AN OBJECTIVE METHOD OF DETERMINING RECOVERY PERIOD AND ASYMPTOTIC PERIOD FROM LOUDNESS ADAPTATION

VIDYA HOSAKOTE

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CERTIFICATE

This is to certify that the dissertation entitled "AN OBJECTIVE METHOD OF DETERMINING RECOVERY PERIOD AND ASYMPTOTIC PERIOD FROM LOUDNESS ADAPTATION" is the bona fide work in part fulfillment for the degree of M.Sc. (Speech and Hearing) of the student with Register No.

Director
All India Institute
of Speech & Hearing
Mysore

CERTIFICATE

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

Guide

DECLARATION

This dissertation is the result of my own study undertaken under the guidance of Mr. M.N.Vyasamurthy, 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.

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Dr. SHailaja Nikam	-	Head, Audiology Dept., AIISH
Dr. J. Bharath Raj	-	Head, Psychology Dept., AIISH
Mr. S.S.Murthy	-	Lecturer in Electronics, AIISH
Mr. N.Raju	-	Electronics Engineer, AIISH
Mrs. Shakuntala Sharma	-	Research Officer, Central Institute of Indian Languages, Mysore
Mr. M.Jayaram	-	Research Fellow, Indian Institute of Science, Bangalore
Mr. M.S.Nagaraj	-	Department of Aeronautics, Indian Institute of Science, Bangalore
Mr. K.H.Radhakrishna	-	P.A. to Director, AIISH

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CHAPTER I

INDTRODUCTION

All sensory systems follow the general process of reduction in sensitivity following exposure to any stimulus of significant duration and intensity. This reduction in rate of discharge corresponds to the point when the sensory system has diminished in magnitude or is adapted.

"Adaptation" is a process by which the sensitivity of the sensory system is modified due to the continuous presentation of a stimulus at a constant level of sensitivity (Corso, 1967).

One of the sensory adaptation is the Auditory adaptation. Auditory adaptation is the change in the functional state of the auditory system brought by an acoustic stimulus or merely a reduction in apparent magnitude or an increase in the threshold (Elliot and Fraser, 1970).

Small (1963) operationally defines auditory adaptation as "shift in some aspect of the intensive dimension of subjective experience, often in the threshold brought about by previous stimulation of a sense organ by the same type of stimulus as used to determine the threshold”.

Perstimulatory auditory adaptation is a decrease in loudness of an auditory stimulus usually measured as a function of time. This phenomenon of loudness decrement is not immediately experienced on a casual listening. If a pure tone is presented to a listener continuously and at the end of few minutes, if the listener is asked if the stimulus sounds different than it did in the beginning, The listener will say “no, it sounds the same,” as the perceived loudness remains nearly unchanged.

This phenomenon of loudness decrement has been investigated and measured by a variety of techniques. Most investigators used a similar method to Hood (1950). a constant stimulus is presen-ted to the test ear (Mapting ear) and interrupted stimulus to the opposite ear (Comparison ear). In these methods the subject adjusts the interrupted stimulus to maintain a loudness balance between the stimuli. Egan (1955), Thwing (1955), Egan and Thwing (1955), Carterette (1955, 1966), Jerger (1957), Wright (1959), and Sergeant and Harris (1963) used procedures of Fixed inten-sity, while Hood (1950), Palva (1955) and Stokinger (1972) used Tracking method. Wright (1960) used method of Asymptotic locali-zation and Moving Phantom to measure maximum adaptation and Bekesy (1929), Egan and Thwing

(1955) and Flugel (1920) used method of Intensive and Phase localization to measure recovery from adaptation.

Ward (1973) has categorized the phenomena included under adaptation in two different ways: whether adaptation is observed during or after exposure to the acoustic stimulus – concomitant or residual and whether they require one ear – monaural or two, binaural for their measurement. Examples of these four categories are: Concomitant Monaural – Tone Decay test; Conco-mitant Binaural – Perstimulatory adaptation: Residual Monaural – Temporary threshold shift (TTS); Residual Binaural – Loudness reduction (ABLB test).

Need for the Study

Egan (1955a, b) Egan and Thwing (1955), Wright (1959), Palva (1955), Jerger (1957), Small and Minific (1961a) and Sergeant and Harris (1963) have used simultaneous dichotic loudness balance (SDLB) – Fixed, Tracking and Varied intensity to measure the course of loudness adaptation and recovery process. This method has certain drawbacks and procedurally little has done for the cross over when the stimulus exceeds 70 dB SPL. Stimulus manipulation for equal loudness judgement should reflect the actual loudness of the stimulus and should not be contaminated by interval loudness standards. When SDLB method is used it has been reported that the results are affected by binaural interaction effects.

To overcome these drawbacks in measuring loudness adap- tation, an objective method has been developed by Vyasamurthy (1977).

In this present study, recovery from adaptation is measured on similar lines as that of the objective method developed by Vyasamurthy (1977).

In this method., measurements are made after the ear has been exposed to the acoustic stimulus and it is measured using on eear – the same adapted ear. Measurements are made objectively using Electroacousdtic Impedance bridge (Madsen z072). It is believed that elicitation of the acoustic reflex is directly related to the loudness experience of an acoustic stimulus (Metz, 1952; Thomsen, 1955; Ewertsen, et al, 1958; Terkildsen, 1960; Moller, 1961; Terkildsen, 1964; Lamb, Petersan and Hansen, 1968; Djupesland, Flottorp and Winther, 1970; Jerger, 1970; Flottorp, et al, 1971; Alberti and Kristensen, 1972; Petersan and Lidney, 1972; Fitzaland and Borton, 1974; Vyasamurthy, 1975; and Rangasayee, 1975).

Based on this belief, Vyasamurthy (1977) in his paper reports:

> “. . .difference in the magnitude of the reflex beween pre-adapted stimulus and post-adapted stimulus at equal intensity levels is considered as a measure of loudness adaptation i.e. the amount of loudness adaptation in decibels is the difference between the intensity of the post-adapted stimulus and the intensity of the pre-adapted stimulus which produces the same magnitude of reflex as that of the post-adapted stimulus. This way, loudness adaptation is measured in decibels objectively. Loudness adaptation measured in this manner may be termed as ‘objective residual monaural loudness adaptation’.”

Marglois and Popelkar (1975) have observed that there is no close relation between loudness and acoustic reflex. But, Vyasamurthy (1977) has reported that it may be true that the relation between acoustic reflex and loudness of a stimulus is not a simple one, the relation appears to be complex. However, it may not be wrong to assume that whatever relation exists prior to adaptation, the same relation continues to exist even after the ear is adapted.

With this understanding a method has been developed to measure the recovery from loudness adaptation objectively.

This study aims at measuring recovery from adaptation (objective residual monaural loudness adaptation) by means of an objective method using Electroacoustic impedance bridge (Madsen Z072). Further, using this method, asymptotic period for 1000 Hz tone at acoustic reflex threshold or ± 5 dB acoustic reflex threshold of the normal hearing subjects has been determined.

Brief Plan of the Study

Three experiments were conducted to measure recovery from adaptation for pure tones.

Experiment I

The phone ear was adapted for 3 minutes at 20 dB above acoustic reflex threshold (ART) of the normal hearing subjects at one of the frequencies (500 Hz, 1000 Hz and 2000 Hz). Recovery time was measured at the adapted frequency.

Experiment II

The phone ear was adapted for 3 minutes at 20 dB above the acoustic reflex threshold (ART) of the normal hearing subjects at one of the frequencies (500 Hz, 1000 Hz and 2000Hz). Recovery time was measured at one octave higher than the adapted frequency.

Experiment III

The phone ear was adapted at 1000 Hz for different duration of exposure (3 minutes, 5 minutes, 7 minutes, 9 minutes, 11 minutes and 13 minutes) at acoustic reflex threshold

(ART) or ± 5 dB acoustic reflex threshold of the normal hearing subjects. Complete recovery time was determined in each case.

Limitation

As the present study is an original study, not reported anywhere, selection of suitable subjects for the study and repeated tests to arrive at suitable levels of exposure took a considerable part or time. so, more number of subjects could not be tested.

Implication

At present, there is not satisfactory method available for measuring recovery from loudness adaptation. The present method appears to be a promising technique for the measurement of recovery time from objective residual monaural loudness adaptation. It is hoped that the present method would be a starting point for further research in the field of adaptation.

Definitions

Concomitant Binaural

A Shift in the lateralization of a diotic tone following a period of monotic adaptation to a steady sound (Ward, 1973).

Residual Binaural

Refers to adaptation observed after exposure to the acoustic stimulus and measured using both the ears (adapted and unadapted). For example, ABLB test (Alternate binaural loudness balance).

Concomitant Monaural

Refers to adaptation measured during the process of adaptation and measured using the same adapted ear (unadapted ear is not made use of for measuring adaptation). Example: Tone decay test (Carhart, 1957; Rosenberg, 1958; and Green, 1963).

Residual Monaural

Refers to post stimulatory shift in threshold. Example: Temporary threshold shift (TTS)

Objective Residual Monaural Loudness Adaptation

The amount of loudness adaptation in decibels is the difference between the intensity of the post adapted stimulus and the intensity of the pre adapted stimulus which produces the same magnitude of reflex as that of the post adapted stimulus (Vyasamurthy, 1977).

Recovery Time

Recovery time is the interval between the cessation of the adapting stimulus and the introduction of the same stimulus at acoustic reflex threshold at which BM needle deflection is as same as the deflection of the BM needle before adaptation.

CHAPTER II

REVIEW OF LITERATURE

Adaptation and fatigue are the resultant of continuous acoustic stimulation of the auditory system. They have been termed differently as the physiology of adaptation is quite different from the physiology of fatigue. At one time these two phenomena were thought to be similar, now the similarity appears to be superficial for the relation between the two is limited, to the fact that both phenomena lead to the threshold displacement and a concomitant loudness change. This loudness decrement is termed auditory adaptation or perstimulatory auditory fatigue; and the temporary threshold shift (TTS) has been referred to as auditory fatigue or post stimulatory auditory fatigue.

Elliott and Fraser (1970) have quoted many of the studies of how the auditory system handles continuous signals. During the process of continuous stimulation of the auditory system, functional changes will take place at the hair cells, endolymph, and the neural discharge. These changes are:

Neural changes

Reduction in neural responsiveness occurs when a continuous auditory stimuli is presented and the neural response rate decreases rapidly until after about three minutes, a stable level is reached. Cessation of the stimulus, neural discharge rates rapidly increase and reach their original level within one minute (Derbyshire and Davis, 1935).

Hair Cell changes

When moderate or high intensity is presented continuously, decrease in cochlear microphonics (CM) occurs in the form of shift in linear portion of Input-Output curve an also reduction in the level of the maximum CM, with some sharpening of the peak of the Input-output curve (Wever and Smith, 1944; Wever and Lawrence, 1955; Shimuzu et al, 1957; and Gisselsson and Srenson, 1959).

Endolymphatic changes

Continuous stimulation produces reduction in oxygen and decrease in endolymphatic do potential (Bekesy, 1951; Tonndorf and Brogan, 1952). It is quite possible that these changes are related (Misrahy, et al., 1958a). There will be reduction in CM and Action potential (AP) also due to the reduction in oxygen in endolymph. if this continuous stimulation continues, there will be accumulation of metabolic waste product and interfere with nerve cell responses (Butler, et al., 1962).

Although both these phenomena reflect different changes in the auditory system, sensitivity decrement are measured at the threshold. TO show that these phenomena reflect different physiological changes evidences are available from the psychophysical data.

Adaptation to low or moderate stimuli levels is usually completely developed within 3 minutes, recovery is usually complete within one or two minutes. These results are similar to those observed by Derbyshire and Davis (1935) which suggest that adaptation is defined by loudness balance test results from neural adaptation (Hood, 1950), while TTS may continue to increase for much longer periods of time. The rate and extent of the change are generally proportional to the intensity and duration of the fatiguing stimulus. Recovery time is propor- tional to the size of the initial TTS and may require several hours or even days before it is complete. This Clearly indicates that the difference in time of development and recovery alone conclude that the different measures reflect different physhio-logical process.

Adaptation is less near threshold but increase at higher intensities (Hood, 1950; and Egan, 1955), while fatigue enhances loudness growth which is the result of hair cell dysfunction (Davis, et al., 1950; and Beksey 1960).

Corso (1967) described adaptation as short duration auditory fatigue in which the threshold shift is produced by relatively weak and brief stimuli and is of short duration and auditory fatigue which arises from more intense stimulation and is of larger duration.

Harris and Rawnsley (1953) have said adaptation to be a special pheonomenon of fatigue. They differentiate adaptation and fatigue as follows: (1) In adaptation, the duration of stim- ulation does not have a cumulative effect on threshold upto 10 sec., while in fatigue the effect of duration are cumulative from 30 sec. to 10 min.; (2) The recovery curve for adaptation is a straight line, Whereas the temporal course of recovery of threshold from fatigue is negatively accelerated; and (3) In adaptation, the maximal threshold shift occurs at the stimulus frequency, but in fatigue, the maximal effect may lie a half octave higher.

Adaptation is categorised in two different ways by Ward (1973); whether the phenomena included under adaptation are observed during or after exposure to the acoustic stimulus is Concomitant or Residual and Whether one ear is required, Monaural or two ears, Binaural for their measurement. Example for each of these categories are - Concomitant Monaural – Tone Decay test, Concomitant Binaural – Perstimulatory adaptation, Residual Binaural – Loudness reduction – ABLB test, and Residual Monaural – Temproray threshold shift (TTS)

Many techniques have been developed for measuring adaptat-ion in its development, asymptotic state, and recovery.

Most frequently used technique to measure all aspects of adaptation is the simulataneous dichotic loudness balance (SDLB). Variation have been developed within the framework of this method. Hood (1950), Palva (1955) and Small and Minifie (1961) used tracking method. Egan (1955a, b), Egan and Thwing (1955), Jerger (1957), Wright (1959), and Sergant and Harris (1963) used method of fixed intensity. Carterette (1955), Thwing (1955) and Egan and Thwing (1955) used modified method in which the stimulus in the adapted ear was varied during the preadapt- ing balance but kept constant during the adapting segment of the test run.

In these above methods, the experimental paradigm for meas- uring adaptation is: ear that is adapted to a sustained sound is called the experimental or adapting ear, while the ear used to estimate the amount of adaptation is called the control or the comparison ear. Acoustic signal to the adapting ear is called the adapting stimulus and the acoustic signal to the contralateral control ear is called the comparison stimulus. The experiment is divided into three successive periods called a test run. The unadapted level for adapting ear is established during the first period by matching the comparison stimulus to the adapting stimulus. The course of adaptation is measured during the second or adapting period, while recovery is measured during the third or the final period of a test run.

When SDLB is used to measured adaptation, it is reported that results are varied of each investigator. Some of these mea-suring problems have been overcome by means of an objective method developed by Vyasamurthy (1977). In this method. measurements are made using one ear – the same adapted eaer, by means of Madson Electroacoustic Impedance bridge (z072). Similar to the method of loudness judgement procedure, this method also has three successive test runs, the measurement of the unadapted level, the adapting period and measurement of recovery time. Loudness adaptation measured by this method is objective resi-dual monaural loudness adaptation.

Maximum adaption or asymptotic state of adaptation is dependent on the intensity and duration of the acoustic stimulus, frequency dependency being negligible. Hood (1950) reported that maximum adaptation is reached within 3 to 3.5 min. regardless of the intensity or frequency of the adapting stimuli. Jerger (1957) supported this study only for intensities up to 60 dB and frequencies up to 1000 Hz. Asymp-totic state is delayed between 5 and 7 minutes, if the adapting stimulus is of high intensity.

Cartertte (1956), in his original article reported that adaptation was still increasing at seven minutes when the intensity of the adapting stimulus was 90 dB SPL. The method used to measure maximum adaptation was SDLB (varied intensity). The subjects attenuator dial was kept at infinite attenuation until a balance was made, the noise in the unadapted ear always grew from zero loudness or from a barely audible level. He measured the degree of adaptation by subtracting the mean attenuation required for the preadaptation balance from that required to make a balance during adaptation.

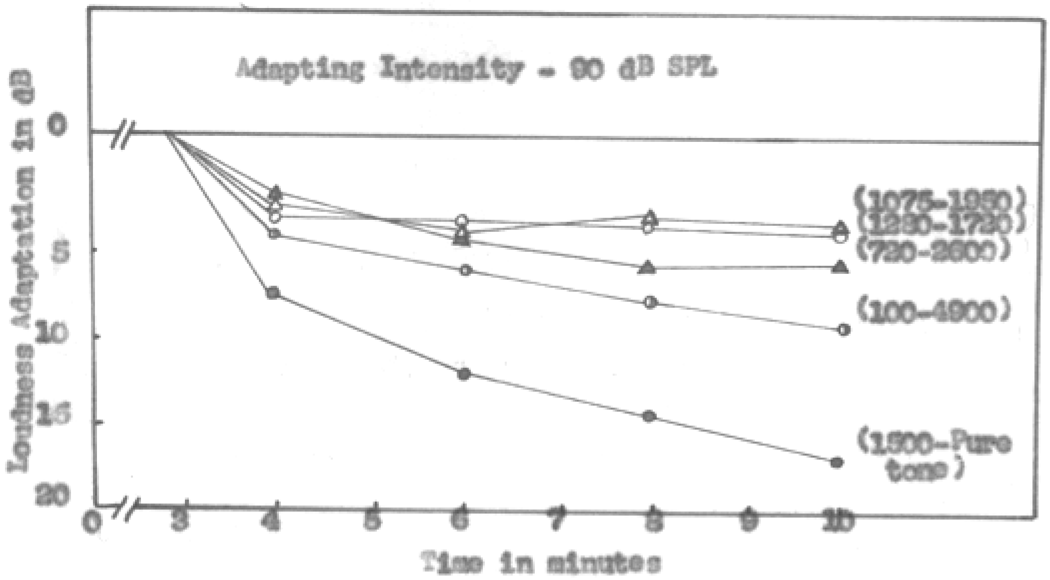
In his earlier paper, Carterette (1955) had reported that fatigue (adaptation) was an increasing function of the intensity of the noise and for a fixed intensity. The adaptation was directly proportional to the rate of interruption. As this study was done with few subjects. this present study was reported with 36 subjects.

In his study, Carterette (1956) had two experiments on loudness balance for bands of noise. The first experiment was conducted using 36 subjects. Loudness adaptation for wide band thermal noise of 100-1000 Hz was studied as a function of five SPL’s: 40, 70, 90, 100 and 105 dB over all, and in the second experiment, 12 subjects were chosen. The loudness adaptation for a 1500 Hz tone was compared with bands of noise whose centers were at 1500 Hz, and whose overall SPL’s were equal to the SPL of the pure tone. For each band adaptation was measured at 50, 70, and 90 dB SPL.

Results show that adaptation were negatively accelerated with about half the maximum adaptation occurring at the first 90 sec. Adaptation resulting from 1500 Hz adapting stimulus increases from 50 dB to 70 dB but not from 70 dB to 90 dB. Asymptotic level is reached only after continuous stimulation for 5 minutes and adap-tation increases as adapting stimulus increases 90 dB SPL and that maximum adaptation is not reached within 3 minutes, as it depends on the intensity of the stimulus (Fig. 1).

The extent to which the perstimulatory adapttion induced by a pure tone spreads to the neighbouring frequencies has been reported by Thwing (1955). He measured adaptation by series of SDLB prior, during and subsequent to stimulation by a adapting stimulus of 1000 Hz at SPL of 80 dB. Ten subjects were chosen for the experiment. Nine test frequencies were selected to form

Figure 1



Temporal course of adaptation as duration of adapting stimulus

the frequency gradient. Upward gradient was above 1000 Hz, i.e., 1000, 1200, 1600 and 2000 Hz and down gradient was below 1000 Hz, i.e., 100, 300, 600, 800, and 1000 Hz. For measuring adaptation at a frequency other than of the adapting tone, the adapting stimulus which was on for 1, 3, 5 and 7 minutes was turned off for 15 sec. interval to make a balance at the frequency of the test tone.

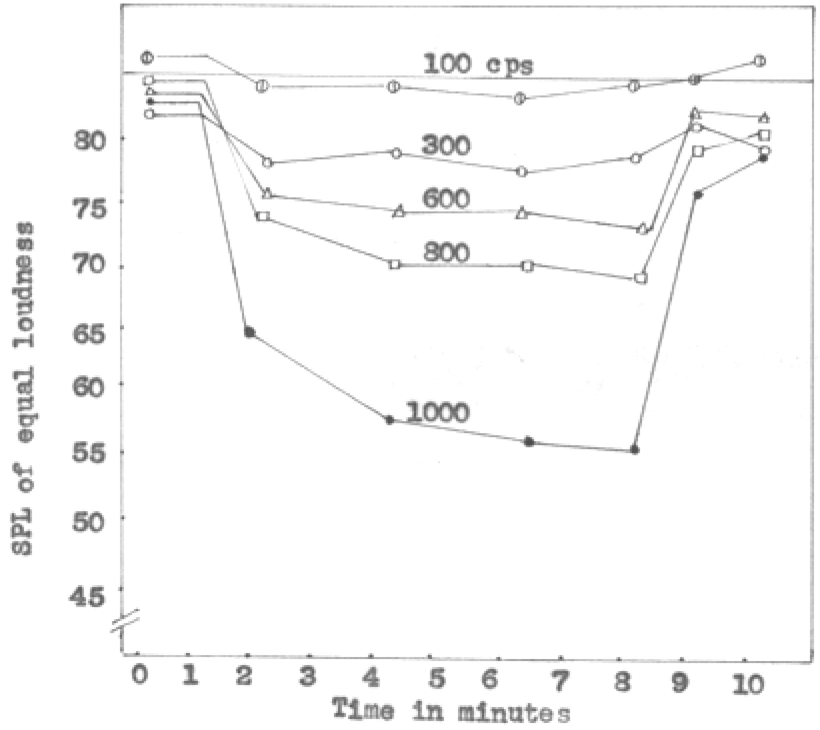
Thwing concluded that maximum adaptation was produced at the frequency of the adapting stimulus. Greater the magnitude of fatigue the longer it takes for it to reach maximum adaptation. Frequencies 100 and 2500 Hz have reached maximum within the first minute after the onset of the adapting stimulus, while at the other extreme, maximum adaptation is not reached even after 3 or more minutes after the onset of the adapting stimulus. Maximum adaptation is contributed at the adapting frequency. (Figures 2, 3 and 4).

Egan (1955a), Thwing (1955) and Wright (1959) have used the method of SDLB to measure recovery from adaptation. They first used the method of fixed intensity to determine the course of adaptation and later traced the recovery process by presenting a stimulus for every 10 sec. to 20 sec. following cessation of the adapting stimulus.

Wright (1959) has measured the initial rate, the asymptotic level and recovery from adaptation in the presence of and absence of noise in 10 normal hearing subjects, by the method of fixed intensity at 250, 1000 and 4000 Hz.

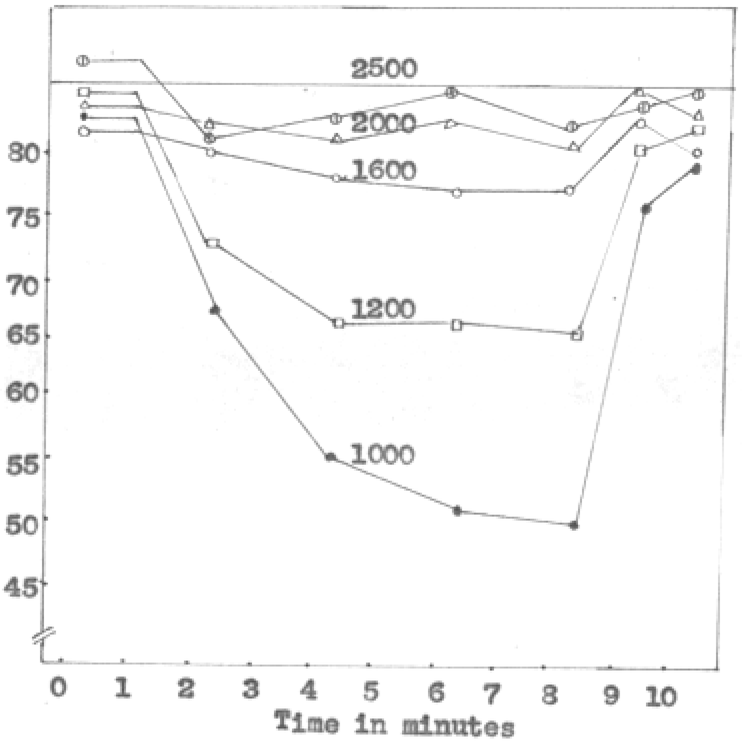
In the first part of the experiment, the unadapted level was established; second part was the adapting period, i.e., the ear was stimulated continuously at the experiment ear for 7 minutes. The recovery period was measured after

Figure 2



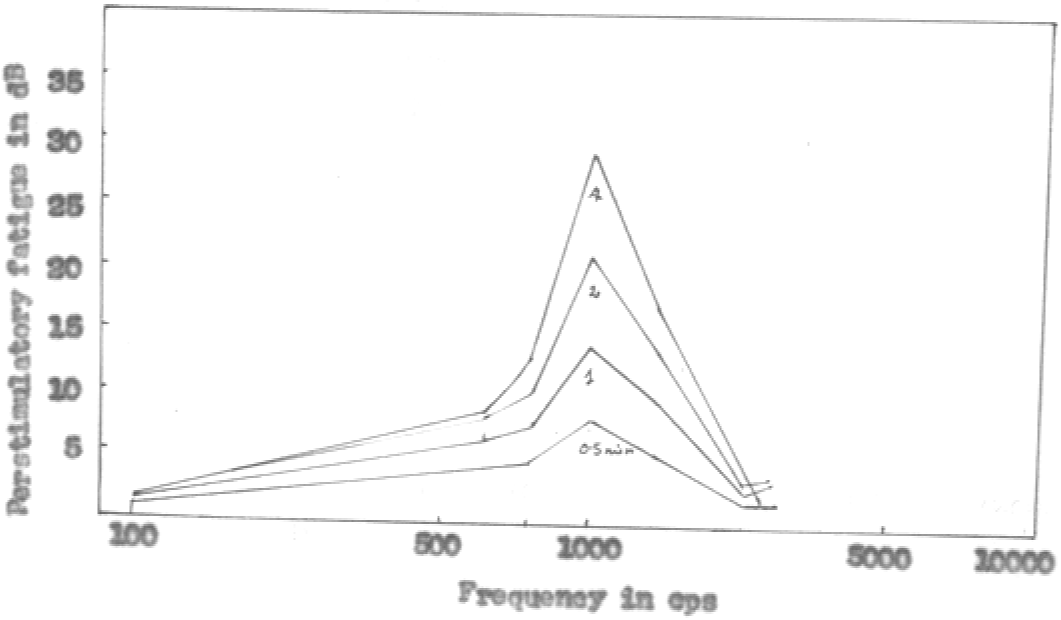
Temporal course of development and re-
covery from perstimulatory fatigue
(1000 cps 80 dB SPL) - Down gradient
of perstimulatory fatigue

Figure 3



Temporal course of development and re-
covery from perstimulatory fatigue
(1000 cps 80 dB SPL) - Upward gradient
of perstimulatory fatigue

Figure 4



Spread of perstimulatory fatigue of a pure tone (1000 Hz, 80 dB SPL) to neighbouring frequencies with duration of fatiguing stimulus as the parameter

the sustained stimulus was removed, i.e., the residual amount of adaptation was measured till the 3rd minute after the adapting stimulus was removed.

The initial rate and asymptotic level of adaptation were measured during the adaption period. The initial rate of adaptation was defined as the “amount of adaptation at the first minute”. The asymptotic level was defined as the “mean adaptation at the 5, 6 and 7 minutes of the adapting period, a region in which the adaptation curves were essentially constant”.

Results show that, by the introduction of noise, its initial rate and asymptotic level of adaptation to tones is excessive at 4000 Hz, but not at 250 or 1000 Hz. Recovery from adaptation was not complete for any of the experimental condition at any frequency.

Summarising the results regarding recovery from adaptation, Egan reported recovery at first minute of about 70%, Thwing reported 80%, and Wright 75%. Interesting aspect of the data is that, regard-less of the extent of adaptation at asymptotic, a similar propo-ration of recovery takes places in the first minute.

Bekesy (1960), using 0.2 sec. stimulus duration reported that 80% of the recovery occurred during the first 5 sec., and almost complete recovery occurred within 10 sec., as the initial level of adaptation was low (15 dB), the results were not generalized. Recovery from high intensity adaptation was not reported.

Elliott and Fraser (1970) comment that more work needs to be done before definitive statements can be made about recovery from adaptation.

The above review of literature gives us an idea for further research on this topic of adaptation. Detailed investigations on the recovery of adaptation using an appropriate method are warranted at present.

In the present study, recovery from loudness adaptation is measured using an objective method. However, this method is not free the major problem of restimulation of the adapted ear. The uniquecess of this method of measuring recovery from adaptation objectively should be considered.

CHAPTER III

METHODOLOGY

The study consists of three experiments.

Experiment I

To determine recovery time from adaptation when adapted at the adapting frequency.

Experiment II

To determine recovery time from adaptation one octave higher than the adapting frequency.

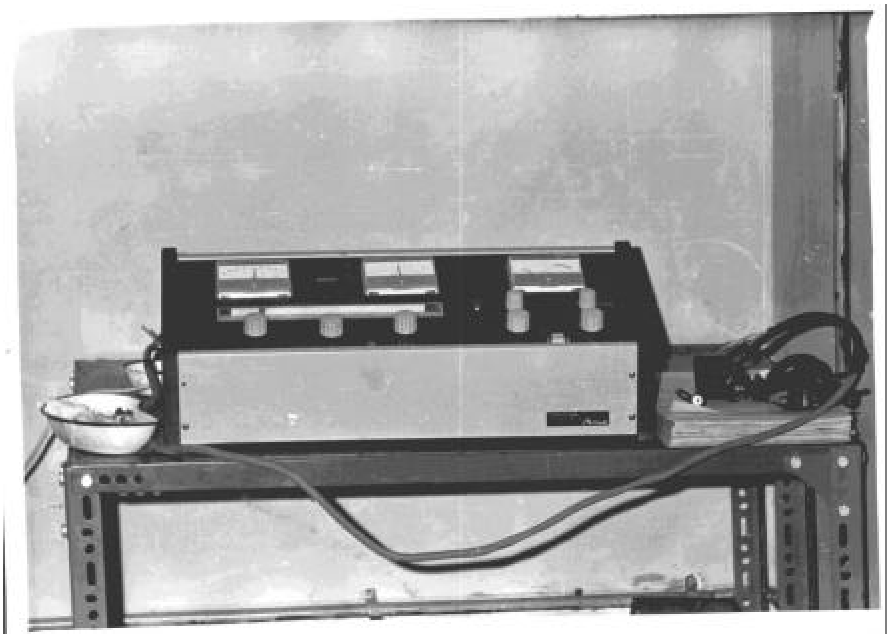
Experiment III

To determine asymptotic state of adaptation at the adapting frequency and at a particular level by means of recovery time.

The stimuli used in all the three experiments were pure tone.

Equipment

All the three experiments were conducted using the same –



ELECTRO ACOUSTIC IMPEDENCE BRIDGE – Z072

Electroacoustic Impedance bridge (Madsen z072).

Pure tone Audimetric results were obtained using a calibrated Madsen Audimeter with TDH 39 and bone vibrator X 120.

Acoustic Reflex Thresholds (ART) for pure tone and tympanograms were obtained using Electroacoustic impedance bridge z072. For description of the instrument see Appendix

A stop watch with two divisions for each second was used (Anglo Swiss and Company).

Calibration

The output (pure tone) of Telex earphone with Mx_41/AR cushion of Z072 Impedance bridge was checked using the artificial ear Bruel and Kjaer (B & K) No.4152, condensor microphone (B & K) No.4144 attached to a sound pressure level meter (B & K 2203). Probe tone (220 Hz) of the bridge was calibrated for 85 dB SPL by using (B & K) sound pressure level meter (2203) attached to a 2cc soupler with 4144 (B&K) condensor microphone. Frequency of 220 Hz and the pure tones were checked by using 205 Timer/Counter Eastern Elecgtronics. Balance meter, cavity scale, sensitivity and pump were calibrated according to the procedure even by the manual of the z072 Impedance bridge.

Test Environment

Impedance Audiometer findings: Reflex thresholds, Middle ear pressure and Tympanograms were determined in the Electronics Laboratory of the All India Institute of Speech and Hearing after the regular working hours. Average ambient noise level of the test room was 46 dB SPL as measured on the ‘C’ net work of Sound Level Meter (B&K) No.2203 and Condensor Microphone (B&K) No.4144.

Pure tone Audiometric results were obtained in one of the sound treated rooms of the All India Institute of Speech and Hearing.

Experiment I

Six subjects in the age range of 18 to 26 years were chosen randomly. The student were chosen on the basis of the following criteria.

1. No previous history of ear surgery or active ear pathology.
2. Bilateral normal hearing, thresholds not poorer than 25 dB HTL (ANSI 1971) at octave frequencies 250 through 8000 Hz.

3. Normal Acoustic reflex threshold (ART) bilaterally for pure tones (Acoustic reflex threshold within 70 dB to 80 dB above absolute thresholds for pure tones).

4. Normal middle ear pressure 0 to 20 mm of water present bilaterally.

5. Normal tympanograms present bilaterally, the range of maximum compliance is within 0 to 5.5 of Balance meter (BM) reading.

6. Normal static compliance present bilaterally within 0.4 cc to 1.0 cc.

7. Subjects who exhibited recovery from adaptation within 5 minutes for the adapting stimulus of 500, 1000 and 2000 Hz tone when presented for 3 minutes at 20 dB above the reflex threshold of the subject. The duration of exposure and the level of exposure were chosen after the pilot study.

8. Subjects who were not exposed to noise levels exceeding damage Risk Criteria (DRC) before or during the study.

The experiment was conducted in two stages.

Stage I - Procedure to measure the acoustic reflex threshold at 500, 1000 and 2000 Hz.

Stage II - Procedure to determine the recovery time at 500, 1000 and 2000 Hz (at the adapted frequency).

Stage I

To measure acoustic reflex threshold at one of the frequencies (500, 1000 and 2000 Hz), the following steps were adopted.

1. The sensitivity and pump control were set to zero.

2. A suitable ear tip, for the subject was fitted to the probe and the air tight sealing was obtained.

3. The pump control was adjusted till the monometer read the middle ear pressure

4. Sensitivity control was set to position 1 and the compliance control was adjusted to obtain a zero reading on the Balance Meter. The Balance Meter sensitivity was increased through sensitivity positions 2 and 3 and each time the compliance control was adjusted to obtain a zero reading on the Balance Meter.

5. The frequency was set at one of the frequencies (500, 1000 and 2000 Hz). The pure tone stimulus was presented for every 10th second and the duration of the tone was 1.5 sec. If there was no detectable Balance Meter needle deflection, the intensity control was increased by 5 dB and progressively in 5 dB steps, till the stimulus gave a clearly defined and repeated compliance changes, as indicated by the Balance Meter. Thus, the minimum level (Dial reading) at which there was consistent deflection of Balance Meter needle was considered as the ART. The displacement of BM needle at the ART was noted for each of the frequencies (500, 1000 and 2000 Hz).

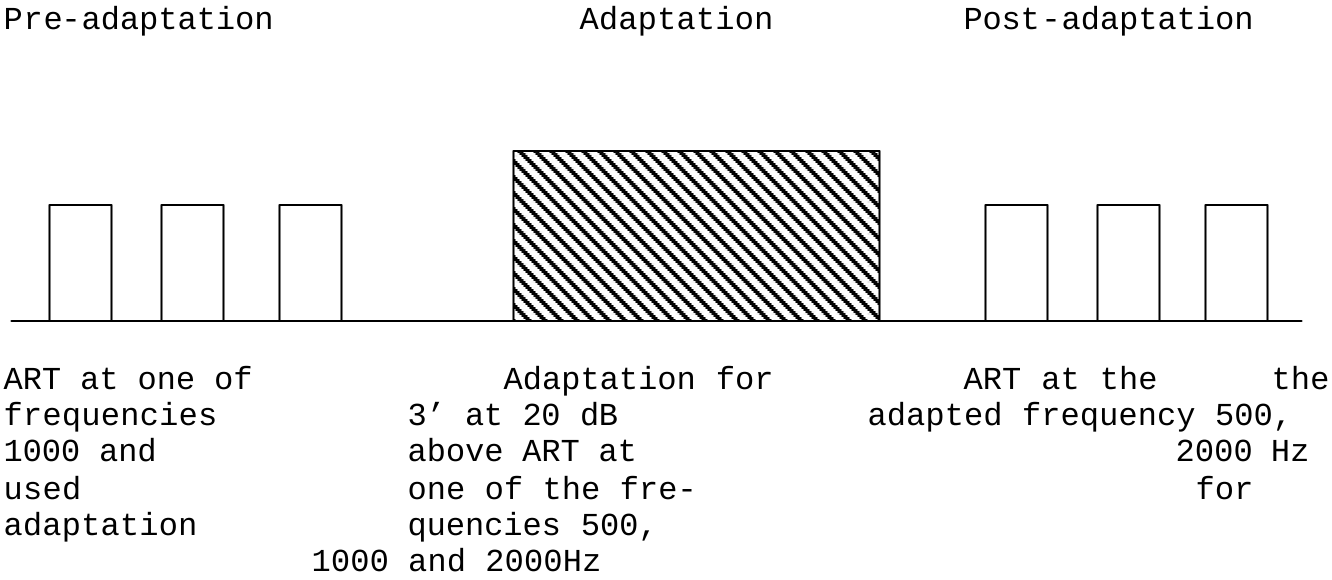
Stage II

To measure recovery time for anyone of the frequencies 500, 1000 and 2000 Hz.

The phone ear was adapted for 3 min. at one of the frequencies (500, 1000 and 2000 Hz). Recovery time was determined at the adapted frequency as in Stage I.

Recovery time is the time taken to get the same magnitude of acoustic reflex for the same intensity of the stimulus after the ear was adapted with the adapting stimulus (either at 500, 1000 or 2000 Hz), the same stimulus (adapted frequency) was presented at ART, at intervals of 10 sec. until the BM needle deflection was as same as the pre adapted ART.

Recovery time is the interval between the cessation of the adapting stimulus and the introduction of the same stimulus at acoustic reflex threshold at which BM needle deflection is as same as the defelction of the BM needle before adaptation.



Ten subjects were tested at a frequency of 2000 Hz and, two subjects at each frequency were tested. The same experiment was repeated on different days to check the reliability of the results. A minimum of six sessions were required to complete the testing. with a minimum of 24 to 48 hours of rest period.

Experiment II

Six subjects (five females and one male) in the age range of 18 to 23 years (Mean age 19.6) were randomly chosen. The subjects were chosen on the basis similar to that of Experiment I.

Test Procedure

Stage I - To measure ART at 500, 1000 and 2000 Hz.

Stage II - To determine recovery time one octave higher than the adapting stimulus frequency.

Stage I

To measure the ART at one of these pairs of frequencies (500 – 1000 Hz, 1000 – 2000 Hz and 2000 – 4000 Hz), the procedure as given in Experiment I – Stage I – Was followed till the 4th step. The 5th step was as follows:

> The frequency was set to 500 Hz and the intensity control was adjusted to 70 dB HL. The pure tone stimulus was presented for every 10th sec. and the duration of the tone was for 1.5 sec. If there was no detectable BM needle deflection, the intensity control was increased by 5 dB and progressively in 5 dB steps till the stimulus gave a clearly defined deflection of the BM needle. The minimal intensity level (dial reading) which produced consistently noticeable deflection at the

BM needle was considered as the ART of the phone ear (the BM needle displacement was noted). In the same manner ART for 1000 Hz tone was also measured and the displacement of BM needle for 1000 Hz tone was noted. Thus, BM needle deflection for the remaining frequencies, 2000 Hz and 4000 Hz at ART were noted.

Stage II

To measure recovery time at one octave higher than the adapting frequencies, the phone ear was adapted for 3 min. at one octave lower than the adapting frequency (500 – 1000Hz), 1000 – 2000 Hz) and (2000 – 4000 Hz) at 20 dB above the ART. for example, if the ear was adapted at 500 Hz, the recovery time was measured at 1000 Hz. The recovery time was measured s in Stage I.

Recovery time is the time taken to get the same magnitude of ART for the same intensity of the stimulus (1000 Hz) after the ear was adapted with the adapting stimulus (500 Hz), the octave frequency stimulus (1000 Hz) was presented at ART at intervals of 10 sec. until the BM needle deflection was as same as the pre adapted ART (1000Hz).

Recovery time is the interval between the cessation of the adapting stimulus and the introduction of the stimulus (octave frequency) at ART at which BM needle deflection is as same as the deflection of the BM needle before adaptation.

Two subjects at each of the above mentioned pair of frequencies were tested. The same experiment was repeated on different days to check the reliability of the results. A minimum of six sessions were necessary to complete the testing. with a minimum of 24 to 48 hours of rest period.

Experiment III

Nine subjects in the age range of 17 to 21 years (Mean age 19.2) were randomly selected. Out of nine subjects only five subjects satisfied the criteria used for this study. Criteria for choosing the subjects were same as those of Experiment I and an additional criterion was followed for this experiment. That was:

Subjects who exhibited recovery from adaptation within 5 minutes for the adapting stimulus of 1000 Hz tone when presented for 7 minutes continuously at or ± dB of ART of the subject. Subjects were selected after the pilot study.

The experiment was conducted in two stages.

Stage I - To measure the ART at 1000 Hz.

Stage II - To determine the recovery time for different durations of exposure, viz., 5 min., 7 min., 9 min., 11 min., and 13 min

Stage I

The ART at 1000 Hz tone was measured as in Experiment I – Stage I.

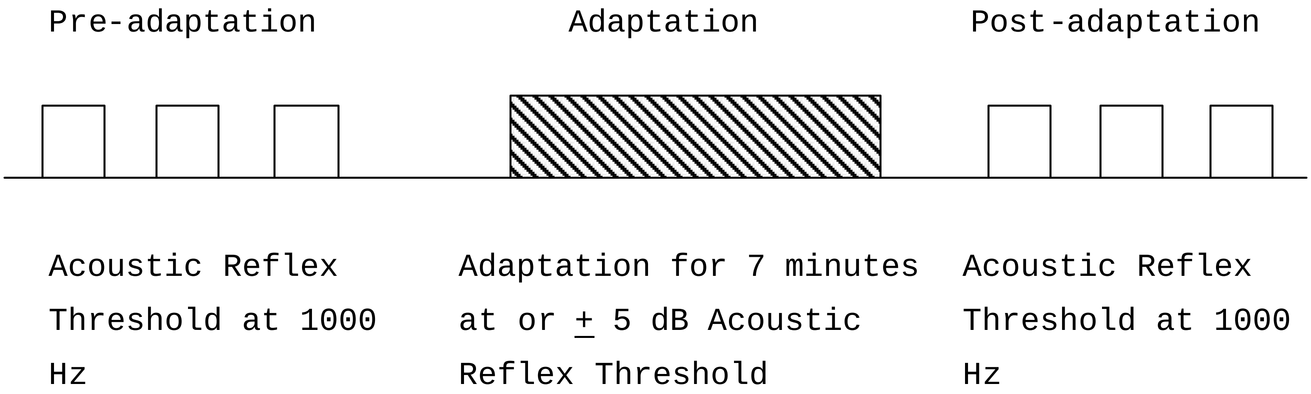
Stage II

To determine the recovery time, the following steps were adapted.

At the ART for 1000 Hz tone, the phone ear was adapted for seven minutes and the recovery time was measured as in Experiment I – Stage I.

Recovery time is the time taken to get the same magnitude of acoustic reflex for the same intensity of the stimulus after the ear was adapted with the adapting stimulus (1000 Hz), the same stimulus (1000 Hz) was presented at ART at intervals of 10 seconds until the BM needle deflection was as same as the pre-adapted ART.

Recovery time is the interval between the cessation of the adapting stimulus and the introduction of the same stimulus at ART at which BM needle deflection is as same as the deflection of the BM needle before adaptation.



For the measurement of Recovery time and for the selection of adapting level a minimum of three days were required.

After the adapting level was determined for each subject, the same phone ear was adapted for 9 minutes, 11 minutes and 13 minutes. The same experiment (finding recovery time for 9 minutes, 11 minutes and 13 minutes exposure separately) was repeated on different days to check the reliability of the results. To determine whether the ear reached a steady state of adaptation.

(asymptotic state), the recovery periods were also measured for 3 minutes and 5 minutes of exposure time.

To complete the experiment for each subject, a minimum of 15 messions were required and a minimum rest period of 24 to 48 hours. Test Retest reliability was found using product Movement Coefficient of Correlation.

CHAPTER IV

RESULTS AND DISCUSSION

Results of the Experiment I are given in Table I. The mean values of recovery time at the frequencies are: no adaptation at 500 Hz, 86 sec. at 1000 Hz and 80.5 sec. at 2000 Hz. Ten more subjects were tested at 2000 Hz and the mean recovery time (Table I-a) was 108.9 sec., ranging from 58.5 sec. to 193 sec. The results indicated that there is wide variation in the recovery time aming individuals. Test-retest reliability was established on all the ten subjects. Reliability was statistically computed using Product Movement coefficient of Correlation.

Experiment I led to the Second experiment. In Experiment II, recovery time was measured at one octave higher than the adapting frequency. This was done to see whether the recovery time is longer when measured at a frequency one octave higher than the adapting frequency. Results of this experiment are given in Table II. Recovery time increased progressively from 1000 Hz to 4000 Hz. The mean recovery time at each of these three frequencies are 18.5 sec. at 1000 Hz, 52.5 sec. at 2000 Hz and 230 sec. at 4000 Hz. Results of these two Experiments I and II

Table I – Showing the Mean Recovery Time when measured at the Adapted Frequency (500 Hz, 1000 Hz and 2000 Hz) N=6

Serial Number	Adapting Frequency in Hz	Test Frequency in Hz	ART dB HL	Presentation level for 3 minutes (20 dB ART)	Recovery Time in seconds	Mean Recovery Time in seconds
1	500	500	95 (2)	115	No adaptation	--
2	500	500	90 (1½)	110	-do-	--
3	1000	1000	95 (3)	115	90	86.0
4	1000	1000	115 (1½)	125	82	
5	2000	2000	95 (5)	115	69	80.5
6	2000	2000	95 (2½)	115	92	

Note : Figures in parentheses indicate BM needle deflection.

Table I-a – Showing the Mean Recovery Time when measured at the Adapted Frequency (2000 Hz) N=10

Serial Number	Adapting Frequency in Hz	Test Frequency in Hz	ART dB HL	Presentation level for 3 minutes (20 dB ART)	Recovery Time in seconds	Mean Recovery Time in seconds
1 (a)	2000	2000	100 (1½)	120	128	
(b)	2000	2000	100 (1½)	120	152	140.0
2 (a)	2000	2000	90 (1)	110	180	
(b)	2000	2000	90 (1)	110	192	186.0
3 (a)	2000	2000	90 (1)	110	92	
(b)	2000	2000	90 (1)	110	51	71.5
4 (a)	2000	2000	85 (1½)	105	111	
(b)	2000	2000	85 (½)	105	106	108.5
5 (a)	2000	2000	95 (2)	115	79	
(b)	2000	2000	95 (½)	115	70	74.5

Table I-a – contd.

Serial Number	Adapting Frequency in Hz	Test Frequency in Hz	ART dB HL	Presentation level for 3 minutes (20 dB ART)	Recovery Time in seconds	Mean Recovery Time in seconds
6 (a)	2000	2000	100 (5)	120	86	
(b)	2000	2000	100 (3)	120	84	85.0
7 (a)	2000	2000	90 (1)	110	60	
(b)	2000	2000	90 (1)	110	57	58.5
8 (a)	2000	2000	95 (1½)	115	196	
(b)	2000	2000	95 (1)	115	190	193.0
9 (a)	2000	2000	100 (1½)	120	83	
(b)	2000	2000	100 (1½)	120	60	71.5
10(a)	2000	2000	95 (1)	115	191	
(b)	2000	2000	95 (1)	115	210	100.5

Notes : 1. Figures in parentheses indicate BM needle deflection.

2. Range of Mean Recovery Time – 58.5 sec. to 193.0 sec.

indicate that recovery time when measured at 4000 Hz (one octave higher than the adapting frequency 2000 Hz) is more than the rec-overy time when measured at 2000 Hz (adapting frequency). The mean recovery periods are 230 sec. and 108.9 sec. respectively. This finding leads one to speculate that adaptation like fatigue, is more at one octave higher than the adapting frequency. However, this observation is in contrast to the previous reports about adaptation studies, indicate that adaptation is maximum only at the adapting frequency. Further, it is available in the literature that fatigue and adaptation differ with regard to the maximum effect observed in the measuring frequency – fatigue produces maximum effect at one octave higher than the fatiguing frequency and adaptation produces maximum effect at adapting frequency.

In the present study, maximum effect was observed at one octave higher than the adapting frequency. Maximum effect is believed to have resulted at one octave higher than the adapting frequency, bec-ause the recovery time is longer at one octave higher than the adapting frequency. It may be improper to assume that when recovery time is more the adaptation must also be more. However, it is likely that the assumption – greater the adaptation greater would be the recovery time – may turn out to be a wrong assumption. Thus, the results of experiments I and II are

Table II – Showing the Mean Recovery Time when measured at a frequency one octave higher than the Adapting Frequency (1000 Hz, 3000 Hz and 4000 Hz) N=8

Serial Number	Adapting Frequency in Hz	Test Frequency in Hz	ART dB HL at Adapting Frequency	ART dB HL at Test Frequency	Presentation level for 3 minutes (20 dB ART)	Recovery Time in seconds	Mean Recovery Time in seconds
1	500	1000	90 (3)	90 (4)	110	20	
2	500	1000	85 (2)	90 (3)	105	17	18.5
3	1000	2000	95 (2)	100 (1)	115	45	52.5
4	1000	2000	95 (1)	105 (2)	115	60	
5	2000	4000	95 (4)	1000 (5)	115	210	
6	2000	4000	95 (3)	120 (2)	115	210	
7	2000	4000	105 (4)	110 (5)	125	270	230.0
8	2000	4000	95 (2)	105 (4)	115	230	

Note: Figures in parentheses indicate BM needle deflection.

interesting and warrant further investigation.

Experiment III was done to measure asymptotic state of adaptation by determining recovery time at different durations of exposure using 1000 Hz pure tone. The basis for this study is that if recovery time is fairly constant for different duration of exposure to a stimulus at constant level, it can be inferred that the adaptation has reached asymptotic. On the other hand, if the recovery time goes on changing with respect to the duration of exposure to a stimulus of a constant intensity level, it can be inferred that the asymptotic state has not reached. Experiment III was carried out with this reasoning.

In this experiment, five subjects were tested and the results are as follows (Table III). In subject I, recovery periods were; no adaptation, 25 sec., 206 sec., 207 sec., 205.5 sec., and 200.5 sec., to 180 sec., 300 sec., 420 sec., 540 sec., 660 sec., and 780 sec., of exposure time respectively. Recovery time was nearly steady from the 420 sec. (Table IIIa)

In subject II, recovery periods were: 66 sec., 95 sec., 195 sec., 200 sec., 207.5 sec. and 206 sec. to 180 sec., 300 sec., 420 sec., 540 sec., 660 sec., and 780 sec., of exposure time respect-ively. Recovery was nearly steady

Table IIIa – Showing the Mean Recovery Time when measured at different duration of exposure at 1000Hz with respect to Subject I

Duration of Exposure in seconds	Test Frequency in Hz	ART dB HL at Test Frequency	Adapting level at 5 dB below ART	Recovery Time in seconds	Mean Recovery Time in seconds
300	1000	85 (4) 85 (2)	80 80	30 20	25.0
420	1000	85 (1/2) 85 (2 ½)	80 80	221 191	206.0
540	1000	90 (4 ½) 90 (4)	85 85	214 200	207.0
660	1000	90 (3 ½) 90 (5)	85 85	204 207	205.5
780	1000	90 (4) 90 (5)	85 85	196 207	200.5

Note: Figure in Parentheses indicate BM needle defection.

At 180 seconds of exposure duration there was no adaptation.

from the 420 sec. of exposure time. (Table IIIb).

In subject III, recovery periods were: no adaptation, 218 sec., 95 sec., 115 sec., 91 sec. to 300 sec., 420 sec., 540 sec., 660 sec. and 780 sec. of exposure time respectively. Recovery time in this subject was fairly steady, though not consistant from the 420 sec. of exposure time. (Table IIIc).

In subject IV, the recovery periods were: no adaptation, 281 sec., 295 sec., 207 sec. and 207 sec. to 300 sec., 420 sec., 540 sec., 660 sec. and 780 sec. of exposure time respectively. Recovery time decreased after the 540 sec. of exposure and remained steady for 660 sec. and 780 sec. of exposure time. (Table IIId).

In subject V, the recovery periods were: 95 sec., 136., 159.5 sec., 136 sec., 131 sec. and 131 sec. to 180 sec., 300 sec., 420 sec., 540 sec., 660 sec. and 780 sec. of exposure respectively. Recovery time was nearly steady after the 420 sec. of exposure duration. (Table IIIe)

In all these subjects, except subject IV, the recovery period appear to have reached a steady state from 420 sec. of exposure time. Graph shows the Recovery

Table IIIb – Showing the Mean Recovery Time when measured at different duration of exposure at 1000Hz with respect to Subject II

Duration of Exposure in seconds	Test Frequency in Hz	ART dB HL at Test Frequency	Adapting level at 5 dB below ART	Recovery Time in seconds	Mean Recovery Time in seconds
180	1000	85 (1)	90	72	66.0
		85 (1½)	90	60	
300	1000	85 (1½)	90	110	95.0
		85 (1)	90	80	
420	1000	85 (2½)	90	195	195.0
		85 (2)	90	195	
540	1000	85 (2)	90	180	200.0
		85 (2½)	90	220	
660	1000	85 (2½)	90	195	207.5
		85 (2½)	90	220	
780	1000	85 (1½)	90	200	206.0
		85 (1½)	90	212	

Note: Figures in parentheses indicate BM needle deflection.

Table IIIc – Showing the Mean Recovery Time when measured at different duration of exposure at 1000Hz with respect to Subject III

Duration of Exposure in seconds	Test Frequency in Hz	ART dB HL at Test Frequency	Adapting level at 5 dB below ART	Recovery Time in seconds	Mean Recovery Time in seconds
300	1000	100 (2)	95	No adaptation	--
		100 (2½)	95	-do-	
420	1000	95 (2½)	90	180	218.0
		100 (2½)	95	256	
540	1000	100 (1½)	95	90	95.0
		100 (2½)	95	100	
660	1000	100 (3)	95	110	115.0
		100 (1½)	95	120	
780	1000	100 (1)	95	120	91.0
		100 (1½)	95	62	

Note: Figures in parentheses indicate BM needle deflection.

Table IIId – Showing the Mean Recovery Time when measured at different duration of exposure at 1000Hz with respect to Subject IV

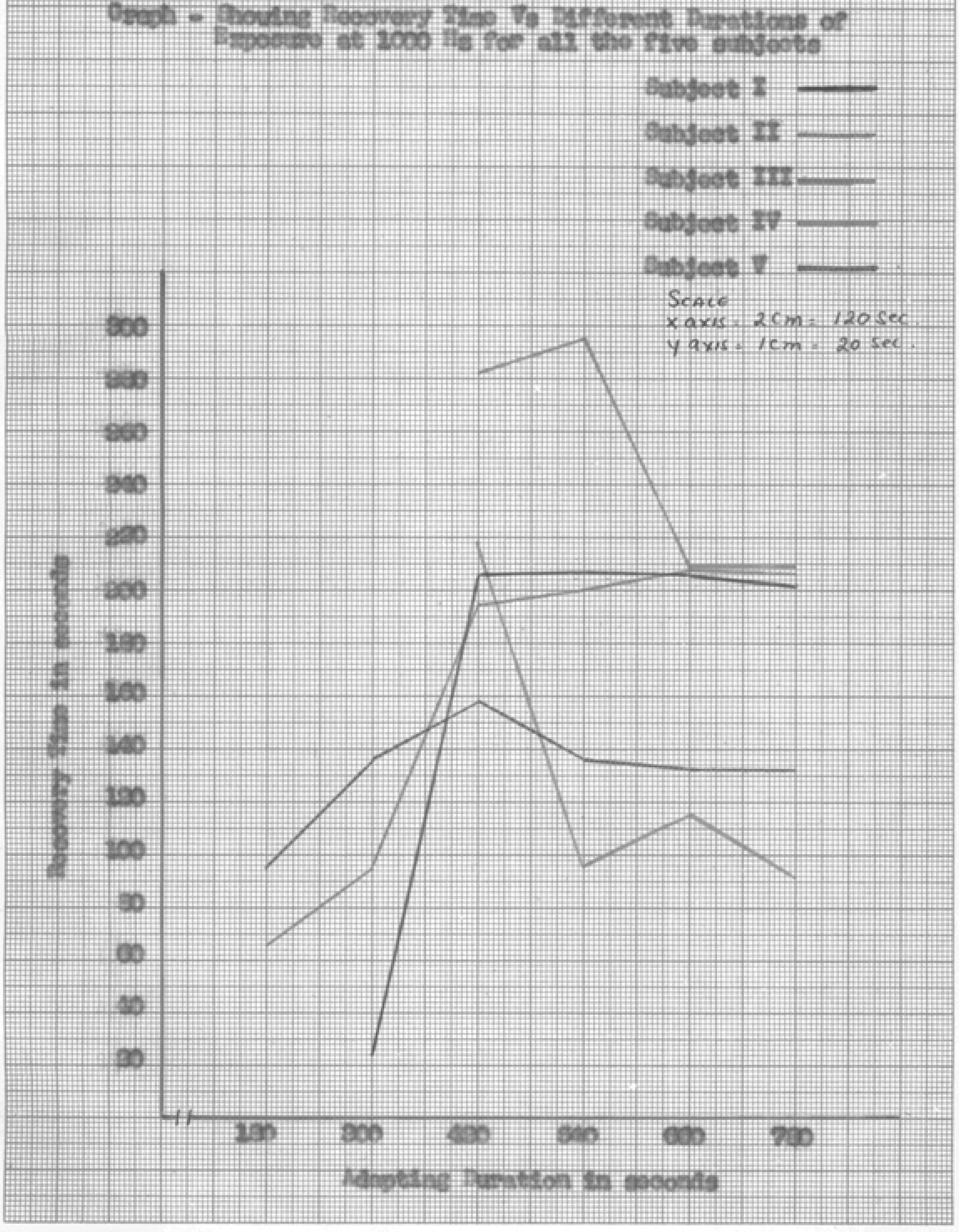
Duration of Exposure in seconds	Test Frequency in Hz	ART dB HL at Test Frequency	Adapting level at 5 dB below ART	Recovery Time in seconds	Mean Recovery Time in seconds
300	1000	95(3½) 95 (2)	95 95	No adaptation -do-	--
420	1000	90 (5) 90 (3)	90 95	280 282	281.0
540	1000	95 (4) 90 (4)	95 90	270 320	295.0
660	1000	95 (1) 90 (1)	95 90	204 210	207.0
780	1000	90(1½) 90 (1)	90 90	214 200	207.0

Note: Figures in parentheses indicate BM needle deflection.

Table IIIe – Showing the Mean Recovery Time when measured at different duration of exposure at 1000Hz with respect to Subject V

Duration of Exposure in seconds	Test Frequency in Hz	ART dB HL at Test Frequency	Adapting level at 5 dB below ART	Recovery Time in seconds	Mean Recovery Time in seconds
180	1000	95 (½) 95 (1)	95 95	70 120	95.0
300	1000	95 (½) 95 (1)	95 95	130 132	136.0
420	1000	95 (1) 95(1½)	95 95	157 162	159.5
540	1000	95(1½) 95 (1)	95 95	120 152	136.5
660	1000	95 (1) 95(1½)	95 95	142 120	131.0
780	1000	95(1) 95(1½)	95 95	132 130	131.0

Note: Figures in parentheses indicate BM needle deflection.



Graph - Showing Recovery Time Vs Different Durations of Exposure at 1000 Hz for all the five subjects time at different duration of exposure for all the five subjects.

Pilot studies were conducted to choose the duration of exposure time and the adapting level. In Experiments I & II, 3 min. duration of exposure was chosen as there was no adaptation at 2 min. duration of exposure to 20 dB ART. At 5 min. of exposure time, the recovery time exceeded to about 5 minutes. Because of practical difficulty, 3 min. of exposure time was used instead of 5 min. of exposure time.

In Experiment III, the adapting level in each individual which produced recovery from adaptation within 5 minutes was selected by many trail studies.

CHAPTER V

SUMMARY AND CONCLUSIONS

This study deals with a new objective method of measuring recovery from loudness adaptation (Objective residual monaural loudness adaptation) and also asymptotic period of loudness adaptation in normal hearing subjects using Madsen (ZO72)electroacoustic impedance bridge. Three experiments were carried out. In brief, Experiment I was do determine recovery time at the adapting frequency 500, 1000 and 2000 Hz. The ear was adapted for 3 minutes at 30 dB above acoustic reflex threshold of the normal hearing subjects at one of the frequencies 500 Hz to 1000 Hz or 2000 Hz. Recovery time was measured at the adapted frequency. Minimum of two subjects were tested at each frequency and ten more subjects were tested at 2000 Hz. The same experiment was repeated on different days to check the reliability of the results with a minimum of 24 to 48 hours of rest periods. The recovery time among individuals was found to be varied. On the basis of these results, the second experiment was conducted.

In Experiment II, recovery time was determined at one octave higher than the adapting frequency. Minimum of two subjects were chosen to measure recovery time at octave frequencies 1000 Hz, 2000 Hz and 4000Hz. One of the ears was adapted for 3 minutes at 20 dB above ART threshold of the normal hearing subjects and recovery time was measured at one octave higher than the adapted frequency, viz., 1000 Hz or 2000 Hz or 4000 Hz. The results showed that recovery time increased progressively from 1000 Hz to 4000 Hz, adaptation being more at a frequency one octave higher than the adapting frequency.

Experiment III was conducted to determine asymptotic state of adaptation on the basic of recovery time. Five subjects were tested for this experiment. One of the ears was adapted for 1000 Hz tone for different duration of exposure (3 min., 5 min., 7 min., 9 min., 11 min., and 13 min.) at or ±5 dB above acoustic reflex threshold. A minimum of fifteen sessions were required to complete the experiment for each subject, with a minimum rest period of 24 to 48 hours. The same experiment was repeated twice to check the reliability. Results of this experiment indicated that this method could be used effectively for determining asymptotic period for loudness adaptation.

Conclusions

1. Recovery time and asymptotic state of adaptation can be measured objectively using this method.

2. Recovery time at one octave higher than the adapting frequency is more than when measured at the adapting frequency. This leads to the conclusion that adaptation is more at a frequency one octave higher than the adapting frequency. (Here, in this study it is assumed that greater the recovery time greater would be the adaptation).

3. Adaptation (objective residual monaural loudness adaptation) reached asymptotic state at about 7 minutes when the adapting level was at or ±5 dB acoustic reflex threshold of the normal hearing subjects.

Recommendations

1. It would be necessary to find relation between loudness adaptation and recovery from loudness adaptation in a large number of normal hearing subjects using the present objective method.

2. As the present study has demonstrated that in one of the subjects there was decrease in recovery time with increase in the duration of exposure to adapting stimulus, further research on this aspect is needed.

3. Contrary to earlier reports, the present study has indicated that the adaptation at a frequency one octave higher than the adapting frequency is more. This needs further investigation.

4. As this method is an objective method, its use on clinical population is worth consideration.

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APPENDIX

APPENDIX I

Electro Acoustic Impedance Bridge Z072

Madsen Z072 Impedance Bridge is used to detect and measure middle ear malfunctions, monitor the action of middle ear muscles with implications for the differential diagnosis of cochlear and retrocochlear lesions. The Z072 Impedance Bridge works on the principle that when a hard walled cavity has a calibrated audio tone applied to it, a sound pressure level (SPL) will be established. If the Volume of such a cavity is large, the intensity of the tone must be relatively large to attain a given SPL within the cavity. Conversely, if the cavity is small, the intensity of the tone necessary to attain the same SPL will be relatively smaller. When this sound pressure level is measured, the volume of that cavity can be determined and any change in that cavity can also be distinguished.

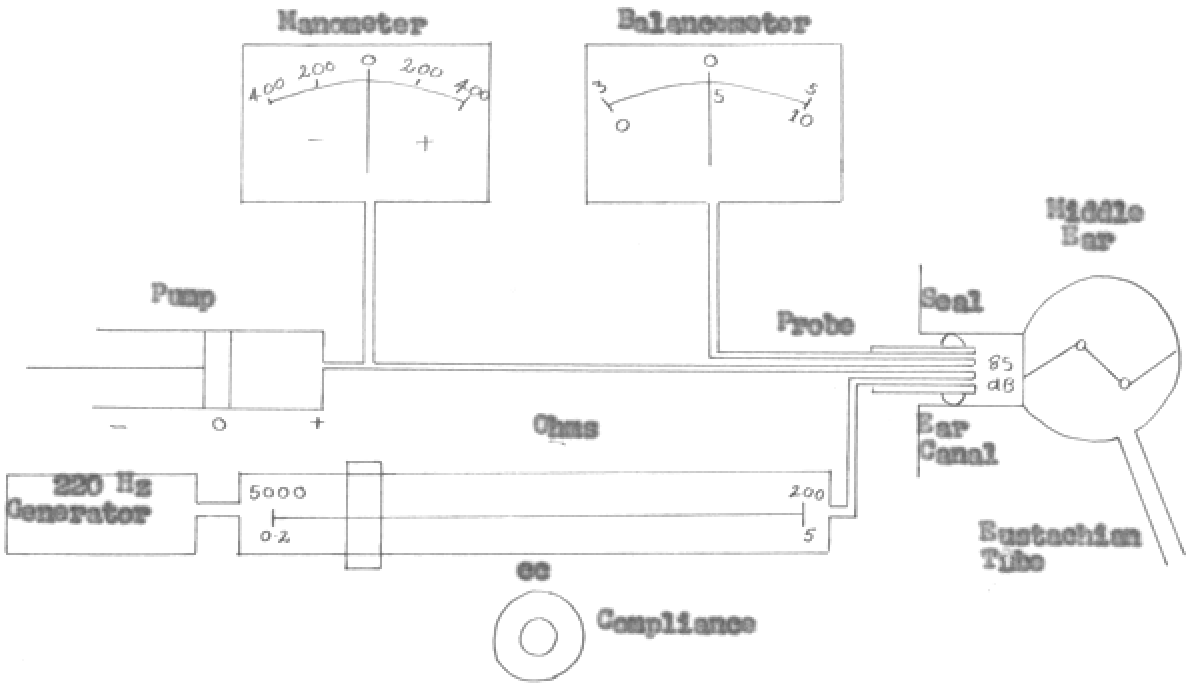
Attached to the Z072 headband is a small metal case containing a receiver and a microphone. The metal probe section contains three small pipes. Soft ear tips of different sizes enable the probe to make an air tight fit in the ear canal. A cavity is thus formed by the air tight closure of the ear canal terminated by the ear drum. A pure tone generator produces a fixed frequency of 220 Hz. termed the probe tone, which is the basis for the acoustic impedance measurements. The probe tone is applied to the receiver, the sound output of which is coupled by a rubber tube to one of three pipes in the probe. The microphone which is connected by a second rubber tube to another of the probe pipes, serves to monitor the SPL within the canal. The remaining pipe in the probe section is connected by flexible tubing to a pressure system consisting of a pump and electro-monometer by means of which specific positive or negative pressures can be applied to the ear canal. The ear phone on the other side of the head set, is connected to the stimulus section of the Impedance Bridge so that different types of audio signals at different frequencies and levels can be applied to the contralateral or other ear. The stimulus section is used to create calibrated acoustic signals which, upon simulating one ear will cause both ears to react, and this reaction can be monitored by the impedance section.

The compliance control is a multi-turn potentiometer acting as an attenuator to govern the probe tone intensity. When the compliance control is adjusted to give a zero reading on the Balance meter, the SPL in the ear canal is precisely 85 dB (55 dB above the threshold for normal hearing). When the SPL exceeds 85 dB, the Balance meter reading is to the right of zero and if below, 85 dB, to the left of zero.

The main scale cursor for the compliance control traverses alternative scales, one for the readings of Acoustic Impedance engraved in Acoustic ohms and the other for compliance readings engraved in Cubic Centimeters (cc). Acoustic Impedance and Volume (cc) are in direct relation for hard-walled cavities and it is on this basis that the compliance control is calibrated. Thus, if the probe is fitted to a herd-walled cavity having a volume within the measuring range of the Z072, the volume, in cc, may be measured and read off the compliance scale. For a given ear canal volume, the measured compliance will differ from that in a hard-walled cavity of similar volume due to absorption of acoustic energy at the ear drum and through the middle ear. As the absorption of energy increases, the compliance increases, or, expressed another way, the acoustic impedance decreases.

APPENDIX II

BLOCK DIAGRAM OF ELECTROACOUSTIC IMPEDANCE BRIDGE ZO72



APPENDIX III

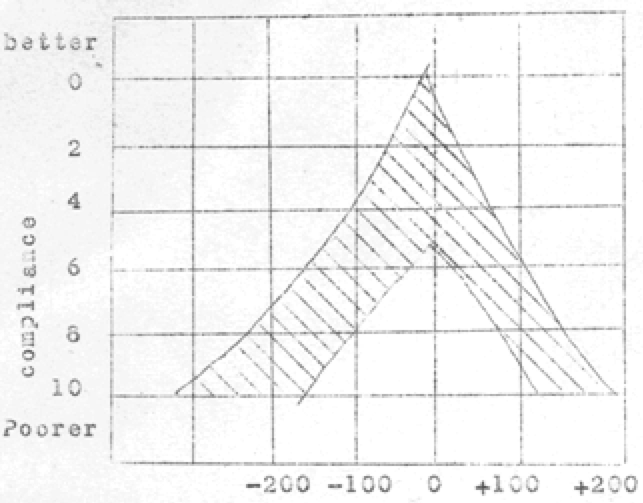
IMPEDANCE AUDIOMETRY

File No:

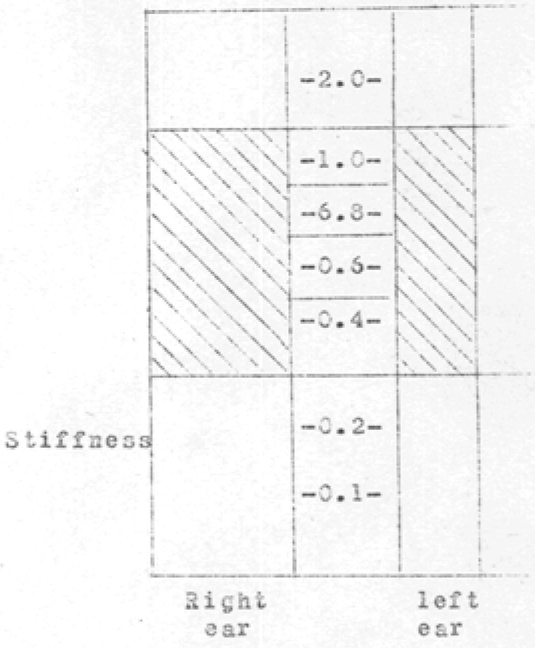
Case Name________________________Age ______ Audiologist____________

Audiometer________________ Date:

TYMPANOGRAM



STATIC COMPLIANCE



C_2

C_1

$C_s = C_2 - C_1$

Test tone ear	Probe tone ear	Test tone ear					
		Reflex threshold				Reflex decay	
		500Hz	1000Hz	2000Hz	4000Hz	500Hz	1000Hz
Right	Left	dB SL	dB SL	dB SL	dB SL		
Left	Right	dB SL	dB SL	dB SL	dB SL		

Normal reflex threshold - 70-100 dB above patient's pure tone threshold
A = absent reflex

No (no decay) reflex sustained for 10 sec.
D (decay) = reflex sustained less than 5 sec.

Audiological impression.

APPENDIX IV

Table showing Test-Retest Reliability Scores for measurement of Recovery Time N=10

Sl.No.	**Test**	**Retest**
1	128	153
2	180	192
3	92	51
4	111	106
5	79	70
6	86	84
7	60	57
8	196	190
9	83	60
10	191	210

Reliability Coefficient = 0.90 indicating high reliability