0	132.5	133.0	134.5
Group 3	121.0	125.0	127.0	128.0	126.0	128.0	129.0	131.0	128.0	130.0	131.0	131.0	127.0	128.0	130.5	130.5
Mean of Test	121.0	125.0	127.2	128.3	124.3	127.3	128.3	129.3	126.0	128.7	130.3	131.3	127.3	129.5	131.3	131.7
Mean of Session	125.4				127.3				129.1				130.0			
Thresholds of Tickle in decibels above 0.0002 dynes/cm²																
Group 1	125.0	128.0	130.0	130.0	126.0	129.0	129.0	130.5	128.0	130.0	131.5	133.0	131.0	133.0	134.0	133.5
Group 2	135.0	135.5	137.5	136.5	136.0	134.5	135.0	135.5	135.5	135.5	137.0	136.5	135.0	135.5	135.5	136.0
Group 3	128.0	129.0	129.5	129.5	131.0	131.0	131.5	132.0	130.0	131.0	132.5	132.0	131.0	132.0	132.5	133.5
Mean of Test	129.3	130.8	132.3	132.0	131.0	131.5	131.8	132.7	131.2	132.2	133.7	133.8	132.3	133.5	134.0	134.3
Mean of Session	131.1				131.8				132.7				133.5			
Thresholds of Pain in decibels above 0.0002 dynes/cm²																
Group 1	130.0	134.0	135.5	135.5	132.0	133.5	135.0	134.5	135.0	135.0	136.5	137.5	137.0	139.0	139.0	139.5
Group 2	140.0	*140.0*	*140.0*	*140.0*	*140.0*	*140.0*	*140.0*	*140.0*	*140.0*	*140.0*	*140.0*	*140.0*	*140.0*	*140.0*	*140.0*	*140.0*
Group 3	136.0	137.0	138.0	138.5	138.5	138.5	139.0	138.5	137.5	139.0	140.0	*140.0*	139.5	139.5	140.0	139.5
Mean of Test	135.3	*137.0*	*137.8*	*138.0*	*136.8*	*137.3*	*138.0*	*137.7*	*137.5*	138.0	138.8	139.2	*138.8*	*139.5*	*139.7*	*139.7*
Mean of Session	*137.0*				*137.5*				*138.4*				*139.4*			

Figures in italics indicate values above limit of apparatus.

Results — Hard-of-Hearing

The logic and procedure used in arriving at speech tolerance thresholds for the normals were also employed for the hard-of-hearing.

Thresholds for each group, including shift with experience: Table 19 and Figs. 33, 34, 35 show the thresholds for discomfort, tickle, and pain for groups 1, 2, and 3, respectively.

Comparisons of the different sequences of exposure — Mean levels reached: The means (for all tests, IA, IB . . . . IVC, IVD) of the medians for each test for the three procedures are shown in Table 20 and indicate that tolerance levels may have been slightly influenced by the sequence and the interval (RRRRLLLL vs. RLRLRLRL). However, on examination of the subjects there appears to be a chance grouping which may well have influenced the mean levels. Groups 1 and 3 were relatively tender with later onset of deafness; group 2 was unusually tough with earlier onset. The presence of this chance grouping, coupled with the evidence from the 30 hearing ears, leads us to believe that the sequences, per se, did not influence the relative effectiveness of the tests in elevating the tolerance thresholds.

TABLE 20 — COMPARISON OF SPEECH TOLERANCE GROUPS 1, 2, 3, — HARD-OF-HEARING

Means of Medians in decibels above 0.0002 dynes/cm²

	Group 1	Group 2	Group 3
Discomfort	124.6	131.0	128.2
Tickle	130.1	135.8	131.0
Pain	135.5	>140.0	>138.7

Data for the thresholds of discomfort were further examined by the same techniques used with the normal group to study the effects of contralateral tolerance. The means of the differences were 1.15 db and 3.1 db for groups 1 and 2 respectively. The chances were 98 to 100 that there was a significant elevation of tolerance resulting from the exposure of the right ear in group 2, but there was no significant contralateral tolerance from the right ear to the left ear in group 1.

It is thus clear that two successive exposures of the same ear were likely to produce a real elevation of tolerance as detected by the second test in that ear while exposure of one followed immediately by exposure of the other ear was not likely to produce an elevation of tolerance in the latter ear. The data for all procedures were then combined and the mean of the medians for all tests of all sessions computed for the three thresholds. The results are plotted in Fig. 36.

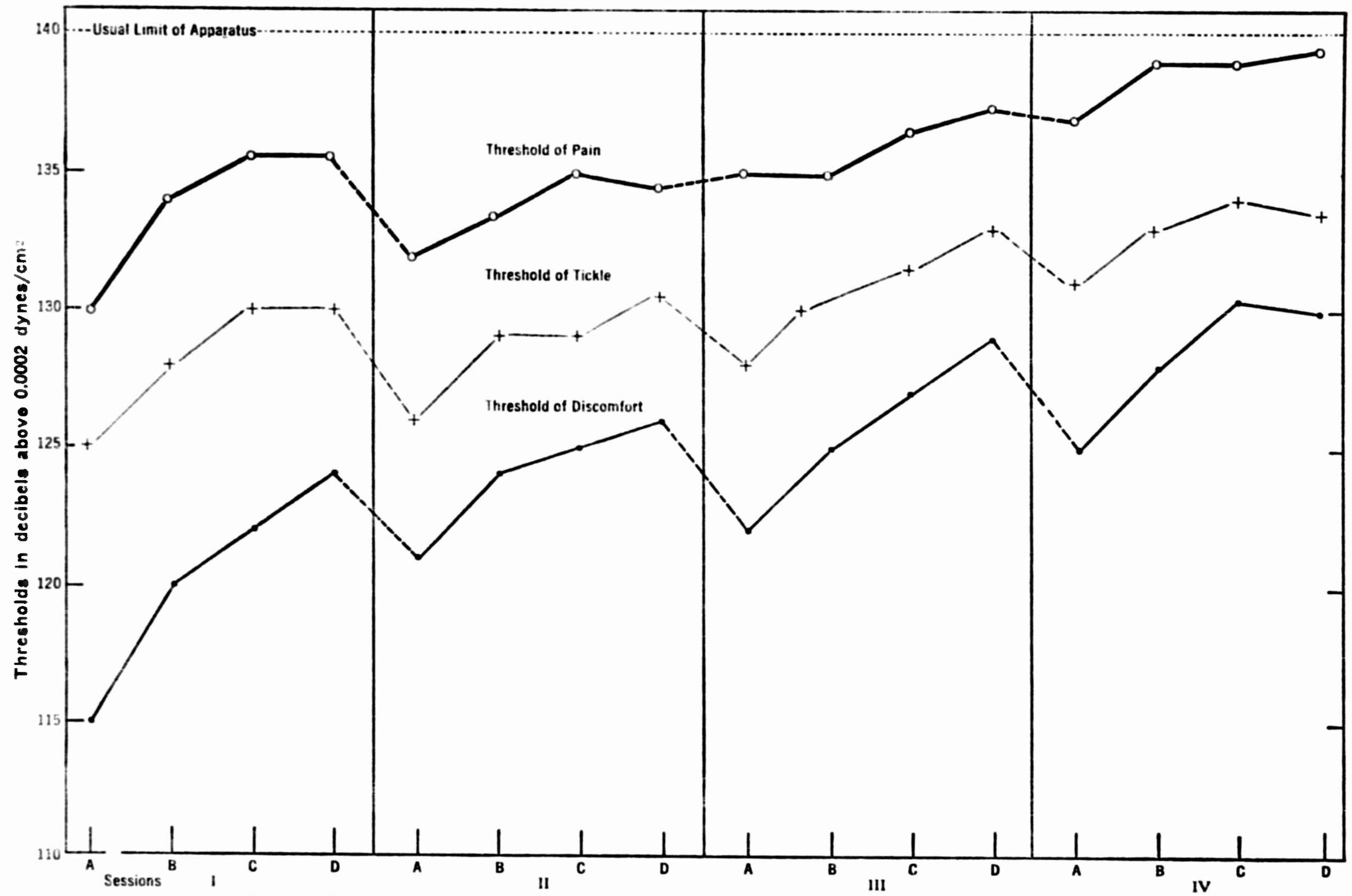

Fig. 33. Elevation of tolerance for speech—Hard-of-Hearing. Group 1. Median values for 10 ears.

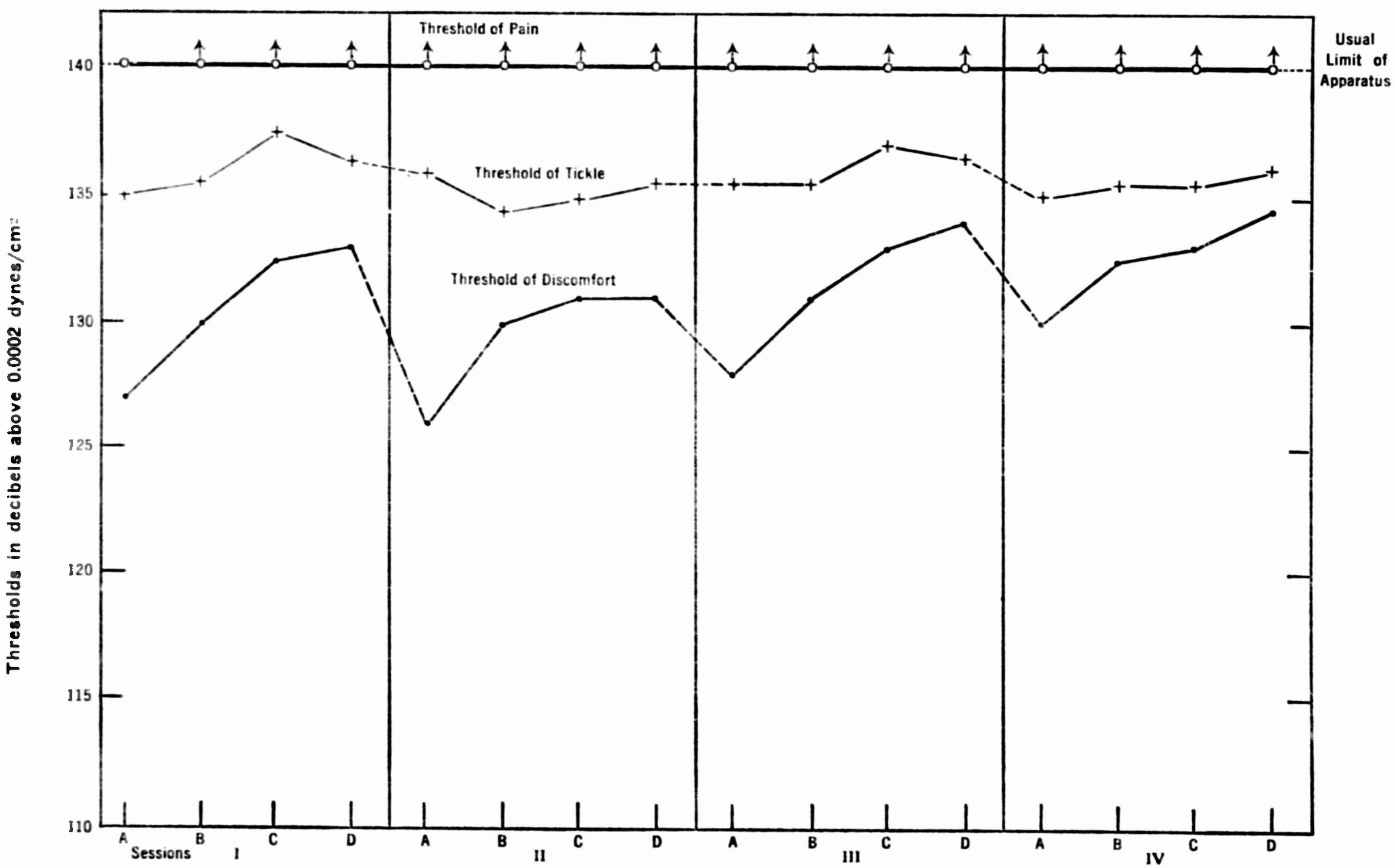

Fig. 34. Elevation of tolerance for speech—Hard-of-Hearing. Group 2. Median values for 10 ears.

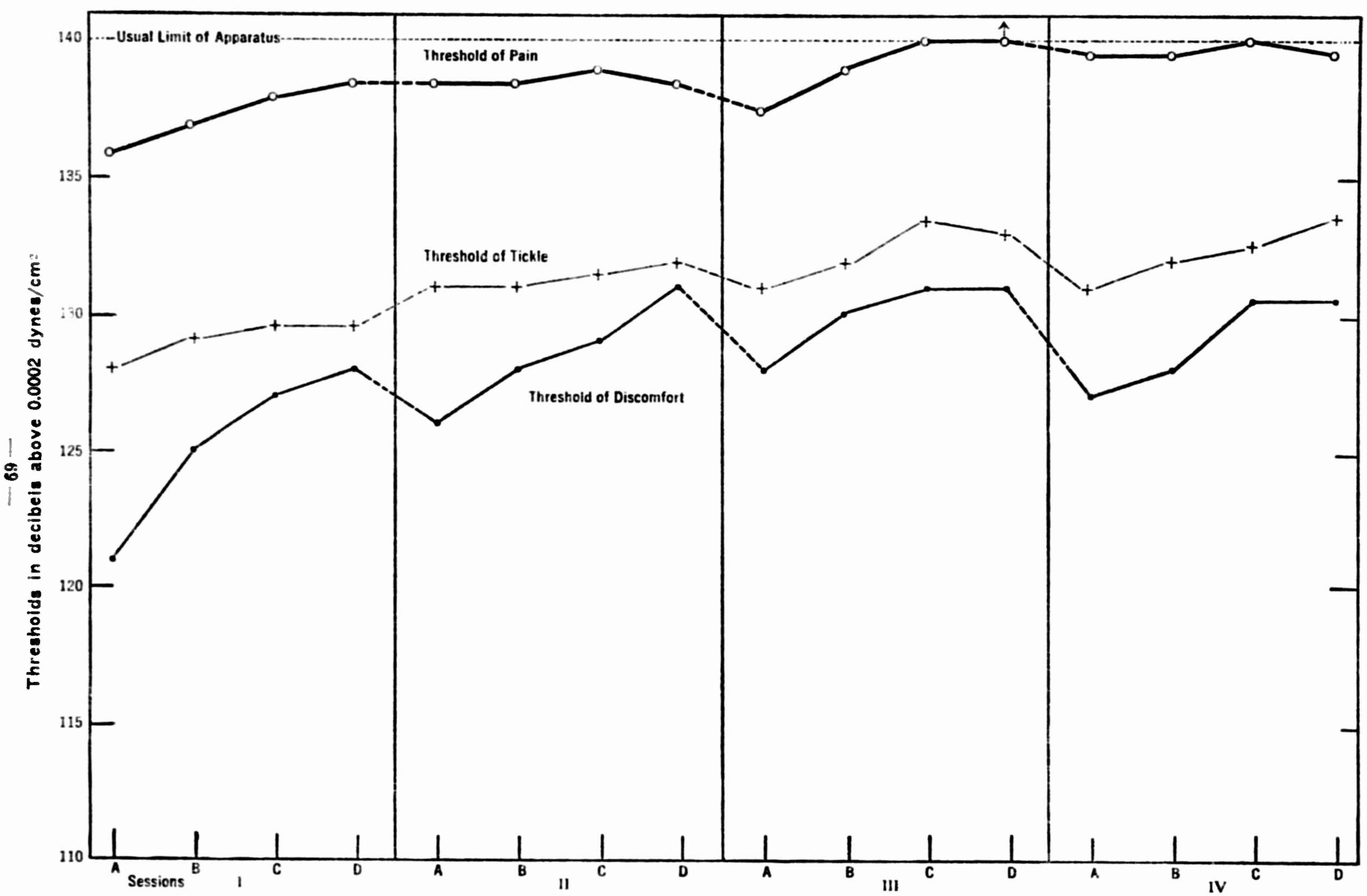

Fig. 35. Elevation of tolerance for speech—Hard-of-Hearing. Group 3. Median values for 10 ears.

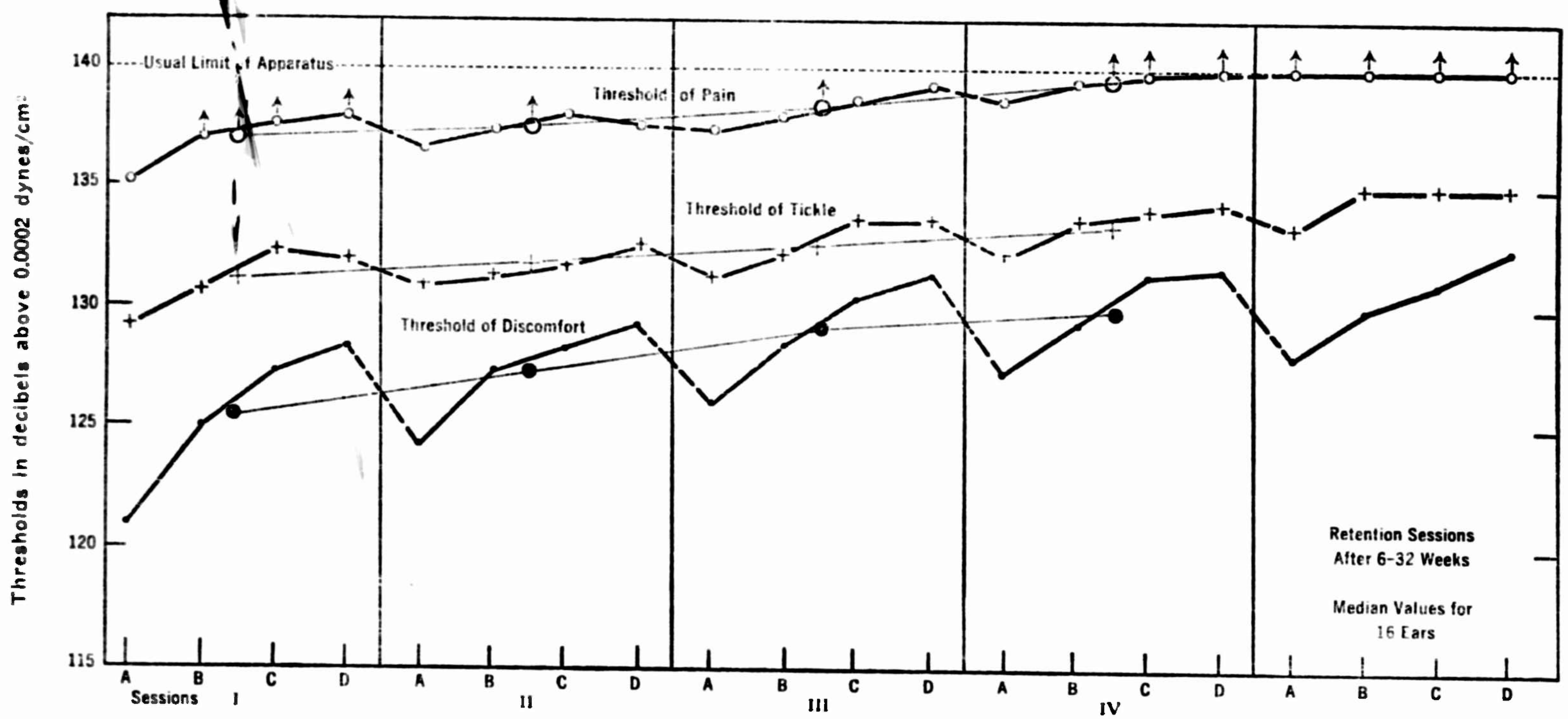

Fig. 36. Elevation of tolerance for speech—Hard-of-Hearing. All groups. Mean of median values for 30 ears.
Heavy lines indicate means of median for each test; light lines indicate means for each session.

Dispersion and shift of thresholds: In Fig. 37 are plotted the frequency distributions of the thresholds of discomfort of the entire group on the first (IA) and on the last (IVD) tests. The upward shift of the thresholds as a group is clearly indicated. It also appears that the dispersion is much reduced on the final test. There are a few responses at the extremes representing two tender ears of the same subject at the low extreme and one tough ear at the high extreme.

Fig. 38 indicates a similar trend for the tickle threshold. The initial dispersion is from 103 to greater than 140 db. On the final test most subjects showed thresholds of 130 db or higher. The initial (IA) distribution for pain in Fig. 39 shows a range from 106 to greater than 140 db with the values of eight responses lying beyond the limits of the apparatus. As in the case of the discomfort and tickle thresholds, two tender ears increase considerably the dispersion for the initial and final pain thresholds. The curve for the final test (IVD) clearly shows the upward shift of the pain threshold.

Ultimate thresholds of tolerance: The ultimate level for each threshold was derived from the asymptotes of the curves in Fig. 36 which represent the mean for each session. *These values were 130, 133.5 and greater than 137 db for discomfort, tickle, and pain, respectively.* In addition the means for each test are plotted in Fig. 36 to show in greater detail the elevation of thresholds with experience. Exact values for both sets of data are given in Table 19.

Threshold shift: The amounts of elevation of tolerance from test IA to the highest values of the curves in Fig. 36 are given in Table 21.

TABLE 21 — ELEVATION OF TOLERANCE FOR SPEECH IN DECIBELS — HARD-OF-HEARING

	Mean of Medians Test IA *	Highest Value of Mean for Individual Test *	Elevation
Discomfort	121.0	131.7	10.7
Tickle	129.3	134.3	5.0
Pain	135.3	135.3	Not known **

* decibels above 0.0002 dynes/cm²
** values as early as test IB lay beyond range of apparatus

It is further evident from Table 19 and Fig. 36 *that there is a constant pattern of elevation within a given session with test A usually the low point and test D the high point.* As the number of sessions increases the elevation within a given session decreases. For the discomfort threshold the elevation within session I was 7.3 while it was 4.4 within session IV. A similar comparison for the tickle threshold shows an elevation of 3 db within session I and 2 db within session IV.

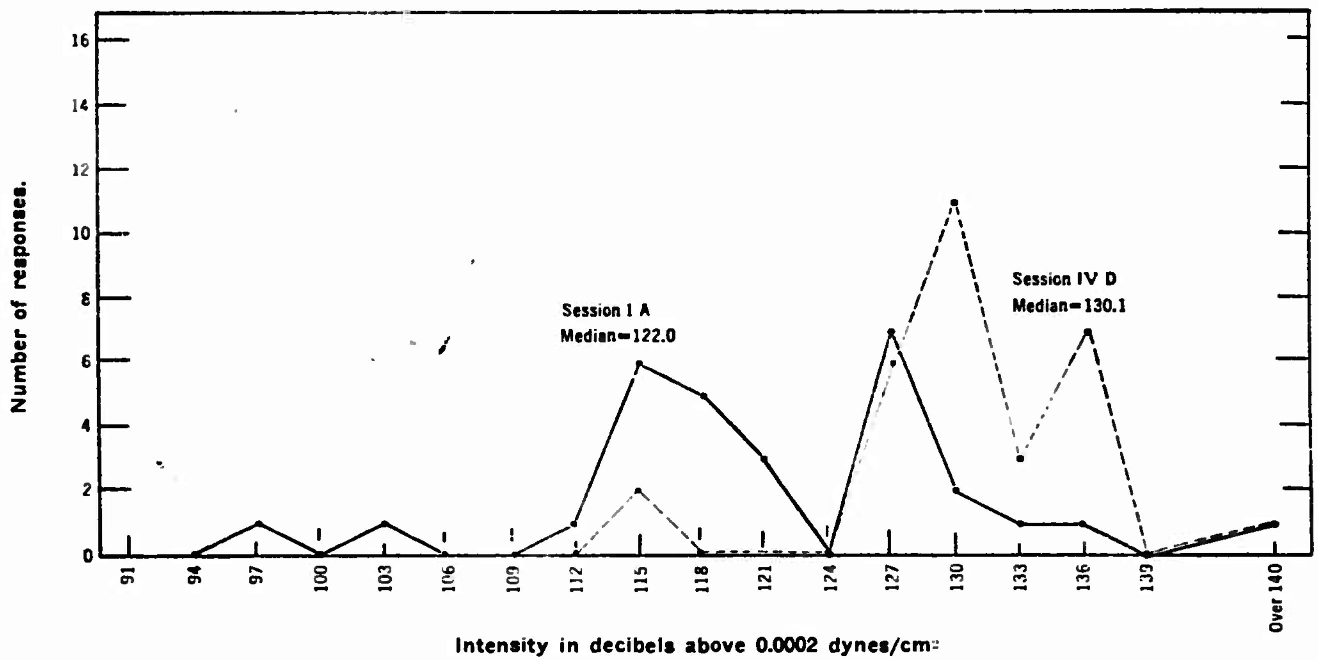

Fig. 37. Frequency distribution of thresholds of discomfort—Hard-of-Hearing. 30 ears.

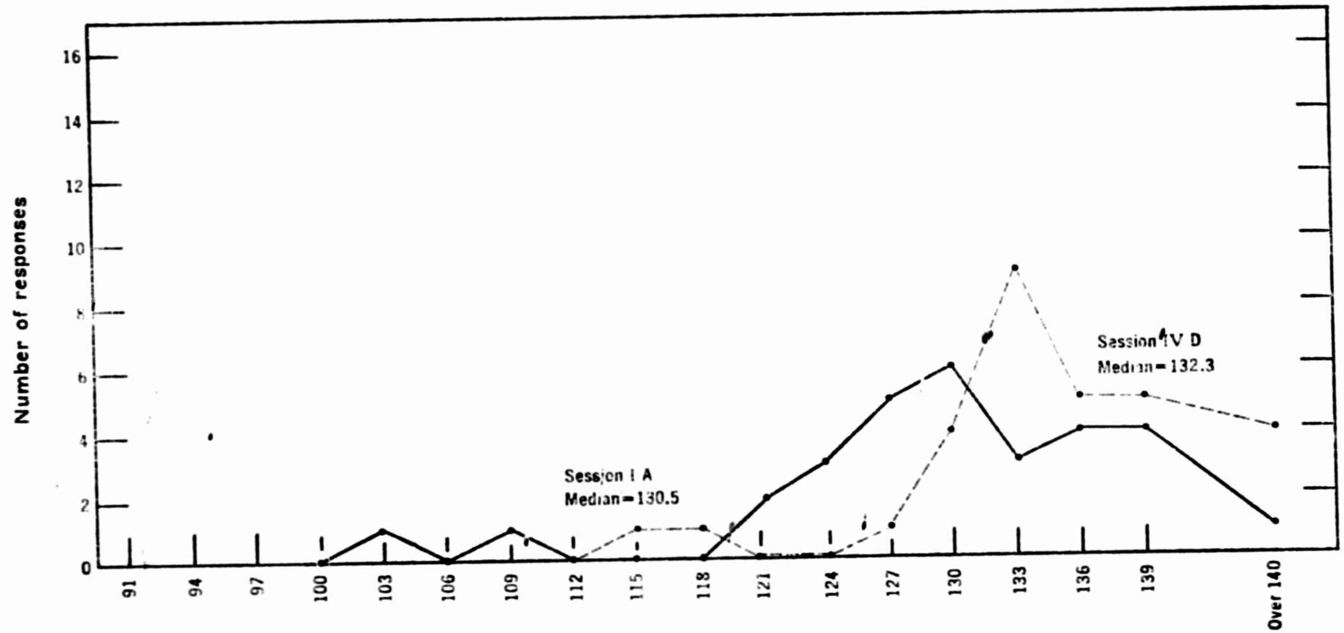

Fig. 38. Frequency distribution of thresholds of tickle—Hard-of-Hearing. 30 ears.

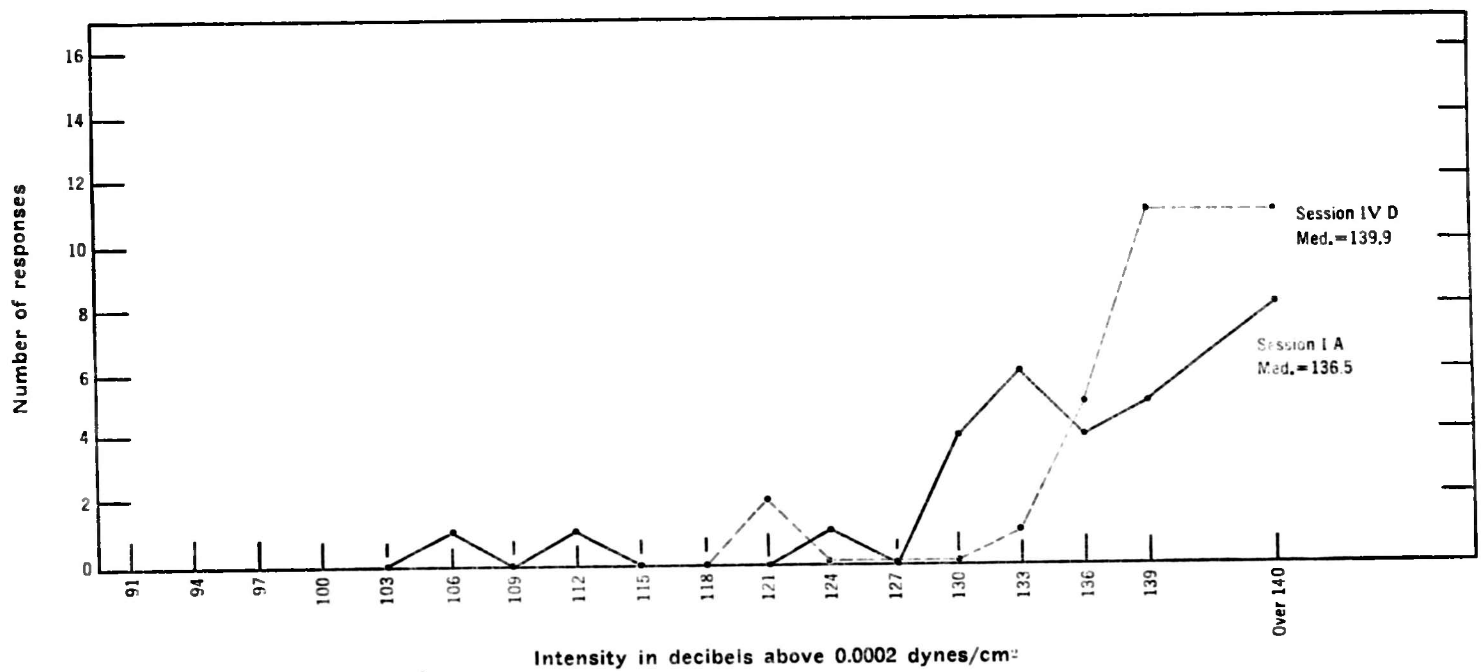

Fig. 39. Frequency distribution of thresholds of pain—Hard-of-Hearing. 30 ears.

Table 22 — Speech Tolerance — Hard-of-Hearing

Individual Threshold Indices in decibels above 0.0002 dynes/cm²										
Subject	Ear	Discomfort		Tickle		Pain		Threshold Shift		Mean Hearing Loss
		Initial	Final	Initial	Final	Initial	Final	Discomfort	Tickle	Temporary
R.M.	R	102	114	110	118	112	120	12	8	.8
	L	96	116	104	116	106	120	20	12	10.3
F.H.	R	116	126	124	130	130	135	10	6	-3.5
	L	114	130	122	132	130	135	16	10	11.3
E.D.	R	116	136	130	139	134	*140*	20	9	.8
	L	114	135	124	138	124	140	21	14	.5
J.M.	R	112	130	128	134	132	140	18	6	-.8
	L	116	130	132	133	130	140	14	1	-.3
M.N.	R	118	128	124	128	130	133	10	4	1.8
	L	122	131	126	132	134	139	9	6	.8
A.C.	R	116	130	122	136	131	139	14	14	- .3
	L	118	130	130	134	137	*140*	12	4	- .3
B.M.	R	118	128	130	130	138	136	10	0	- .3
	L	118	126	132	131	134	140	8	-1	.0
B.S.	R	118	132	126	135	*140*	*140*	14	9	.0
	L	120	130	126	132	*140*	*140*	10	6	1.0
V.C.	R	126	128	131	133	140	*140*	2	2	.0
	L	124	128	135	133	137	139	4	-2	- .3
J.D.	R	120	130	126	138	140	139	10	12	
	L	132	130	138	136	*140*	140	-2	-2	
S.C.	R	128	137	138	140	140	140	9	>2	1.0
	L	128	133	130	135	136	140	5	5	- .3
C.S.	R	128	132	136	138	140	140	4	2	.8
	L	130	130	132	133	134	138	0	1	.0
R.E.	R	126	137	137	*140*	*140*	*140*	11	>3	.0
	L	128	137	140	*140*	140	*140*	9	0	.0
H.E.	R	128	131	131	131	135	138	3	0	1.0
	L	*140*	*140*	*140*	*140*	*140*	*140*	>0	>0	.0
E.L.	R	130	136	138	137	*140*	*140*	6	-1	.8
	L	135	137	135	140	*140*	*140*	2	5	.0

Figures in italics indicate values above limit of apparatus.

Comparisons of the final threshold of discomfort for speech with the analogous threshold for pure tones shows that the speech threshold is higher by the hardly significant amount of 0.5 db. The thresholds of tickle and pain for speech fall below similar thresholds for pure tones. These comparisons are subject to the limitations described for normals.

Individual Differences

The subjects are ranked according to tenderness in Table 22 employing the same criteria used for normals. Where values were greater than 140 db, the decision on rank was arbitrary with some importance attached to initial discomfort values.

Relationship of ears: The rank order correlation on initial discomfort between the two ears was .92 and on final discomfort .74. The high correlations show again that if an individual was tender in one ear, he was likely to be tender in the other ear. An exception to this statement is H.E. whose initial and final responses for all three thresholds on the left ear were greater than 140 db. It will be noted from H.E.'s audiogram (Table 13) for this ear that he showed a 90-95 db loss from 512 to 1024 cps with no response in the other frequencies.

Relationship of initial and final thresholds; age and sex: The rank order correlation between the initial and final discomfort measure on each ear was .57. The relatively high correlation as compared with that of the normals may be due to close grouping on the initial thresholds which was maintained for the final threshold. The data suggest no relationship between tenderness and age.

Table 23 comparing the sexes for initial and final discomfort and initial tickle values suggests no appreciable differences with respect to tenderness. In addition, the males and females are quite evenly distributed on the tenderness scale in Table 23.

TABLE 23 — THRESHOLD OF TOLERANCE FOR SPEECH — HARD-OF-HEARING

Mean of Values, as in Table 22, in decibels above 0.0002 dynes/cm²

Sex	Discomfort Initial	Discomfort Final	Tickle Initial
Male	120.0	129.4	127.4
Female	121.7	132.0	131.7

Relationship to hearing loss (512-2048 cps): There is a slight, but not conclusive positive relationship between the initial discomfort threshold and hearing loss at frequencies 512, 1024, and 2048 cps. *It seems that the greater the hearing loss the higher the initial tolerance threshold.* This is shown most dramatically in the case of H.E. who had a wide difference in hearing loss between the two ears. R.M., the subject with the smallest hearing loss, had the lowest initial discomfort threshold.

TABLE 24 — THRESHOLDS OF TOLERANCE FOR SPEECH — HARD-OF-HEARING
Grouped According to Clinical Types

Sub-Groups Arranged by Hearing Loss for Better Ear

Initial and Final Values in decibels above 0.0002 dynes/cm²							
		Discomfort		Tickle		Pain	
	Ear	Initial	Final	Initial	Final	Initial	Final
Conductive							
B.M.	R	118	128	130	130	138	136
	L	118	126	132	131	134	140
J.D.	R	120	130	126	138	140	139
	L	132	130	138	136	*140*	140
B.S.	R	118	132	126	135	*140*	*140*
	L	120	130	126	132	*140*	*140*
A.C.	R	116	130	122	136	131	139
	L	118	130	130	134	137	*140*
Mean		120	129.5	128.8	134	*137.5*	139.3
Nerve							
S.C.	R	128	132	136	138	140	140
	L	130	130	132	133	134	138
H.E.*	R	128	131	131	131	135	138
S.C.	R	128	137	138	*140*	*140*	*140*
	L	128	133	130	135	136	140
E.L.	R	130	136	138	137	*140*	*140*
	L	135	137	135	140	*140*	*140*
Mean		128.6	133.7	134.3	*136.3*	*137.8*	*139.4*
Mixed							
R.M.	R	102	114	110	118	112	120
	L	96	116	104	116	106	120
F.H.	R	116	126	124	130	130	135
	L	114	130	122	132	130	135
R.E.	R	126	137	137	*140*	*140*	*140*
	L	128	137	140	*140*	140	*140*
E.D.	R	116	136	130	139	134	*140*
	L	114	125	124	138	124	140
M.N.	R	118	128	124	128	130	133
	L	122	131	126	132	134	139
V.C.	R	126	128	131	133	140	*140*
	L	124	128	135	133	137	139
J.M.	R	112	130	128	134	132	140
	L	116	130	132	133	130	140
Mean		116.4	129.0	126.2	*131.9*	*129.9*	*135.8*
Mean without R.M.		119.3	131.3	129.4	*134.3*	*133.4*	*138.4*

*Left ear of H.E. not included — no tolerance thresholds reached within limit of apparatus.
Figures in italics indicate values above limit of apparatus.

Relationship to use of hearing aid: The data concerning the use of hearing aids are too meagre and too variable to indicate whether habitual use of a hearing aid might have already caused a significant elevation of tolerance thresholds above the expected levels. Some of the major variables among hearing aid users were the type of instrument, length of time it had been worn, hours per day it was in use, and the acoustic environment in which the user spent the greater portion of his time using the instrument.

Relationship to clinical types of deafness: Table 24, showing individual initial and final values of each threshold for each clinical type, indicates that the "nerve deafened" group had the highest initial and final discomfort thresholds and the highest initial tickle thresholds. The group with conductive deafness came next and then the subjects with mixed types. However, subject R.M., who was unusually tender, lowers the average threshold of the mixed group by 3.1 db for initial discomfort, by 2.3 db for final discomfort, and 3.2 db for initial tickle. If the values for R.M. are eliminated from the calculation, the average values for the conductive and mixed groups do not differ significantly. The order of clinical types does not correlate with that found in the pure tone experiment. This observation is based on inspection of Table 24, since means for each clinical group could not be calculated because many values lay beyond the limitations of the apparatus.

The difference in order is probably due to the wide scatter of hearing losses and the small samples. The data suggest only that the "nerve deafened" group have the highest tolerance for speech. However, *the difference in discomfort values for the three groups are least at the final session, which indicates that the thresholds of the three types ultimately reach the same levels.*

Stability of Threshold of Acuity

The mean hearing loss resulting from exposure to one test was only 0.9 db. This hearing loss is not statistically significant, but the SD of 2.90 db suggests relatively wide spread of the individual losses. The latter are given in Table 22.

Comparisons Between Normals and Hard-of-Hearing

Both groups showed a progressive elevation of tolerance thresholds with experience. Although the normals showed a greater elevation for discomfort by 3.5 db and for tickle by 1.9 db (Tables 16 and 21) *both groups reach approximately the same mean threshold levels.* The normals and hard-of-hearing also showed a similar pattern of rise from tests A to D within a given session. Neither group showed any significant effect on the threshold of acuity (detectability of speech) as a result of exposure to the testing procedure.

VII. TRANSFER TOLERANCE

It will be recalled that "transfer tolerance" is defined as either the increase in tolerance for pure tones produced by the procedure of testing speech tolerance or the increase in tolerance for speech produced by testing the tolerance for pure tones.

Procedure

Elevation of pure tone tolerance: All individuals (30 normal ears and 30 hard-of-hearing ears), both normal and hard-of-hearing, who had been exposed to tests of speech tolerance were tested for their tolerance to pure tones in one session, as described in Chapter V. These subjects are designated as "pure tone transfers." Those subjects in speech tolerance groups 1 and 2 were tested with pure tones one week after their last speech tolerance test. Those who had been in speech tolerance group 3 were tested 24 hours after their last speech tolerance test.

Transfer to speech tolerance: Those subjects (16 normal and 16 hard-of-hearing ears) who had been through the pure tone tolerance procedure were tested for their tolerance for speech in one session one week after their last pure tone tolerance test, according to the procedure described for speech tolerance group 1. (See Ch. VI) These subjects are designated as "speech transfers."

Results for Pure Tone Transfers — Normals

The median for each frequency was computed for all pure tone transfers. Then the means of the medians for the A and B tests were calculated for the discomfort threshold. (A similar calculation could not be made for tickle and pain because of values lying beyond the range of the apparatus.) Table 25 shows their initial and final thresholds compared with the thresholds of the original pure tone group. When the initial discomfort thresholds of the original pure tone group are compared with the thresholds of the pure tone transfers (exposed to pure tones for the first time), the mean of the A and B tests of the pure tone transfers is 9.0 db.

TABLE 25 — PURE TONE TRANSFERS — NORMALS

Means of Medians of All Frequencies

Thresholds of Discomfort in decibels above 0.0002 dynes/cm²

	Session	N. Ears	Test A	Test B	Mean
Original Group	I	16	109.9	112.4	111.2
	VI	16	117.4	122.6	120.0
Transfer Group		30	117.5	122.8	120.2
Difference between Transfer and Session I			7.6	10.4	9.0
Difference between Transfer and Session VI			.1	.2	.2

It is clear, therefore, that *the exposure to the speech tolerance procedure elevated the initial pure tone thresholds of the transfer group.* In fact the pure tone threshold of the transfer group was almost identical with the final threshold (VI) of the original group.

Results for Speech Transfers — Normals

The medians for Tests A and D and the means of the medians for the complete session were computed for discomfort and tickle and related to the initial and final sessions of the original speech group in Table 26. When the initial discomfort threshold of the original speech group is compared with the thresholds of the speech transfers (exposed to speech for the first time), the mean of the session of the speech transfers is 2.5 db higher than the initial threshold of the original group.

TABLE 26 — SPEECH TOLERANCE TRANSFERS — NORMALS

Mean Values for Each Test

Thresholds of Discomfort in Decibels above 0.0002 dynes/cm²

	Session	N. Ears	Test A	Test D	Mean of Session
Original Group	I	30	117.0	124.3	120.8
	IV	30	126.3	131.2	129.5
Transfer Group		16	120.0 *	126.0 *	123.3
Difference between Transfer and Session I			3.0	1.7	2.5
Difference between Transfer and Session IV			-6.3	-5.2	-6.2
Thresholds of Tickle in decibels above 0.0002 dynes/cm²					
Original Group	1	30	128.3	131.8	130.0
	IV	30	134.5	134.3	134.6
Transfer Group		16	130.5 *	133.0 *	131.6
Difference between Transfer and Session I			2.2	1.2	1.6
Difference between Transfer and Session IV			-4.0	-1.3	-3.0

* Median of Tests

Exposure to pure tones, therefore, slightly elevated the initial (speech) discomfort threshold of the transfer group. The relatively slight positive effect is further demonstrated in Table 26 where the final threshold of the original group is 6.2 db higher than the threshold of the threshold of the transfer group. A similar but smaller elevation of the tickle threshold also occurs.

For our normal subjects the speech tolerance procedure was relatively more effective in building tolerance (discomfort) for pure tones than the pure tone procedure in building tolerance (discomfort and tickle) for speech.

Results for Pure Tone Transfers — Hard-of-Hearing

When the initial discomfort thresholds of the original pure tone group are compared (Table 27) with the thresholds of the pure tone transfers (exposed to pure tones for the first time), the mean of the A and B tests of the pure tone transfers is 6.5 db higher than the initial thresholds of the original group.

TABLE 27 — PURE TONE TRANSFERS — HARD-OF-HEARING

Mean of Medians of all Frequencies

Thresholds of Discomfort in decibels above 0.0002 dynes/cm ^{2}

	Session	N. Ears	Test A	Test B	Mean
Original Group	I	20	118.4	*	118.4
	VI	16	126.9	130.8	128.9
Transfer Group		30	122.0	127.8	124.9
Difference between Transfer and Session I			3.6	—	6.5
Difference between Transfer and Session VI			-4.9	-3.0	-4.0

* There was no B test for Session I

It is evident, therefore, that *the exposure to the speech procedure was appreciably effective in elevating the initial pure tone thresholds of the transfer group.* However, the threshold of the transfer group and the threshold of the final session (VI) of the original group given in Table 27 was 4.0 db higher than the threshold of the transfer group, indicating that the speech test was not as effective in elevating tolerance for pure tones as the *complete* pure tone procedure.

Results for Speech Transfers — Hard-of-Hearing

When the initial discomfort thresholds of the original speech group are compared with the thresholds of the speech transfers (exposed to speech for the first time), the mean of the session of the speech transfers is 6.0 db higher than the initial threshold of the original group.

TABLE 28 — SPEECH TOLERANCE TRANSFERS — HARD-OF-HEARING

Mean Values for Each Test

Thresholds of Discomfort in decibels above 0.0002 dynes/cm ^{2}

	Session	N. Ears	Test A	Test B	Mean of Session
Original Group	I	30	121.0	128.3	125.4
	IV	30	127.3	131.7	130.0
Transfer Group		16	127.0 *	134.5 *	131.4
Difference between Transfer and Session I			6.0	6.2	6.0
Difference between Transfer and Session IV			- .3	2.8	1.4
Thresholds of Tickle in decibels above 0.0002 dynes/cm ^{2}					
Original Group	I	30	129.3	132.0	131.1
	IV	30	132.3	134.3	133.5
Transfer Group		16	136.5 *	137.0 *	136.6
Difference between Transfer and Session I			7.2	5.0	5.5
Difference between Transfer and Session IV			4.2	2.7	3.1

* Medians of Tests

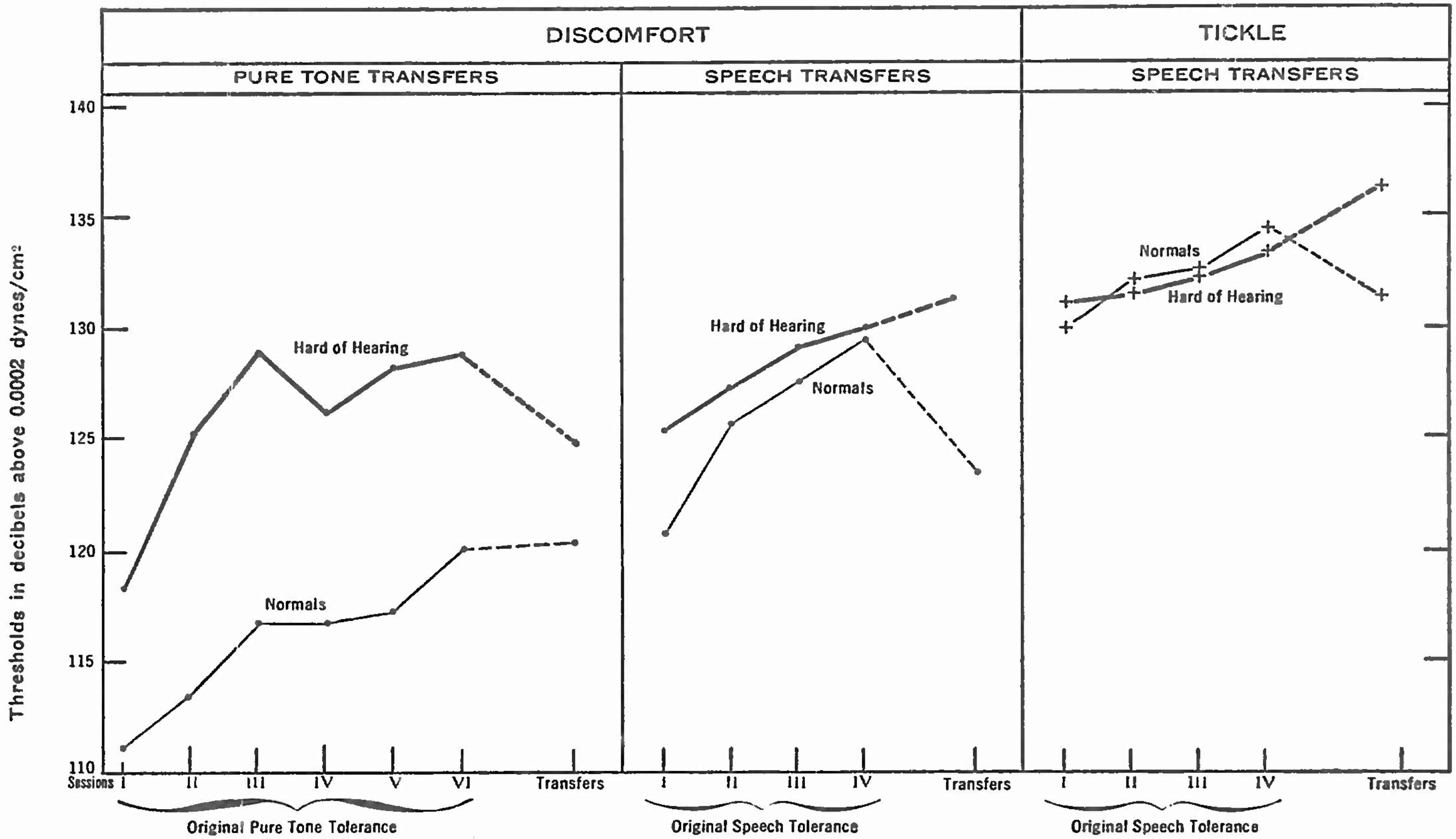

Fig. 40. Transfer tolerance for thresholds of discomfort and tickle.

Pure tone transfers are those subjects who originally had been exposed to tests of tolerance for speech and then exposed to one session of tests for tolerance for pure tones. Speech transfers are those subjects who originally had been exposed to tests of tolerance for pure tones and then exposed to one session of tests for tolerance for speech.

Exposure to pure tones, therefore, appreciably elevated the initial (speech) discomfort threshold of the transfer group. Furthermore, the threshold of the transfer group was 1.4 db higher than the threshold of the final session (IV) of the original group, given in Table 28, indicating that *the pure tone tests were slightly more effective in elevating tolerance for speech than the complete speech tests.* The data in Table 28 indicate that the same observations can be made for the tickle threshold.

The data suggest that in hard-of-hearing ears the pure tone tests were relatively more effective in building tolerance (discomfort and tickle) for speech than the speech tolerance procedure in building tolerance (discomfort) for pure tones.

Comparison of Normals and Hard-of-Hearing

Fig. 40 suggests that the speech tolerance procedure was more effective in building discomfort tolerance for pure tones in the normal group than in the hard-of-hearing group. However, there was more elevation of both discomfort and tickle thresholds for speech in the hard-of-hearing than in the normal group as a result of exposure to pure tones. It is possible that the difference between the two groups may be due to sampling. *The significant observation, nevertheless, is the fact that some transfer tolerance does take place for both groups.*

VIII. RETENTION OF SPEECH TOLERANCE

Study of retention of tolerance was confined to speech because speech seemed to yield a sharper end point of more practical significance than pure tones. At various intervals after the last session of speech tolerance testing, 11 normal (22 ears) and 8 hard-of-hearing subjects (16 ears) were retested using the *Speech Tolerance 1* procedure (Ch. VI) for one session.

Results — Normals

In Fig. 41 are plotted (at the left) the median values for the tolerance thresholds of the entire normal group in the last session of the regular tests, indicating the levels to which these thresholds had been elevated. The corresponding median values for the groups retested after 6-8 weeks, 10-14 weeks, and 20-26 weeks are plotted in the same manner. It is clear that there is a slight loss of tolerance, particularly for the small group tested after 10-14 weeks, but the losses are not clearly related to the length of the interval. If all of the tests made 6 weeks or more after the end of the original series are grouped together, the net result (means of the medians) is a loss of 1.2 db for discomfort and 1 db for tickle. These losses are negligible, and we may conclude that the elevation of tolerance is retained virtually intact for periods up to 26 weeks.

Results — Hard-of-Hearing

The results for the hard-of-hearing were almost identical with those for the normals. The data are presented graphically in Fig. 42. There is no systematic loss of tolerance with increasing interval after the last regular exposure; and the group as a whole, combined without regard to the length of the interval, shows a slight but negligible *rise* in tolerance when retested. The 4 ears tested at intervals of 20-26 weeks happened to be two of the "tenderest" subjects (E.D. and J.M.) in the original ranking (Table 22), and their thresholds on their thresholds on retest are only slightly below *their own* final thresholds.

We conclude, therefore, that the hard-of-hearing as well as normals retain effectively for at least 32 weeks the added tolerance for loud speech that they gained during the original testing procedures.

In general, tolerance was maintained by both groups over the time intervals studied. There was no appreciable difference in retention for either group. Since the maximum time interval studied was only 32 weeks, no generalization can be made concerning the permanency of elevation of tolerance.

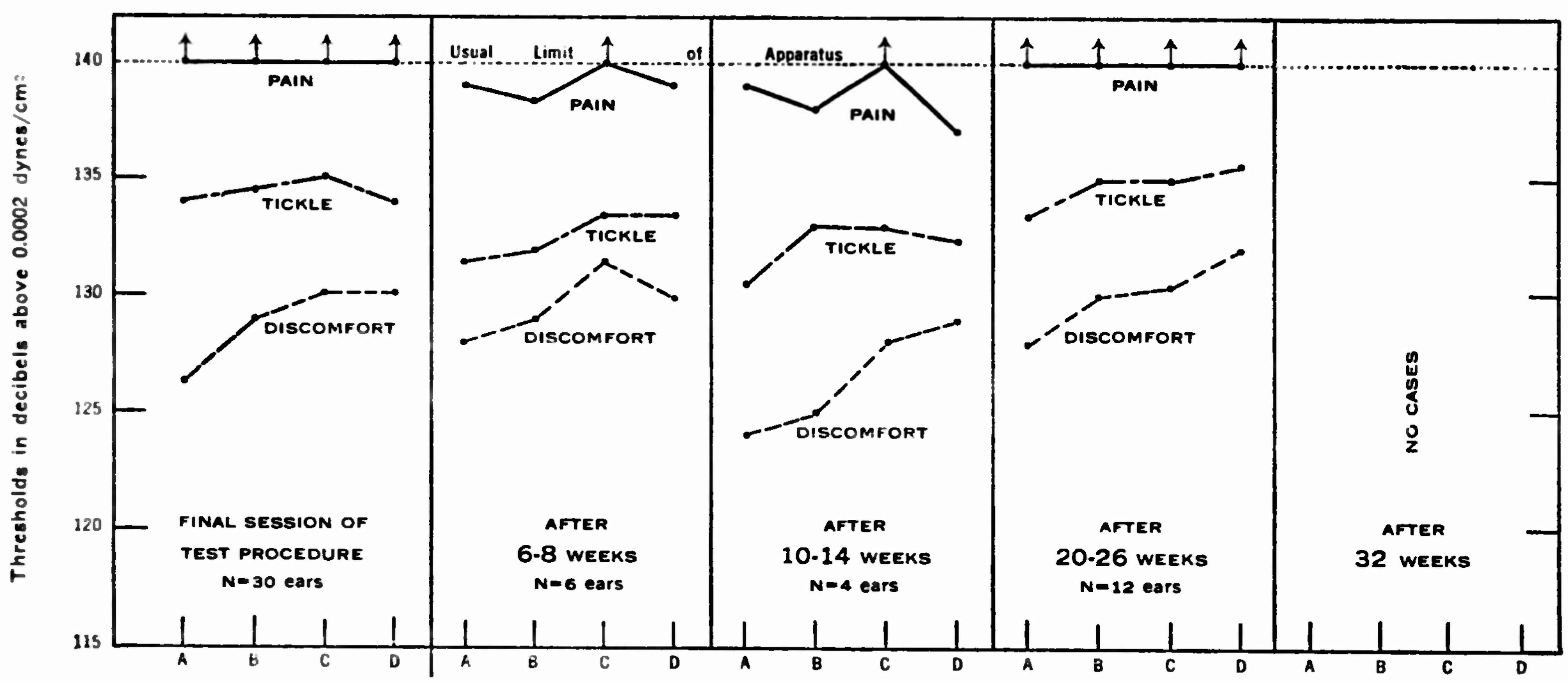

Fig. 41. Retention of tolerance of thresholds for speech—Normals. Median values for each test.

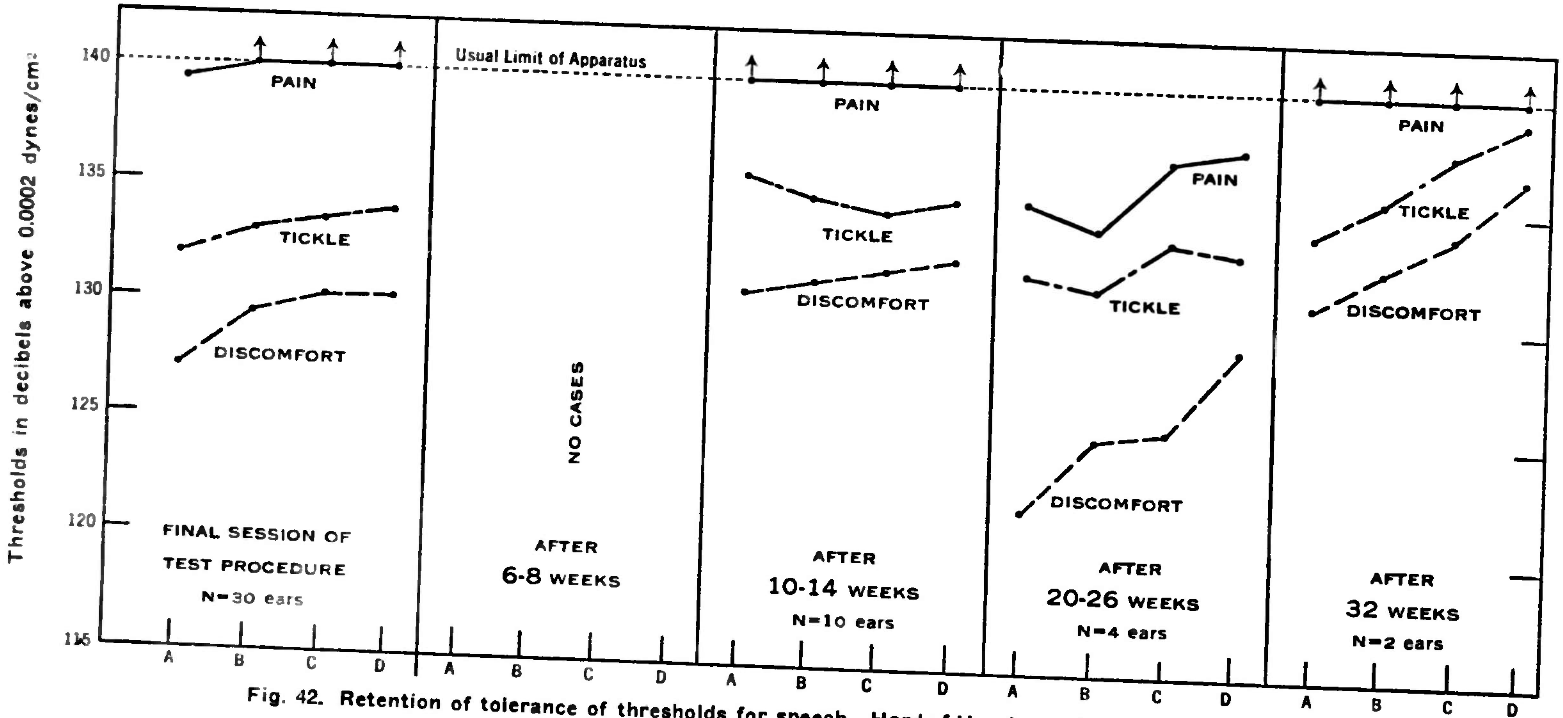

Fig. 42. Retention of tolerance of thresholds for speech—Hard-of-Hearing. Median values for each test.

IX. METHODS OF ELEVATING TOLERANCE

When the phenomenon of progressive elevation of tolerance through exposure to the testing procedure was observed, it was decided to explore experimentally the possibility of deliberate elevation of tolerance through systematic exposure to loud sounds.

Procedure

Speech was chosen as the exposure material and also for the tests of tolerance, since it was anticipated that the method might be tried at the Army or Navy Aural Rehabilitation Centers; and it would have been easy to provide pressings of our original recordings for such use. Also, with a view to clinical application, it was decided to test the effectiveness of speech delivered at a level *below* the tickle threshold and also at a level *below* the threshold of discomfort. To compare the relative effectiveness of these two levels, the right ear of each subject was always exposed to speech 2 db below the discomfort level of that ear, determined at the beginning of the session, and the left ear to speech 2 db below his tickle threshold also determined at the beginning of that session.

The complete sequence of procedure for each subject was as follows:

1. *Sequence of procedure for right ear:*

TEST A

Acuity Threshold (detectability for speech)
Discomfort Threshold
Tickle Threshold
Exposure to 4 minutes 45 seconds of connected discourse at *2 db below discomfort level*
Acuity Threshold (detectability for speech)

Two and one-half minute rest

TEST B

Discomfort Threshold
Tickle Threshold
Exposure as in test A
Acuity Threshold (detectability for speech)

Two and one-half minute rest

TEST C

Discomfort Threshold
Tickle Threshold
Exposure as in test A
Acuity Threshold (detectability for speech)

Two and one-half minute rest

TEST D

Discomfort Threshold
Tickle Threshold

2. *Sequence of procedure for left ear:*

TEST A

Acuity Threshold (detectability for speech)
Discomfort Threshold
Exposure to 4 minutes 45 seconds of connected discourse at ***2 db below tickle threshold***
Acuity Threshold (detectability for speech)

Two and one-half minute rest

TEST B

Discomfort Threshold
Tickle Threshold
Exposure as in test A
Acuity Threshold (detectability for speech)

Two and one-half minute rest

TEST C

Discomfort Threshold
Tickle Threshold
Exposure as in test A
Acuity Threshold (detectability for speech)

Two and one-half minute rest

TEST D

Discomfort Threshold
Tickle Threshold

It will be noted that the pain thresholds were never determined in this experiment since the purpose was to determine the effectiveness of sounds ***below*** the tickle threshold in elevating the thresholds of tolerance.

The procedures and the instructions to the subjects for the discomfort and tickle thresholds were identical with those employed in the main experiment. At the beginning of the "exposures" the subject was told, "You will hear a man talking about a housing project. It will be rather loud. Relax and just listen to the speech." The material was the same news broadcast by Fulton Lewis, Jr. previously described.

The above procedure constituted the work of one session. The subjects were exposed to four sessions (I through IV) at weekly intervals, and a session generally lasted 75 minutes.

Thresholds of detectability for speech were determined at the beginning of each session and after each exposure to determine what effect the exposure might have on acuity for speech. Ten hard-of-hearing men and women who had not participated in the earlier tests served as subjects. Table 29 gives the pertinent information concerning their impairments of hearing.

Table 29 — Subjects for Elevation of Speech Tolerance*

Subject	Age	Sex		Air Conduction Audiogram**	Type of Deafness***	Age of Onset of Deafness	Loss for Speech(db)	Use of Hearing Aid
A.R.	21	F	R.	1 1 2 6 9 x x	HFN	Birth	R. 29	—
			L.	1 1 1 5 6 8 6			L. 14	
W.S.	37	M	R.	1 1 2 2 5 5 5	HFN	30	R. 16	—
			L.	1 2 3 5 6 8 6			L. 28	
R.M.	35	M	R.	4 3 5 5 6 6 x	N	15	R. 40	—
			L.	4 3 4 5 5 7 x			L. 42	
A.P.	35	F	R.	5 6 7 8 8 8 x	N	11	R. 55	—
			L.	6 5 6 8 8 8 x			L. 65	
M.C.	39	F	R.	5 6 7 7 7 6 x	N	13	R. 82	R
			L.	5 6 7 6 8 7 x			L. 79	
D.H.	29	F	R.	4 4 4 4 5 4 2	C	26	R. 54	—
			L.	2 1 2 2 1 1 1			L. 22	
R.H.	30	M	R.	4 5 5 5 4 4 3	C	?	R. 54	L
			L.	5 6 6 5 5 8 5			L. 57	
A.S.	21	M	R.	5 5 6 7 4 x x	M	4	R. 60	R
			L.	5 5 6 7 7 x x			L. 72	
A.K.	32	F	R.	5 5 5 5 4 4 4	M	18	R. 59	L
			L.	5 6 7 7 4 4 3			L. 52	
R.G.	39	M	R.	1 2 2 2 2 4 6	M	12	R. 47	—
			L.	4 5 5 5 4 6 7				

*Group included only hard-of-hearing subjects.

**See page 7 for explanation of figures.

***HFN—High Frequency Nerve. N—Nerve. C—Conduction. M—Mixed.

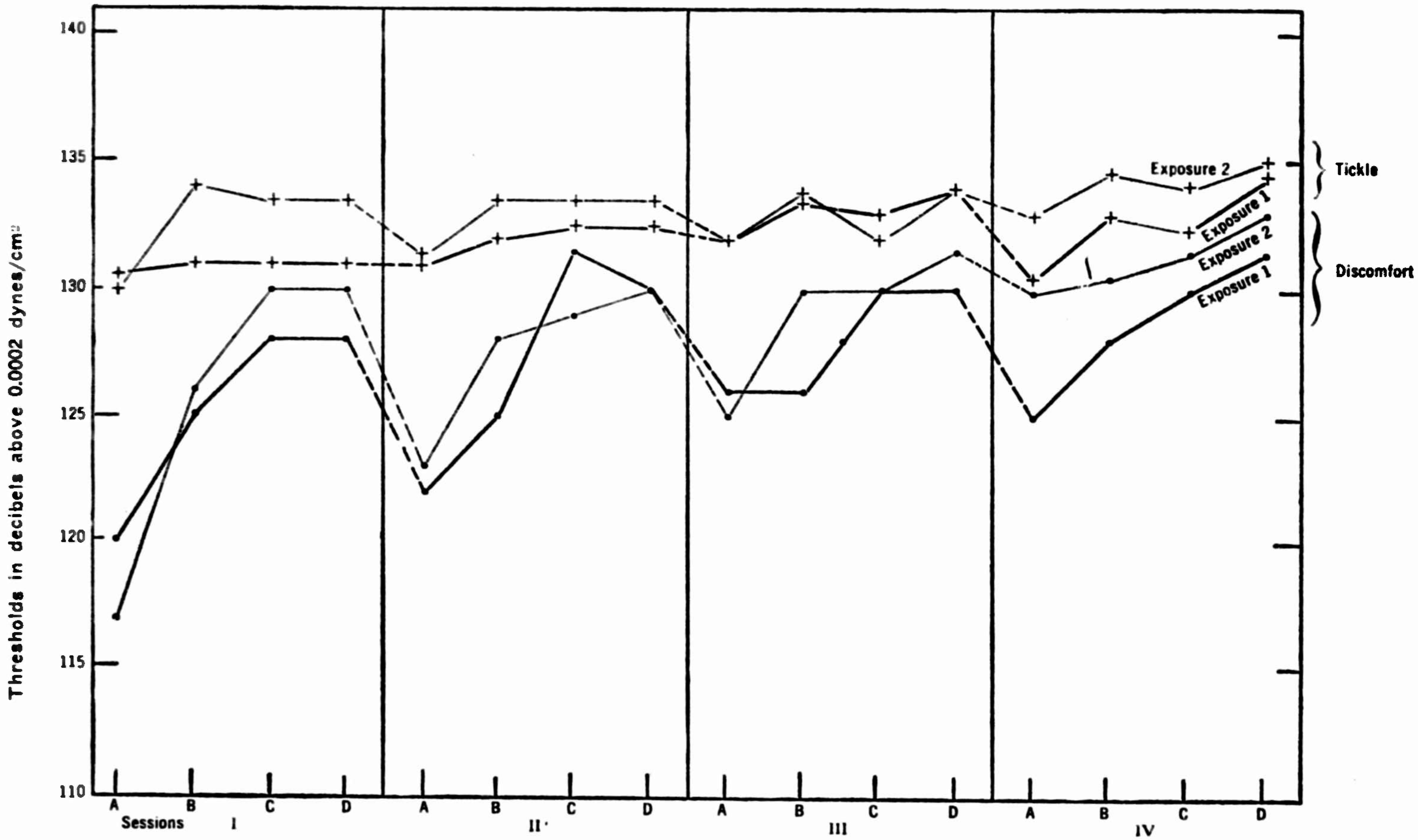

Fig. 43. Elevation of tolerance for speech; discomfort and tickle thresholds—Hard-of-Hearing. Medians for each test.

Exposure 1—2 decibels below original threshold of discomfort for speech. 10 ears.
Exposure 2—2 decibels below original threshold of tickle for speech. 10 ears.

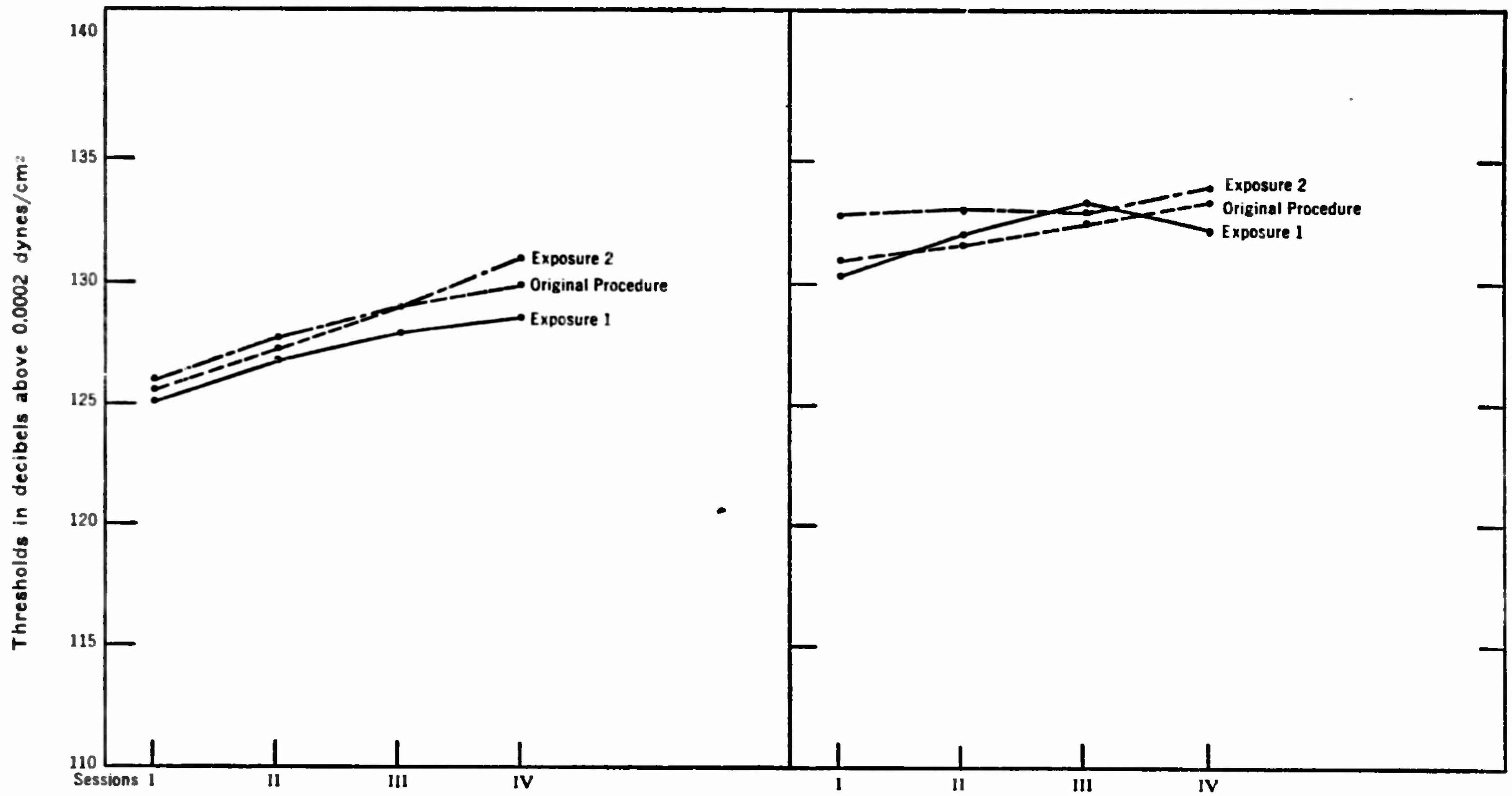

Fig. 44. Elevation of tolerance for speech; discomfort and tickle thresholds—Hard-of-Hearing. Means for each session. Comparison with original testing procedure.

Results

Fig. 43, showing the medians for the discomfort and tickle thresholds, indicates that, as might be expected, exposure 2 db below the tickle threshold was slightly more effective in elevating the discomfort threshold than exposure to the weaker sound 2 db below the discomfort threshold. The asymptotes of the curves representing the means, 131.3 db and 128.6 db, respectively, are 2.7 db apart. Likewise, the louder exposure elevated the tickle threshold to a slightly higher level 134.1 db and 133.1 db, respectively.

We had anticipated that the longer exposure to high intensity speech, either near the discomfort or near the tickle threshold, would result in a higher mean discomfort threshold than that resulting from the original speech tolerance procedure, but it is clear from Fig. 44 that such was not the case. The close proximity of the three means, all lying between 131.3 and 128.6 db, suggests that *the point to which the discomfort threshold can ultimately rise is very definitely limited. The point is roughly 130 db above 0.0002 dynes c/m ².* In order to examine dispersion around this point, the mean of all discomfort thresholds for exposures 2 db below the discomfort threshold was computed (since no values lay beyond the range of the apparatus) and the SD of this distribution was found to be 5.79 db which indicates relatively small dispersion.

It is to be noted further that the mean of the final points for both of the new procedures combined is 129.9 + db, which is for all practical purposes precisely the value derived for the final discomfort threshold for the hard-of-hearing in the original speech tests.

Furthermore, the curves in Fig. 43 suggest that the discomfort threshold is limited by the tickle threshold which shows relatively little elevation with any of our procedures. It will be recalled that the tickle sensation for speech is definite and persistent. *The tickle threshold seems to be a "biological constant," which is approached but never exceeded by the discomfort threshold.* Again the mean of the asymptotes of the tickle threshold for both of the new procedures, combined is 133.6 db, which is almost precisely the value obtained as a result of the original testing procedure. Dispersion for any of the end points of the tickle threshold could not be computed because of many values lying beyond the limits of the apparatus.

These results suggest that long exposure to still weaker speech, perhaps 10 db below the discomfort thresholds might be almost equally effective in elevating the threshold of discomfort until it approached its limiting value of 130 db.

Stability of threshold of acuity: The relatively long exposures to high-intensity speech did not significantly affect the threshold of acuity for speech detectability. The mean change of threshold, measured before and after each exposure, was 0.4 db for the weaker and 0.9 db for the stronger exposure. The SDs for these shifts (involving 10 ears each) were 4.54 and 4.70, respectively. The dispersion measure is not very meaningful because of the small samples and the values are within the 5 db margin of error that is considered allowable in clinical audiometry.

X. SUMMARY

The thresholds of *discomfort, tickle,* and of *pain* produced by pure tones and speech were determined in approximately 16,000 observations on 46 normal and 46 hard-of-hearing ears, the latter representing a fairly balanced distribution of clinical types of deafness. Table 30 summarizes the number of tests for the various experimental procedures.

TABLE 30 — SUMMARY

	N Subjects	N Ears	Sex	Age Range	Number of Threshold determinations: Discomfort	Tickle	Pain
Pure Tone Tolerance							
Original P.T.T. Group							
Normals	9	16	4M 5F	18–42	1392	1392	1392
Hard-of-Hearing	10	20	6M 4F	19–41	1520	1520	1520
Transfer Group							
Normals	15	30	8M 7F	16–40	480	480	480
Hard-of-Hearing	15	30	10M 5F	17–38	480	480	480
TOTAL	49	96	28M 21F	16–42	3872	3872	3872
Total Pure Tone Tests						11,616	
Speech Tolerance							
Original S.T. Group							
Normals	15	30	8M 7F	16–40	480	480	480
Hard-of-Hearing	15	30	10M 5F	17–38	480	480	480
Transfer Group							
Normals	9	16	4M 5F	18–42	64	64	64
Hard-of-Hearing	8	16	5M 3F	19–41	64	64	64
Retention Group							
Normals	11	22	6M 5F		88	88	88
Hard-of-Hearing	8	16	4M 4F		64	64	64
Elevation Tolerance							
Hard-of-Hearing	10	20	5M 5F	21–39	320	320	
TOTAL	76	150	42M 34F	16–42	1560	1560	1240
Total Speech Tests						4,360	
TOTAL							15,976

The initial pure tone thresholds for pain and for tickle lie at about 140 db and 133 db above 0.0002 dynes/cm ^{2}, respectively, for all frequencies from 250 to 5600 cps. The median thresholds are higher for the normal than for the hard-of-hearing group owing to the presence of more "tender" hard-of-hearing individuals reporting tickle and sometimes pain between 120 db and 130 db.

The contour of the threshold of discomfort approximates that of an equal-loudness contour and shows a broad minimum (3 db below the mean) between 1400 and 4000 cps. The initial median threshold for the normal (110 db) lies below the threshold for the hard-of-hearing (118 db), but there is great dispersion, particularly among the hard-of-hearing.

Similar determinations made with carefully monitored (recorded) speech gave a similar set of values given in Table 31. Tickle is a more constant phenomenon for speech than for pure tones and has a lower threshold as measured by a VU meter, but pure tones cause discomfort at lower intensities in normal ears than does speech.

The thresholds of discomfort, tickle, and pain rise systematically and significantly, with successive test sessions either daily or weekly, and approach limiting values after several test sessions.

TABLE 31—INITIAL AND FINAL THRESHOLDS OF NORMALS AND HARD-OF-HEARING FOR PURE TONES AND SPEECH

Mean of Median Values in decibels above 0.0002 dynes/cm²

	Discomfort		Tickle		Pain	
Normals	Initial	Final	Initial	Final	Initial	Final
Pure Tones	109.9	120.0	>133.1	>141.9	>140.1	>139.2
Speech	117.0	129.5	128.3	134.6	137.9	>139.2
Hard-of-Hearing						
Pure Tones	118.4	129.5	129.4	>141.1	>136.3	>141.3
Speech	121.0	130.0	129.3	133.5	135.3	137.0

The increased tolerance is largely but not entirely retained after an interval of a week, and more than half of the increase is retained for at least 26 weeks for the normal group and 32 weeks for the hard-of-hearing group.

Development of tolerance in one ear does not increase the corresponding tolerance of the other ear of the same individual. In the normal group exposure to speech testing is as effective as exposure to pure tone tests in elevating tolerance for pure tones. In this group the pure tone tests are only one-third as effective as the original speech tests in elevating tolerance thresholds for speech. A reverse relationship exists for the hard-of-hearing.

Tolerance may be developed effectively by exposure to loud speech at a level just below the threshold of discomfort for several minutes a day at three or four weekly intervals.

Exposure sufficient to produce maximal elevation of the tolerance threshold causes at most only a small transient rise in the threshold of acuity.

XI. GENERAL OBSERVATIONS AND DISCUSSION

After each test throughout all experiments, the subjects were asked to comment on how they felt as a result of the exposure to the tests. In about half the cases the subjects made no comment. In about 75% of the comments which were made, the report mentioned a "tickling" sensation. The next most frequent comment was "buzzing" (tinnitus) and "fullness in the ear." About 3% of the reports suggested "dizziness." Two subjects in early experiments on pure tones reported a feeling of nausea after the exposure. In all cases the conditions were temporary, disappearing usually a few minutes after the test. In two individuals, the feeling of "fullness" did not disappear for a few days. The subjects were unusually cooperative and were probably motivated by the feeling that despite their handicaps they were making a unique contribution to the war effort.

Those subjects who were habitual hearing aid users all reported that the experimental electro-acoustic system was far superior in quality to their own hearing aids, even when the subjects were perfectly satisfied with the latter. The comment, "I wish I had a hearing aid like that" (the experimental apparatus) was practically universal. This confirms the report [1] of the Psycho-Acoustic Laboratory that a high fidelity system is most desirable in a hearing aid regardless of any theories concerning "selective amplification."

The data indicate that 130 db appears to be the greatest useful maximum output of a hearing aid. The phenomenon of progressive elevation of tolerance with exposure to high-intensity stimuli suggests that preliminary determination of the tolerance threshold in the clinical selection of hearing aids should allow for an eventual rise in the tolerance threshold. Moreover, clinical practise should be directed toward elevating the tolerance threshold, since the high level of tolerance thresholds reached experimentally suggests that there is an approachable and potentially useful portion of the auditory area beyond the range of present audiometry. Consequently, some individuals who have heretofore been termed "totally deaf" as a result of audiometric tests might be reached by auditory stimulation through properly designed apparatus.

[1] OSRD Report. Design Objectives for Hearing Aids, (In press)

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ABSTRACT:

The investigation represents a systematic study of the quantitative and qualitative nature of the tolerance limits for speech and pure tones of normal and deafened ears. With reference to the Aural Rehabilitation Program of the armed forces, the tests were made to yield data pertinent to the design characteristics of future hearing aids, and to provide information which would guide procedures in the clinical selection of hearing aids. The threshold of discomfort, tickle, and pain produced by pure tones and speech were determined in approximately 16,000 observations on 46 normal and 46 hard-of-hearing cases, the latter representing a fairly balanced distribution of clinical types of deafness. The results of the tests are summarized and tabulated, and the data indicate that 130 db appears to be the greatest useful maximum output in a hearing aid.

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