VERIFICATION OF THE HYPOTHESIS-"RECREUITMENT IS AN ARTIFACT"

A Dissertation

Submitted to the University

Of

Mysore

By

R.RANGASAYEE

In Partial Fulfillment of the

Requirements for the Degree

Of

Master of Science

In

Speech and Hearing

May,1975

To my Parents and Uncles

to whom

I owe my education and life

C E R T I F I C A T E

This is to certify that the dissertation entitled' Verification of the hypothesis - "Recruitment is an Artifact"', is the bonafide work in part fulfillment for M.Sc., Speech and Hearing, carrying 100 marks of the student with Register Number 27.

D I R E C T O R

All India Institute of Speech
and Hearing.
MYSORE - 6.

C E R T I F I C A T E

This is to certify that this dissertation has been prepared under my supervision and guidance.

(M.N.VYASA MURTHY.)

G U I D E

C E R T I F I C A T E

This is to certify that this dissertation has been prepared under my supervision and guidance.

(M.N.VYASA MURTHY.)
G U I D E

D E C L A R A T I O N

This dissertation is the result of my own study undertaken under the guidance of Mr. M.N. Vyasa Murthy, Lecturer in Audiology, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier at any University for any other Diploma or Degree.

MYSORE

Dated Register No;

A C K N O W L E D G E M E N T S

The experimenter is highly grateful to Mr. M.N. Vyasa Murthy, Lecturer in Audiology, All India Institute of Speech & Hearing, Mysore, for his expert guidance and valuable alterations, without which this work would have been impossible.

The experimenter is thankful to Dr. P.R. Kulkarni, Director, AIISH, for the facilities and the concessions provided in submitting the dissertation.

The experimenter is highly grateful to Dr. N. Rathna, Joint Director, Professor & Head of the Dept. of Speech Pathology, AIISH, for his valuable suggestions and criticisms which refined the approach towards the study.

The investigator wis-hes to acknowledge Dr. (Miss) S. Nikam, Head of the Dept. of Audiology, AIISH, for her constructive criticisms and facilities provided towards completing the study,

Thanks are also proffered to Dr. J. Bharath Raj, Head of the Dept. of Psychology, AIISH, for his stastical counselling.

Thanks are also due to Mr. S.S. Murthy, Lecturer in Elecronics, for timely help rendered in terms of instrumentation.

The experimenter is especially grateful to Mr. P.D. Manohar, Mr. N.P. Nataraja, Dr. B.N. Prabhakar and Mr. G.D. Bishnoi for their help, co-operation and constant encouragement without which it would have been highly difficult to proceed with the study.

High regards to all the subjects and friends who helped in completing the study.

Lastly, the experimenter wishes to express his deep appriciations to Mr. B.V. Prabhakar and Mr. Kalaisan for kind and enthusiastic assistance.

CONTENTS

CHAPTER I

I N T R O D U C T I O N

"It would seem that in spite of what has been said over the years there is considerable confusion over the measuring of 'recruitment of loudness' as a phenomenon of cochlear pathology with diagnostic importance. This may be in part due to the fact that no entirely satisfactory definition has been put forth". (Fowler, 1963)

Fowler when he first had two high fidelity matched ear phones, could switch the sound from one ear to the other without disturbing the ear phones, could balance the sensations of loudness in the two ears; and also he could explore for any variations that occurred in frequency, quantity, and quality between the two ears.

Fowler's notion was that it might be possible at some intensity to detect a difference in response that would be useful in diagnosis. He noticed that some cases with unilateral hearing loss, at high intensity levels could balance at equal HL with the opposite normal ear in spite of the threshold in the impaired ear being as low as 60dB. This was made graphically apparent by plotting the binaural alternate equal loudness balance on a pole ladder graph he had devised along with R.L. Wegel. (Fowler, 1963).

Since Fowler had been in the National Guard and the Army for nearly 30 years, the word “recruitment” came to his mind. To him it seemed an adequate word to describe what he had observed, a recruitment to full unit capacity, to full loudness of firing power if not a full efficiency of firing power.

“Sound, as a physical phenomenon, is the legitimate domain of the physicist; as a concept, it comes within the province of the psychologist. Many Clinicians would gladly surrender all claims of these territories but for the fact that modern otology and audiology have brought us right up to the frontiers into a “No Man’s Land” where all is vague and ill defined. The phenomenon of loudness recruitment lies in that “No Man’s Land” and it is a remarkable fact that although this phenomenon has been universally recognized as of prime diagnostic significance, no clear explanation of its mechanism has so for been proffered”.

The phenomenon of “Recruitment” was first reported by Edmund Prince Fowler in 1928 before the Section of Otology of the New York Academy of Medicine. Though the term “recruitment” is commonly used, the terms ‘regression’, ‘recuperation’, ‘lautstarkeausgleich’ (i.e. loudness-compensation), and ‘Fowler phenomenon’, are common in some countries. (Harris, 1952; p.5).

"Recruitment, it is seen, is an acknowledged recognizable clinical entity. It is only when the attempt is made to explain the etiology and basic effects upon the individual that vagueness and uncertainity enter. Hence, determination of the significance of recruitment within the framework of auditory theory to-day is claiming the attention of a large number of laboratories and clinics. Data relating to the manifestations of the recruiting individual are being analysed. Tests are being devised to indicate the presence or absence or recruitment in the individual with impaired hearing". (Spuehler, 1955).

Since the observation of Dix, Hallpike and Hood (1948) relating recruitment to cochlear pathology the audiologist has been able to determine with some degree of certainity that the presence of recruitment is an indicator of cochlear disorder. "Recruitment of loudness is a symptom important for diagnosis, medical and surgical treatment, and for a better understanding of how the ear functions." (Fowler, 1963).

Classically, Fowler's (1936) Alternate Binaural Loudness Balance (ABLB) test in cases with unilateral hearing impairment and Reger's (1936) Monaural Bi-Frequency Loudness Balance (MBFLB) test for bilateral sensory neural hearing loss have been used for the measurement of recruitment and thus for differential diagnosis of cochlear Vs retrocochlear impairment.

Stapedial Reflex Audiometry (SRA) (Kristensen and Jepsen, 1952; Metz, 1952; Thomsen, 1955; Ewetsen, Filluig, Terkildsen and Thomsen, 1958; and recently by Liden, 1970; Jerger, 1970; Alberti and Kristensen, 1970), Loudness Discomfort Level (LDL) Test (Hood and Poole, 1966), Aural overload (Lawrence and Yantis, 1956) Test, and Short Increment Sensitivity Index (SISI) Test (Jerger, Shedd, and Harford, 1959) have also been used to differentiate cochlear impairment Vs retrocochlear impairment. All these suprathreshold tests are based upon different principles but claim to elucidate the same phenomenon, namely, 'loudness recruitment' except the SISI test. The ABLB test (Fowler, 1936), and MBFLB test (Roger, 1936) are considered as direct tests for measuring the growth of loudness, all other tests being indirect measures for loudness recruitment (Jerger, 1968).

A Closer observation into the normal and abnormal growth of loudness patterns have led to the question – Whether recruitment is a fact or an artifact? Recruitment has been believed to be a fact by many investigators, i.e., the growth of loudness in the impaired ear (cochlear loss) is abnormal and it is associated with cochlear pathology only.

It is Jagadeesh (1970) who first questioned the concept of recruitment stating that, “The concept of loudness recruitment widely accepted as an abnormal auditory phenomenon does not appear to be justified”. Further Jagadeesh (1970) substantiates that, “Experimental results provided by Stevens and Davis(1938) adequately show that the phenomenon of recruitment is not abnormal. The data shown in the loudness function curve (Stevens and Davis, 1938, p.118) reveals that the loudness level of 1000 Hz tone at 40, 70 and 100 dB SPLs is approximately 1, 10 and 100 sones respectively for normal subjects. Therefore , if an individual has a sensori neural loss of about 40 dB SPL (equal to one sone) there will be loudness loss of 1 sone throughout the intensity range. That is, he will perceive a tone of 70 dB SPL at a loudness level of 9 sones and a tone of 100 dB SPL at a level of 99 sones. Thus the difference in the loudness perceived by the normal and the abnormal ears is very small.

“Adding further to the confusion is the common usage of the decibel concept. It is thought naively that a tone of 60 dB SPL should sound as loud to an individual with a sensori neural hearing loss of 40 dB SPL, as a ton of 20 dB SPL would to an individual with a threshold of 0 dB SPL. But taking into consideration the loudness levels and the absolute sound pressures of these tones (Stevens and Davis, 1938; p.1180 it can be seen that the two ears are NOT stimulated identically either with equal sound pressure or with equal loudness increments but only at equal SLs (20 dB SL in this ease). Furthermore , in 'pure' sensorineural cases the basilar membrane will be stimulated by ALL of the energy reaching the cochlea and not just by the energy corresponding to the Sensation Level". (Jagadeesh, 1970).

"Thus the loudness of a tone seems to depend on the energy reaching the cochlea and not on the sensation level of the tone, within certain limits (The terms 'within certain limits' are used in the sense that there will be inherent variability associated with the psychophysical experiments of this kind and we may have to allow 5-10 dB variability especially with unsophisticated subjects.) Therefore, the loudness produced by a tone of 60 dB HL at a normal ear will be equal to the loudness produced by a tone of 60-75 dB HL in an ear with 30 dB of sensorineural loss."

Further Jagadeesh (1970) explains that tests mentioned earlier failed to show recruitment in some of the S-N loss cases. The reason advanced is the influence of tone decay on the perception of loudness. Further Jagadeesh (1970) explains that recruitment is not an abnormal phenomenon and that the presence or absence or presence of tone decay respectively. "The reasons advanced to explain that recruitment is not an abnormal phenomenon as summarized by Vyasamurthy (1972) are: (1) the difference in the loudness perceived by the normal and the abnormal ears is very small; (2) Loudness depends on the energy of the tone reaching the Cochlea and not on the sensation level of the tone; and (3) In 'pure' sensorineural hearing loss cases, the Basilar membrane will be stimulated by the energy corresponding to the sensation level".

To clarify, Jagadeesh (1970) considers the ABLB test administered to a case with unilateral sensorineural hearing loss. "The test would, it is hypothesized, indicate the presence of recruitment if there is no tone decay in the affected ear. Since there is no loss in the intensity of the tone that has reached the cochlea the loudness perceived will be almost equal to that in the normal ear in spite of the reduced auditory acuity. On the other hand, if the tone decays, the subject will need greater intensity levels to compensate for the loss due to the 'decay' of the tone. Hence, he may be said to show no recruitment or he may be said to show partial or delayed recruitment. This is so because, tone decay is not an all or none phenomenon, the amount and rate varying from 0-50 dB or more depending on the IL (Ownes, 1964). Thus partial or complete or no recruitment may reflect the rate of tone decay, Delayed recruitment seen in cases where there will be rapid tone decay at low sensation levels with no decay at higher SLs. The decruitment phenomenon may also be another manifestation of rapid tone decay even at high SLs. In decruitment cases, at equal loudness balance point, the Hl at the impaired ear will be greater than that at the normal ear, even at high SLs. This is as it should be if there is rapid tone decay even at high SLs."

Just noticeable difference (jnd) is a function of the intensity level of the tone, in normal ears (Reisz, 1928). It has been found that the jnd is a function of the intensity level of the tone and not of the sensation level, even in the case of subjects with sensorineural loss (Swisher et al, 1966; Luscher, 1955). "If at a particular level there is tone decay, then the jnd at that level will be larger, indicating no recruitment or partial recruitment as compared with a normal ear." (Jagadeesh, 1970).

This holds good with the SISI test also. Some of the recently reported studies have shown that the SISI scores obtained depend not on the SL but on the IL reaching the cochlea (Herbert, Young and Weiss, 1969; Young and Herbert, 1967).

Thus in all three groups, normal conductive loss, and sensorineural loss without tone decay, when the IL of the tone reaching the cochlea is about 60 dB SPL, high SISI scores will be obtained, whereas those with retro-cochlear type of sensorineural hearing loss showing high tone decay, fail to detect the 1-dB increments at the same intensity levels. “This failure, it is surmised, is due to tone decay because of which the tone is not perceived with a loudness corresponding to the set IL.” (Jagadeesh, 1970).

Hood and Poole (1966) using the Loudness Discomfort Level test showed that the intensity distribution over a frequency range of 500-400 cps in normals and unilateral end-organ deafness cases was similar, i.e., around 100 dB HL. Dix (1968) has shown that the LDL both for normals and for subjects with “end-organ deafness” was between 90-105 dB, in spite of the hearing loss being as much as 80 dB in the “end-organ deafness” group. In cases with conductive impairment no LDL could be established even at the maximum audiometric limits. “This is as expected. The conductive impairment reduced the intensity level at which the tone reaches the cochlea. Further support to this view comes from findings in the same (Dix, 1968) study that for those with conductive loss of less than 20 dB, LDLs were elevated by the amount of hearing loss. Similarly among subjects with ‘nerve-fiber’ deaness it was seen that no LDL could be established within the maximum audiometric intenscities.” (Jagadeesh, 1970). Results from Jerger and Hardford’s (1960)

Study on simultaneous binaural balance test also shows that the Ss with cochlear type of impairment require approximately equal HLs in both ears at the point of balance, whereas the subjects with retro-cochlear type of impairment required greater HL at poorer ear at the point of balance.

Results of Jerger's (1969) study using acoustic stapedial reflex in S.N. loss cases shows that the reflex SL decline as a function of increasing hearing loss in patients with loudness recruitment. AS S-N loss increases the SL decreases in regular one to one fashion. The relationship is linear and of unit slope.

So the elicitation of the acoustic reflex is believed to be directly related to the loudness experience of an acoustic stimulus (Eweretsen et al, 1967; Flottorp, Djupesland and Wither, 1971; Moller, 1961; Thomsen, 1955).

Alberti and Kristensen (1970) stated that in the presence of recruitment the intensity level required to stimulate the reflex may be unchanged, or even lowered, while the pure tone threshold is markedly elevated.

Using Lawrence and Yantis (1956) test of aural overload Herbert and Young (1964) found that the point of overload for normal ears was 63 dB (Mean Value) and in a series of unilateral Meniere's syndrome cases, the Mean Value was 67 dB at 1 KHz which is not significantly different form normal ears. This test is not applicable in cases with tone decay as the tone fades before the test could be administered.

"Whether or not recruitment is present depends on the procedure employed – does it allow the tone to fade? It is generally accepted that continuous tone as a stimulus is more susceptible to tone decay rather than an automatic pulsed tone; in the former instance it is highly unlikely that tone decay and recruitment will be positive unless the tone fades at as slow rate, and in the latter case it is more likely that recruitment will be positive even if tone decay is reapid and the intensity levels are high. Thus it seems that results of all above tests depend on the rapidity with which the tone decays." (Jagadeesh, 1970).

Here an attempt is made to verify the hypothesis – "Recruitment is an artifact". To verify this above hypothesis attempts are being made to verify three shbhypotheses.

Subhypotheses

1) The difference in loudness experienced by normal ear and the ear with induced (TTS) hearing loss (Cochlear) is negligible.

2) It will solve many atypical observations made by many investigators. Examples: (i) Cochlear findings in surgically confirmed acoustic neuroma cases; and (ii) Cochlear and retrocochlear findings in surgically confirmed acoustic neuroma cases.

This study may show that the concern expressed by many investigators regarding atypical findings in surgically confirmed acoustic neuroma cases is unwarranted.

Brief Plan of the Study

The study consisted of three Experiments.

Experiment I

Inducing hearing loss (cochlear type) temporarily in 10 normal hearing subjects by fatiguing the ear by 1 KHz pureton at 110 dB for a period of 30 minutes, and comparison of Stapedial reflex thresholds obtained at 1 KHz and 2 Khz before and after inducing temporary hearing loss. Statistical significance and test-retest reliability has been established.

Experiment II

Obtaining stapedial reflex thresholds of all cases reported to All India Institute of Speech and Hearing, Mysore, (between September 1974 to February 1975) with Moderate Sensorineural hearing loss (40-70 dB) with no tone decay. All cases were administered complete tone-decay (Carhart, 1957) test and cases exhibiting even 5 dB decay were excluded from the study. The obtained reflex thresholds in the audiometric frequencies from 250 Hz - 4000 Hz have been compared with that of normal reflex thresholds (from Basavaraj, 1973). Test-retest reliability has been established.

Experiment III

Adminstering screening ABLB test, as reported by several investigators, for the then available 4 cases with unilateral high frequency sensorineural hearing loss. Thus finding out the hearing level at which a pure tone sounds equally loud in the normal ear when a reference tone of 80-90 dB Hl was fed to the affected ear. The test was administered at the highest bilateral normal hearing frequency. The interaural intensity difference at the point of balance was determined.

The results are analysed and discussed.

Operational Definitions

Recruitment :	Interaural intensity difference at the point of balance is less than the Interaural intensity difference at threshold by more than 10 dB.
Decruitment :	Interaural intensity difference at the point of balance is more than the Interaural intensity difference at threshold by more than 10 dB.
No Recruitment:	Interaural intensity difference at the point of balance is nearly ($\pm$ 10 dB) equal to Interaural intensity difference at threshold.

CHAPTER II

REVIEW OF LITERATURE

A review of literature concerned with recruitment shows several hypotheses. An excellent review on recruitment has been reported by Harris (1952). here, Harris' review has been made use of extensively.

The term 'recruitment' was first coined by Folwer in the year 1928. It has been defined as abnormal growth of loudness with increase in the intensity of the sound.

Pohlman and Kranz (1924) reported first on the recruitment phenomenon studied with pure tones. They used an oscillator with continuously variable frequency output. The output was maintained at threshold strength for all frequencies, or at a definite energy value greater than threshold as the frequency was gradually altered. They stated, ". . . .When the intensity of the stimulus was about ten times that required to hear the weakest part of the range, this low sensitivity portion was no longer noticeable as the frequency was varied to pass through it. . . . Once the threshold of such a range of decreased acuity is attained, it takes comparatively little additional energy to cause the deficiency to seemingly disappear quite completely.” The method they used is a fore-runner of the quantitative method of monaural loudness balancing between two frequencies, to one of which the ear is relatively insensitive (as quoted by Harris, 1952).

Gradenigo (1912) devised the phrase ‘Index Vocalis’ for the quotient of the distance at which the whispered voice is just audible, devided by the same measure for the spoken voice. In a recruiting ear the distance for the spoken voice is relatively large, and the ‘Index Vocalis’ is smaller (Harris, 1952). Veis (1913) first applied the Index to clinical material, finding a smaller value than normal with some types of hearing loss. Fowler (1928) studied a patient with one normal ear, the other exhibiting a 40 dB loss sharply localized at 4096 cps. He noted two peculiarities about this loss : (1) “The threshold of hearing in the left ear was the same as that in all normal ears. . . . . a little indefinite without repeated search . . . .whereas in the right ear (near 4000) there was no hesitancy in the sensing of the exact point every time it was reached.” and (2) “Comparitive loudness (J.D. Harris’ note: Apparently standard test with Fowler since 1921) showed that the loudness of tones (near 4096) of from 10 to 25 sensation units above the threshold in the left (non-affected) ear appeared the same loudness as 5 sensation units above the threshold in the right (affected) ear."

This first use of the method of ABLB was extended to hundreds of patients in Fowler's practice in succeeding years (as quoted by Harris, 1952).

Fowler in 1936 published the conclusions reached from an intensive clinical study of recruitment in 200 patients. He investigated several types of techniques like (1) Intensity discrimination at various intensity levels, (2) Masking in the same ear of bone conducted sounds by air conducted sounds, and (3) Alternate binaural loudness balance for a single frequency. The latter method was preferred for its simplicity and reliability although it requires one ear of the patient to be normal or near normal to serve as reference. Fowler devised two methods of graphing the data from alternate binaural loudness balancing: (1) on the usual audiogram chart, and 92) on a grid with ordinates representing dB above normal threshold. The first method is handy for the clinician, telling whether recruitment is present, the second method gives a clearer picture of the characteristics of the phenomenon, the SL at which it begins and its rate. Comparing (by the second method) the decibels above normal threshold which produce equal loudness in the two ears, results in a graph which is not expressed in loudness units at all, but in sensation level units. Using the standard loudness level to loudness conversion table (Geiger, 1940), it is possible to redraw the graph in true loudness units converting sensation level to loudness level (Stevens, 1938).

> "Fowler present s both types of graph showing recruitment for two cases of unilateral nerve deafness. In both cases it was found that by the time a tone was raised to 100 db over the normal threshold, a partial deafness of up to 50 or 60 db was rendered negligible; that is to say, the patients reported that in a partially deafened ear a tone only 40 or 50 db over threshold for that ear, sounded as loud as a tone in the other, normal ear 100 db over threshold." (Harris, 1952).

Fowler also pointed out that the phenomenon recruitment is helpful in diagnosing the perceptive deafness overcoming the flaws of inadequate masking leading a case to be diagnosed as conductive loss (1937).

> "Data were presented from one typical patient to the effect that recruitment is faster for low tones (256 cps) than for higher tones (1024 and 4096 cps). THe explanation was offered that the higher the frequency, the fewer the nerve elements available for recruitment." (Harris, 1952).

> "Fowler (1937) was first to show over-recruitment intwo patients with whom the initially poorer ear required less intensity than the normal ear for equal loudness."

Fought (1944) found strong positive recruitment in all his Meniere's disease cases, and observed over-recruitmetn occasionally. However, Newby (1965) stated that it may be difficult to rationalize the existence of hyper-recruitment on any tehoritical neurological basis.

Harris (1952) has quoted Lorente de No's explanation of recruitment in a discussion of Fowler's paper as follows:-

> "If a number of hair cells in the ear or a number of fibers in the cochlear nerve is missing, the tones will appear to be weaker in intensity when hear threshold stimuli are used; but if the intensity of the tone is increased, the more strongly activated hair cells or cochlear fibers will be sufficient to saturate, i.e., to excite the limiting intensity of the cochlear fiber or the cells of the cochlear nuclei, so that the cerebral cortex will receive the same number of impulses per second for both ears and will perceive the tone delivered to the diseased ear as strongly as the tone delivered to the normal or less affected ear." This is known as the <u>Occlusion Theory</u>.

> "Guttman and Ham (1928) encountered a manifestation of recruitment in some experiments on pure tone masking. They found that a tone of given intensity above threshold produced less masking in a partially deafened than in a normal ear."

Langenbeck (1926) in his study on 8 patients with nerve deafness, 10 with conductive or mixed hearing loss and 4 normal subjects showed that intelligibility for speech in noise was different for the two clinical groups, the group with nerve deafness suffering relatively more from increasing the intensity of a masking noise.

Bekesy (1930) used Fowler's binaural loudness matching technique in the case of an ear partially deafened by stimulation with an 800 cps tone. He determined equal loudness contours through the range 300-2000 Hz, at 4 intensity levels; the effect of fatigue though amounting to 30 dB at threshold, was reduced to a very few dBs at the more intense level; Harris (1952) stated that it could b eexplained by assuming that auditory fatigue produced an analogue of recruitment.

However, the information regarding the intensity, duration and post-experimental level of the fatigue is not available.

"Larsen (1940, 1942) studied simulated or pseudo-recruitment, by inducing residual fatigue in a normal ear with a loud tone, then conducting binaural balance test against the other, non-stimulated ear. the pitch of the 2048 cps tone used was shifted a half-octave higher than normal, and the 30 dB residual fatigue at threshold was completely overcome by pseudo-recruitment at an intensity 80 dB over normal threshold." De Mare (1948_ first published a brief account of some experiments with short-duration fatigue as it is related to perceptive deafness (and therefore presumably related to

> Recruitment). He found a sharp difference between the amount of fatigue occurring in conductive hearing loss as against ‘nerve deafness’, but makes no point of possible correspondences between recruitment and fatigue.”

Davis et al (1943) studied pseudo-recruitment, administering equal-loudness contours on 3 subjects and binaural loudness balancing on 4 subjects, after exposure to loud sounds. Equal loudness contours were generally normal or nearly so at the 70 dB level, though thresholds were shifted considerably. From the loudness balance data he concluded that the fatigued ear may or may not show recruitment, complete recruitment is not the rule, and finally that may of the curves show an initial delay before recruitment begins, may be due to slight residual fatigue in the supposedly normal ear.

Huizing (1949) gave a specific test procedure that he had found useful in testing for recruitment. His patients with recruitment when stimulated with the 2000 Hz tone for 3 min. at 30 dB above the pathologic threshold gave threshold shifts of between 19 and 22 dB whereas at the same SL the threshold shift in normals, conductive loss, and nerve- deafness cases without recruitment was within the range of 5 to 12 dB. Thus Huizing concluded that the amount of fatigue produced by a tone depends upon its loudness than to its intensity.

Hickling (1967) showed that in an ear with TTS recruitment would be linear and complete at a SPL of about 95 dB.

To quote WHO (1966), “In animal experiments even when the hair cells are completely destroyed by excessive noise exposure, no detectable changes can be found in the corresponding nerve bundles.” Further as stated by Hickling (1967), a fraction of the initial loss, physiological adaptation, is probably of retrocochlear origin, but ephemeral and of no apparent significance after 1 or 2 min. recovery. That a further fraction may also be of retrocochlear origin is not impossible, but if so, it must on al evidence be very small. Thus noise-induced temporary threshold shift (TTS) is at least one neat pure lesion malfunction of the hair cells of the organ of Corti.

Hickling (1967) selected 7 listeners in the age range of 22-25 years. Temporary Threshold Shift (TTS) was induced in them by a 2.4-4.8 kc/s noise band in a reverberant room for 10 min. at SPLs upto 108 dB according to individual susceptibility. Of the 11 ears performance considered for analysis, mean induced shift was 30 dB (range from 21-48 dB), all demonstrated loudness recruitment. Measurement was made at 4 kc/s and complete recruitment was apparently present in all the ears.

Gabrielli and Tarsitani (1963) reported interesting observation on 2 cases of periodic and reversible high frequency S.N. hearing loss associated with menstrual phase of the overian cycle. The loss was bilateral with a flat configuration averaging 40-45 dB and not accompanied by recruitment as measured by intensity difference limen.

Similarly, Miller (1967) reported two patients with fluctuating hearing loss occurring in relation to the menstrual cycle accompanied by the audiological evidence locating the cochlear lesion. A positive recruitment findings on loudness balance testing, positive SISI scores, minimal tone decay and Type II Bekesy tracings were observed. Hearing dropped between 6-10 days prior to the onset of the menses and recovered either during the period or several days later. Vestibular functions were intact.

> “Steinberg and Gardner(1937) and Steinberg (1937) first attempted an explanation of recruitment in psychological terms, using the loudness as contained in the classic paper of Fletcher and Munson (1933). Suppose an ear to be 20 db deaf for a certain frequency. A tone at threshold for this particular ear amounts to a loudness of about 100 loudness units for the normal ear. But suppose the tone were increased 20 db over the deafened threshold. A tone of this intensity amounts to about 1000 loudness units for the normal ear. A further increase of 20 dB intensity produced

4500 loudness units; and so on. It is easily seen that because of the nature of the relationship between sensation level and loudness, an ear with a type of deafness resulting in a constant loudness loss would tend to overcome this handicap at high intensities, where the per cent loudness loss could b eunnoticeable (in the above illustration, at 40 dB sensation level per cent loudness loss is only 2.0). This constant loudness-loss theory has been given wide currency (Stevens, 1938)."

"On the theory that a wide frequency-band of noise would occupy many nerve fibers, and thereby stimulate nerve deafness. Steinberg and Gardner investigated recruitment by the binaural balance technique, introducing thermal noise into one ear along with the test tone. They obtained with great regularity an analogue of recruitment which could well be predicted on the basis of their concept of constant loudness loss."

However, Harris (1952) from the available evidences stated that noise masking by no means simulate nerve deafness; moreover, the constant loudness loss concept is unable to account for the over-recruitment.

Laugenbeck (1932) published his study on the problem of hearing in noise together with rather complete masking on 10 patients with conductive or mixed loss, and 9 patients with 'nerve' deafness, and with adequate information on the normal ear. He used saw tooth wave. He found that in some cases it was very difficult to distinguish types of hearing loss by the effect of masking of noise on pure tones, but in general, patients with nerve deafness exhibited greater masking than normal.

De Mare and Rosler (1950) studied masking effects in 12 normals, 14 cases of conductive hearing loss and a few inner ear hearing loss cases. When the SL of the masking noise was equated, no difference appeared between normals and patients with conductive impairment. With inner ear hearing loss, on the other hand, the same SL had marked additional effect.

Huizing (1942) measured the masking of one tone by another as a function of the intensity of the masking tone. He found abnormally steep masking functions to be associated with hearing losses that exhibited recruitment. He concluded that a sound's ability to mask is directly related to its loudness.

Reger (1935, 1936) adapted the standard procedure for constructing isophonic contours (equal-loudness curves), namely, Monaural loudness matching of different frequencies in 21 patients with high tone hearing loss. By comparing the results with normals he tentatively concluded that (1) Some partial hearing loss cases exhibit more rapid growth of loudness than normal when intensity is raised; (2 The greater the hearing loss, the more rapid the growth of loudness; and (3) The growth of loudness is greatest at intensity levels just over threshold.

Steinberg (1935) likewise suggested the loudness matching of different frequencies as a clinical test. His explanation of recruitment was that if a few nerve fibers were defective this would have a smaller effect as the stimulus intensity increased. The explanation makes the assumption that loudness is some function of number of active fibers. This is referred to as fiber loss theory.

Hawkins and Stevens (1950) plotted equal masking contours, obtained by measuring the masked threshold of pure tones at various frequencies in the presence of white noise at several levels. Laugenbeck (1950 a,b,c) found that the contours obtained from patients with either conductive or recruiting-type hearing loss are the same as those for normal listeners; however, cases with nerve type hearing loss without recruitment typically showed more masking than normal.

Laugenbeck's (1950 a,b,c) observations supported the hypothesis advanced by Dix, Hallpike, and Hood (1948) that recruitment is observed only in cases of pathologic conditions of the cochlea.

Lurie (1940) explaining recruitment in terms of the difference in sensitivity of the outer hair cells, wrote, “If the more sensitive outer hair cells are defective, then the threshold would be raised; but if the sound intensity were raised sufficiently to stimulate the inner hair cells, these would respond normally and a rather sudden increase of loudness might result.” This explanation makes the implicit assumption, however, that in the normal ear the outer hair cells no longer contribute significantly to loudness at intensities which stimulate the inner hair cells. Leurie’s explanation of recruitment has been named the duplicity theory. In this theory the first attempt is made to explain recruitment in terms of the hair cells rather than auditory fibers.

Attempts have been made in obtaining Discrimination score and Discrimination loss in cases with recruitment (Huizing and Reyntjes, 1950; Palva, 1952; Dix, Hallpike and Hood, 1948; and Eby and Williams, 1951). In recruiting cases the discrimination reaches a maximum of considerably less than 100 per cent and then never goes higher even though the intensity is increased further.

Hirsh (1952) reported Davis’ (1948) findings showing the low maximum articulation score in patients with perceptive recruiting loss.

Difference limen intensity (DLI) has been typically smaller in cases with cochlear pathology when compared with normals (Luscher and Zwislocki, 1949; Denes and Naunton, 1950; Jerger, 1952, 1953, 1962, etc.). Thus the cases exhibiting recruitment show a greater ability for intensity discrimination yet poor ability to discriminate speech sounds.

Hirsh (1952, p.201) stated that,

> "Here lies one of the most important paradoxical problems in contemporary clinical audiology."

Bekesy (1947) using his automatic audiometer based upon the method of adjustment observed small (2-8 dB) excursion width (i.e., the range from audibility to inaudibility) in cases with cochlear disorder in contrast to the normal range of 8-10 dB. He considered this range as the first difference limen, and attributed this narrowing to the loudness recruitment phenomenon. Other investigators prefer to consider this range simply as the zone of uncertainty at threshold, and to seek an alternative explanation for the abnormal narrowing.

In 1946, de Bruine-Altes Published a monograph on recruittment. She concluded from a study that there is no necessity to expect recruitment, either complete or incomplete, from all inner ear deafness - nor is all pure conductive deafness free from the phenomenon. Recruitment in presbycusis was absent and might have been absent in explosion truma and basal skull fracture. All Meniere's, and all traumatic perceptive deafnesses, yielded complete or all but complete recruitment in the administered battery of test.

Dix et al gave a neurological explanation for the lack of recruitment in their nerve-deaf patients, an explanation depending heavily upon there being a constant fiber-survial rate in the lesion. This is known as <u>constant fiber-survival rate theory</u>.

Further, Galletti (1965) stated that the measurement of recruitment cannot be determined with any degree of precision in the presence of auditory adaptation in cases with perceptive deafness.

> "Another most important and most overlooked entries in the catalogue of aberrant psychoacoustic phenomenon associated with cochlear disorder is the phenomenon of aural overload." (Lawrence and Yantis, 1956).

The audiometric aural overload test is based on the electrophysiologic principle that cochlear microphonics become nonlinear and reveal harmonic distortion when the intensity of a tone exceeds 50 dB above threshold. These harmonics can be measured psychophysically with an exploring tone. The objective is to ascertain a minimum intensity level necessary to produce harmonic distortion as a consequence of overloading.

Lawrence of Blanchard (1954) reported that the overload threshold in subjects with normal hearing varied over a considerable range. According to Lawrence and Yantis (1956), when the inner ear is involved the threshold of overload is lowered and the range is restricted. In every case with loudness recruitment, there was a lowering of overload thereshold. In four cases of VIII nerve lesions, they reported that the range from thereshold to point of overload was usually greater than that of cases with cochlear involvement.

Point of overload for normal ears in a previous study (Herbert and Young, 1964) was 63 dB (Mean value) re 1951 ASA Standards at 1 kc/s. In a series of unilateral Meniere's Syndrome cases, the mean value was 67 dB at 1 kc/s which is not significantly different from normal ears.

Herbert and Young (1966) reported that there was no significant difference in point of overload between recruiting and non-recruiting presbycusis. Increased aural overload in presbycusis was related more to age than hearing level. Herbert and Young suggested that the increased aural overload in the absence of abnormal adaptation in presbycusis may be considered a measure of mechanical cochlear dysfunction, possibly the increased stiffness of the Basilar Membrane.

Determination of the level at which a tonal or speech stimulus becomes uncomfortable was first advocated by Watson (1944) as an assessment of the recruitment phenomenon. Bangs and Mullins (1953 in a study of various tests of recruitment felt that, taken in conjunction with the most comfortable level, this test provided the most desirable technique for measuring recruitment. From that time there was little mention of this in the literature until the work of Hood and Poole (1966) rekindled an interest in it as a diagnostic aid.

Hood and Poole (1966) described a method using the tolerable limit of loudness as the Loudness Discomfort Level (LDL) that can be used when the loudness balance test is not applicable. In the normal hearing subject, a sensation of unpleasant loudness is invariably associated with intensities of the order of 100 dB within the frequency range of 500-4000 cps. These authors established the intensity distribution of LDL in a large group of subjects with unilateral end-organ deafness, in all of whom the presence of loudness recruitment had been verified using ABLB procedure. In these cases, the distribution was similar to that of a normal hearing group, that is the gap between threshold and LDL was diminished.

On the other hand, in subjects with nerve fibre lesion or conductive losses of hearing this gap was increased so that the maximum available audiometer intensity of 120 dB was insufficient to produce LDL.

Hood (1968) stated that loudness continues to increase in intensity well beyond 100 dB. The fact that all th recruitment curves (angle) converge to this point, rather than any other, in itself suggests that some special and perhaps critical physiological significance attaches to hearing in this particular region. Loudness function shows considerable inter-subject variability and is dependent upon hearing acuity.

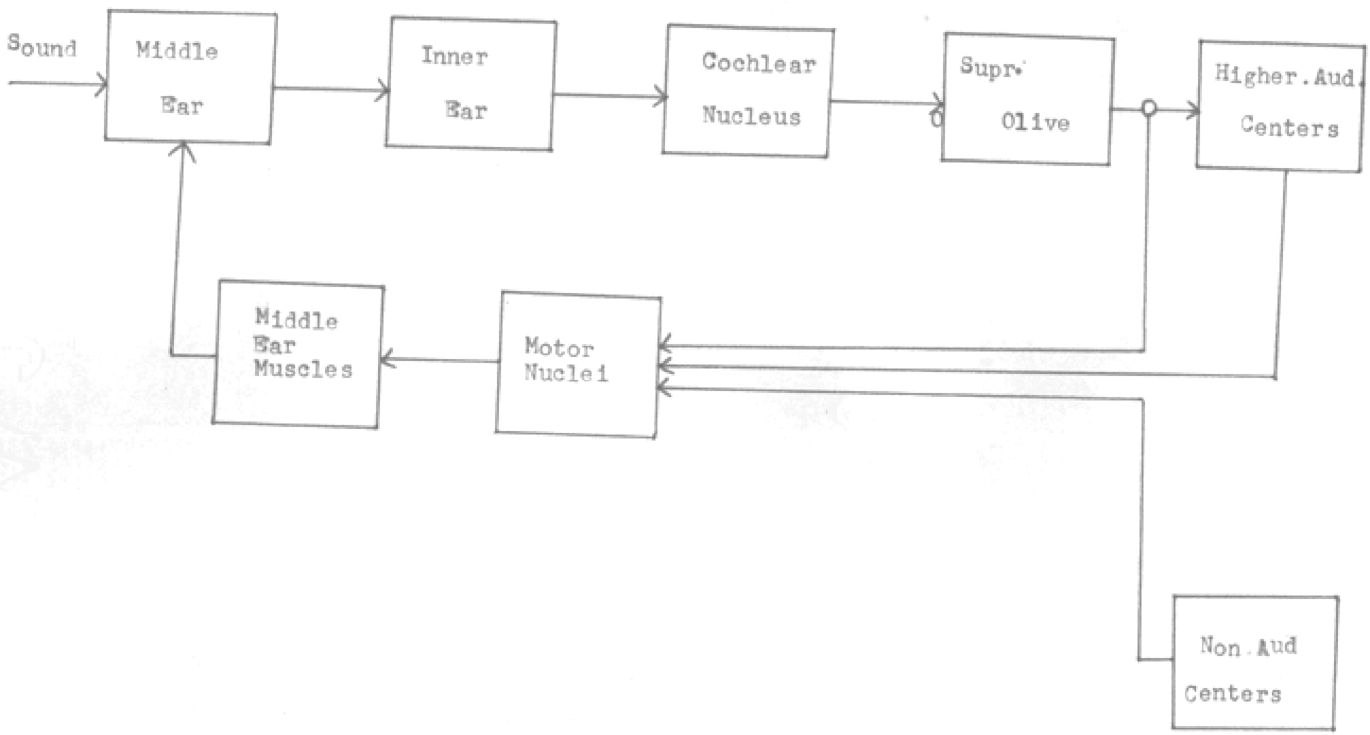
Electro Cochleography (E.Co.G.) has largely been used in the differential diagnosis of peripheral auditory disorders. Portmann (1973) observed recruitment-like phenomenon in the obtained E.Co.G. responses of cases with cochlear loss. The response may be labeled “recruiting” when the following three characteristics are persent at the same time: (1) a short latent interval (about 2 m.sec.) at the threshold which is always found above 40 dB HL. A latent interval of this order is found at the same level of intensity in a normal subject; (2 a diphasic (negative – positive) response pattern at all sound levels; and (3) an amplitude which increases rapidly with increasing click intensity, without a plateau, and with occasional high readings at high sound levels. The amplitude very rapidly catches up with that of a normal subject at the same level of intensity. Above threshold it increases within 10 dB as much as it would in a normal subject within 50 dB. This phenomenon is similar to recruitment. Both amplitude and latency curves show that the sensory and/or neural structures responsible for the low-intensity sensitivity are affected while the structures for high levels are normal (Jean-Marie Aran, 1971).

ROLE OF ACOUSTIC STAPEDIAL REFLEX AUDIOMETRY IN THE MEASUREMENT OF LOUDNESS RECRUITMENT :-

As early as 1946, Metz demonstrated that an intense acoustic stimulus gives rise to a distinct change in the impedance due to connection of the middle ear muscles. Experimental and clinical investigations have shown that the middle ear muscle reflexes in man are stable phenomenon and gives valuable information both on the middle ear muscles activity and on the auditory system.

A block diagram depicting the various way stations of the middle ear muscle reflex is shown in the Figure 1. (Dallos, 1973).

Fig.1 - Simplified block diagram of the Middle Ear Muscle reflex as a Multipath feedback mechanism (Dallos, 1973, p.473)



Acoustic and tactile stimuli may be used to elicit the reflex.

An audiometer serves as a sound source for eleicitation of the reflex. the sound stimuli are delivered through a single mount head phone having the contralateral ear free for inserting the probe tip of the impedance bridge.

The phone ear is the test ear as far as the measurement of recruitment is concerned.

Stapedial reflex has been used to provide an “objective” measure for recruitment of loudness (Alberti and Kristensen, 1970; Djupesland and Flottorp, 1970; Ewertsen et al, 1958; Anderson and Barr, 1968; Beedle and Harford, 1973; Djupesland, 1964; Franzen and Lilly, 1970; Harper, 1961; Jerger, 1970; Klockoff, 1961; Kockhoff and Anderson, 1959; Kristensen and Jepsen, 1952; Lamb et al, 1968; Liden, 1969, 1970; Metz, 1952; Terkildsen, 1960, 1964; Thomsen, 1955; Wilmot, 1969).

Anderson (1975, Personal Communication) States, “The excellent agreement between the stapedius reflex test and the Fowler test as indicators of recruitment is generally accepted. I have seen no exception to the rule that if the stapedius reflex threshold is recorded at normal level all other subjective tests will also indicate recruitment in cases with sensorineural hearing loss".

The reflex audiometry overcomes the loudness balancing task, on the part of the subject, involved in conventional subjective tests.

However, with stapedial reflex measurement, we arbitrarily set a positive-negative dichotomy, providing no criteria for partial recruitment (Lamb, 1968).

Investigations of the acoustic reflex reveal a very consistent finding: hearing impaired patients who manifest recruitment of loudness yield acoustic reflex thresholds at lower sensation levels than do normal hearing subjects who show an absence of loudness recruitment (Ewertsen, et al, 1967; Jerger, 1969; Feldman, 1963; Jepsen, 1963; Lamb, Peterson and Hanse, 1968; Metz, 1946, 1952; Thomsen , 1955). Since the normal reflex threshold occurs between 80-90 dB above pure ton thresholds, the presence of an acoustic reflex threshold less than 50-70 dB sensation level has been interpreted as an indication of loudness recruitment. However, Manual of Madsen Electroacoustic Impedance Bridge Model z070 published by Madsen Electronics has Considered loudness recruitment is present if the difference between the reflex threshold and the hearing threshold is less than 60 dB. Presumably, elicitation of the acoustic reflex is believed to be directly related to the loudness experience of an acoustic stimulus (Ewertsen et al, 1967; Flottorp, Djupesland, and Winther, 1971; Moller, 1961; Thomsen, 1955). Conversely, the findings of Anderson and Bar (1966) and Ross (1968) suggest that the acoustic reflex may not depend exclusively on the perception of loudness.

Anderson and Barr (1968) used 20 ‘fixation’ and 10 ‘interruption’ unilateral moderate conductive hearing loss cases as subjects. Using Stapedial reflex threshold as a measure of recruitment, his data confirmed the presence of recruitment of about 30 dB. When ABLB test was administered on the same subjects non-parallel relationship was demonstrated suggesting positive recruitment. In these cases recruitment never attained complete loudness balance in the ABLB test. However, the subjects BC thresholds have not been provided in the article.

Ross (1968) attempted to construct equal reflex contours on 4 subjects employing the method of reflex matching. Among two subjects the obtained patterns matched with the equal loudness contour. Among the remaining two subjects, for one he could explain for obtaining a different pattern but for the other subject it was not possible to explain on the similar grounds. He proposed an hypothesis that two sinusoidal stimulations are judged to be of the same loudness when they both produce the same intergrated number of neural impulses.

For subjects characterized by seemingly ‘abnormal’ equal loudness controus this relation does not appear to hold.

Ross (1968) quoted Perlman’s (1960) interesting hypothesis regarding why the reflex threshold is generally high when compared with the pure tone thresholds. Perlman stated that the internal hair cells may serve to elicit the acoustic reflex. Such hypothesis is attractive because it accounts for the high threshold of the acoustic reflex and because it assigns functional role to the internal hair cells. However, till now there is no evidence to support this hypothesis.

Several investigators have reported regarding the reflex threshold in normals and S.N. hearing loss subjects compared with their hearing levels.

Alberti and Kristensen (1970) concluded that in the presence of recruitment the intensity level required to stimulate the reflex may be unchanged, or even lowered, while the pure tone threshold is markedly elevated.

Jerger (1969) reported reflex measurements obtained from the test results of S.W. patients in the age range from 14-59 years. He arrived at the following conclusion:

1) The reflex SL declines as a function of increasing hearing loss in patients with loudness recruitment.

2) As S.N. loss increases the reflex SL decreases in regular one to one fashion. The relationship is linear and of unit slope. Also for any particular level of hearing loss the range of variability among patients is about 40 dB, a range comparable to the distribution of reflex levels in normal ears.

Liden (1970) exposed few cats to broad-band noise at a sound pressure level of 115 dB for 8 hours and measured the reflex thresholds. He concluded that induced sensorineural hearing loss did not change the intra-aural reflex thresholds.

Peterson and Liden (1972 studied 67 normals in the age range of 19-43 years and 32 S.N. loss cases of varying degree of cochlear nature. The only major difference in reflex thresholds between normals and S.N. loss cases was found at 4 KHz where, in general, the greatest degree of hearing loss was noted for the subjects in the sensorineural group.

Beedle and Harford (1973) compared acoustic reflex growth and loudness growth at 500, 1000, and 2000 Hz. Two groups of 10 subjects were tested: a group with normal hearing, and a group with a unilateral hearing loss resulting from endolymphatic hydrops and demonstrating loudness recruitment. Acoustic reflexes were recorded graphically at successive 2 dB increments from the reflex threshold to a sensation level of 16 dB.

Alternate binaural loudness balances were performed at three sensation levels relative to the acoustic reflex threshold. Results indicated that the acoustic reflex growth is essentially the same for the impaired ears and the good ears of the subjects with a unilateral hearing loss.

Basavaraj (1973) established reflex threshold norms for Indian population. His study also included few cases with S.N. hearing loss of varying degree of severity. His data also have been discussed in the present study.

Summation Loudness Decrement Principle

Loudness information is coded by the cochlea and auditory nerve. This coding is explained on the basis of two operational mechanisms. The first is essentially a Place Principle wherein the nerve fibers excited by outer hair cells require a less intense stimulus than do the fibers excited by inner hair cells (Harris, 1953). Traditionally, defects in this coding mechanism have been associated with Fowler's recruitment phenomenon (Simmons and Dixon, 1966). When the more sensitive outer hair cells (or related structures) are damaged, auditory threshold is elevated. When the intensity of a sound is increased and excites undamaged inner hair cells, the resulting loudness sensation eventually equals the undamaged ear.

The second mechanism for loudness depends upon a Summation Principle – the total number of nerve fibers excited (Harris, 1953; Wever, 1949). More intense sounds excite a larger area of the cochlea and ultimately more nerve fibers. An important feature of this code is its distribution within the cochlea; As intensity increases, most of the additional energy is distributed toward the basal end; low frequencies spread further than high frequencies. The audiological consequences of these features have been studied in normal and are clinically recognized in masking phenomena. However, the consequence of summation loudness defects are not as well described (Simmons and Dixon, 1966).

Simmons and Dixon (1966) chose two typical unilateral high frequency S.N. hearing loss cases with following audiometeric configurations:

Case 1: Unilateral Right Ear high frequency S.N. loss of Sudden Onset

AC THs

	250 Hz	500 Hz	1000 Hz	1500 Hz	2000 Hz	4000 Hz	8000 Hz	
Lt	10	5	5	10	20	5	5	dB HL
Rt	10	10	10	10	60	95	NR	dB HL

Case 2: Right eared Meniere's Syndreome

AC THs

Lt	15	10	15	–	10	10	30	dB HL
Rt	30	25	15	–	25	55	60	dB HL

In Case 1, when ABLB was administered at 1000 or 15000 Hz where the threshold was normal, an abnormally slow loudness growth occurred in the damaged ear.

In Case 2, Abnormally Slow growth of loudness occurred when the test frequency (1000 cps) was normal and below the region of the hearing loss.

Simmons and Dixon (1966) stated that the Case 2 is important because it demonstrates that summation loudness defects are not tied inexplicably to eighth nerve defects (intra cochlear portion of the nerve), but also can be observed in classically recruiting ears.

Figure 2

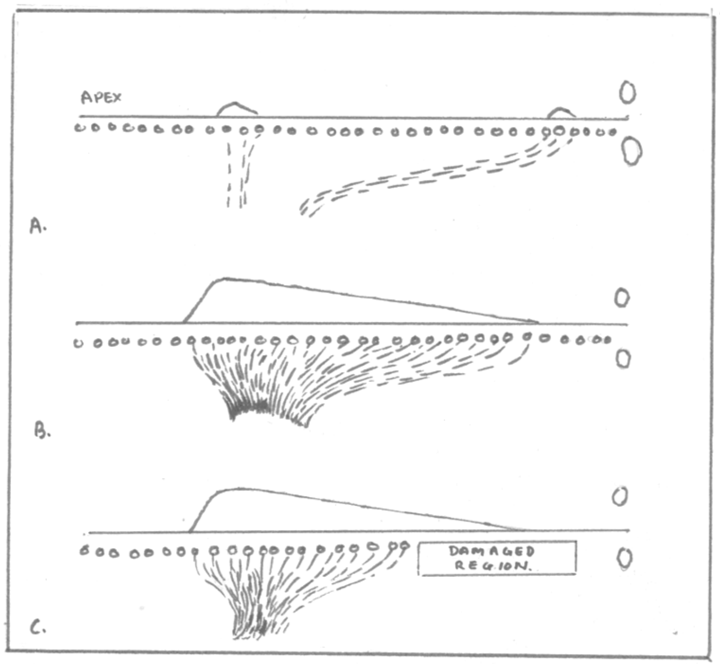


Diagram of sound energy distribution in cochlea. A. Near threshold the traveling wave excites neuroepithelial tissue over a small area with low frequencies centered more apically than high frequencies. All frequencies excite about the same number of nerve fibers.

B. As stimulus intensity increases, more and more energy is distributed towards the basal end (high frequency example omitted).

c. If this basal cochlear tissue (or nerve fibers) is damaged or destroyed, the number of nerve fibers excited will increase at a slower rate than the normal ear (B).

These cases were selected because both are “cochlear losses” and because they possessed the necessary threshold contours for demonstrating the frequency-dependent nature of the summation loudness.

The frequency dependence of summation loudness results from the shape and speed of the cochlear traveling wave. This is illustrated in Figure 2 (Simmons and Dixon, 1966). Its energy distribution at, and slightly above, threshold is shown in Figure 2 A. The area of basilar membrane excited by a given frequency is shown to be about equal to any other, but lower frequencies are distributed to a more apical point than higher frequencies. If the ear is normal, about-equal numbers of nerve fibers are presumed to be excited by either the high- or low frequency sound (Scharf, 1959; Greenwood, 1961). Continuing in Figure 2 B and showing only the low-frequency example, an increase in sound intensity causes an increase in amplitude and spread of the traveling wave. This spread is mainly toward the base of the cochlea (Schuknecht, 1960). Thus the additional fibers stimulated as intensity increases will always be those which innervate hair cells whose most sensitive (threshold) frequencies are higher than the frequency of the stimulating tone. Figure 2 C is an illustration of what may happen to summation loudness in an ear where those higher-frequency cells (or fibers) are missing, just as they probably were in Case 1. Compared to the normal ear (Figure 2B), the relative number of discharging fibers decreases as the wave spreads into the damaged region of the cochlea.

According to Case 1 findings, however, the growth of loudness does not entirely stop beyond the beginning point of damage (in the vicinity of 1500 cps in this example). Instead, loudness grows more slowly. A higher intensity is required to gain equal status with the opposite ear. Loudness by the place principle (outer-inner hair cells, etc.) still functions in non-damaged areas.

In case 2. place-principle-sensitive cells within the damaged region may also have been functioning at high intensities, thus causing loss of a loudness decrement. (Simmons and Dixon, 1966).

A summation loudness decrement can occur in several places, just as long as increasing stimulus intensity leads to spreading of excitation from relatively normal into more damaged regions. (Simmons and Dixon, 1966).

Having considered several hypotheses about recruitment the present study attempts to verify the hypothesis – “Recruitment is an artifact”.

CHAPTER III

METHODOLOGY

Experiment I

This part consisted of finding the difference in the acoustic stapedial reflex threshold obtained before and after inducing temporary hearing loss (cochlear) in normal hearing (-10 to 15 dB HL, ISO 1964) subjects.

Subjects

Ten college students in the age range of 17-25 years were chosen for participation in this study. There were 9 males and 1 female. The subjects selected were only those with bilateral normal hearing (according to ISO 1964 specifications) and whose acoustic stapedial reflex threshold was less than 95 dB HL at test frequencies, i.e., 1 KHz and 2 KHz. In order to measure the reflex threshold (elevated reflex threshold) after fatiguing the ear, subjects with low reflex thresholds were selected. All subjects were free from any otologic complaints.

Procedure

The following measures were obtained for each subject.

1) Pure tone thresholds of both ears at test frequencies, i.e., 1 KHz and 1 KHz.

2) Acoustic stapedial reflex threshold of both ears at 1 KHz and 2 KHz.

3) The ear fulfilling the reflex threshold criteria as specified earlier (hereafter known as test ear) was subjected for a continuous 1 KHz tone at 110 dB HL for a period of 30 minutes. At the end of 30 minutes pure tone threshold at 1 KHz and 2 KHz were obtained for that ear.

4) Acoustic stapedial reflex threshold were once again obtained in the test ear for the test frequencies.

5) After obtaining the acoustic stapedial reflex thresholds, pure tone AC thresholds were once again measured in the test ear for test frequencies.

The post stimulatory measures were obtained within the first 2 minutes after cessation of the fatiguing stimulus, i.e., 1 KHz tone at 110 dB HL for 30 minutes.

Pure tone thresholds were obtained by Modified Hughson

Westlake (Jerger and Carhart, 1959) method for all the subjects. Madsen Portable (Model 4251) audiometer with TDH 39 earphones calibrated to ISO (1964) standards was used for all purposes of this experiment. The calibration was checked using Artificial Ear Bruel & Kjaer Model 4152 with Condensor Microphone B & K Model 4144 and AF Analyser B & K Model 2106. The acoustic reflex measurements were made using Madsen z070 Electroacoustic Impedance Bridge (calibrated using Bruel & Kjaer equipments). The experiment was conducted in a sound treated room with the sound pressure levels as provided in the Appendix I (Table 1).

The earphone of the Madson protable audiometer was connected with the head band of the Madson zo 70 Electro Acoustic Impedance Bridge. Thus at a stretch pure tone and reflex thresholds were obtained at 1 KHz and 2 KHz for a particular ear. Similar findings were recorded for the other ear. The ear fulfilling less than 95 dB HL reflex criteria was chosen for inducing hearing loss.

Procedure for obtaining acoustic reflex threshold

The procedure given in the Manual (Manual of Madsen Electro Acoustic Impedance Bridge Model zo 70 published by Madsen Electronics) was followed with a slight modification for obtaining the acoustic reflex threshold (Procedure: See Appendix II).

As air tight sealing was not possible, reflex thresholds were measured in the absence of air tight sealing. A pilot study was conducted to see the difference between the reflex thresholds obtained with and without air tight sealing. The difference in reflex threshold was about 5 to 10 dB.

Loudness recruitment is present if the difference between the reflex threshold and the hearing threshold is less than 60dB

"Difference Method" (Garrett, 1971; p.227) was used as a test of significance between the mean values of pre and post stimulatory reflex thresholds.

Four subjects of the original sample were tested once again to check the test-retest reliability after a period of 8 days.

<u>Experiment II</u>

Obtaining the acoustic stapedial reflex threshold in moderate sensorineural hearing loss ears with no tone decay.

<u>Subjecs</u>

All ears with moderate sensorineural hearing loss reported (between September 1974 to February 1975) at the All India Institute of Speech and Hearing, Mysore 6, were included as subjects for this study.

<u>Procedure</u>

The following measures were obtained for each subject.

1) AC and BC thresholds at audiometric frequencies ranging from 250 Hz to 4000 Hz.

2) Carhart (1957) complete tone decay test measurements.

3) Acoustic stapedial reflex threshold for frequencies showing moderate sensorineural hearing loss.

Pure tone thresholds were obtained by Modified Hughson and Westlake (Jerger and Carhart, 1959) method for all the subjects.

Acoustic stapedial reflex thresholds were obtained by following the procedure recommended by the Manual of Madsen Electroacoustic Impedance Bridge Model zo 70 published by Madsen Electronics (Appendix II).

Madsen portable (Model 4251) audiometer with TDH 39 ear phones calibrated to ISO (1964) standards was used for this experiment. The calibration was checked using Artificial Ear Bruel and Kjaer Model 4152 with Condensor Microphone B & K Model 4144 and AF Analyser B & K Model 2106. The acoustic reflex measurements were made using Madsen zo 70 Electro Acoustic Impedance Bridge (Calibrated using Bruel & Kjaer equipments). The head phone of the audiometer was connected with the Impedance bridge head band as to feed the signal for eliciting the stapedial reflex. The experiment was conducted in a sound treated room with the sound pressure levels as provided in the Appendix I (Table 1).

Five subjects of the original sample were tested again to check the test-retest reliability.

Experiment III

Administering screening ABLB test for cases with unilateral high frequency sensorineural hearing loss. Thus finding out the hearing level at which a pure tone sounds equally loud in the normal ear when a reference tone of 80-90 dB HL was fed to the affected ear. The test was administered at the highest bilateral normal hearing frequency. The Interaural intensity difference at the point of balance was determined.

Subjects

Four adult males with unilateral high frequency sensorineural hearing loss were available as subjects for this experiment.

Procedure

The following measures were obtained for each subject.

1) Pure tone thresholds of both ears at all audiometric frequencies from 250 Hz to 8000 Hz.

2) Screening ABLB test. (Tillman, 1969)

Hughson and Westlake procedure is used for obtaining pure tone thresholds.

Screening ABLB as reported in literature was administered. The procedure was as follows:-

Instructions to the subject

"You are going to hear pure tones in your ears alternately. The tone will be at constant intensity in the poorer ear and the intensity of the tone in the better ear will vary. Hold your right hand (if right ear is poorer) at constant level and vary the height of the left hand (if left ear is normal). If equal, hold the two hands at equal levels. if the loudness in the left ear (normal) is more, hold the left hand at a higher level than the right hand. If the loudness in the left ear (normal) is less, hold the left hand at a lower level than the right hand."

After giving the instructions, the subject was asked to repeat the instructions to make sure whether he had understood the instructions.

Procedure

The frequency adjacent to the impaired frequency of the affected ear, having normal hearing was chosen for loudness balancing. At about 100 dB HL the tone was presented to the poorer ear. The same tone was presented alternately to the two ears for brief intervals (auto presentation). The intensity of the tone in the better ear was varied until the subject reported equal loudness. The hearing levels at which the subject reported equal loudness was noted. The experiment was repeated thrice to check the reliability of the loudness judgements.

The Interaural intensity difference at threshold and inter-aural intencity difference at the point of balance were computed. For example,

Interaural intensity difference at threshold = x dB

Interaural intensity difference at the point) of balance = y dB)

y - x 10 dB was considered as an indicator of decruitment.

Madsen portable (Model 4251) audiometer with TDH 39 earphones calibrated to ISO (1964) standards was used for obtaining thresholds. Beltone 15 CX Model equipped with TDH 39 earphones was used for screening ABLB test. The audiometric output was measured using Artifical Ear Bruel and Kjaer Model 4152 with Condensor Microphone B & K Model 4144, and A.F. Analyser B & K Model 2106. Beltone 15 CX audiometer output was measured at ABLB setting for each channel. The experiment was conducted in a sound treated room with the Sound Pressure levels as provided in the Appendix I (Table 2).

CHAPTER IV

RESULTS AND DISCUSSION

Experiment I

Table 1 and Table 2 show the obtained data and mean values before and after inducing temporary hearing loss (cochlear type), respectively at 1 KHz and 2 KHz in 10 normal hearing subjects.

At 1 KHz, the mean pure tone threshold is 7 dB. Post-stimulatorily, it has raised to 53.5 dB, exhibiting a mean threshold shift of 46.5 dB. The mean acoustic Stapedial reflex threshold (ART) of 87.5 dB is elevated to 101 dB, by a mean shift of 13.5 dB.

At 2 KHz, the mean pure tone threshold of 3 dB is raised to 51.5 dB, post stimulatorily, by a mean shift of 48.5 dB. The mean reflex threshold of 86.5 dB is elevated to 97 dB by a mean shift of 10.5 dB.

The mean pure tone thresholds obtained, after measuring the elevated reflex thresholds, are 46 dB and 43.5 dB respectively at 1 KHz and 2 KHz.

The obtained mean pure tone thresholds show, that for all experimental purposes the subjects had moderate hearing

EXPERIMENT I

Table 1 – Puretone and Acoustic Stapedial Reflex Thresholds (ART) before and after inducing temporary hearing loss (cochlear) in 10 normal subjects at 1 KHz

Subjects	Absolute Threshold dB HL	Acoustic Stapedial Reflex Threshold (ART) dB HL	Post Stimulatory Pure Tone Threshold dB HL	Post Stimulatory Acoustic Stapedial Reflex Threshold dB HL	Post Stimu Pure Tone Thereshold after Post Stimulatory ART measurement dB HL
1	5	85	60	95	50
2	10	85	65	100	55
3	5	85	50	95	40
4	5	80	55	100	50
5	-5	85	50	105	45
6	5	90	55	105	50
7	15	95	40	105	35
8	10	80	55	95	45
9	10	95	50	105	45
10	10	95	55	105	45
Mean	7	87.5 (A)	535	101 (B)	46

There is significant difference between the two means (A) and (B) at 0.05 level and at 0.01 level. The obtained t-value is 10.367. The expected t-value is 2.26 and 3.25 at 0.05 level and at 0.01 level respectively.

EXPERIMENT I

Table 2 – Puretone and Acoustic Stapedial Reflex Thresholds (ART) before and after inducing temporary hearing loss (cochlear) in 10 normal subjects at 2 KHz

Subjects	Absolute Threshold dB HL	Acoustic Stapedial Reflex Threshold (ART) dB HL	Post Stimulato-ry Pure Tone Threshold dB HL	Post Stimulato-ry Acoustic Stapedial Reflex Threshold dB HL	Post Stimu Pure Tone Thereshold after Post Stimulatory ART measurement dB HL
1	0	80	55	85	45
2	5	75	50	90	50
3	10	90	45	95	40
4	0	95	60	105	50
5	0	80	50	95	40
6	0	85	55	105	45
7	5	95	50	110	40
8	5	85	50	90	40
9	5	95	50	100	45
10	0	85	50	95	40
Mean	3	86.5 (A)	51.5	97 (B)	43.5

There is significant difference between the two means (A) and (B) at 0.05 level and at 0.01 level. The obtained t-value is 6.037. The expected t-value is 2.26 and 3.25 at 0.05 level and at 0.01 level respectively.

EXPERIMENT I

Table 1 – Showing the Amount of TTS and subsequent shift in Acoustic Reflex Thereshold

No.	At 1 KHz		At 2 KHz	
	TTS in dB	Shift in ARTH dB	TTS in dB	Shift in ARTH dB
1	55	10	55	5
2	55	15	45	15
3	45	10	35	5
4	50	20	60	10
5	55	20	50	15
6	50	15	55	20
7	25	10	45	15
8	45	15	45	5
9	40	10	45	5
10	45	10	50	10
Mean	46.5	13.5	48.5	10.5

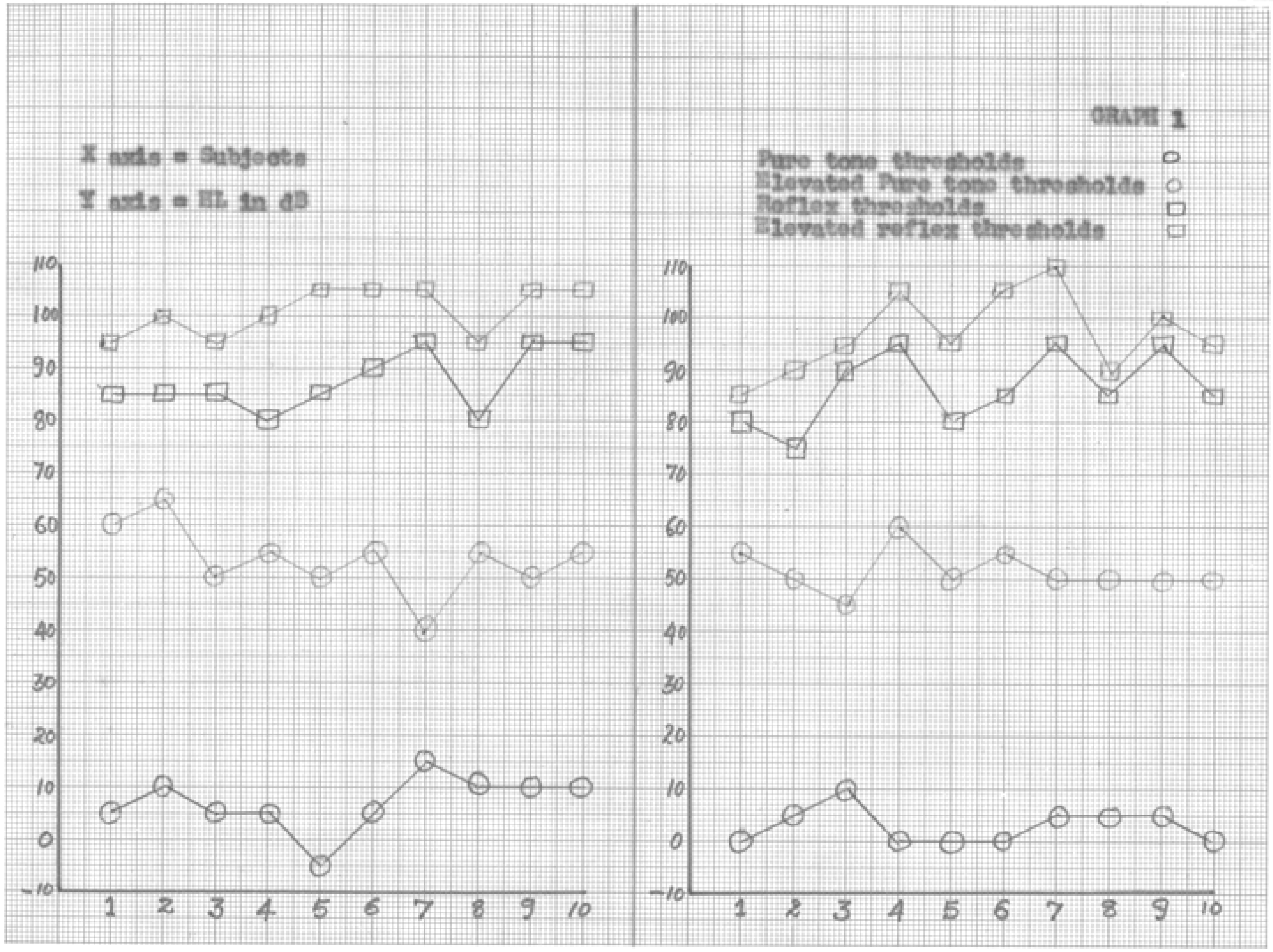
loss (40-70 dB).

There is significant difference between the mean pre and post stimulatory reflex thresholds, at .05 level and .01 level, at 1 KHz and 2 KHz.

The results of the first experiment reveal that the growth of loudness in the temporarily induced (Sensori-neural) hearing loss is not abnormal. Observation of the Temporary Threshold Shift (TTS) and the shift in acoustic reflex threshold (ART) in the present study and in the previous study (Vyasamurthy et al, 1975) shows that the shift in acoustic reflex threshold (ART) is about 10-15 dB, irrespective of the amount of TTS (Graph 1). Table 3 gives the relation between TTS and shift in acoustic reflex threshold (ART) for 10 subjects.

This constant shift in acoustic reflex threshold (ART), irrespective of the amount of TTS, is an evidence to show that the growth of loudness in the induced temporary hearing loss (Sensorineural loss) is not abnormal.

To exemplify further, consider a subject whose absolute threshold at 1 KHz is 0 dB (ISO 1964) and acoustic reflex threshold (ART) at 1 KHz is 95 dB. It is known that the reflex is elicited when a stimulus is perceived at a particular loudness level (Flottorp, Djupesland, and WInther,


GRAPH 1
X axis = Subjects
Y axis = HL in dB
Pure tone thresholds
Elevated Pure tone thresholds
Reflex thresholds
Elevated reflex thresholds

1971; Brooks, 1968; Ewertsen et al, 1967; Moller, 1961; Thomsen, 1955). Here, in this particular subject. the reflex is elicited when the loudness level is 85 phons or 32 sones; phon and dB are same as far as 1 KHz tone is concerned). When the subject's ear is fatigued (TTS–50 dB). acoustic reflex occurs at 95 dB HL. If the loudness depends on the sensation level (recruitment is a fact). acoustic reflex threshold (ART) should by 50 dB (as TTS=50 dB) i.e., shift in ART should correspond to the amount of TTS. Now, a question arises – why this shift in ART is just 10 dB, even though the TTS is about 50 dB?

This can be explained on the basis of loudness perceived. As mentioned earlier, the reflex occurs when the stimulus is perceived at a particular loudness level. In the presence of 50 dB TTS (threshold=50 dB). the reflex can be expected when the loudness perceived is 85 phons or 32 sones. Now, let me consider at what intensity level of the tone (1 KHz), the loudness level reaches 85 phons or 32 sones, when the subject's threshold is 50 dB? Using Fletcher's (1953) formula, we know that loudness in sones $= 2\left[\frac{L-40}{9}\right]$, where

L=loudness level in phons. From the formula, approximately 50 dB loss is equivalent to loudness loss of 2 sones. When 58 dB tone (1 Khz) is presented to the subject's ear (Threshold=50), the loudness experienced by that ear is 2 sones (because, 2 $\left[\frac{59-40}{9}\right]$ - 2 sones = 2). When 67 dB tone is presented, the loudness experienced is 4 sones (for every 9 dB rise, the loudness becomes double - from 58 dB, the intensity is raised to 67 dB i.e., by 9 dB). At 76 dB, the loudness experienced is 8 sones. At 85 dB, the loudness perceived is 16 sones. At 94 dB, the loudness perceived is 32 sones.

Now, if we look into the acoustic reflex threshold, after the ear is fatigued, we find that the reflex threshold in the presence of 50 dB TTS, is 95 dB, which is equal to 32 sones (Threshold=50 dB). This clearly induced hearing loss (Sensorineural loss). is not abnormal. Constant shift in acoustic reflex threshold (ART), irrespective of the amount of TTS, can be well understood if we look into the following examples and the Tables 4 and 5.

Examples (from Table 4) :-

	ART in dB HL	ART Sones	Elevated pure tone TH_S in dB HL	Post Stimulatory ART in dB HL	Post Stimulatory ART in sones
1	85	32	60 (4)	95	32
2	85	32	50 (2)	95	32

Note : The numbers in parentheses are approximate Sone values.

EXPERIMENT I

Table 4 – Showing the relationship between the Normal Acoustic Reflex Threshold (ART) and the Post Stimulatory ART (i.e. after inducting temporary hearing loss of S.N. type) in terms of perceived loudness among 10 normal hearing subjects at 1 KHz

	ART in dB HL	ART Sones	Elevated pure tone TH_S in dB HL	Post Stimulatory ART in dB HL	Post Stimulatory ART in sones
1	85	32	60 (4)	95	32
2	85	32	65 (8)	100	64
3	85	32	50 (2)	95	32
4	80	22	55 (4)	100	64
5	25	32	50 (2)	105	64
6	90	47	55 (4)	105	64
7	95	69	40 (1)	105	64
8	80	22	55 (4)	95	32
9	95	69	50 (2)	105	64
10	95	69	55 (4)	105	64

Note : The numbers in parentheses equals to the loudness loss in Sones.

EXPERIMENT I

Table 5 – Showing the relationship between the Normal ART and the Post Stimulatory ART (i.e. after inducing temporary hearing loss of S.N. type) in terms of perceived Loudness in 10 normal hearing subjects at 2 Khz

No.	ART in dB HL	ART Sones	Elevated pure tone TH_S in dB HL	Post Stimulatory ART in dB HL	Post Stimulatory ART in sones
1	80	22	55 (4)	85	16
2	85	32	50 (2)	90	32
3	90	47	45 (2)	95	32
4	95	69	60 (4)	105	64
5	80	22	50 (2)	95	32
6	85	32	55 (4)	105	32
7	95	69	50 (2)	110	128
8	75	15	50 (2)	90	16
9	95	69	50 (2)	100	64
10	85	3232	50 (2)	95	32

Note : The numbers in parentheses equals to the loudness loss in Sones.

The acoustic refles threshold (ART) is converted into sone value using Fletcher's (1953) formual. The following table shows the growth of loudness in sones with increase in intensity, in normal hearing subjects.

dB HL	Loudness in Sones
40	1
49	2
58	4
67	8
76	16
85	32
94	64
103	128

According to this table, an ear with 60 dB loss incurs a loudness loss, approximately of 4 sones. It is explained as follows.

0 Loudness in Sones $= 2 \left[\frac{L-40}{9}\right]$

$$= 2 \left[\frac{60-40}{9}\right]$$

$$= 2^{2.22}$$

2.22 log 2 = 2.22 X 0.301 = 0.066822

0 antilog of 0.66822 = 4.63 sones

Thus, the subject loses, approximately, 4 sones, if the loss is 60dB. But for every 9 dB increase above threshold, he perceives half the loudness of what normals would perceive. Therefore, the difference between the impaired ear and the normal ear is just about 10 dB. In this particular example (1), it is 10 dB above the normal acoustic reflex threshold.

Such observations have been reported in Table 4 and Table 5. However, the above explanation does not hold good for all subjects, because, some extreme variations are observed in few subjects. This may be because of the inherent limitation of the audiometric dial calibration (in 5 dB steps) or due to the ‘subjective’ judgement of the Balance Meter needle movement of the Impedance Bridge (Madsen, zo 70), to ascertain the reflex.

Thus, the obtained results from most of the subjects show that the growth of loudness in an abnormal ear (temporarily induced sensor-neural hearing loss) is not abnormal. This may be true with real sensori-neural hearing loss cases also. However, the conclusion drawn here is based on the assumption that the formula,

$$N \text{ in sones} = 2 \left[\frac{L-40}{9}\right]$$

holds good for temporarily induced sensori-neural hearing loss, as well as real sensori-neural hearing loss cases. There appears to be no reason why the formula should not hold good with the sensori-neural cases, or temporarily induced sensori-neural hearing loss cases. Assuming that it may be wrong to use the Fletcher's (1953) sone formula for sensori-neural hearing loss, or temporarily induced sensori-neural hearing loss cases, we will be left with no answer, as far as the presumably constant shift in acoustic reflex threshold (ART) irrespective of the amount of TTS is concerned.

Test-Retest Reliability

Test-retest reliability has been established on four subjects. The findings are given in Appendix III. in one subject, the obtained retest score differed by 10 dB. Otherwise, Audiologically acceptable scores obtained. Reliability was statistically computed by using the 'Rulon Method' as given by Guilford (1965).

Experiment II

Table 6 shows the mean absolute threshold and mean Stapedial reflex threshold obtained in typical moderate sensori-neural hearing loss cases, with no tone decay.

Comparison of mean reflex thresholds of normal subjects

EXPERIMENT II

Table 6 - Showing the Mean Absolute Threshold and Mean Stapedial Reflex Threshold in typical Moderate Sensori-neural hearing loss group with no tone decay

Frequency in Hz	Number of Subjects	Mean Absolute Threshold in dB HL	Mean Acoustic Stapedial Reflex Threshold in dB HL
250	23	48.69	84.78
500	31	52.42	92.26
1000	26	54.81	94.42
2000	14	53.57	86.43
4000	4	43.75	91.25

EXPERIMENT II

Table 7 – Showing the obtained Mean difference in Acoustic Reflex Thresholds (ART) between Normals and Moderate Sensori-neural hearing loss (D_1); and between Normals and Sensori-neural hearing loss group (D_2)

Frequency in Hz	No. of Normal Subjects	* Mean ART in Normals in dB HL	No. of Moderate S.N. hearing loss subjects	Mean ART in Moderate S.N. hearing loss group dB HL	D_1 in dB	*No. of S.N. loss Subjects	Mean Art in S.N. loss group in dB HL	D_2 in dB
250	119	71.72	23	84.78	13.06	11	84.09	12.37
500	140	77.99	31	92.26	14.27	12	88.75	10.76
1000	131	82.34	26	94.42	12.08	12	96.66	14.32
2000	125	80.00	14	86.43	6.43	11	92.72	12.72
4000	104	82.76	4	91.25	8.49	6	91.66	8.90

- Data obtained from Basavaraju (1973).

(Basavaraju, 1973), and mean reflex thresholds of typical moderate sensori-neural hearing loss cases with no tone decay, shows that the mean reflex thresholds of the latter is higher than the former (Table 7). Similar observation is made on comparing sensori-neural hearing loss group (from Basavaraj, 1973 - also included in the Table 7).

Table 8 gives a comparison of the normal acoustic reflex threshold (obtained from Basavaraj, 1973), with the acoustic reflex threshold in typical moderate sensori-neural hearing loss cases in terms of perceived loudness in sones. (At 2 KHz and 4 KHz the HL itself is considered as L value, i.e., loudness level in phons, as there is negligible difference between 1, 2, and 4 KHz in the equal loudness contours - Stevens and Davis, 1938; p.124).

The findings are in agreement with the hypothesis that loudness (determined by elicitation of reflex perceived by sensori-neural hearing loss ears without tone decay, is diminished by half the normal loudness (equivalent to about 10-15 dB loss in intensity. See Table 7).

In other words, the difference in the loudness perceived by normal and sensori-neural hearing loss ear is negligible as diminution by half the normal loudness is just 9 dB loss in terms of intensity. (However, the observation extends

EXPERIMENT II

Table 8 – Comparison of the normal acoustic reflex thresholds (ART; obtained from Basavaraj, 1973) with the ART obtained in typical Moderates S.N. hearing loss cases in terms of perceived loudness at 1, 2, and 4 KHz

Frequency in Hz	Mean Normal ART dB HL	Mean Normal ART in Sones	Mean Mod. S.N. hearing loss	Mean ART in Mod. S.N. loss dB HL	Mean ART in Mod. S.N. loss in Sones
1000	82	25	54.81 (4)	96.66	32
2000	80	22	53.57 (4)	92.72	32
4000	83	27	43.75 (1)	91.66	32

Note: The number in parentheses equal to the loudness loss in Sones.

upto a loss of 15 dB. This could b due to factors which are explained earlier in Experiment I).

Test-Retest Reliablitiy

Test-retest reliability has been established on 5 cases. The findings are given in Appendix III. Reliability was statistically computed by using the 'Rulon Method' as given by Gruilford (1965).

Experiment III

Verification of the third hypothesis, i.e., Simmon's and Dixon's 'Summation Loudness Decrement' principle to explain the phenomenon of decruitment in 4 unilateral high frequency sensori-neural hearing loss cases (See Audiograms) shows that decruitment is an artifact. The findings support the third hypothesis of the study.

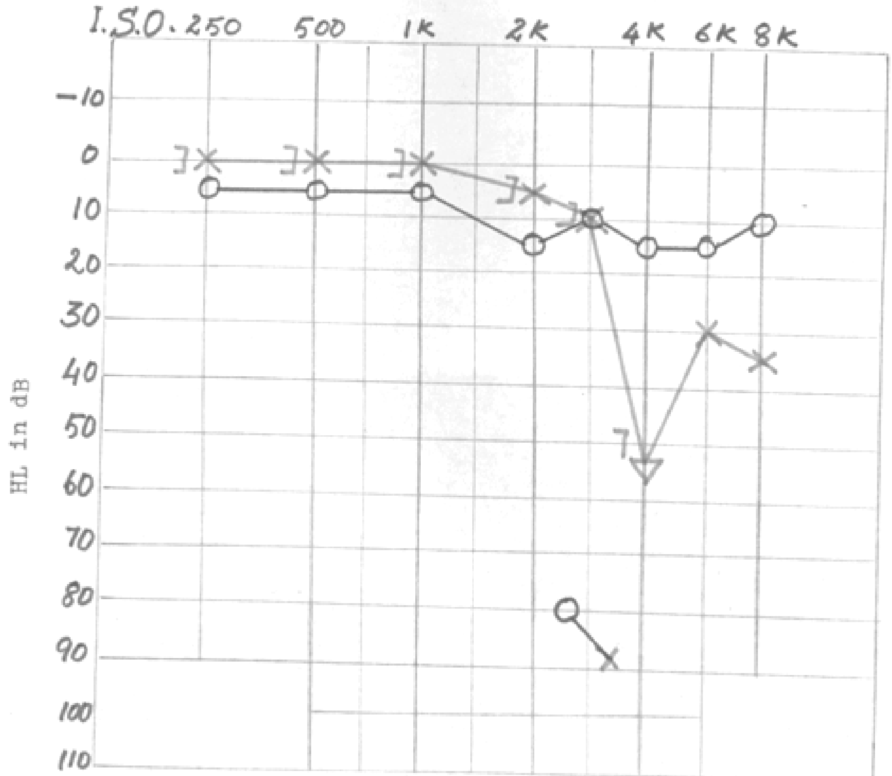
Table 9 shows the SPL values required to perceive the pure tone equally loud in both the ears, when screening ABLB was administered at the normal frequency in 4 subjects with unilateral high frequency sensori-neural hearing loss. Interaural intensity difference at threshold and at the point of balance are compared.

The column (y-x) in Table 9 gives the difference between the interaural intensity difference at the point of balance and Interaural intensity difference at threshold. Decruitment is said to be present if (y–x) value exceeds 10 dB. But even the maximum obtained (y–x) value is +6.5 dB, indicating no decruitment and refuting Simmons and Dixon’s (1963) hypothesis. Thus, it appears that decruitment is an artifact.

AUDIOGRAM

Case: 1.
Age : 17 Yrs.

Frequency

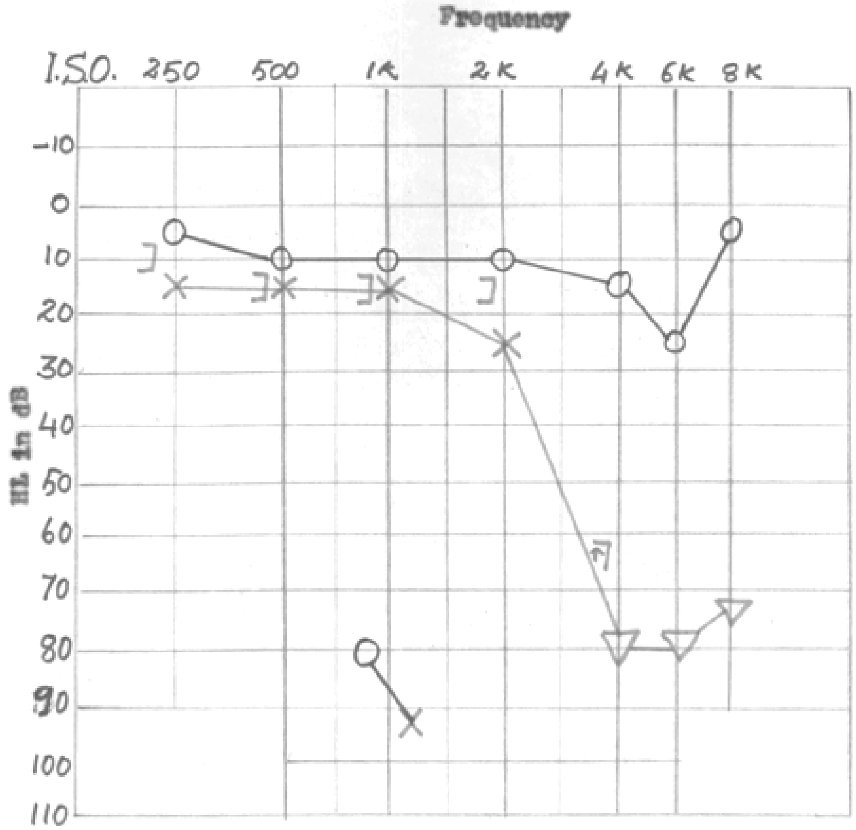


Left Unilateral High Frequency Sensori neural Hearing loss.

AUDIOGRAM

Case No.2

Age 18 years

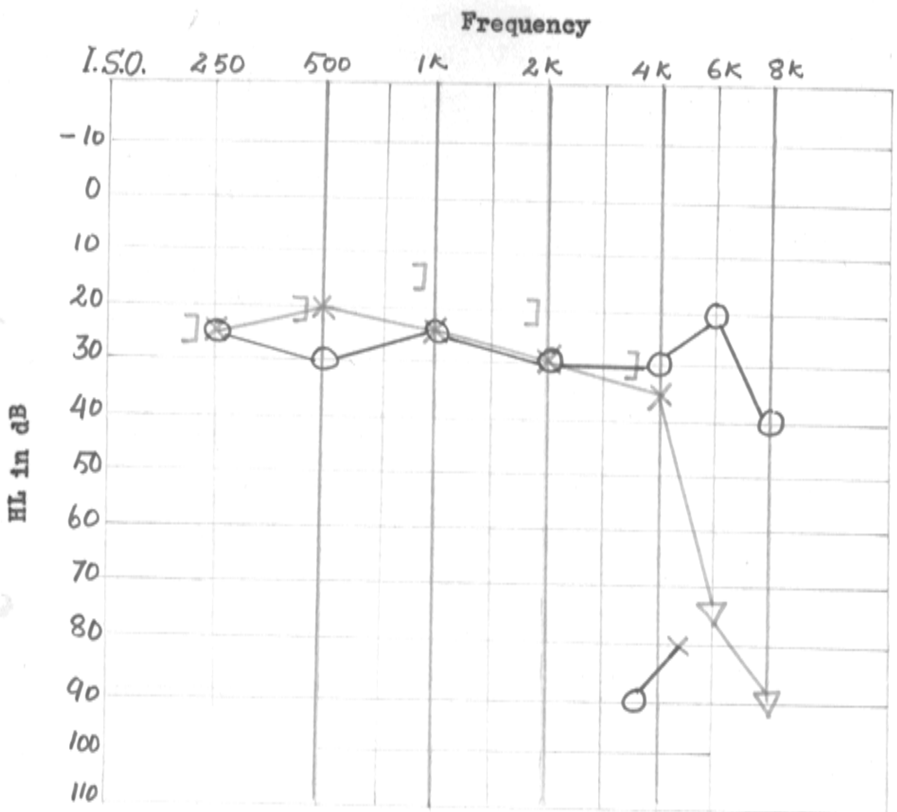


Left Unilateral High Frequency Sensori Neural Hearing Loss.

AUDIOGRAM

Case No. 3

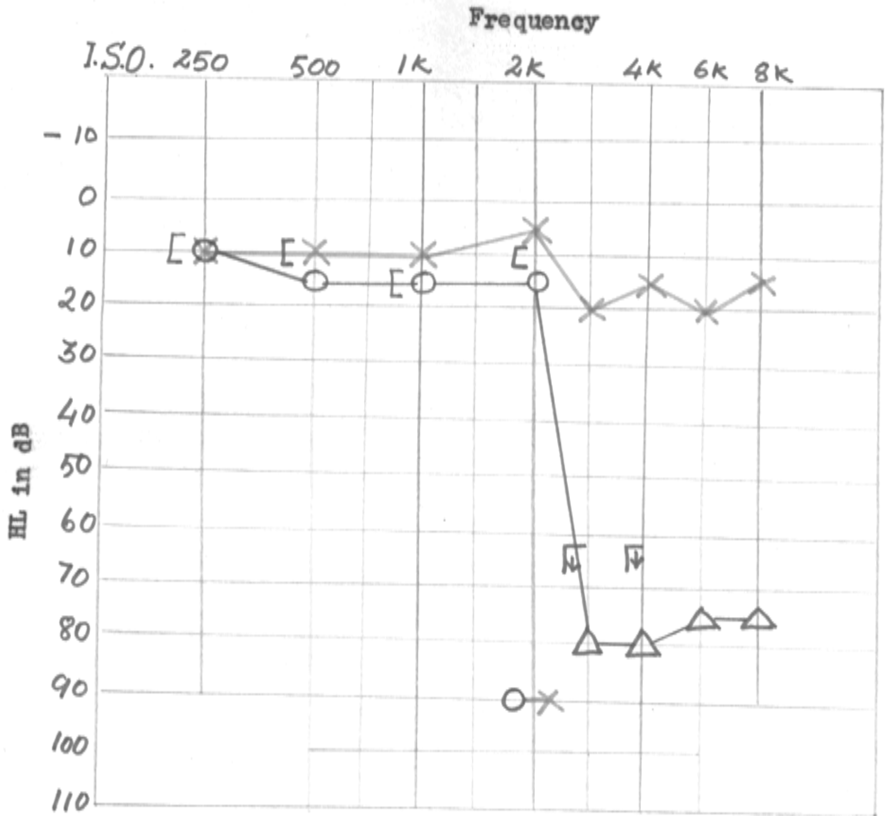
Age 42 years



Left Unilateral High Frequency S$_e$nsori Neural Hearing Loss

AUDIOGRAM

Case No.4
Age 33 years



Right Unilateral High Frequency Sensori Neural Hearing Loss

EXPERIMENT III

Table 9 shows the SPL values required to perceive the puretone equally loud in both the ears, when screening ABLB was administered at the normal frequency in 4 subjects with unilateral high frequency sensorineural hearing loss. Internal intensity difference at threshold and at the point of balance are compared and no decruitment is observed.

Subjects	Test Frequency in Hz	SPL value in the path. ear at the point of balance	SPL value in the normal ear at the point of balance	(x) Interaural intensity difference at TH. (P-N)	(y) Interaural intensity difference at the point of balance (P-N)	(y - x)	Interpret-ation
1	3000	86 dB	80 dB	6 dB	6 dB	6 dB	Not greater than +10 dB. So, no de Decruitment.
2	1000	91.5dB	80 dB	5 dB	11.5 dB	6.5 dB	- do -
3	4000	80 dB	90 dB	5 dB	-10 dB	-15 dB	- do -
4	2000	90 dB	90 dB	10 dB	0 dB	-10 dB	- do -

* (P-N) - in (Pathological ear - Normal ear).

CHAPTER V

SUMMARY AND CONCLUSIONS

An attempt was made to verify whether recruitment is a fact or an artifact. Three experiments were carried out.

Experiment I was comparison of acoustic stapedial reflex thresholds (ART) obtained before and after inducing temporary hearing loss (cochlear) in 10 normal hearing subjects, at 1 KHz and 2 KHz. After sufficient time gap, the procedure was repeated on 4 subjects for test-retest reliability. Statistical significance has been determined.

In the Experiment II, the reflex thresholds at 250, 500, 1 K, 2 K and 4 KHz, of typical moderate sensori-neural hearing loss cases with no tone decay, were compared with that of normal reflex thresholds. After sufficient time gap, the measurements were repeated on 5 subjects for test-retest reliability.

In Experiment III, screening ABLB was administered on 4 cases with unilateral high frequency sensori-neural hearing loss. The test was administered at the highest bilateral normal hearing frequency. The hearing level at which a pure tone sounds equally loud in the normal ear, when a reference tone of 80-90 dB HL was fed to the affected ear was determined. The Interaural intensity difference at the point of balance was determined.

Conclusions

1) The difference in loudness, experienced by normal ear and the ear with induced hearing loss (cochlear) is negligible.

2) The difference between the acoustic reflex threshold of moderate (40-70 dB HL ISO 1964) typical sensori-neural hearing loss cases without tone decay and acoustic reflex thresholds of normal ears is less than 10-15 dB.

3) The stapedial reflex thresholds are elevated in sensori-neural hearing loss cases, by approximately 10-15 dB as to compensate the loudness loss resulting from the elevated pure one thresholds.

4) The growth of loudness in abnormal ears is not abnormal, as shown by the I and II experiments. So, recruitment, a presumed abnormal growth of loudness, is an artifact.

5) Decruitment, a presumed slow growth of loudness, is an artifact.

Implications

1) As recruitment is an artifact, it no longer stands as an indicator of cochlear pathology. So, the ABLB (automatic presentation) test may not be valid in differential diagnosis of cochlear Vs. retro-cochlear hearing impairment. It can only be used to differentiate between conductive and sensori-neural impairment.

2. The concern expressed by many investigators regarding atypical findings in surgically confirmed acoustic neuroma cases in unwarranted.

Suggestions for further research

1) The first and second experiments may be carried out with air tight sealing in the probe ear, obtained clear knowledge about the middle ear which would be beneficial as supportive studies.

2) ABLB automatic presentation and ABLB manual presentation methods may be tried on hearing loss cases exhibiting tone decay of different degree.

3) Investigations on cases exhibiting ‘hyper-recruitment’ may be carried out.

BIBLIOGRAPHY

Alberti and Kristensen, H.K. (1970) “The Clinical Application of Imedance Audiometry”. Laryngoscope. 80, 735-746.

Anderson, H, and Barr, B. (1968) “Conductive Recruitment”. J. Audiol. 7, 48-54

Basavaraj, V. (1973) “Measurements of Acoustic Impedance in Indians”. A dissertation submitted in part fulfillment for the degree of Master of Science (Speech and Hearing) of Mysore University.

Beedle, R.K. and Harford, E.R. (1973) “A Comparison of Acoustic Reflex and Loudness growth in Normal and Pathological Ears”. J. Speech Hearing Res. 16, 271-281

Bekesy, G.V. (1947) “A New Audiometer”. Acta Otc-Laryngol., stockh., 25, 411-422 (Cited by Jerger, 1968)

Bekesy, G.V. (1929) “Zur Therie des Horens. Uber die eben merkbare Amplituden - und Frequenzanderung eines Tones. Die Theories der Schwebungen”. Phys. Z 30, 721-745 (Cited by Harris, 1952)

Blegvad, B. (1969) “Differential Intensity Sensitivity and Clinical Masking”. Acta Oto-Laryngol. 67, 423-434

Bruine-Altes, Johanna, C., de (1946) "The Symptom of Regression in Different kinds of Deafness". Gromingen: J.B. Walters, p.176 (as quoted by Harris, 1952)

Garhart, R. (1957) "Clinical Determination of Abnormal Auditory Adaptation". Arch. Otolaryngol. 65, 32-39] (as quoted by Katz, 1972)

Dallas, P. (1973) The Auditory Perinhery: Bio Physics and Physiology. New York. Academic Press, p.473

Davis, H. (1948) "The Articulation Area and the Social Adequacy Index for Hearing". Laryngoscope. St. Louis, 58, 761-778 (as quoted by Hirsh, 1952)

Davis, H., Morgan, C.T., Hawkins, J.E. Jr., Galambos, R., and Smith, F.W. (1943) "Temporary Deafness following Exposure to Loud Tones and Noise". Report No. PBN 57250, Comm. on Med. Sciences, OSRD, Sep. 30, Available in microfilm or photostat from the Office of Technical Services, Dept. of Commerce, Washington 25, D.C. (as quoted by Harris, 1952)

Dones, P., and Naunton, R.E. (1950) "The Clinical Detection of Auditory Recruitment". Laryngoscope, 64, 375-398 (as quoted by Harris, 1952)

Dix, M.R. (1968) "Loudness Recruitment and its Measurement with especial reference to Loudness Discomfort Level Test and its value in Diagnosis". Ann. Otol. Rhinol. Laryngol. 77, 1131-1151

Dix, M.R., Hallpike, C.S. and Hood, J.D. (1948) "Observation upon the Loudness Recruitment Phenomenon with especial Reference to the Differential Diagnosis of Disorders of Internal Ear and VIII Nerve". Proc. Roy. Soc. Med., 61, 516-526 (as quoted by Katz, 1972)

Dix, M.R., Hallpike, C.S., and Hood, J.D. "Nerve" Deafness: Its Clinical Criteria, Old and New. Proc. Roy. Soc. Med, 42, 527-536 (as quoted by Harris, 1952)

Djupesland, G., and Flottorp, G. (1970) "Correlation between the Fowler Loudness Balance Test, the Metz Recruitment Test, and the Flottorp-Opheim's Aural Hormic Test in Various Types of Hearing Impairment". J. Int. Aud. 9, 156-178.

Djupesland, G. (1964) Discussion. Acta. Oto-Laryngol. 188, 207-208. As quoted by Lilly, D.J. in Modern Developments in Audiology. (Jerger, J., Ed.) 1973

Eby, L.G. and Williams, H.L. (1951) "Recruitment of Loudness in the Differential Diagnosis of End-Organ and Nerve fibre Deafness". Laryngoscope. 41, 400-414 (as quoted by spuehler, 1955)

Ewertson, H. et al (1958) "Comparitive Recruitment Testing". Aeta. Oto-Laryngol. Suppl. 140, 116-122 (as quoted by Jerger, 1973)

Flottorp, G., Djupesland, G., and Winther, F. (1971). "The Acoustic Reflex in Relation to Critical Band Width". J. Acoust. Sec. Amer., 49, 457.

Fletcher, H., and Munson, W.A. (1933) "Loudness, Its Definition Measurement and Calculation". J. Acoust. Soc. Amer. 5, 82-108.

Foght, E. (1944) "Bemer Kungen Uber des akustische Leiden bei der Meniere Schen Krankheit". Acta Oto-Laryngol. Suppl. 51, 230-240 (as quoted by Harris, 1952)

Fowler, E.P. (1928) "Marked Deafened Areas in Normal Ears". Arch. Otolaryngol. 8, 151-155 (as quoted by Harris, 1952)

Fowler, E.P. (1936) "A Method for the Early Detection of Otosclerosis". Arch. Otolaryngol, 24, 731-741

Fowler, E.P. (1937) "The Diagnosis of Diseases of the Neural Mechanism of Hearing by the Aid of Sounds Well Above Threshold". Trans. Amer. Otolaryngol. Soc., 27, 207-220 (as quoted by Harris, 1952)

Fowler, E.P. (1963) "Loudness Recruitment: Definition and Clarification". Arch. Otolaryngol. p.748

Franzen, R.L., and Lilly, D.J. (1970) "Threshold of the Accustic Reflex for Pure-Tones". Amer. Speech Hearing Assoc. 12, 435

Gabrielli and Tarsitani (1963) ORL. Ital. 32, 503-511 (as quoted by Miller, 1967)

Galletti, c. (1965) "The results of Gertain Adaptation Tests in Cases with Perceptive Deafness with Recruitment". ORL. Ital. 34, 95-101 (as from dSH Abst. 1966, 6, 25)

Geiper, P.H. (1940) "Loudness Level to Loudness Conversion Chart". J. Acoust. Soc. Amer., 11, 308-310

Gradenigo, G. (1912) "Studie Proposte de acumetria. Indice Vocale (Index Vocalis) Auditus". Arch. Ital. di. Otolog. 23, 177-208 (as quoted by Harris, 1952, p.6)

Greenwood, D.C. (1961) "Critical Band Width and the Frequency Coordinates of the Pasliar Membrane". J. Acoust. Soc. Amer. 33, 1344-1356 (as quoted by Simmons and Dixon, 1966)

Guttman, J., and Ham. L.B. (1928) "Effect of an interfering tone upon the Hearing of a Normal and a Deafened Ear". Phys. Rev., 31, 712 (as quoted by Harris, 1952)

Harper, A.R. (1961) "Acoustic Impedance as an Aid to Diagnosis in Otology". J. Laryngol. Otol., 75, 614-620 (as cited by Jerger, J. (Ed) 1973)

Harris, H.D. (1953) “A Brief Critical Review of Loudness Recruitment”. Psychol. bull., 50, 193-203 (as quoted by Simmons and Dixon, 1966)

Harris, J.D. (1952) “An Historical and Critical Review of Loudness Recruitment”. Medl. Research Laboratory. U.S. Naval Submarine Base. New London

Hawkins, J.E., Jr. and Stevens, S.S. (1950) “The Masking of Pure Tones and of Speech by White Koise”. J. Acoust. Soc. Amer., 32, 6-13

Harbert, F. and Young, I. N. (1964) “Audiologic Findings in Meniere’s Syndrome”. Acta Ota-Laryngol., 57, 145-154 (as quoted by Young, 1971)

Harbert, F. and Young, I.H. and Menduke, H. (1966) “Audiologie Findings in Preslyeusis”. J. Auditory. Res. 6, 297-312

Harbert, F., Young, I.N. and Weiss, B.G. (1969) “Clinical Application of Intensity Difference Limen”. Acta Ota-Laryngol. 67, 435-143

Hickling, S. (1967) “Hearing Test Patterns in Noise Induced Temporary Hearing Loss.” J. Auditory Res. 7. 63-67

Hirsh, J. (1952) “The Measurement of Hearing. McGraw-Hill, New York

Hood, J.D. and Poole, J.P. (1566) J. Acoust. Soc. Amer. 40/1 47 (as quoted by M. Spencer-Harrison, 1969)

Hood, J.D. (1968) “Boservations upon the Relationship of Loudness Discomfort Level and Auditory Fatigue to Sound Pressure Level and sensation Level”. J. Acoust. Soc. Amer., 44, 959

Huizing, H.C. (1943) “Die Bestimmung der Regression bei der Cehorprufung und der physikalische, Physiogische und Psychologicsche Zusammenhang bei der Cehorprothese”. Acta Oto-Laryngol. 36, 346-355 (as cited by Hirsh, 1952)

Huizing, H.c. (1949) “The Relation between Auditory Fatigue and Recruitment”. Acta Oto-Laryngol. Suppl. 78, 169-172

Huizing, H.C. and Reyntjes, J.A. (1950) “Recruitment and Optimum Speech Intelligibility”. Revue De Laryngologia, (as qucted by Spuehler, 1955)

ISO (1964) Report No.339 Standard Reference Zero for the Calibration of Pure-tone Auidometers, I.S.O.

Jagadeesh, R.K. (1970) “Recruitment – A Fact or an Artifact?” J. AIISH, 1, 50-53

Jean – Marie Aran (1971) “The Electro-Cochleogram: Recent Results in Children and in Some Pathological Cases”. Arch. Klin. exp. Ohr., Nas-u. Kehlk. Heik, 198, 128-141

Jerger, J.S. and Carhart, R. (1959) “Preferred Method for Clinical Determination of Pure-Tone Thresholds”. J. Speech Hearing Dis., 24, 330-345

Jerger, J.F. (1952) "A Difference Limen Recruitment Test and its Diagnostic Significance". Laryngoscope. 62, 1316-1332

Jerger, J. (1953) "DL Difference Test Improved Method for Clinical Measurement of Recruitment". Arch. Otolarygol. 57, 490-500 (as quoted by Martin, 1972)

Jerger, J. et al (1959) "On the Detection of Extremely small Changes in Sound Intesity". Arch. Otolaryngol. 69, 200-211 (as quoted by Katz, 1972)

Jepsen, O. (1963) "Middle Ear Muscle Reflexes in Man". (as cited in Jerger, Ed. 1973)

Jerger, J. and Harford, E. (1960) "Alternate and Binaural Bal-ancing of Pure Tone". J. Speech Hearing Res. 3,15-30

Jerger, J. (1962) "The SISI Test". Int. Audiol., 1, 246-247 (as quoted by Martin, 1972)

Jerger, J. (1968) "Review of Diagnostic Audiometry". Ann. Otol. Rhinol. Laryngol., 77, 1042

Jerger, J. (1970) "Clinical Experience with Impedance Audio-metry". Arch. Otolaryngol, 92, 311-324

Jerger, J. (Ed) (1973) <u>Modern Developments in Audiology</u>: 2nd Edition, Academic Press, New York

Katz (Ed) (1972) Handbook of Clinical Audiology: Williams and Wilkins and Co.

Klockhoff, I. and Anderson, H. (1959) “Recording of Stapedius Reflex Elicited by Cutaneous Stimulation”. Acta. Oto-Laryngol. 50, 451-454 (as quoted by Jerger, Ed. 1973)

Klockhoff, I. (1961) “Middle Ear Muscle Reflexes in Man”. Acta. Oto-Laryngol. Suppl. 164 (as quoted by Jerger, Ed. 1973)

Kristensen, H.K. and Jepsen, O. (1952) “Recruitment in Oto-neurological Diagnosgtics”. Acta Oto-Laryngol. 42, 553-560 (as quoted by Jerger, Ed. 1973)

Lamb, L.E., and Norris, T.W. “Acoustic Impedance Measurement”. In Audiometry for the Retarded. (R.T. Fulton and LL. Llyod, Eds. Williams and Wilkins, Baltimore)

Lamb, L.E. (1968) “Application of Stapedius Muscle Reflex Measures to Diagnosis of Audiological Problems”. J. Int. Audiol, 7, 188

Langenbeck, B. (1928) “Uber die Unzulanglichkeit Unserer Horshcarfenbe Stimmungen”. Z. Hals-Nas-u. Ohrenheilk, 20, 313-321 (as quoted by Harris, 1952)

Langenbeck, B. (1932) “Das Horen in Larm”. Z. Hals-Nas-u. Ohrenheilk, 30, 1-64 (as quoted by Harris, 1952)

Langenbeck, B. (1950a) “Die Geranschaudiometrie als diagnostische Methode”. Z. Laryngol. Rhinol. Otol. 29, 103-121 (as quoted by Hirsh, 1952)

Langenbeck, B. (1950b) “Die Geranscheudiometrie als diagnostische Methode II. Schwellennache und Schwellenferne Gerauschaudiogramme”. Z. Laryngol. Rhinol. Otol., 29, 470-487 (as quoted by Hirsh, 1952)

Langenbeck, B. (1950c) “Gerauschaudiometrische Diagnostik Die Absolutanswertung”. Arch. Ohr.u. Z. Hals Heil Kunde; 158, 458-468 (as quoted by Hirsh, 1952)

Lawrence, N. and Blanchard, C.L. (1954) “Prediction of Suceptibility to Acoustic Trauma by Determination of Threshold of Distortion”. Univ. Michigan. Medl. Bull., 20, 81-92 (as quoted by Young, 1971)

Lawrence, N., and Yantis, P.A. (1956) “Thresholds of Overload in Normal and Pathological Ears”. Arch. Otolaryngol. 43, 67-77 (as cited by Young, 1971)

Liden, G. (1970) “The Stapedius Muscle Reflex used as an Objective Recruitment Test: A Clinical and Experimental Study”. In Sensori N-eural Hearing Loss. Symposium, CIBA Foundation (G.E.W. WOlstenholme and Julie Knight Eds.)

Larsen, B. Dansk Oto-Laryngologisk Selskabs Forhandlinger P-1940-1941 (as quoted by Harris, 1952)

Larsen, B. (1942) Nordisk Med., 14, 1714 (as quoted by Harris, 1952)

Lurie, M.H. (1940) “Studies of Acquired and Inherited Deafness in Animals”. J. Acoust. Soc. Amer., 11, 420-426 (as quoted by Harris, 1952)

Luscher, E., and J. Zwislocki “A Simple Method for Indirect Monaural Determination of the Recruitment Phenomenon (Difference Limen in Intensity in different types of Deafness)”. Acta Oto-Laryngol. Suppl. 78, 156-168 (as quoted by Martin, 1972)

Luscher, E. (1955) “Unsere Bestimmung der Unterschiedswelle der Intensitat modulation reiner Tones deren Auswertung und deren topisch-diegnostiche Leistungsfahigkeit”. Acta. Oto-Laryngol. 45, 402 (as quoted by Blegvad, 1969)

de Mare, G., and Rosler, G. (1950) “Untersuchungen Uber den verdeckungseffekt bei Leitungs-und Innehohrs-chwerhorigkeit Acta Oto-Laryngol., 38, 179-190 (as cited by Harris, 1952)

Martin, F.N. (1972) “The Short Increment Sensitivity Index”. In Handbook of Clinical Audiology (Katz. Ed.) Baltimore: The Williams and Wilkins Co.

Metz, O. (1946) “The Acoustic Impedance Measured on normal and Pathological Ears”. Acta Oto-Laryngol. Suppl. 63, (as quoted by Jerger, Ed. 1973)

Metz, O. (1952) "The Threshold of Reflex Contractions of Muscles of Middle Ear and Recruitment of Loudness". Arch. Otolaryngol. 55, 536-543 (as quoted by Beedle and Harford, 1973)

Miller, M.H. (1967) "Fluctuating Sensori Neural Hearing Impa-irment Associated with the Menstrual Cycle". J. Auditory Res., 7, 373-385

Moller , A.R. (1961) "Bilateral Contraction of the Tympanic Muscle in Man". Ann. Otol. Rhinol. Laryngol. 70, 735 (as quoted by Beedle and Harford, 1973)

Newby (1965) Audiology. Vision Press.

Owens, F. (1964) "Tone Decay in VIII Nerve and Cochlear Lesion". J. Speech Hearing Dis. 29, 14-22 (as quoted by Jagadeesh, 1970)

Palva, T. (1952) "Finnish Speech Audiometry". Acta Oto-Laryngol. Suppl. 101. (as quoted by Supehler, 1955)

Perlman, H.B. (1960) "The Place of the Middle Ear Muscle Reflex in Auditory Research". Arch. Otolaryngol., 72, 201-206 (as quoted by Ross, S., 1968)

Peterson, J.L. and Liden, G. (1972) "Some Static Characteristics of Stapedial Muscle Reflex". J. Audiol. 11, 97-114

Pholman, A.G., and Kranz, F.W. (1924) “Binaural Minimum Audition in a Subject with Ranges of Deficient Acuity”. Proc. Soc. Expt. Biol., New York, 21, 335–337 (as quoted by Harris, 1952)

Portmann, M. (1973 “Testing for Recruitment by Electro Cochleo Graphy”. Ann. Otol. Rhinol. Laryngol. 82, 36

Reger, S.N. (1935) “Loudness Level Contours and Intensity Discrimination of Ears with Raised Thresholds”. J. Acoust Soc. Amer., 7, 73 (as quoted by Harris, 1952)

Reger, S.N. (1936) “Differences in Loudness Response of Normal and Hard of Hearing Ears at Intensity levels Slightly Above Threshold”. Ann. Otol. Rhinol. Laryngol. 45, 1029–1039 (as quoted by Katz, 1972)

Reisz, R.R. (1928) “Differential Intensity Sensitivity for Pure tones”. Phys. Rev., 31, 867–875 (as quoted by Stevens and Davis 1938)

Ross, S. (1968) “On the Relation between Acoustic Reflex and Loudness”. J. Acoust. Soc. Amer., 43, 468–479

Scharf, B. (1959) “Critical Bands and the Loudness of Complex Sounds Near Threshold”. J. Acoust. Soc. Amer., 31, 365–370 (as quoted by Simmons and Dixon, 1966)

Schukneckt, H.F. (1960) “Neural Mechanisms of the Auditory and Vestibular systems”. Rasmussen, G.L., and Windle, W.F. (Eds.) Springfield, III: Charles C. Thomas Publisher (as quoted by Simmons and Dixon, 1966)

Simmons, F.B., and Dixon, R.F. (1966) “Clinical Implications of Loudness Balancing”. Arch. Otolaryngol, 83, 67-72

Spencer-Harrison, M. (1968) “Audiological Aspects of Neuro-Otology”. J. Sound. Vol. 3/1, 61-67

Spuehler, H.E. (1955) “An Auditory Loudness Recruitment Test Battery: Analysis and Comparison of Sub Tests”. A Thesis Submitted to the Faculty of Purdue University

Steinberg, J.C. (1935) “The Function of the Apical turns of the Cochlea and the Symptoms of a Lesion in this Location. IV. Discussion from the point of view of the Physicist”. Trans. Amer Otol. Soc., 25, 131-135 (as quoted by Harris, 1952)

Steinberg, J.C. (1937) “Nerve Deafness of known Pathology or Etiology”. In symposium: The Neural Mechanism of Hearing. V. Etiological and Clinical Types of So-called Nerve Deafness”. Laryngoscope, 47, 603-611

Steinberg, J.C., and Gardner, M.B. (1940) “On the Auditory Significance of the term Hearing loss”. J. Acoust. Soc. Amer., 11, 270-277 (as quoted by Harris, 1952)

Stevens, S.S., and Davis, N. (1938) Hearing: Its Psychology and Physiology. New York: Wiley (p.113)

Swisher, L.P., Stephens, M.M., and Doehring, D.G. (1966) "The Effect of Hearing level and Normal Variability on Sensitivity to Intensity Change". J. Audioty Res. 6, 249 (as quoted by Blagvad, 1969)

Terkildsen, K. (1964) "Clinical Application of Impedance Measurements with a Fixed Frequency Technique". J. Int. Audiol. 3, 147-155 (as quoted by Jerger Ed. 1973)

Terkildsen, K. (1960) "An Evaluation of Perceptive Hearing losses in Children, based on Recruitment Determinations". Acta Oto-Laryngol., 51, 476-484 (as quoted by Jerger, Ed. 1973)

Thomsen, K.A. (1955) "The Metz Recruitment Test". Acta. Oto-Laryngol., 45, 544-552 (as quoted by Jerger Ed. 1973)

Tillman, T.W. (1969) "Special Hearing Tests in Otoneurologic Diagnosis". 89, 53. Arch. Otolaryngol.

Tumarkin, A. (1945) "A Contribution to the Theory of the Mechanism of the Auditory Apparatus". J. Laryngoscope. 60, 337-368

Veis, J. (1913) "Flustersprache und Konversationassprache in thren Beziehungen Zueinander". Arch. Ohrenheilk. 90, 200-211 (as quoted by Harris, 1952, p.7)

Vyasamurthy, M.H. (1972) "ABLB – A Test for Functional Hearing loss". J. AIISH, 3, 125

Vyasamurthy, M.H., and Sathyan, H.S. (1975) "Effect of Masking and Fatigue on Acoustic Reflex Threshold". Under Publication in J. AIISH

Vyasamurthy, M.N. (1975) – To be published

Watson (1944) – Not available

Wever, E.G. (1949) Theory of Hearing, New York: John Wiley & Sons, Inc. (as quoted by Simmons & Dixon, 1966)

Wilmot, T.J. (1968) "Auditory Analysis in some common Hearing Problems". J. Laryngol. Otol. 83, 521-527 (as quoted by Jerger, Ed. 1973)

World Health Organisation (1966) Noise: An Occupation Hazard and Public Nuisance. W.H.O. Chron., 20, 191-203 (as quoted by Hickling, 1967)

Young, I.M., and Harbert, F. (1967) "Significance of the SISI test". J. Auditory Res. 7, 303-311

Young, I.M. (1971) "Threshold of Aural Over-load in Abnormally Adapting Ears". J. Auditory Res., 11, 144-147

APPENDIX I – TABLE 1

The following table shows the noise level present in the testing room as compared to the Maximum Allowable Noise level proposed by ISO-1964.

Sl. No.	Freq./Scale	Maximum Allowable Noise Levels in dB_SPL (ISO)	Noise levels in the Testing Room "C" in dB-SPL
A.	C-Scale	30	30
B.	Octave-Bands		
1	75 -150 Hz	31	15.5
2	150 - 300 Hz	25	12.5
3	300 - 600 Hz	26	13
4	600 -1200 HZ	30	8
5	1200 - 2400 Hz	38	14
6	2400 - 4800 Hz	51	11
7	4800 - 9600 Hz	51	10.5

APPENDIX I – TABLE 2

The following table shows the noise level present in the testing room as compared to the Maximum Allowable Noise level proposed by ISO-1964. (Adopted from Hirschoran (1967) in "Hearing Measurement" – Ventry, Chaiklin & Dixon (eds) – 1970).

Sl. No.	Freq./Scale	Maximum Allowable Noise Levels in dB_SPL (ISO)	Noise levels in the Testing Room "A" in dB-SPL
A.	C-Scale	30	30
B.	Octave-Bands		
1	75 -150 Hz	31	18
2	150 – 300 Hz	25	17
3	300 – 600 Hz	26	15
4	600 -1200 HZ	30	9
5	1200 – 2400 Hz	38	11
6	2400 – 4800 Hz	51	10.5
7	4800 – 9600 Hz	51	10

APPENDIX II

A. <u>Procedure for obtaining acoustic reflex threshold</u>: (Madsen zo70)

The procedure given in the manual (Manual of Madsen Electroacoustic Impedance Bridge Model Zo 70 published by Madsen Electronics) is as follows:-

For this test the type TDH-39 earphone must be connected to an audiometer capable of producing at 100-110 dB above the threshold over the mid-range of puretone frequencies. Due allowance must be made for the fact that no reflex indication will be possible if the patient's hearing loss, plus the necessary stimulus level exceed the maximum output of the audiometer at the test frequency. For this reason only, the mid-range of frequencies should be employed for the stimulus, if the hearing loss is relatively large, the mid-range. frequencies of the audiometer being at the highest level. The middle ear pressures should be measured in advance.

Reasonably quiet conditions are desirable and the patient should be comfortably seated, relaxed and still during the measurements.

1) Set sensitivity and pump controls to zero.

2) Fit the head set with the audiometer earphone on the ear under investigation. Select a suitable ear tip and fit the probe into the other (indicator) ear. Check that the probe fitting is air-tight.

3) Adjust the pump control so that the Mano-meter reads middle ear pressure on the indicator ear.

4) Set sensitivity control to position 1 and adjust compliance control to obtain a zero reading on the Balance Meter. Increase the Balance Meter sensitivity progressively through sensitivity positions 2, 3 and 4 each time adjusting the compliance control to obtain a zero reading on the Balance Meter.

5) Adjust audiometer frequency to 1000 Hz (or as desired0 and the hearing loss control to 70 dB - check that the audiometer earphone in use is correctly switched.

6) Press the audiometer tone interruptor - pulses of 1-2 seconds are preferable - to give a stimulus to the ear under investigation and

observe whether the Balance Meter needle is deflected, if not advance the hearing loss control by 5 dB and progressively in 5 dB steps until the stimulus gives a clearly defined and repeatable compliance change AS indicated by the Balance Meter. The audiometer hearing loss control will then indicate the muscle reflex threshold.

APPENDIX II

B. Carhart’s Complete Tone Decay Test Procedure (1957)

After obtaining the subject’s threshold for an interrupted tone, he was instructed to raise his finger as long as he heard the tone and to lower it if the signal faded into inaudibility. A sustained tone below the established threshold was presented and increased in 5 dB steps, until the subject responded. As soon as the subject responded, the stop-watch was started. If the tone was heard for a full minute, the test was terminated. If the subject indicated that he no longer heard the tone before the 1 minute criterion was met, the intensity of the tone was raised by 5 dB without interrupting the tone. The stop watch was set back to zero. The intensity was raised in 5 dB steps as indicated until the subject heard the tone for a complete minute. Amount of tone decay was obtained by finding the difference between the hearing level at which the subject heard completely for 60 secs. and the pure tone threshold at that particular test frequency.

APPENDIX III

Table 1 – Test-Retest Reliability for TTS at 1 KHz and 2 KHz in 4 randomly selected subjects.

	1 KHz		2 KHz	
No.	Test	Retest	Test	Retest
1	60	60	55	50
2	55	55	60	50
3	55	60	55	50
4	55	65	50	50
Mean	56.25	60.00	55	50

Reliability Coef. value = 0.974 0.925

High reliability coef. value is obtained.

APPENDIX III

Table 2 - Test-Retest Reliability for Post Stimulatory Reflex TH at 1 KHz and 2 KHz in 4 randomly selected subjects.

	1 KHz		2 KHz	
No.	Test	Retest	Test	Retest
1	95	95	85	90
2	100	100	105	100
3	105	100	105	95
4	95	100	90	90
Mean	98.75	98.75	96.25	93.75

Reliability Coef. value = 0.998 0.983

High reliability coef. value is obtained.

APPENDIX III

Experiment II – Test-Retest Reliability

Table 3 – Absolute Thresholds and Reflex Thresholds at Frequencies 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz

	250 Hz		500 Hz		1000 Hz		2000 Hz		4000 Hz	
Sl.No.	AT	RT	AT	RT	AT	RT	AT	RT	AT	RT
1	60	80	50	90	40	95	60	85	50	95
2	40	80	50	75	55	85	65	90	45	100
3	50	90	50	85	55	85	40	75	–	–
4	55	85	50	100	60	95	55	90	–	–
5	40	90	65	90	55	85	–	–	–	–
Mean	49	85	53	88	53	89	55	85	47.5	97.5

Retest Scores

1	60	80	50	90	40	95	60	85	50	95
2	40	80	50	75	55	85	65	90	45	100
3	50	90	50	85	55	90	40	75		
4	55	85	50	100	60	95	55	90		
5	40	85	65	90	55	80	–	–		
Mean	49	85	53	88	52	89	55	85	47.5	97.5
Reliability Coefficient	1.994 1 1 .991 .994 1 1 1 1									

High Reliabiltiy Coefficient Value is obtained.

VERIFICATION OF THE HYPOTHESIS _ “RECRUITMETN IS AN ARTIFACT”

A Dissertation

Submitted to the University

of

MYSORE

by

R. RANGASAYEE

In Partial Fulfillment of the

Requirements for the Degree

of

Master of Science

in

Speech and Hearing

May, 1975