THE EFFECT OF AUDITORY FATIGUE ON SISI SCORES

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To

Amma and Anna

CERTIFICATE

This is to certify that this dissertation titled "THE EFFECT OF AUDITORY FATIGUE ON SISI SCORES" is the bonafide work in part of fulfilment for the Degree of Waster of Science (Speech and Hearing), of the student with Register No. 10

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CERTIFICATE

This is to certify that this Dissertation titled "THE EFFECT OF AUDITORY FATIGUE ON SISI SCORES" has been prepared under my supervision and guidance.

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DECLARATION

This Dissertation titled "THE EFFECT OF AUDITORY FATIGUE ON SISI SCORES" ia the result of my own study undertaken under the guidance of Dr. H.N. Vyasamurthy, Lecturer in Audiology and has not been submitted earlier at any University or Institution for any other Diploma or Degree.

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C O N T E N T S

CHAPTER-I

INTRODUCTION

In the late 1950's, the problems associated with determination of site of lesion were substantially greater than those encountered today. ABLB, TDT and Bekesy were the tests which sufficiently provided reliable diagnostic information.

The audiologist's horizons have broadened and his task is becoming both more precise and complex than ever before. His view of the auditory system is more complete than ever before and he is increasingly aware of its incredible complexity. The Audiologist is called upon to make statements concerning the hearing of his patients. Not only must he ascertain the existence of a hearing impairment, but he must also make judgements concerning its severity, its influence upon the patient's life, the locus of the lesion or lesions responsible for the pathology and possible areas of remediation of the disorder (Rosenburg, 1978).

Since the observations of Dix, Hallpike and Hood (1948) relating loudness recruitment to cochlear pathology, the audiologists have been able to determine to some extent that recruitment implies a cochlear disorder (cited in Martin, 1978).

For some time it has been known that as intensity is increased in a normal ear, the ability to detect small changes in intensity in that ear also increases. That is, at low SL a tone might change in intensity several decibels before the listener becomes aware of any change in loudness. When that same tone is very loud, a change in intensity equal to a fraction of a decibel often can be detected. The smallest change in intensity that can be recognised as a change in loudness is the difference limen for intensity (DLI). Since it is the increased loudness of a tone that mediates the normal listener's ability to tell when the tone has changed in intensity. It seemed logical to use the DLI procedure as an "indirect" measurement recruit-ment. If a patient with hearing loss had a small DLI at fairly low SLs, recruitment was implied (Martin, 1981).

The 1950's saw the development of a number of variations on the DLI theme. Many audiometers came equipped with separate attenuators for performance of OLI measurements. Audiologists eventually began to despair over the lack of reliability afforded by these tests. A procedure as delicate as the OLI requires, for one thing, a great deal more practice and familiarization on the part of the patient than is truly practical in most clinical situation.

Changes in the differential sensitivity to intensity was thought to provide a new and reliable test in audlological differential diagnosis 20 years ago. On the basis of above findings Jerger et al (1959) designed new test using sustained stimulation, to replace the conventional DLI tests. They called it SISI, short form for "Short Increment Sensitivity Index". The test procedure is designed to test the ability of a patient to detect the presence of a 1 dB increment superimposed on a tone presented at 20 dB SL. Any subject, with or without a hearing impairment can be tested with the SISI procedure.

The introduction of the SISI test improved the efficiency of audiologic evaluations. They introduced SISI as another approach to the measurement of the ear's ability to detect small intensity changes. In a sense, all audiometry is diagnostic since it contributes, in some sense, to the ultimate localization of the auditory disorder. SISI test is one of the reserve tests in peripheral Test Battery. Its purpose is to differentiate among three possible peripheral sites; the middle ear, the cochlea and the eighth nerve.

Scores on the SISI above 70% are usually considered to indicate the presence of a hearing loss produced by damage to the inner ear. This is a positive SISL. Scores below 30% are considered negative and are found in patients with disorders elsewhere than in the inner ear and also in persons with normal hearing. Scores lying between 30% and 70% have only limited diagnostic significance and must be interpreted carefully.

Several other variables of the SISI procedure in normal material have been investigated. Discripancies between SISI results and otologic and neurologic findings, the difficulties in interpreting significance of scores falling within the 15-70% range have led investigators to suggest modifications of the test procedure (Thompson, 1963; Herbert et al, 1969; Martin, 1978, Owen, 1965; Jerger, 1969; and Hanley and Utting, 1965). Such factors as method of presentation, practice, increment size, test frequency end intensity level of the carrier signal have been shown to affect the SISI score.

Since the SISI test is a suprathreshold test contralateral masking was suggested when ever necessary. The coDss hearing for the SISI is stated as:

$$\text{SISI} \quad HL_{TE} - IA \geq BC_{NTE}$$

Effect of contralateral maaking on the SISI scores was studied since masking is used for this procedure only in selected cases. Bleguod and Terkildsen (1966) found that masking the nontest ear exerts an influence on SISI score. SISI scores tended to increase in high frequencies. Similar results were obtained in a study by Shimizu (1969); Osterhammel et al (1970).

Another problem in the clinical use of the SISI is the interpretation of the test in ears with abnormal adaptation. When an ear demonstrates abnormal adaptation the auditory threahold is elevated. Therefore, the 20 dB SL of the SISI test is lowered in proportion to the degree of adaptation. The effects by Bartholomeus and Swisher (19/1) who found that even slight adaptation lowered the SISI scores. Studies by Owens (1965), Young and Harbert (1967) reported that negative scores occurred in abnormally adapting ears.

From the results of suprathreshold adaptation tests (Palva and Palva, 1903; Karja, 1968) it ia known that at even at 20 dB SL, a marked adaptation can develop quite rapidly even in normal ears. In the SISI procedure, the sustained tone must also be subjected to similar adaptation. Rehko (1971, 1975a, 1975b) studied the effect of adaptation on—normal hearing persons, patients with conductive defect, patients with recruiting ears and patients with acoustic neuroma.

There have been, however, a number of investigations of the differential sensitivity for intensity following intense stimulation. Bekesy (1947), Rciedi (1954), and Epstein and Schubert (1957) have all used the peri excursions at absolute threshold of a Bekesy type audiometer as their measure of the differential threshold. Their findings are consistent and indicate that pen excursion decreases following stimulation. Elliott et al (1962) also found that differential threshold decrease following intense stimulation (cited in Small, 1963). Thus, there is fair amount of evidence that intensive differential threshold, at least, change following intense stimulation. Although Elliott et al, have provided a start, relatively little is known regarding specific nature of the changes (Small, 1963).

The following study was conducted to determine the effect of auditory fatigue on SISI scores in normal hearing subjects.

The present study was carried out to find answers to the following:

(1) Does SISI score change after the ear is fatigued?

(2) Is there any frequency effect in the change of SISI score after the ear is fatigued?

(3) In general, Does the differential sensitivity for intensity change efter the ear is fatigued? i.e., Does the performance of normal hearing subjects become better or worse after the ear is fatigued?

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C H A P T E R - II

REVIEW OF LITERATURE

TEST PROCEDURE FOR CLINICAL USE

Dix, Hallpike & Hood (1948) related loudness recruitment to Cochlear Pathology (cited in Martin, 1978).

There appears to be a strong association between detection of small intensity changes at low SL's and loudness recruitment. A number of investigators evaluated the difference limen (DL) vales for normals and cochlear and other pathologies. But their results were confusing mainly because of the methodology they used.

Jerger, Shedd and Harford (1959) cleared the confusions by introducing the Short Increment Sensitivity Index (SISI) Test. It is an another approach to the measurement of ear's ability to detect small changes in the intensity. On this test a puretone is presented to the patient at a SL of 20 dB and a small increase in intensity is superimposed upon the steady-state tone at periodic intervale. The size of this increment is varied from 5 to 1 dB. They found that the ability to detect the 1 dB increments was largely restricted to patients with cochlear pathology. Conversely, this ability was absent in subjects with normal hearing or with conductive or retro-cochlear hearing losses. Most importantly, the test was easy to administer and was less confusing than the DLI test, for most patients.

Jerger et al (1959) recommended that the carrier tone be introduced at an SL of 20 dB. The intensity level of the carrier tone increased by 1 dB for 200 ms every 5 sec. Increment had fall rise time of 50 msec, so that the total duration from the beginning to end of the increment was 300 msec. The patient is instructed to indicate that he has heard a brief "jump" in the loudness of the tone. Twenty 1 dB increments are introduced. If a number of consecutive increments are heard i.e., about 5 in a row the examiner is advised to delete several increments so that it can be ascertained that the subject is responding to the change in intensity rather than to learned time interval. If the patient fails to respond to several increments in a row the increment size can be increased for retraining.

The total SISI score is multiplied by 5 to give percentage. Jerger et al (1959) recommended that SISI scores of 0 to 70% should be considered negative, indicating normal hearing or a non-cochlear lesion, while scores between 70 and 100% should be considered positive, indicating the presence of a cochleer lesion. The range from 25 to 75% should be considered as not strongly diagnostic either way.

Harford (1967) recommended a gradual reduction in the increment to make sure that the patient won't feel 1 dB increment to be too small to be real.

Martin (1978) recommended e catch trial to be inserted after every 5 increments to control the false positive and responding rhythmically. After the catch trial, 5 more 1-dB increments are presented followed by another catch trial until a total of 20 1-dB increments has bean presented.

After the introduction of SISI by Jerger et al (1959), many investigators used it to find out SISI scores in normal hearing population.

Rubinstein et al (1970) administered SISI test to 100 subjects in good general physical condition, with no past history of ear diseases and with normal hearing, at 500, 1000, 2000 and 4000 Hz with incremental changes of 1, 2, 3, 4 and 5 dB. The test was also repeated on 20 of these subjects within a 2 month period, one ear was tested in each subject. Analysis of their data showed that the test criteria proposed by Jerger (1959) by Owens (1965) and by others still leave a high percentage of normal listeners outside the group of negative scores for pathologic loudness findings. They suggested to consider only the mean value obtained at the four frequencies (0.5, 1, 2, and 4 KHz) where applicable to limit the number of false positive results.

Liebman (1975) obtained SISI scores from 31 normal hearing college students at 250, 500 and 1000 Hz, at SPL's from 37-100.5 dB. Positive scores were yielded with SPL as low as 37 dB. They say SISI test appears to have limited use as a diagnostic tool if administered using the procedure originally described.

Jerger (1976) believes that the conclusion drawn by Liebman (1975) is based on a faulty grasp of the "procedure originally described". We says that Liebman has not administered the test as described by Jerger et al (1959).

In 1976, Romanujaneyalu conducted a study comparing the presentation level of the test tone with SISI score, reveals that to be effective even when presented et levels less than 20 dB above threshold. In normal individuals the scores raised gradually with increase of the carrier tone to reach 100% at 60 dB above threshold. In sensory deafness the maximum was reached with carrier tone at 30 dB above threshold.

The strong tendency toward an all-or-none type of response on the SISI test led Owens (1965) to conclude that the test may be justifiably shortened to the use of 10 increments, allotting a credit of 10% to each increment.

MODIFICATION Of SISI

Many experimenters have studied the effect of varying different parameters of the SISI test. Especially, the test level and the increment size. The purpose of this section is to review the many modifications of SISI that have been suggested.

Thompson (1963) hypothesized that patients with retrocochlear hearing losses would obtain low SISI scores at high test levels, whereas normal listeners and patients with cochlear impairments would obtain high SISI scores at high test levels. Two cases of mild unilateral loss were tested. They were suspected to have 8th nerve tumor. The conventional SISI test procedure was kept intact, except that instead of pressenting the steady tone and superimposing 1 dB increment at 20 dB SL, the tone was administered at HL dial setting of 75 dB. Both cases detected the increments in the normal ear (100%), but failed to detect the increments in the affected ear (0%) in the affected ear even though the hearing loss was slight at that test frequency. Koch et al (1969) and Herbert et al (1969) later support this finding in patients with retrocochlear impairment. The procedure used by Koch et al involves repeating the SISI test at higher and higher SLs, beginning at 20 dB SL, until a positive score is obtained. Patients with mild inner ear hearing losses and normals will show higher and higher scores as the levels are raised, while those with damage to the higher auditory centers do not show on increase in SISI scores as level is increased. They suggested that the SISI to be performed with increment sizes larger than 1 dB when scores at 20 dB SL are low. Harbert et al, administered SISI test at various SPL's in normal and pathologic subjects. The results indicate that when the inner ear receives an audible signal of 60 dB SPL or greater, a positive SISI score will occur in both normal and SN hearing losses except in those with abnormal adaptation. A negative SISI score in the absence of a conductive barrier occured only in abnormally adapting ears and is probably indicative of suprathreshold adaptation. Their data indicate that recruiting ears and normal ears perceive intensity increments of equal size at equivalent SPL. In abnormally adapting ears, as Bekesy separation increases, the increment tends to become larger than normal continuous tone. Bekesy thresholds measured at the bottom of the first spike increased directly with starting intensity and inversely with attenuation rate.

Although the high-level SISI appears to be a powerful test, only one-third of the audiologists use it in the diagnosis of suspected 8th nerve lesion (Martin and Forbis, 1978).

Martin (1978) supports the Koch et al conclusion that in some cases of pathology in the higher centers of the auditory system even increasing the increment size does not allow the patient to identify the increments, and suggested the appropriateness of testing retro-cochlear hearing losses using larger increments (i.e., 2 or 3 dB). He says that these large increments would usually be heard by normally hearing, conductively impaired and cochlearly impaired listeners, whereas patients with retrocochlear impairment should have difficulty hearing these increments.

Owens (1965) administered SISI test to 27 normal subjects, 95 patients with cochlear lesion, 15 patients with 8th nerve lesion, and 3 patients of uncertain classification. He reported that 5 out of 12 patients with confirmed retrocochlear lesion could hear 2 and 3 dB increments, whereas the other 7 patients failed to respond even to 5 dB increments. Thus, he concludes that such a test would presumably have a high false negative rate and seems inferior to the high level SISI with 1-dB increments.

Jerger et al (1969) suggested employment of large increments in the SISI test. They obtained SISI scores as a function increment size in two listeners; one with bilateral temporal lobe lesion and the other with normal hearing. The test level was 80 dB SPL. The normal hearing subject yielded almost identical results in the right and left ear, where as the patient with temporal lobe lesion yielded a much shallower psychometric function in the right ear than in the left ear. These results are in support of Hodgson's (1967) finding in a patient with left hemispherectomy who showed a reduced SISI score at high intensity in the right ear. These results suggest a much shallower psychometric function in the ear opposite to the affected side of the brain (Buus, 1982b).

Jerger et al (1969) also measured SISI scores as a function of SPL. They found roughly symmetrical performance in the listeners with normal hearing, whereas there was gross asymmetry in patients with bilateral temporal lobe lesions. The right ear performance was much poorer than the left ear performance, suggesting a lesion on the left side of the brain.

Cooper (1976) reviewing the SISI in terms of its performance with a variety of sites of lesion and its likely physiologic basis conclude that its original scheme can be broadened to extend its clinical application if changes are made in the parameters of its routine use. The two major changes involve (1) a presentation level of no less than 90 dB HTL and (2) a bimodal interpretation of results based on the premise that high scores indicate normal cochlear function and low scores indicate extensive cochlear damage or neural dysfunction. He suggest that routine use of the modifications suggested here can provide useful diagnostic information and bring to light a group of neurally impaired patients that has been relatively ignored.

Although detailed measurement of the SISI scores as a function of level and increment size provide interesting insights into the auditory functioning of the patient, it seems that sufficient information for diagnosis could be obtained in a much shorter time by the high-level SISI test suggested by Thompson, 1963.

The different use of the SISI score as a function of level was suggested by Byers (1974). Since SISI scores in normal hearing and cochlear impairment are similar when compared at equal SPL, the difference between the SL at which normally hearing listeners obtain a 100% score may be used to estimate bone conduction threshold. A listener with a 30 dB cochlear impairment will reach SPL necessary for a 100% SISI score at a 30 dB lower SL than normally hearing listeners. He found that listeners with normal hearing obtained a 100% at 50-60 dB SL which indicate that BC threshold might be estimated by the formula

BC (dB HTL) = 60 dB + AC (dB HTL) - dB HTL (100% SISI)

Where BC (dB HTL) is the estimated BC threshold in dB HTL. AC (dB HTL) is the AC threshold in dB HTL, and dB HTL (100% SISI) is the lowest level (in dB HTL) at which the patient obtained a 100% SISI score.

Byers (1974) results showed no significant difference between the mean values of predicted and actual BC thresholds.

Narendran's (1975) study is in accordance with Byers results. In conductive loss cases for frequencies 500, 1000 and 4000 Hz., there was no significant difference between the BC thresholds one obtained using Byers formula another by conventional method. At 2 KHz, there wes significant difference in thresholds obtained by 2 different methods. He attributes this to Carhart notch. In mixed and SN hearing loss also, there was no difference in BC thresholds between 2 methods and he concludes that conductive SISI given better picture ebout the cochleer reserve in mixed hearing losses which will help in selection of cases for surgery.

Hanley and Utting (1965) suggest that, if a SISI score of 60% or higher is to be accepted as indicative of cochlear pathology, the use of 0.75 dB increment rather then a 1-dB increment might more definitely isolate cochlear involvement from other types of pathology. The authors in an attempt to find a SISI increment size of sufficient challenge that no more than one in 20 of the normal hearing population could score as high as 60%, administered the SISI to 48 normal hearing subjects. Increment sizes of 1 dB, 0.75 dB and 0.5 dB were utilized in separate test runs for each subject. In addition, they tested 11 males with SN loss who had scored 60% or higher with 1-dB increment. They found that 16 of 48 listeners with normal hearing scored 60% or more and 13 of 48 scored more than 70% on the standard SISI test. Only 2 of the 48 listeners scored 60% or higher and none scored 70% or more when 0.75 dB increment was used.

Sanders and Sampson (1966) tested the proposal of Hanley and Utting (1965) that the SISI test should employ an increment magnitude of 0.75 dB rather than 1 dB increment originally proposed by Jerger et al, (1959). The SISI was given with three increment magnitude 1.00 dB; 0.75 dB, and 0.50 dB to a group of normal hearing and to a group of subjects with cochlear lesion hearing loss. The test results indicated that the SISI test distinguishes the cochlear pathology ear from the normal ear more consistently with the 1.00 dB increment than with either of the two smaller increment magnitudes investigated. They conclude that the SISI test should be continued Mith the 1.00 dB increment magnitude originally proposed.

THE SISI TEST AND CONTRALATERAL MASKING

In this section effect of masking on the SISI test is reviewed. Since the SISI is a suprathreshold procedure, we have the problem of cross-hearing.

One consideration of SISI teat administration is the use or non-use of contralateral masking. It is appropriate to mask during any auditory test, When there is danger of cross hearing of the signal. There is a chance that when the carrier tone of the SISI, minus the interaural attenuation for the test frequency, is equal to or above the bone conduction threshold of the nontest ear. It is natural to wonder whether contralateral masking has an affect on SISI scores since masking is sued for this procedure only in selected cases.

$$SISI = HL_{TE} - IA \geq BC_{NTE}$$

If the Audiometer is calibrated in units of effective masking, the effective masking level of the masked ear is equal to the hearing level of the SISI carrier tone, minus interaural attenuation if it is known (if not use 40 dB), plus any air bone gap in the masked ear at the test frequency.

$$EM = SISI\ HL_{TE} - IA + ABG_{NTE} \qquad \text{Martin (1978)}$$

Young & Wenner (1968) tried to find out the effect of masking noise on the SISI test. They performed SISI test on 5 trained normal hearing subjects in the presence of ipsilateral masking noise. They found that when the S/N ratio was +5 dB or greater for white noise and +15 dB or greater for narrow band noise, all subjects showed similar high SISI scores for the various frequencies and testing levels. The larger the increment size in the modified SISI teat, the less the S/N ratio necessary to obtain high scores.

Patients with unilateral perceptive hearing loss have been examined by Bleguad (1969) to determine whether masking of the good ear influences the difference limen for intensity. The measurements Mere carried out with the aid of the SISI procedure using increments of different magnitudes, until the psychometric function was determined both without and with masking (80 dB SPL). The level of the test tone was maintained constant (20 dB above the threshold determined without masking). He found that at 1000 and 4000 Hz, the contralateral noise resulted in a significant improvement in the intensity discrimination, while no chenge occurred at 250 Hz. With a few exceptions, the masking had no significance for the result of the topognostic SISI test using 1 dB increments.

Even more striking effects of contralataral masking were reported by Shimizu (1969). The study was designed to investigate the influence of contralateral noise stimulation on the results of tone dscay and SISI tests. SISI test was administered to 12 adults who had either normal hearing in both ears or a mild unilateral conductive hearing loss. In patients with a unilateral conductive hearing loss, the test tones were always given to the impaired ear. Only 2000 Hz was used for SISI testing. The difference between the ears was not greater than 40 dB. The test was administered first in quiet and then with white noise at 40 dB SL in the opposite ear. The affect was pronounced at 2000 Hz. All subjects obtained negative scores (0-20% in quiet; however, positive score, (65-100%) were obtained from half the subjects during contralateral masking. The phenomenon was believed to be neural interaural interference, since the intensity of the contralateral noise was too low to produce pericranial or transcortical direct masking. He concludes that the result suggest the careful use of masking noise during SISI test on patients with unilateral SN hearing loss in order to avoid false positive results.

Swisher et al (1969) obtained SISI scores at 2000 Hz for the left and right ears of normal listeners at intensity levels of 23 to 78 dB SPL in the presence of contralateral white noise and saw-tooth noise from quiet to 63 dB SPL. It was hypothesized that contralateral noise might affect the left temporal lobe in a manner analogous to left-temporal excision, resulting in improved intensity discrimination only in the left ear. Results showed that intensity discrimination was significantly improved in ears by contralateral noise for subjects receiving test tones of 38 dB and above. Contralateral noise did not improve intensity discrimination in subjects who received test tones of 38 dB and below, but the difference limen for the left ear were significantly smaller in both quiet and noise. The original hypothesis was not upheld, and further study of the limiting condition for the enhancement of differential sensitivity for contralateral noise is suggested.

The increased SISI score obtained with contralateral masking is further reported by evoked response recordings (Osterhammel et al, 1970). They reported that evoked cortical responses to SISI type stimuli at

20 dB SL and increment magnitude 2, 3 and 5 dB tend to be enhanced by the application of contralateral masking noise. They also report that with 5 dB increments and the continuous tone at the threshold of hearing the same masking noise caused the responses to disappear. The enhancement of auditory discrimination at suprathreshold levels through application of contralateral masking and the "central masking effect" at the threshold were thought to be comparable to the so called indirect adaptation mechanism of the eye, and an indication that the efferent innervation to the cochlea is important for the adaptation of the ear.

Buus (1982b) while reviewing these studies conclude that the data seem to indicate that application of an intense contralataral masker may increase the SISI score, at least for test tone levels above 38 dB SPL. Therefore he says that it seems advisable to minimize the application of masking and, when masking is necessary, minimize its level.

To minimize the application of masking, we may consider the SISI score obtained as a function of SPL. The SISI scores obtained by listeners with normal hearing and listeners with cochlear impairment remains close to 0% at levels below 35-40 dB SPL (Young and Herbert, 1967) only at SPL's above 45 dB are high scores obtained.

Also the findings of Martin and Sales (1970) indicate thet the absolute level of the SISI test largely determines the SISI score. They showed that SISI scores obtained in 12 patients with unilateral SN hearing losses were much lower in normal ears than in impaired ears when the tests were presented at equal SL or equal loudness level, but when the test was presented at equal SPL, the scores obtained in the normal and impaired ears were equal. This indicates that the SISI increment is not audible when the test tone is below levels of 35-40 dB SPL, it seems reasonable only to apply contralataral masking when the cross-over of the test signal is above 30 dB HTL in the non-test ear and only if the cross-over of the test signal is above threshold.

The masking rule becomes:

Mask if SISI HTL $-$ IA $>$ 30 dB If $BC_{NTE} <$ 30 dB HL

or

SISI HTL $-$ IA $\geq BC_{nTE} <$ 30 dB HTL

Where SISI HTL is the level (dB HTL) at which the SISI is performed, IA is the interaural attenuation (40 dB), and BC_{NTE} is the bone conduction threshold (in dB HTL) in the nontest ear. (Martin 1978)

SISI AND TONE DECAY

Another problem that has arisen in the clinical use of the SISI test is the interpretation of the test in cases of where the test signal become softer or even faded to inaudibility due to tone decay. (Buua 1982). When an ear demonastrates abnormal tone decay the auditory threshold is elevated. Therefore, the 20 dB SL of the SISI test is lowered in proportion to the degree of adaptation (Martin, 1978).

Bartholomeus and Swisher (1971) obtained SISI scores of patients with and without tone decay were compared to determine the effect of small amount of tone decay on responses to the SISI test. Similar distribution of SISI scores were obtained for patients with and without tone decay when scores were compared without regard to the hearing level (HL) of the SISI test tone. However, a trand toward lower SISI scores for patients with tone decay was observed when comparisons were restricted to scores obtained at equivalent HL's. For both patients with and without tone decay, a significant positive correlation was obtainadbetween SISI scores and the HL of the SISI test tone. They came to the conclusion that tone decay may affect the SISI score obtained by patients even with slight adaptation (5 to 20 dB).

Owens (1965) also reported results from 12 patients with retrocochlear lesion showing abnormal tone decay. All these patients had a SISI score of 0.1. In 7 patients, the tone faded to inaudibility within a few seconds, after which they did not even respond to 5 dB increments. The other 5 patients responded to 2 or 3 dB increments after the tone faded.

Young & Herbert (1967) found that negative scores occurred in abnormally adapting ears regardless of intensity level of the carrier signal. They came to the conclusion that positive SISI indicate that the ear under teat is functioning as a normal ear at equivalent SPL.

Negative SISI scores for audible signals of 60 dB or greater are indicative of abnormal adaptation.

Hughe's (1968) report presents a brief discussion of 18 subjects who achieved high SISI scores (80-100%) and reported that the 1 dB increments of the procedure seemed to emerge from silence. Despite the aberration of the test procedure caused by the intrusion of tone Decay on the steady-state tone, the high SISI value are consistent with the diagnosis of cochlear involvement in the majority of these cases. His conclusion was that although cochlear lesions may occasionally exhibit greater tone decay than normally observed, the value of the SISI procedure is not lessened by this deviation.

Herbert et al, (1969) administered SISI tests at various SPL's in normal and pathological subjects. Their results showed that a negative SISI score in the absence of a conductive barrier occurs only in abnormally adapting ears and is probably indicative of supra-threshold adaptation. Also reduced amplitude of Bekesy continuous tone tracings is probably a measure of rapid adaptation.

In summary, the available data suggest that the SISI teat remains valid in the presence of tone decay. Although scores tend to be lower in the cochlearly impaired listeners with tone decay, the scores are usually in the high range. In part, this may be due to the somewhat greater hearing loss usually seen in these patients than in patients without tone decay. When the presence of tone decay is suspected, it is always helpful to ask the patient the time-honored question

"What do you hear?" before interpreting the outcome of the test (Simmons and Dixon, 1964).

A COMPARISON Of SISI WITH OTHER SITE OF LESION TESTS

Jerger (1961) provided the comparison between the SISI scores, results of ABLB, and results of Bekesy tracking. The results showed that combination of Bekesy type II trackings and high SISI scores obtained in 75 patients with SN hearing loss of unknown etiology occurred with approximately equal frequency in groups with no recruitment, partial recruitment, and complete recruitment.

An even poorer correlation between recruitment and high SISI scores was obtained by Hickling (1967). He observed recruitment in 11 ears which he was able to test in 7 listeners with a noise induced temporary hearing loss. A low SISI score was obtained in all but 1 of these recruiting ears. Yantis & Decker (1964) also found better correlation between high SISI scores and recruitment.

As stated by Jerger (1962) "SISI is not an indirect test for loudness recruitment; it is nothing more than a way of telling whether a patient can hear very small changes in sound intensity. There is only one reason for wanting to know this. Evidence exists that the ability to hear these very small changee is unique to disorders of the cochlfa".

Jerger (1973) presented another comparison of 4 tests (SISI, ABLB, TDT and Bekesy tracking). All tests with the exception of the TDT show a high percentage of expected outcome in patients with meniere's syndrome. If a negative cochlear outcome is taken to suggest a retrocochlear involvement, the false alarm ratio was rather high in tone decay, very low in other tests and lowest in the Bekesy tracking. In cases of acoustic neuroma, the tests are considerably poorer. SISI ranked best, yielding a false-negative rate of 20% where as the other tests yielded between 24 & 33 false negatives. Buss et al (1982a) say that the false-negative rate for SISI is somewhat lower than the 31%.

SISI TEST, ADAPTATION AND NITTS

From the results of suprathreshold adaptation tests, it is known at over an 20 dB SL, a marked adaptation can develop quite rapidly even in normal ears. In the SISI procedure, the sustained tone lasting for 1 minute 40 sec. must also be subjected to similar adaptation. Rahko (1971) studied the effect of the adaptation of the ear upon the SISI test on 26 normally hearing persons. The average adaptation was found to be 4.2 dB at 500 Hz, 7.5 dB at 500 Hz and about 10 dB at higher frequencies after 3 minutes sustained stimulation. In the preadaptation test the average SISI test values ranged from 22.5% to 36.2%. In the post-adaptation SISI test the average figures ranged from 30.6 to 48.7%. The dispersion of preadaptation SISI values was very large, which makes evaluation of the results difficult in a normal material. 15% showed positive results in Jerger's classification. Adaptation increased the positive values at higher frequencies, but changes to both directions occurred.

Rahko (1975a) also studied the effect of adaptation of the ear on the SISI test in patients with conductive defects, with recruiting ears and in patients with acoustic neuroma. The effect of adaptation of the ear on the SISI test was studied at 500 Hz and 2000 Hz in 43 patients with chronic otitis and in 20 patients with otosclerosis. The mean adaptation was slightly over 10 dB, except in the otosclerosis group at 2000 Hz, for which the value was nearly 20 dB after continuous stimulation at 20 dB SL for 3 minutes. The mean SISI values ranged from 15% to 31% in the preadaptation tests and from 9 to 13% in the postadaptation tests. In the total material 22% of the values at 2000 Hz were positive according to Jerger's classification, and 32% were questionable. Adaptation slightly reduced the proportion of positive values, but there were changes towards both higher and lower levels in the cases of chronic otitis while all the otosclerosis changes were diminutions.

The effect of the adaptation of the ear on the SISI test was studied (Rahko, 1975b) in 60 completely and 18 incompletely recruiting patients and in 5 patients with a verified acoustic neurinoma at 500 and 2000 Hz. The subjective suprathreshold adaptation to a 3 minutes tone of 20 dB SL ranged from 10 dB to over 20 dB, depending on the frequency and the type of defect. The preadaptation mean SISI values in the recruiting groups ranged from 38 to 51% and post-adaptation means from 38-49%. In retrocochlear lesions only one SISI value was questionable before and after adaptation, the others being 0%. Adaptation did not

(3 dB) and apparently constant shift of the SISI threshold, quite unrelated to the degree of conventional threshold shift induced. He suggests that although it is possible that this phenomenon might be of cochlear origin, it is most probably, that this SISI threshold shift is actually a measure of small and constant component of noise-induced TTS which is ratrocochlear in origin.

INTERPRETATION Of SISI

With the results obtained by Harbert and Young (1969) they came to the conclusion that (1) A positive SISI score when the inner ear perceives a signal of 60 dB SPL or more probably has no significance since it occurs in both normal ears and SN deafened ears with a wide variety of diagnosed. (2) A negative SISI score, when the inner ear receives an audible stimulus at 60 dB SPL and above, is an indication of abnormal intensity discrimination and is probably indicative of suprathreshold adaptation. (3) Reduced amplitude of Bekesy continuous tone tracings probably is a measure of rapid adaptation.

Young and Harbert (1967) conducted a study to determine in both normal and pathological ears the effects of sensation level (SL) and sound pressure level (SPL) on the SISI scores. Results showed that at SPL's of 45 and above, every normal subject showed a SISI scores of 65% or higher for all frequency. The results of the unilateral cochlear lesion group at equivalent 8 intensities from 60-120 dB SPL, the affected and control ears behaved identically, obtaining scores of 70% or higher. They concluded that

(1) A positive SISI score in an ear with pure SN hearing loss merely

significantly affect the SISI value. He concluded that high SISI values did not reliably distinguished between the hearing defect types, but if the SISI was low the possibility of a retrocochlear lesion should always be borne in mind.

Studies were undertaken to determine the effect of induced temporary threshold shift. Hickling (1967) administered a battery of supplementary pure tone hearing tests at 4 KHz to 14 ears before and after noise exposure to induced temporary threshold shift. The standard SISI test at 20 dB above threshold was negative in all post exposure ears, except for one questionable ears, but applied at 60 dB above threshold it gave a high proportion of positive scores. The possibility is suggested that perhaps some reduction in the intensity difference limen stem from hair cell malfunction and those small changes apparently related to auditory adaptation may originate in some more central lesion responsible for a fraction of the total loss.

Hickling (1968) determined the effect of induced conductive TTS and of noise induced TTS on the lowest SPL of the steady tone (SISI threshold) at which a positive SISI response could be obtained. The test frequency chosen for study was 4 KHz. 8 subjects with no aural pathology were selected. Noise induced TTS ranging from 10 to 15 dB was produced by exposing subjects to 2.4/4.8 KHz band noise for 10 minutes at SPL's up to 108 dB in a reverberant room. In conductive TTS the ability to recognize the intensity increments is directly related to the SL of the steady tone. Noise-induced TTS demonstrated a very small

(3 dB) and apparently constant shift of the SISI threshold, quite unrelated to the degree of conventional threshold shift induced. He suggests that although it is possible that this phenomenon might be of cochlear origin, it is most probably, that this SISI threshold shift is actually a measure of small and constant component of noise-induced TTS which is retrocochlear in origin.

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(1) A positive SISI score in an ear with pure SN hearing loss merely

means that the test ear is responding as a normal ear at equivalent SPL and is probably of no diagnostic significance

(2) When a negative SISI scores occur in conductively deafened ears, it is due to the conductive barrier which prevents the cochlea from receiving signals at intensities where the SISI is normally positive.

(3) A negative SISI score in the absence of conductive barrier occurs only in abnormally adapting ears and is another measure of abnormal adaptation.

(4) Negative SISI findings are significant if it can be shown that the test is valid (i.e., the carrier signal remains audible throughout the test period in abnormally adapting ears).

(5) Instead of using small increments to demonstrate increased sensitivity due to presumed cochlear pathology, it might be better to use large increments to show decreased intensity difference limens in abnormally adapting ears even at high intensities.

Thus, positive SISI scores indicate that the ear under test is functioning as a normal ear at equivalent SPL. Negative SISI scores for audible signals of 60 dB or greater are indicative of abnormal adaptation.

AUDITORY FATIGUE

Auditory Fatigue is one of a number of terms used to describe a temporary change (usually, but not always, a decrease) in threshold sensitivity following exposure to another auditory stimulus. Auditory fatigue is a time-linked process. Auditory fatigue not only grows with duration of exposure but also disappears, more or less swiftly, as a function of time since exposure.

T. T. S.

Temporary threshold shift (ITS) is any post-stimulatory shift in threshold. Once a given ITS has been generated, it tends, by and large, to recover at a certain rate that depends very little on how the ITS was produced. The recovery is usually exponential in form - faster at first, slower later. The recovery process is independent of test frequency. Production of TTS is dependent on many factors. As far as the fatiguing stimulus is concerned, practically everything one can measure is revelant. If a steady pure tone is used, the frequency, intensity, and duration are important. For continuous noise, the level, band width, duration, and peak factors are the salient aspects. In the case of pulses, the peak intensity and the pulse rise time and duration all determine the TTS produced. If the fatigue is a combination of tones and noises and/or pulses, still other rules seem to apply. Finally, if the fatiguer is intermittent or has time-varying frequency characteristics, the TTS produced will be less than that produced by the same amount of energy in a steady exposure. Furthermore, the parameters are in many cases, interactive. One cannot really discuss unequivocally "the relation between intensity and TTS", because the relation may be quite different for short exposures versus long exposures, for continuous test tones versus interrupted ones, for high frequencies versus low, etc. There are large differences between individuals in the ITS produced by a given exposure.

ITS grows with intensity, ITS increases with intensity at very high levels. Duration of the stimulus is important. The middle ear muscles also affect the growth of TTS with intensity. The growth of TTS with intensity is more rapid for high frequency than for low-frequency stimulation. Because auditory reflex plays an important role in limiting TTS at and from low frequencies. At low levels of stimulation, the maximum effect is produced at the stimulation frequency, less at adjacent frequencies. As the level is raised, higher frequencies are sometimes more affected than lower. Results from long-term TTS also indicate that the maximum gradually shifts upward, sometimes becoming as high as two octaves above the stimulating frequency, although it is more generally one-half to one octove above. Higher the frequency, at least upto 4 or 6 KHz, the more TTS will be produced. Pure tones are assumed to be more dangerous than octave bands of noise. Pure tones below 2000 Hz produce more TTS than corresponding octave bands of noise when both are at the same intensity, the effect is completely explained by the difference in the ability of the two stimuli to produce sustained reflex arousal of the middle ear muscles. At low frequencies pure tones are more dangerous than noise, because of aural reflex TTS grows linearly with the logarithm of time at 4 KHz. (Ward, 1963).

C H A P T E R -III

METHODOLOGY

Twentytwo students of A.I.I.S.H., Mysore, with normal hearing in the age range of 17 and 24 years served as subjects in the study. There were 16 females and 6 males. The mean age was 21.09 years. All subjects had normal hearing (20 dB HL). They did not have any neurological and/or ENT problems.

APPARATUS

All auditory measurements were made under standard clinical conditions. The subjects were tested in the sound treated chamber of two-room test suite of the All India Institute of Speech and Hearing, The equipment used was Beltone 200 C clinical audiometer calibrated to ANSI (1969). Testing each subject took approximately one hour. The increments in SISI tests had 50 msec rise and decay time. The duration and the interval between the increments were 200 msec and 6 sec respectively.

PROCEDURE

Special equipment is required for this test. The intensity is increased briefly over a carrier tone, which is presented as a steady-state pure-tone. Every 6 seconds a 200 msec tone was superimposed upon the carrier tone. The increment could be varied in size, usually from 0.75 to 5 dB. The test was performed in one ear using an air-conduction ear phone.

Subjects Mere instructed as follows:

"you will hear a steady tone in your left ear. Occasionally you will hear a jump in the loudness of the tone. Flicker your finger whenever you hear a jump. Even if it is very small, flicker your finger, provided you are sure of hearing the "jump in loudness".

The tone was presented at 500, 1000, 2000 and 4000 Hz at 40, 50, 60 and 70 dB HL. The presentation order of frequency and intensity was random. Each subject was initially tested at all the test frequencies at all levels.

First, the SISI counter was adjusted so that a 5 dB increment was presented. This increment is large enough for everybody to detect its presence. After several responses to this 5 dB increments, the size of the increment was gradually reduced to 4, 3, 2 and then to 1 dB or 0.75 dB depending on the test situation. Sixteen subjects received 1 dB increment and 6 subjects received 0.75 dB increment.

Each subject was presented with ten 1 dB or 0.75 dB increments for each test, and-the subject was required to indicate whether he heard the increment or not. If the subject responded to 4 or 5 increments in a row, control event was introduced i.e., the increment size was reduced to zero to make sure that the subject was not responding to a learned time interval. If the subject failed to respond to several consecutive test increments, in a row, the increment size was increased to check his response. Then if responses were obtained, the testing was resumed using the test increment.

The SISI score Mas derived by determining the number of correct identification of test increments out of 10 increments. This number was multiplied by 10 to get SISI score in percentage.

The affect of auditory fatigue on the SISI test was determined on 16 subjects using 1 d8 increments. Out of 16 subjects, 9 subjects received 1 KHz tone in test ear at 110 dB HL for 10 minutes continously. TTS and SISI scores were measured at 1 KHz after termination of the fatiguing tone. Out of 9 subjects, 3 subjects' SISI score was measured at 50 dB HL, 3 subjects' SISI score was measured at 60 dB HL and in the remaining 3 subjects, SISI score was measured at 70 dB HL.

Again, out of 16 subjects, 6 subjects received a 1 KHz tone in the test ear at 110 dB HL for 10 minutes. TTS was measured at 2 KHz. SISI score was measured at 50 dB HL for 2 KHz tone after the ear was fatigued. Out of 16 subjects, for the remaining 1 subject, 2 KHz tone was presented to the test ear for 10 minutes at 105 d8 HL. TTS and SISI scores were obtained at 4 KHz. The oresentation level for finding SISI scores was 50 dB HL.

The remaining 6 subjects (out of 22 subjects) received 1 KHz tone in the test ear for 10 minutes at 110 dB HL. TTS and SISI scores were measured at 1 KHz. SISI score was determined at 1 KHz for 0.75 dB increment at 70 dB HL.

CHAPTER - IV

RESULTS AND DISCUSSION

The results of this study provide data on the effect of auditory fatigue on SISI scores in normal hearing adults.

SISI score was obtained before and after fatiguing the ear. Each correct response was given a weightage of 10%. Subject's performance on SISI test at 40, 50, 60 and 70 dB HL for frequencies viz., 500, 1000, 2000 and 4000 Hz was obtained. Mean percentage score was computed for 1 KHz and 2 KHz during the two conditions:

(1) before the ear is fatigued

(2) after the ear is fatigued.

Percentage scores of subjects before and after fatiguing the ear at 1 KHz for 1 dB increment with mean percentage score are given in Table 1.

TABLE - 1

SI. No.	% score before fatiguing the ear	% score after fatiguing the ear	Level of presentation in dB HL	Amount of TTS in dB
1	10	20	50	25
2	40	50	50	40
3	70	90	50	20
4	10	20	60	35
5	10	10	60	10
6	60	0	60	20
7	0	20	70	5
8	20	10	70	10
9	10	70	70	10
	M = 25.55	M = 32.22		

Percentage of scores obtained by subjects at 1 KHz for 0.75 dB increment at 70 dB HL with mean percentage values are shown in Table 2.

Table - 2

Sl. No.	% score before fatiguing the ear	% score after fatiguing the ear	Amount of TTS in dB
1	0	20	30
2	90	100	30
3	30	60	30
4	10	0	30
5	50	20	50
6	0	10	30
	M=30	M = 35	

Percentage of SISI score at 2 KHz for 1 dB increment at 50 dB HL with mean percentage values are given in Table 3

TABLE -3

Sl. No.	% score before fatiguing the ear	% score after fatiguing the ear	Amount of TTS in dB
1	0	10	5
2	10	0	15
3	50	20	35
4	50	40	15
5	10	0	25
6	0	30	30
	M=20	M=16	

Percentage of SISI scores before and after fatiguing the ear at different frequencies are summarized in the Graph 1.

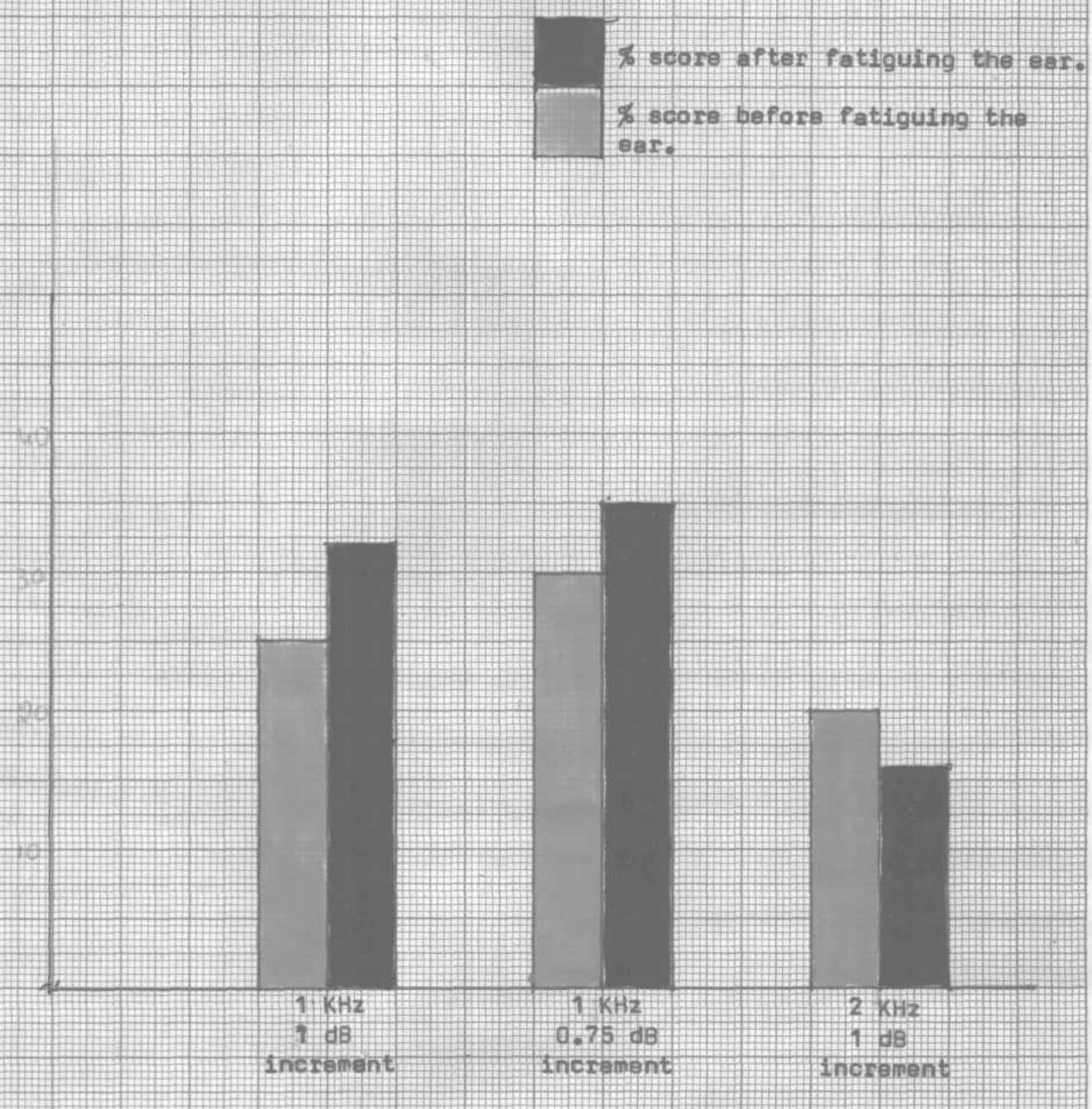
To determine the significance of difference of SISI scores before and after fatiguing the ear the Wilcoxor test was used. The result shows that at 1 KHz with 1 dB increment the difference is significant at 0.01 level ($p < 0.01$). At 1 KHz with 0.75 dB increment and at 2 KHz with 1 dB increment the difference is significant at 0.05 level ($P < 0.05$).

The mean percentage score at 1 KHz with 1 dB increment demonstrates a shift in the SISI scores towards the positive side after the ear was fatigued (Mean (before) = 25.55; Mean (after) = 32.22). The mean percentage score at 1 KHz with 0.75 dB increment also demonstrates shift towards the positive side (M (before) = 30; M (after) = 35). At 2 KHz with 1 dB increment the mean percentage score shows shift of SISI score towards negative side (M (before) = 20; M (after) = 16).

The difference between SISI score, before and after the ear was fatigued, at 1 KHz indicates that it could possibly because of cochlear origin. This is supported by Hickling (1967, 1968) study, that this SISI threshold shift is actually a measure of small and constant component of noise—induced TTS.

For the subject who received fatiguing stimulus at 2 KHz and whose SISI score was obtained at 4 KHz, the SISI score increased from 20 to 100% at 50 dB HL (TTS was 20 dB).

GRAPH 1



% score after fatiguing the ear.
% score before fatiguing the ear.
1 KHz
1 dB
increment
1 KHz
0.75 dB
increment
2 KHz
1 dB
increment

The mean percentage at different HL demonstrate that the number of increments detected grows progressively as the presentation level is increased.

Table 4 shows the mean percentage of SISI scores at different presentation levels (dB HL)

TABLE - 4

Sl. No.	HL in dB	Increment size in dB	Frequency in Hz 500	Frequency in Hz 1000	Frequency in Hz 2000	Frequency in Hz 4000
1	40	1	14.37	11.88	9.38	8.13
2	50	1	28.13	20.63	19.38	15.63
3	60	1	40	27.50	29.38	29.38
4	70	1	50	39.36	42.63	46.88
1	40	0.75	20	11.66	6.66	6.66
2	50	0.75	23.33	13.33	20	21.66
3	60	0.75	26.66	26.66	21.66	35
4	70	0.75	60	30.00	41.66	63.33

^

The result shows that the percentage of SISI score increases as the intensity is increased. This indicates that the energy reaching the cochlea is an important factor. If the inner ear receives an audible signal of 60 dB SPL or more the percentage of SISI also increases. This is in accordance with the findings of Harbert and Young (1969), Harford (1965). These findings indicate that a positive SISI score in normals means the inner ear is receiving a signal at an intensity of 60 dB SPL or more and is behaving as a normal ear at this intensity.

At 0.75 dB increment also the mean percentage of SISI scores increased as the intensity is increased. This is in accordance with Swisher (1960) and Swisher et al (1966) study who showed that normal and nonadapting SN impaired ears discriminated a signal of 1 dB or less equally well at equivalent SPL.

From the Graph 1, it is clear that the difference between Mean percentage SISI scores before end after the ear is fatigued, is less than 6%. The present study was undertaken to see whether the subjects' performance on SISI test improves after the ear is fatigued. It is generally believed that the patients with cochlear pathology can detect small changes in intensity. However, the recent studies show that the patients with cochlear pathology and normal subjects behave in the same manner as far as detection of small changes in intensity is concerned, provided the energy of the tone reaching the cochlea is same (in both cochlear pathology and normal subjects).

It is also known that the ears with cochlear pathology and the fatigued ears behave similarly in many auditory tasks.

In the present study, the fatigued ears did not show a great change with regard to the detection of 1 dB and 0.75 dB increments. This finding corroborates the recent view that the ears with cochlear pathology (fatigued ears) and the normal ears behave in the same manner with regard to the detection of small intensity changes, provided the energy of the tone reaching the cochlea is kept constant.

CHAPTER-V

SUMMARY AND CONCLUSION

The present study aimed at determining the effect of auditory fatigue on SISI scores in normal hearing subjects. The present study was carried out to find answers to the following:

(1) Does the SISI scores change after the ear is fatigued?

(2) Is there any frequency effect in the change of SISI score after the ear is fatigued?

(3) Does the performance become better or worse after the ear is fatigued?

Twentytwo students of AIISH, Mysore, with normal hearing in the age range of 17 and 24 years served as subjects in the study. All audiometric measurements were made under standard clinical conditions. The equipment used was Beltone 200 C Clinical Audiometer.

After establishing pure-tone thresholds, SISI scores were measured at 40, 50, 60 and 70 dB HL at 500, 1000, 2000 and 4000 Hz for the increments 1 dB or 0.75 dB depending on the test condition. The effect of auditory fatigue on the SISI score was determined. The subjects received either 1 KHz or 2 KHz fatiguing tone (depending on testing condition) at 110 dB HL for 10 minutes and after the termination of the fatiguing tone TTS was measured. After determining TTS, SISI score was measured at different presentation level (dB HL) depending on the test condition.

The result shows that the mean percentage scores increased at 1 KHz for 1 dB and 0.75 dB increments after the ear was fatigued and that the mean percentage score decreased at 2 KHz for 1 dB increment after the ear was fatigued.

The result also shows that the percentage of SISI score increases as the intensity is increased. This indicates that the energy reaching the cochlea is an important factor for detecting small changes in intensity.

RECOMMENDATIONS:

(1) The present study showed large individual differences with regard to the SISI scores obtained after the ear was fatigued. Hence, the results are not conclusive. It is recommended that a large number of subjects may be tested on the lines of the present investigation.

(2) Test-retest reliability of SISI ecores after the ear is fatigued, should also be determined.

LIMITATION:

(1) Since the subjects showed large individual differences (in the results of the present study) a large number of subjects should have been included in the study.

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