AUDIOLOGICAL EVALUATION OF BRAIN STEM

Reg. No. 10

An Independent project work submitted as part fulfilment
for First Year M.Sc, (Speech and Hearing) to the
University of Mysore.

ALL INDIA INSTITUTE OF SPEECH AND HEARING
MYSORE - 570 006

TO

MY PARENTS AND

SANJEEVAN MEDICAL FOUNDATION.

CERTIFICATE

This is to certify that the Independent project entitled:

"AUDIOLOCICAL EVALUATION OF BRAIN STEM"

is the bonafide work, done in part fulfilment for First Year M.Sc, Speech and Hearing,of. the student with Register Number: 10

Director,

ALL INDIA INSTITUTE OF SPEECH AND HEARING

MYSORE - 570 006

CERTIFICATE

This is to certify that the Independent project entitled:

"AUDIOLOGICAL EVALUATION OF
BRAIN STEM"

has been prepared under my guidance and supervision.

(GUIDE)

DECLARATION

This independent project entitled

**"AUDIOLOGICAL EVALUATION OF
BRAIN STEM"**

is the result of my work undertaken under the guidance of Mr. M.N.Vyasamurthy, Lecturer in Audiology, All India Institute of Speech and Hearing, Mysore - 570 006, and has not been submitted at any University for any other Diploma and/or Degree.

Mysore.

Register No. 10

Dated:

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CONTENTS

In recent years clinical audiology has developed and grown as a profession. One measure of growth is the sheer members of individuals who are trained and working in the field. In recent years the number of audiologists has increased, the variety of work settings has been increased. At the same time the methods used by audiologists have undergone modification. Some newer procedures have come to the fore gradually or sometimes precitously in a relatively short space of time. Other methods have lessened in popularity. Thereris a trend towards more extensive testing, both in scope and depth.

In the past few years there has been a dramatic increase in the use of central tests in audiology clinics. The audiologic study of the central auditory nervous system (CANS) has its major activity in site of lesion testing. This approach is typically related to medical diagnosis.

Since the type and number of tests to evaluate the site of lesions are increasing during these times, it is necessory for an audiologist to have an overall idea about the past research and present trend in research. As the entire information about the audiological tests used to detect brain stem lesions in hearing disorder patients is not available easily, the present study is attempted to give full information about the "Audiological Evaluation of Brain Stem" in a capsular form.

AUDITORY PATHWAY

Afferent Auditory pathway.

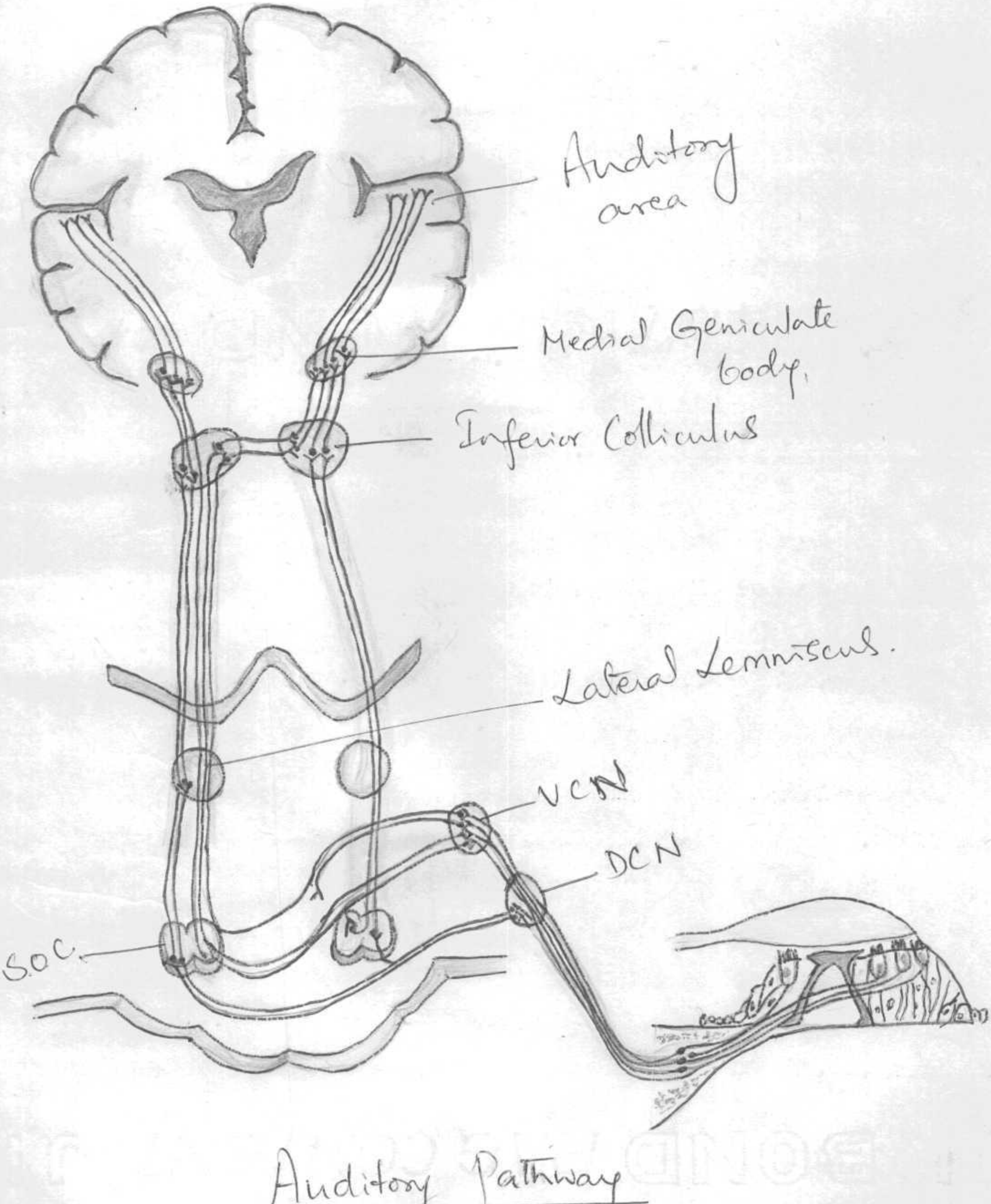
The cochlear or VIII cranial nerve appears as a twisted trunk. Its core made up of fibers derived from the apex of the cochlea and its outer layers coming from more basal regions. The nerve leaves the inner ear via the internal auditory meatus, and enters the brain stem at the lateral aspect of the lower pons. Thus the fibers of the auditory nerve constitute the first order neurons of the ascending central auditory pathways.

Upon entering the brain stem, the first order neurons of the auditory nerve synapse with cell bodies in the dorsal and ventral cochlear nuclei. Specifically neurons arising from the more basal areas of the cochlea terminate in the dorsal portion of the dorsal cochlear nucleus (DCN) and ventral cochlear nucleus (VCN); and the ventral portion of the DCN receive neurons originating in the more apical parts of the cochlea. Several studied have shown that degeneration of cochlear nuclei follows the lesions of the cochlea.

Second order neurons arise from the cochlear nuclei. The traphezoid body is formed from the ventral acoustic stria, which arised from the VCN. The fibers of the traphezoid body decussate cross to the opposite side to synapse with the nuclei of the laters lemniscus. Other fibers of the traphezoid body terminate at the Superior Olivary Complex (SOC) on the ipsilateral side and at the traphezoid nuclei. The dorsal part of the VCN gives rise to the intermediate acoustic stria, which contralateralizes to ascend in the lateral lemniscus of the opposite side. The dorsal acoustic stria is made up of fibers from the DCN which cross to the opposite sede and ascend in the contralateral lateral lemniscus.

The superior olivary complex contains a lateral principal nucleus which approximates an S shape and a medial accessory nucleus. Fibers from the VCN on both sides mainly synapse with the medial accessory nucleus. The medial accessory nucleus in turn is the source of third order neurons which ascend via the lateral lemniscus on the same side. The SOC receives a bilateral representation (at least from the VCN) and the lateral lemniscus include fibers from the SOC as well as from the traphezoid body and acoustic stria, while fibers from the cochlear nuclei of one side ascend directly up the opposite lateral lemniscus, it appears that there are no fibers from homolateral cochlear nuclei.

Also ascending with the lateral lemniscus are fibers arising from the several nuclei of the lateral lemniscus itself. Although the nuclei of the lateral lemniscus have classically been viewed as dorsal and ventral, recent evidence has shown a third nucleus which appears to be a continuation of the nuclei stemming from SOC. Furthermore the ventral nucleus, and to a slightly lesser extent the dorsal nucleus are highly variable, they are infact even quite variable between right and left sides of the same subject. Communication between the lateral lemnisci of the 2 sides is via the commissural fibers of probst, which



Auditory Pathway

appear to involve, at least primarily the dorsal nuclei.

The majority of the ascending fivers synapse with the nuclear mass in the inferior colliculus at the level of the midbrain. There is also communication between the colliculi of the 2 sides via the commissure of the inferior colliculus. Several fivers may pass the inferior colliculus and follow a direct course to the medial geniculate body(MGB) of the Thalamus. The pathway from the inferior colliculus to the MGB goes by way of the brachium of the inferior collAculus. This pathway doesnot appear to contain neuron bodies in the human adult and is made up of fibers from the inferior colliculus as well as of the fibers that bypass the colliculus as they ascend to the MGB.

The MGB is the last subcortical way station and all ascending pathways to the auditory cortex synapse here. The MGB has 2 main parts, the par principalis and a ventral nucleus, fibers ascending from the inferior colliculus terminate primarily in the par principalis.

The auditory (geniculotemporal) radiations project from the MBB to the transverse temporal gyrus on the temporal cortex of the same side.

Efferent Auditory Pathway:

Efferent fibers typically bring information from the cortex to the periphery. There are 2 types of efferent fibers.

Descending tracts may be arising in the auditory certex or in a variety of nuclei and terminate at other nuclei, especially in the cochlear nucleus and the olivary complex. The auditory cortex is the source of 2 descending systems. The first starts at 1 cortex and terminate in the medialgeniculate body. The second is a descending system which connects the cortex with the cochlea and cochlear nuclei via the inferior colliculus and the periolivary masses.

Cojol recognised the existance of descending axons from the cortex to the ventral division of the medial geniculate body. All the auditory areas also send axons to the dorsal and medial divisior of the medial geneculate body. Axons of small diameter descend fron the auditory cortex to the central nucleus of the inferior collicult The majority of the axons terminate in the ipsilateral colliculus but a few apss to the contralateral side. Because of this the relevant parts of the inferior colliculus, the periolivary cell masses, and the dorsal cochlear nucleus are innervated by the auditory cortex of both sides. The efferent axons to the cochlear and to the cochlear nucleus arise principally in the dorso-medial and dorso-lateral periolivary cell masses.

The first experimental study on the efferent innervation of the cochlea were reproted by G.L.Rasmussen (1942, 1946). He used stained specimans to demonstrate the efferent component in the cochlear nerve which was named 'olivo cochlear bundle'(OCB). The bundle was described for cat, rat and opossum (Rasmussen,1948, 1946, 1953,1960) and in man (Gacek, 1961). The OCB consists of two components, crossed and uncrossed. Nerve fibers of both components originate in the brain stem, the crossed in the contralateral and the uncrossed in the homolateral superior olivary region. The origin of crossed OCB (COCB), was confined by Rasmussen (1946) to an area situated medial to the accessory live and dorsal to the nucleus of the trapezoid body, The homolateral OCB, according to Rasmussen (1960) emanates fromthe homolateral S shaped olivary segment.

Central course: The cell bodies of the COCB neurons (about 3/4 of the OCB neurons) are located close to the medial accessory superior olive on the opposite side. Their axons course dorsalwards and decussate between the facial nerve genu, close to the floor of the 4th ventricle. The(OCB) axons then travense the facial nerve roof enroute to the cochlea, cell bodies of the uncrossed OCB neurons are located closer to the main S shaped nucleus of the superior olive on the same side and their axons move dorsalwords to join the COCB axons at the ventral part of the vestibular nucleus.

Peripheral course: The entire efferent bundle that arises from the superior live on both sides contain about 500 to 600 fibers of 3-4 diameter and majority of them are COCB fibers. These enter the cochlea in the basal region and from the intraganglionic spiral bundle. This bundle runs apical-wards and distributed peripherally thoughout all turns towards the organ of corti.

Termination; The COCB fibers compose the tunnel radial fibers, in the cochlea. The tunnel radial fibers come from the modiolus, thorough the habanula perforata between the pillar cells across the upper portion of the tunnel of corti, and synapse at the base of the outer haircells. The uncrossed olivocochlear bundles form the inner spiral bundle in the cochlea. They penitrate the foramina neurosa, then from there it turn in a spiral direction to form inner ppiral bundle. After reachingthe lateral aspect of the inner piller, parts of the efferents fibers from the tunnel spiral bundle. The inner spiral bundle fibers contain a few neurofilaments, Some fibrous material, mitochondria and many vesicles of variable size and density (Smith, 1961). The tunnel radial fibers include a totoal of some 8,000 fibers of varying diameters from 0.3 - 1.5 and finally there are approximately 40,000 vesiculated nerve endings at the base of the outer hair cells.

In the basal turn, each outerhair cell is provided with 6 to 8 efferent nerve endings, a number which is gradually reduced towards the cochlear apex especially in the second and third rows of outer haircells where the nerve endings disappear entirely in the upper turns (Isku and Bolagh Jr. 1968).

Function of Efferent system: The exact function of the effere system is not understood, but electrophysiological evidences suggested that the system ia inhibiting in nature. Because of its accessibility, the crossed OCB fibers has been the component studied most thoroughly. Electrical stimulation of the COCB Results in the fallowing aspects.

(I) Action potential decreases with COCB stimulation,
(ii) The cochlear microphonic increases slightly,
(iii) Endolymphatic potential is reduced,
(iv) Effect of COCB on summating potential.
(v) Presence of a slow potential.
(vi) Effects of COCB stimulation on the acoustic pathway.

THE BRAIN STEM

The audiologist is capable of making distinctions within the peripheral system and there is ample evidence that he can make distinctions in the central portion as well. Auditory tests can divide pathologic responses into at least four groups, conductive, cochlear, retrocochlear (VIII nerve and brain stem) and cerebral (Katz, 1970).

In the figure the division which maynot be familiar is the high and low brain stem. The high brain stem region fefers to the upper portion of the brain stem (including at least the inferior colliculus) the low brain stem refers to the inferior portion (most probably including the cochlear nuclei and the superior olivary complex). The auditory reception (AR) centre refers to Heschl's gyrus (the middle, posterior portion of the superior temporal gyrus in each cerebral hemisphere). The nonauditory reception (NAR) protion includes the entire cerebrum excluding the AR centres.

Auditory symptoms vary as a function of whether the brainstem is affected by an extra- or intra-axial tumor. (Extra-axial tumor means tumors located on the outside of brain stem and intra axial means tumors located with in the brain stem.)

Lesions of the auditory cortex are relatively specific in their auditory effects. Lesions involving the subcortical pathways, on the other hand manifest themselves in a variety of ways. According to the present knowledge concerning the neuroanatormy and neurophysiology of the central auditory nervous system, one might expect a lesion specific to the cochlear nuclei

Outer Ear	Middle Ear	Inner Ear	VIII Nerve	Low Brainstem	High Brainstem	Cerebellum	Auditory Reception (Heschl's Gyrus)	Nonauditory Reception.

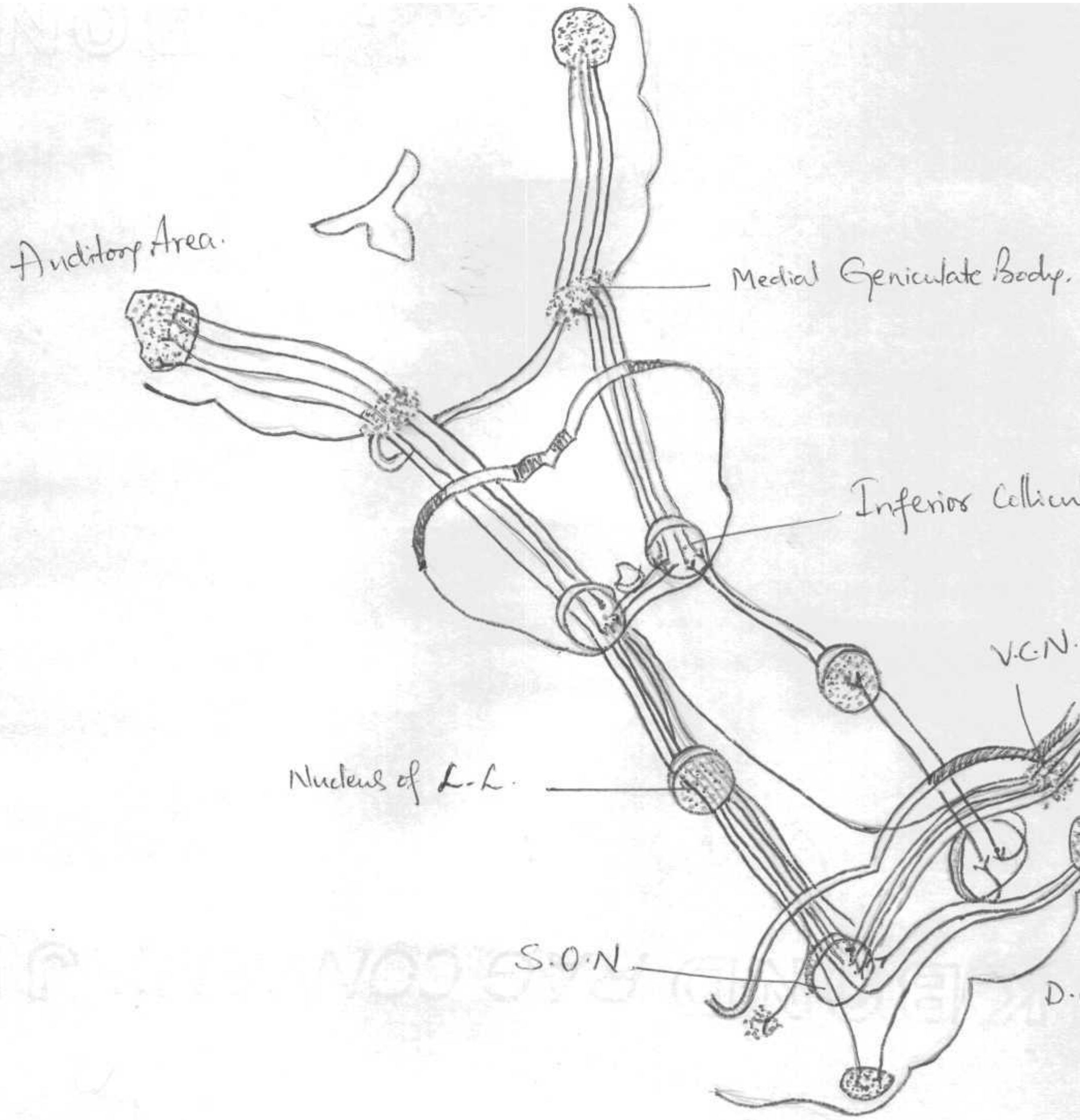
to show ipsilateral effects (Matzke and Foltz, 1972). If the lesion is superior to the major decussation of fibers occuring at the level of the traphezoid bogy contralateral effects might be expected. But clinical research has failed to demonstrate such specific effects from confirmed tumors of the brain stem. One possible explanation might be the relatively small anatomical dimensions of the brainstem as compared to that of the neocortex.

Extra -axial brain stem tumors gave ipsilateral central auditory symptoms, where as intra-axial tumors gave either bilateral or contralateral symptoms.

Extra- and intra-axial tumor cases were dichotomized further in terms of their audiologic manifestations. For example, individuals with extra-axial brain-stem tumors exhibited a greater loss of puretone sensitivity as compared to those with intra-axial tumors by about 10 to 15 dB at all frequencies.

BRIEF ANATOMICAL OUTLINE OF BRAIN STEM

The cochlear nerves enters the brain stem at the lower border of the pons. It afterwards divides immediately in to ascending and descending branches, which run to the ventral and dorsal cochlear nuclei respectively. After synapsis in the cochlear nuclei the majority of the second order neurons cross over to the contralateral side and relay in the superior olivary complex or dorsal cochlear nucleus or join the lateral lemniscus. Some fibers from the ventral cochlear nucleus join the ipsilateral lemniscus after connections in the medial part of the olivary nucleus. The ascending fibers of the lateral lemniscus thus contain neurons of both the second and third order, and mainly from the contralateral cochlearnuclei. The ascending acoustic pathway enters the inferior colliculus in the upper part of the brain stem and after synapses, the fibers run rostrally to the medial geniculate body. There are commissural connections between the medial geniculate bodies. The acoustic pathway then forms the so called 'auditory radiation' which terminates in the temporal lobe deep in the syvian fissure.



'Auditory Pathways in Brain stem'

AUDIOMETRIC FINDINGS IN BRAIN STEM LESIONS

Audiometric investigations of lesions of the central auditory pathology have now become very fashionable and the question is being debated by an increasing number of investigators. Diagnosis of patients with brain and brain stem lesions was made by neurologists or neurosurgeons using surgical, autopsy, radiologic and other methods for locating the disorders (Katz,) The continuous variability of data obtained was not yet allowed a clear cut definition of the audiometric alterations of lesions of the auditory tract at the brain stem level. (Calearo and Antonelli, 1968).

Graphe (1896) has done a pioneer work on central auditory disorders. A considerable incedence of auditory troubles has been pointed out in brain stem diseases. It is stated that heaping defect usually consists in a more or less severe hearingloss for puretones accompanied by a proportional alterations of SRT AND DS. To find qualitative aspects of hearing troubles many tests were devised. Among these tests investigations with puretone material aim at analysing the particular aspects of auditory integration which are charecteristic of every level of brain stem.

Graphe (1896) reports one case of crossed speech deafness in a lesions of the lateral lemniscus with preservation of tonal hearing and similar findings have been reproted by Brunner (1936), Falkenberg(1941), Kos(1955), Antonelli et al., (1963), Antonelli and de Mitri (1963), and Eickel et al., (1966). This phenomenon is labelled as "Tone-Speech dissociation", and it may be due to disintegration of some particular sub-cortical level of elaboration and integration of the auditory message.

PURETONE AUDIOGRAMS

If the pathological precess is localized in the brainstem portion of the auditory system or in the mesencephalon or diencephalon, all degrees of impairment of hearing have been described from the mildest, unilateral to a very severe bilateral increase in the thresholds of audibility, but total unilateral or bilateral deafness has never been observed in this condition. (Krassing, 1950, Greiner et al., 1956; Saltzman, 1952; Arnold, 1951; Ladyzhenskaya, 1960; Poltz1946).

Normal or Transmission type alterations in audiogram were observed by Antonelli and Calearo(1968). Some workers consider that audiograms of parobolic shape resulting from impairment of hearing at low and high frequencies are characteristic of lesions of the brain stem (Appaix et al., 1957; Jatho, 1954; Greiner et al 1954). A tendency toward low frequencey hearingloss in the ipsilateral ear in early brainstem lesion cases. There is often some evidence of a low frequency deviation which shows up in the contralateral ear as well (Katz,1976).

Lesions of all the central parts of the auditory system are characterized by absence-of sound lateralization in webers test despite asymmetry of the thresholds of audibility shortening of bone conduction and absense of the rapid increase in loudness phenomenon. However Greiner et al.,(1957) have recently detected positive recruitment in brain stem lesions, which they associate with disturbances in the cochlea resulting from the involvement of the efferent pathways of the auditory system, through which the system of the inner ear is controlled by the higher centres (Thiebaut et al., 1956, Pfaltz, 1963) in the pathological process. According to Goodman (1957) Wildhagen (1954), and Bittrich (1956), the increase in the threshold discovered in diseases of the brain stem may apply mainly to the homolateral ear.

SPEECH TESTS

Dissociation between a gross distrubance of the discrimination of speech and the slight changes discovered by tonal audiometry is regarded as charecteristic of lesions of the brain stem.(Jerger 1960, Blagoveshchenskaya, 1965; Tsimmerman, 1967). Discrimination score for normal sentences was in accordance with puretone thresholds in approximately 78 percent of the cases and 22 per cent had tone-speech dissociation(Calearo and Antonelli, 1968). Parker, Decker and Richards (1968) found puretone sensitivity ranging from normal to a severe loss of sensitivity with a high frequency loss being the most predominant configuration. Word discrimination score varied between 0 and 100 percent and loudness recruitment varied from absent to complete. Jerger(i96O) presented a case with right side brain stem lesion having normal puretone thresholds in both ears but with a considerably reduced speech discrimination score for left ear (contralateral to lesion), He had a score of 100 percent for right ear and only 24 per cent for the left ear when the speech was presented at 40 dB SL.

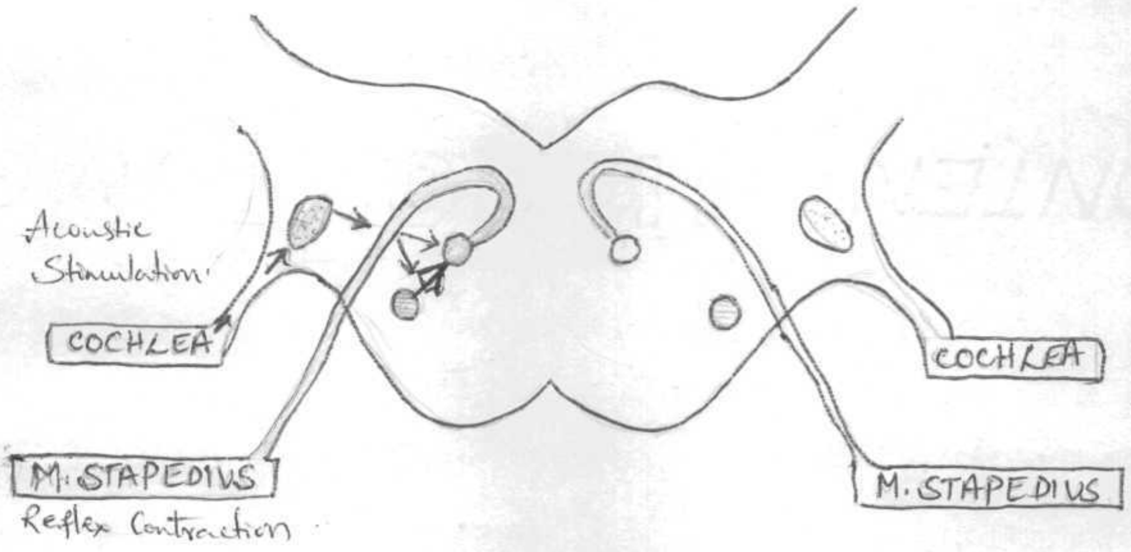
ACOUSTIC REFLEX MEASUREMENTS

The stapedial muscle contracts reflexively when the ear stimulated with a sufficiently loud sound. The contraction occurs bilaterally, even when only one ear is stimulated. It is known that puretones with an intensity level of 60-105 dB above the threshold of hearing produce impedence changes in both ears. (Metz, 1946, 1951, Jepsen 1951, 1955, Ewertsen et al., 1958, Klockhoff, 1961; Terkildsen, 1960;: Ballos; 1964, Jerger et al., 1972; Borg and Zakrisson, 1974; Woodfor et al., 1975; Fria et al., 1975, and Brask, 1978). The median threshold value for the stapedial reflex to puretone signals is approximately 85 dB HTL and approximately 65 dB HTL for white noise.

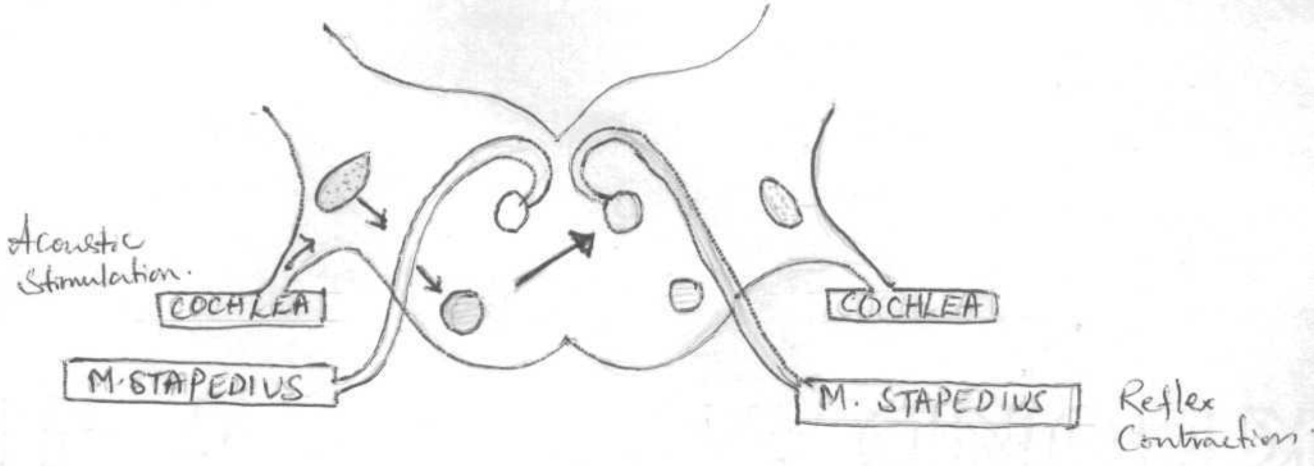
PATHWAYS OF Acoustic Stapedial Reflex: The neural network involved in the reflex activation of the stapedius muscle during acoustic stimulation is not known in detail. Studies done on animals have shown that the pathways of the acoustic ptapedial reflex are located in the lower part of the brain stem.(Cajal, 1909, Hammerschlag, 1899, 1902; Tsukamoto, 1934;: Rasmussen, 1946; Borg, 1973). The pathways for ipsi- and contralateral stapedial reflex are not identical.

Ipsilateral pathway of Stapedial Reflex: During acoustic stimulation, electric impulses from the sensory cells in the cochlea are transmitted through the primary acoustic neuron to the ventral cochlear nucleus. The primary acoustic neurons constitute the acoustic nerve. The majority of axons from the ventral cochlear nucleus pass through the traphezoid body to the medial part of the facial motor nucleus and from this

IPSILATERAL REFLEX (STAPEDIAL) PATHWAYS.



CONTRALATERAL STAPEDIAL REFLEX PATHWAYS.



nucleus the electric impulsesare transmitted through the facial nerve to the ipsilateral stapedius muscle. In addition some nerve fibers pass from the ventral cochlear nucleus through trapezoid body to the ipsilateral medial superior olive. From this nucleus the electrical impulses are transmitted via a third neuron to the medial part of the ipsilateral facial motor nucleus.

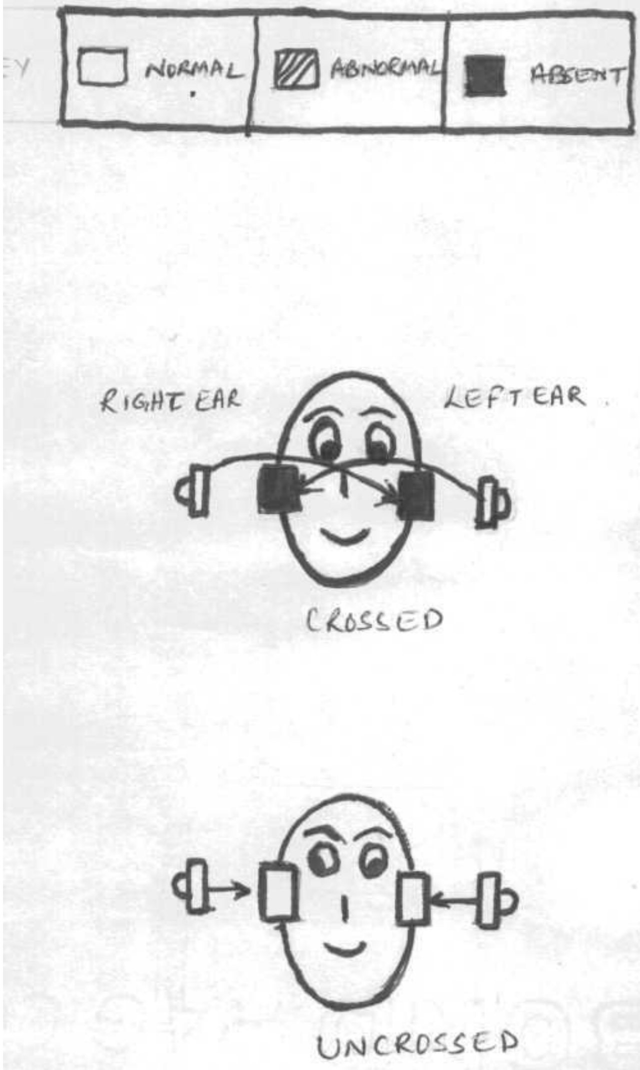
Contralateral Stapedial Reflex pathway: The electrical impulses from the sensory cells in the cochlea pass via the primary acoustic neuron to the ventral cochlear nucleus, from there the electric impulses are transmitted through a second neuron to the region of medial superior olive. A third neuron connects the medial superior olive to the medial part of the contralateral facial motor nucleus. A fourth neuron transmits the electric impulses from the facial motor nucleus to the contralateral stapedius muscle. Thus the ipsilateral Stapedial arc contains three,partly four neurons, and the contralateral reflex are contains four neurons.

In the evaluation of central auditory disorders the goal is to differentiate among three different sites; the eighth nerve, the brain stem, and the temporal lobe. In the application of impedence audiometry toward this goal acoustic reflexes provide the primary basis for differential diagnosis.

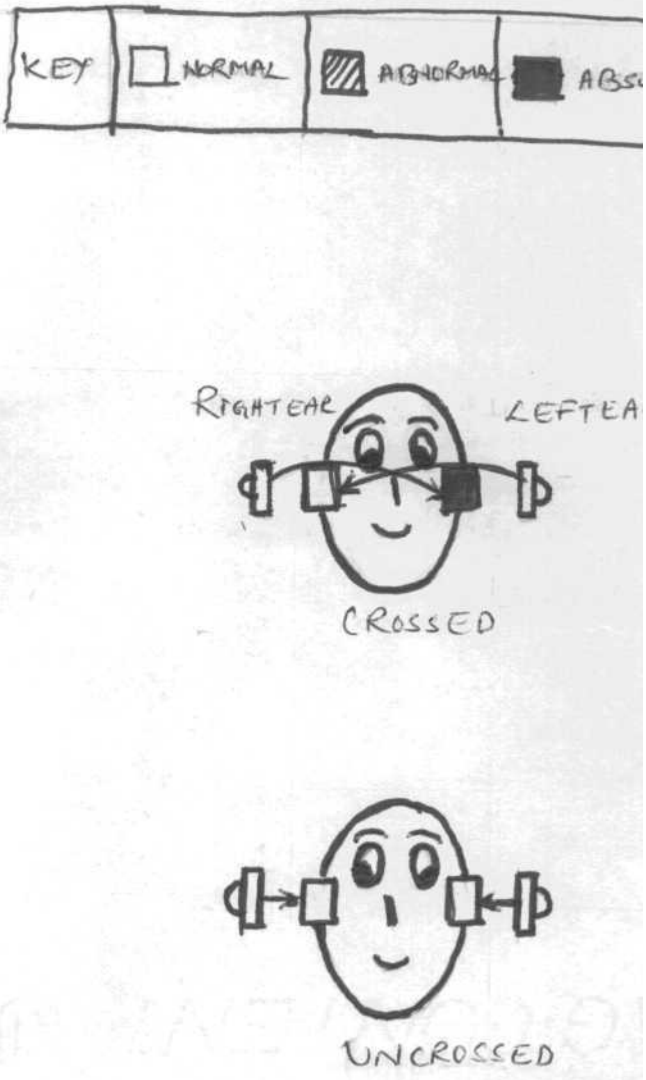
One important distinction between crossed and uncrossed reflex pathways is that the uncrossed reflex pathway contains a direct connection from the Central cochlear nucleus to the ipsilateral seventh nerve nucleus (Borg, 1976). In contrast crossed feflexes donot have a direct collateral to the seventh nerve nucleus from a second order neuron. Crossed reflexes are always activated through one additional relay in the region of MSO.

A more complex neuronal organisation for crossed than for uncrossed pathways has been repeatedly supported by pharmocologic studies demonstrating a greater susceptibility of crossed reflexes to some anasthetics. In rabbits and humansbarbiturates such as Pentobarbital sodium consistantly depress crossed reflex thresholds more than uncrossed thresholds (Borg and Holier, 1967, 1975). Similar crossed reflex abnormalities in normal human subjects with temporary brain stem impairment due to barbiturates (Giacomelli and Mozzo, 1964; and Bostra et al; 1977).

Interest in acoustic reflexes as an integral part of the central auditory system was initiated in 1935 by Lorente de No. In Italy Giacomelli and Mozzo (1964) reported crossed reflex threshold abnormalities in patients with toxic, vascular and/or compressive brain stem disorders and in normal subjects with transient brainstem impairment due to barbiturates. Greisen and Rasmussen (1970)reported a discrepancy between uncrossed and crossed reflex thresholds in 2 patents with intra-axial brain stem disorders. In 1975, Jerger formally classified



HORIZONTAL
TYPE REFLEX PATTERN



UNI BOX TYPE
REFLEX PATTER

the uncrossed vs crossed reflex threshold patterns characteristic of eighth nerve or extra-axial brain stem and intra-axial brain stem sites.

REFLEX PATTERNS IN BRAIN STEM PATHOLOGY:

The useful method for visualising the results of the crossed and uncrossed acoustic reflex are shown in figure.

1,000 Hz is the reflex eleiciting signal both for corssed and uncrossed reflexes. When all reflexes are present at normal HTLs the boxes are left open, If the reflex is abnormal the box is hatched, and if the reflex is absent the box is filledin.

A horizontal pattern of reflexes are seen in brain stem pathologies. The figure shows absence of crossed acoustic reflex in both ears. Reflexes are present to signals presented in uncrossed condition. This type is seen in intra-axial brain stem disorders.

A rare "Unibox pattern" (Jerger, 1979) is also seen in specific brain stem disorders. There is absence of one crossed acoustic reflex. The other crossed reflex and both uncrossed acoustic reflexes are present at noinnal levels.

In Jerger's(1977) study there were no false positive findings in either the eighth nerve or intra-axial brainstem group. Subsequent to Jerger, Borg (1973) demonstrated the unibox type in a rabbit. Clinically however the unibox reflex pattern doesnot distinguish between eighth nerve and intra-axial brain stem sites.

One observation is that in animals and humans with brainstem disorders, acoustic reflexes may show unusually reduced amplitude and/or amplitude decay. Although reflex decay is s diagnostic measure of eighth nerve or extra-axial brain stem disorders, recently it is reported substantially reduced maximum amplitude or reflex amplitude decay in patients with pure intra-axial brain stem auditory disorders and no known abnormality of the eighth nerve per se. Thus reflex decay measures may offer valuable supplementary information to basic threshold data.

Many investigatory (Borg, 1973, 1976, Borg and Moller, 1975, Mc Candless and Harmer, 1975; Coletti, 1975; Bosatra, 1975, and 1977) have shown that the reflex time course in animals and humans with brain stem disorders may show delayed onset latency and an unusually slow rise to maximum amplitude.

When the stapedius reflex response is recorded on a graphic recorder, in cases with brain stem lesions, one observes a cupula like pattern. Both the latency and the threshold of reflex response are increased (Bosatra and Russolo 1970).

Bosatra, Russolo and Poli (1975) investigated the effects of different pathological conditions at the brain stem on the acoustic reflex. Brain stem tumor gave rise to bilateral absence of reflex. An impairment in the central portion of the reflex are affected the shape, development, threshold and latency of reflex contraction.

Reflex measurements were also found to be useful in monitoring the recovery from brain stem diseases (Jerger, Neely and Jerger, 1975).

It may be concluded that brain stem lesions manifest themselves in alterations of contralateral reflex while they donot alter the ipsilateral reflex responses.

The above mentioned acoustic reflex patterns and the reflex decay patterns do not necessorily represent every possible case. Nevertheless, they are helpful in assessing and interpretting results of the acoustic reflex tests. By learning the various reflex configurations associated with different auditory disorders, the clinician can sharpen his/her diagnostic acumen.

THE STAGGERED SPONDAIC WORD TEST (SSW TEST)

Speech audiometry seems to be the most useful approach to the evaluation of the central auditory nervous system (CANS) The SSW test is a dichotic procedure (i.e., different signals are presented to each ear). The subject is expected to repeat both messages.

Katz (1962, 1968) devised SSW test. Here spondaic words were chosen to reduce test errors due to peripheral hearing problems. Spondaic words are relatively familiar to most patients and are essentially 100% intelligible over a wider range of intensities than monosyllabic words. The SSW is a battery of central test, that can be given in ten minutes. It is not a demanding listening task for normal individuals leven to sixty years of age. A spondaic words is presented to each ear at 50 dB above threshold and the listener is asked to repeat both the words.

SSW TEST MATERIAL

Each test item is composed of two spondees recorded in a partially overlapped fashion, so as to send one spondee to each ear. Each ear receives stipulation in isolation as well as in competition with the other.

For example, Here 'Up' is heard as a " right non-competeing" (R-NC) condition, while 'Stairs' and 'Down' are heard as right competing (R-C) and left competing (L-C), and 'Town' is heard as the left non-competeing (L-NC).

The test consists of four practice and forty test items taped on two channel tape recorder. Test is administered with independent control of presentation levels for each ear. It is administered at 50dB sensation level (Speech) i.e., 50 dB above the SRT level

Scoring is done as shown figure. Here an error is counted for each monosyllable or half spondee incorrect. Errors can be word substitutions, non-linguistic substitutions, or omissions.

R-NC	RC	LC	L-NC
17	27	10	5

Right Ear	Left ear.
22	8

Total SSW
15

Initially errors for each condition (R-C, R-NC, L-C & L-NC) are individually summed. Individual ear performance is the average of the competing and non-competing errors for the ear in question.

$$\frac{\frac{(R\text{-}NC+R\text{-}C)}{2} + \frac{(L\text{-}NC + L\text{-}C)}{2}}{2}$$

$$- \quad \frac{\frac{17+27}{2} + \frac{10+5}{2}}{2}$$

$$= \frac{22 + 8}{2} = 15$$

PERCENT OF ERROR Each score is multiplied by 2.5 to convert into percentages.

R-NC	R-C	L-C	L-NC
42%	68%	25%	12%

Right Ear	Left Ear
55%	18%

Total SSW
36%

CORRECTED SSW SCORE:

The raw scores are corrected to reduce the effect of word discrimination errors. The percentage of word discrimination error is subtracted from the SSW error score for the same ear.

For example: A patients discrimination score was 92% for the right ear and 82% for the left leaving 8 and 18% error for right and left ears respectively. For the R-NC condition the corrected SSW (C-SSW) score would now be 34% (42% - 8%). The averageword discrimination error for the two ears would be subtracted from the total SSW error leaving an error of 23% (36% - 13%). The C-SSW score now be

R-NC	R-C	L-C	L-NC
34%	66%	7%	-6%

Right Ear	Left Ear
47%	0%

Total SSW

23%

A very important part of the test is the C-SSW score. Using C-SSW score widens the application of the SSW to patients with peripheral hearingloss. Valuable information then may be derived from patients as to their central auditory system even if they do show the evidence of peripheral hearing loss.

Three patterns of response sometimes ecountered on the SSW are the reversal the ear effect and order effect.

For each test item most patients reports the leading spondee first. However, some will giveword reversals which are noted on the answer sheet but are not included in the basis scoring. The two most common classes of reversals are true reversal and probable reversal. A probable reversal is similar with the exception that an error on one of these reversals is termed total reversals. Katz and Pack (1975) included questionable reversal recently. A questionable reversal is where one of the four half spondeed is omitted while the other three are given out of order. The sum of true probable and questionable reversals is termed maximum reversals.

Sinee test items are presented to each ear serves as the leading ear for half the test items and the trailing earfor the other half the SSW scores should not be contaminated by various response biases. In spite of item counterbalancing an ear effect and/or an order effect is evident in some patients.

NORMATIVE DATA OF SSW TEST: A series of studies have dealt with normal hearing subjects on the SSW test, List EC and its forerunners. In all instances the format of test presentation has been identical.

As would be expected individuals with normal hearing conductive and sensorineural hearing losses generally perform in the normal ranged Patients with moderate or severe scores can be suspected of naving disorder of the auditory reception' center.

Patients with mildly abnormal scores may or may not have a CANS lesion. Some patients have been called for want of more definitive information as abnormal listeners. More commonly this category includes individuals with conductive or sensorineural losses or patients with CNS lesions lying outside the primary auditory reception area.

In clinical application one compares the most extreme corre SSW scores, either positive, or negative, for condition ear and total SSW score to be standard. Katz and associates (1973, 1975)note that among the three score categories, the ear score often is the most sensitive to the presence or absence of a CANS problem.

The SSW test can be used to illustrate the selective sensitivity of central auditory procedures. The most sensitive pathologic regions which can be demonstrated by the corrected staggered spondaic word (C-SSW) score (moderate or severely depressed) are the auditory reception centers and high brain stem.

With low brain stem lesions there is a sharp drop in errors in to the over corrected category (significantly negative) as opposed to high brain stem and auditory reception cases (highly positive).

Lynn, Gilroy et al., (1972, 1974, 1975) have been particularly successful in demonstrating the clinical value of CANS tests. They have demonstrated systamatic performance on central auditory tests such as SSW in patients with lesions in the brain and brain stem.

Katz (1970) showed the C-SSW score is an excellent discriminator between high and low brain stem lesions. We should not combine high and low brain stem results when studying SSW test because the brain stem is very much differentially sensitive. Other wise there will be a wide range of scores for brain stem cases (Jerger and Jerger, 1975).)

SSW scores are compared with the results of the competing environmental sound test (CES) (Katz, 1975).

Thus far there is relatively little known about CES, however it is apparent that the comparisons with the SSW scores can be thrown off by sensorineural hearing loss (Lenox and stone, 1976). Recently Katz reported a study where a man with focal lesion of the thalamus on the left side was tested. The SSW results were quite normal but CES was depressed. The SSW/CES comparisons suggested right hemisphere involvement. This case and other suggest that deep brain disorders and brain stem lesions do not necessorily follow the expected contralateral pattern (Katz 1970, 1977).

SSW test is used in conjunction with both standard and spe special audiological procedures for localizing brain and brain stem disorders. The SSW analysis is highly dependent on the audiologic test battery and should not be interpretted without these data such as pure tone thresholds, word discrimination scores (WDS) tonedecay, and acoustic reflexes. Further confidence and refinement of the audiologic diagnosis could be had by using one or more other central tests.

SYNTHETIC SENTENCE IDENTIFICATION TEST

(S S I TEST)

Sentences which are purposely and systematically diverted from the standard rules of grammer and syntax were developed as an adjunct to standard speech audiometry by Charles Speaks and James Jerger in 1965. The rationale for developing this technique was to avoid the use of single words and single words and single syllable words in particular, The developmental purposeof this test was to have available verbal materials far auditory research that were of sufficient duration to permit systematic alterations of temporal charecteristics of the speech messages. They intended to develop sentences of controlled length and informational content.

The advantages of speech identification over classical techniques are that the message set is closed and of controlled size. Testing procedures presented minimal opportunity for experimentor error and learning or practice effects for a message set could be determined with relative ease. The idea of using synthetic sentences was persued in order to avoid the problems involved in using 'real' sentences, i.e., the meaning of a real sentence and so the whole sentence can be conveyed by one or 2 key words. It is difficult to construct equivalent message sets of real sentences because of factors of vocabulary word familiarity, word length, sentence length, and syntactical structure. The synthetic sentences are verbal materials having minimum contextural clues and minimum redundencey when compared to actual english sentences.

The procedure for constructing artificial sentences was based on Miller and Selfridge (1950) method where successive words in the sentences were selected on the basis of 'conditional probabilities', with each new word conditioned - on the preceding word.

First order approximations of sentences were constructed by choosing successive words at random from the original 1000 Second order approximation sentences were constructed by random selection of the first word and then having an individual supply, a second word from the pool that would reasonably follow the first. This is continued until the desired sentence length was reached. Third order approximations were developed by having any new word conditioned on the 2 words that preceeded it. One of the word pairs was selected at random from the second order sentences and an individual supplied the third word from the word pool. The last two words were given to a new person who selected a third word, and so on.

In 1968, Jerger, Speaks, and Trammel used SSI test clinically. It was recognised from earlier that the identification task was too easy if the sentences were presented in quiet, and although the patient had very poor discrimination scores for monosyllables, the SSI score reached maximum of 100 percent at high intensities. So they used an ipsilateral competing speech message of continuous discourse added to the sentences to make the task more difficult.

Before administering the SSI test, pure tone audiogram should be noted. The SSI test is not administered to patients with peripheral hearingloss since results in these patients could be equivocal reflecting either the peripheral or central auditory problem. In addition to essentially normal puretone sensitivity the hearing thresholds should be bilaterally symmytrical. For example, if one ear is 0 dB and other is 20 dB, the test is not administered although the sensitivity is with in normal limits in both ears.

SSI performance is measured at an intensity necessory for 100% correct performance in both ears, usually 50 dB SPL, although some patients may require intensities higher than 50 dB SPL to achieve the 100% criterion in both ears. Three practice trials (i.e., three blocks of the same 10 sentences in different orders) are sufficient to reach an asymptomatic level of performance and further test results will not reflect learning or practice effects.

PROCEDURE:

In the first mode tape recorded synthetic sentences were presented by melodious male voice to one ear while the other simultaneously received a narrative by the same speaker. Following this technique the ears receiving the message and competition, respectively were reversed. The second mode combined the sentences and the competition of connected discourse for presentation to first one ear and then the other. IN both the opposite side, or contralateral competing message

(CCM) and the ipsilateral competing message (ICM), or same side procedures, performance was measured at various message - to - competition ratios(MCRs). With the competition nerrative generally fixed at 50 dBSPL the MCRs, were varied in 20 dB steps from 0 dB to -40 dB for the CCM condition, and in 10 dB steps from +10 dB to -20 dB for the ICM condition. Results on both measures were plotted as the averages of the scores of the various MCRs. Normal performance was 100% correct at all MCRs for CCMs and ranged from nearly 100% to about 20% on the ICMs with increasing competition intensities.

RESULTS IN BRAIN STEM PATHOLOGY CASES:

Brain stem lesions are characterised by poor performance for ICM and relatively good performance for CCM. The ICM deficit are observed on the ear contralateral to the lesion unless the lesion extends across the midline, in which case ICM performance is depressed bilaterally.

Jerger and Jerger (1975) in their study had the results on 11 patients with carefully defined intra-axial brain stem lesions, who were given both the CCM and ICM tasks were strikingly dissimilar for the two tasks. All the 11 patients exhibited very poor performance on the ICM test, Performance scores on these patients averaged 37% on both ipsilateral ear and contralateral ear. When averaged across MCRs of 0, -10, and -20 dB where as normals avergge 76%. The major finding in this study was that ICM performance, though variable, was consistantly poor in all cases having intra-axial brain stem lesions. CCM performance on the other hand, was normal in all except three cases with mildly abnormal results. An intriguing aspect of these results is the fact that they show ICM to be a measure of brain stem dysfunction.

In a study done by Jerger and Jerger (1975) they used SSI and SSW tests (Katz, 1962) were administered to the two groups. One group consisted of 10 patients with intra-axial brain stem lesions and the other group of 10 patients with temporal lobe lesions. The results were in general agreement with the earlier study, specifically on the ICM test, the brain stem group had an impairment of about 40% on the contralateral ear only. n the temporal lobe group mean ICM performance was depressed about 30% on the ipsilateral ear and 40% on the contralateral ear. CCM results on the other hand, were in the normal range for the brain stem group and the temporal group had a deficit of approximately 20% on the contralateral ear.

Jergers comparison of SSI and SSW results is of considerable interest. The SSW was found to show significantly reduced scores for the temporal group but not for the brain stem group. The overriding principle that characterised the combination of the two procedures was that the brain stem patients consistantly showed SSI-ICM deficits where as temporal lobe

Robert W Keith (1977) demonstrated a case (reprinted from Jerger and Jerger, 1975) a 43 year old lady who . suffered severe head injuries nine years ago. Results indicate

(a) A pure tone average of 30dB HTL in the left ear and 12 dB in right.

(b) Normal tympanometry with acoustic reflexes at 85 dB in both ears. Extremely rapid reflex decy was present on the left and absent in the right ear.

(c) 70-80 dB tone decay in the high frequencies of the left ear none in the right ear

(d) Type III Bekesy tracing in the left ear, Type I in the right ear.

(e) Speech discrimination (PAL PB-50) in white noiseat OdB S/N yielded 24% left and 52% right.

(f) Reduced performance on the binaural fusion and low pass speech subtests of the Willeford battery, the SSW and SSI-ICM on the left.

These results indicate that this person has possible damage of the auditory pathways at all levels from the auditory nerve on the left side, through the brain stem with possible temporal lobe damage to the right hemisphere.

LIMITATIONS OF SSI TEST: It involves visual as well as auditory tasks which might penalize or have limited application for a population of illeterates or retarded adults who cannot read, and those with visual handicaps. Its use would also preclude younger children with undeveloped reading skills or those with whom the central visual and auditory process are not mutually facilitating events.

The SSI procedure seems to be an effective method of differentiating site of lesion when used in conduction with other auditory tests. The procedureappears to distinguish brain stem site of lesion while other tests may be more effective in identifying temporal lobe site. SSI-ICM performance is usually poorer on the ear opposite the brain stem lesion. But performance is some times depressed in both ears. Scores are not usually depressed on the same side as the brain stem lesion. SSI-CCM performance is usually good with brain stem lesions relative to temporal lobe lesions where the performance is reduced in the contralateral ear. This test also has the advantage of having reliable normative data and substantial supportive evidence of ist development that may be useful in future implications.

FILTERED SPEECH TESTS

The neural fibers from each cochleaare represented bilaterally in the system central to the cochlear nuclei. There are numerous commlssural connections at various levels in the auditory neuroanatomy. This arrangement provides for duplicate information in various parts of the system and is referred to as Internal redundancy. (Korson-Bengtsen, 1973) or intrinsic redundancy (Bocca and Calearo, 1963).

Extrinsic redundancy referes to the wealth of information inherent in the speech message. Specifically, extrinsic redundancey refers to those aspects of normal speech such as frequency range, tempo, rhythm, duration and length.

Patients with lesions of the central auditory nervous system but with a normal peripheral hearing mechanism should not show a loss of understanding for an extrinsically redundant message. The implication is that the loss of intrinsic redundancy is compensated for by the full extrinsic redundancy of the message. However, if the extrinsic redundancy of the message is purposefully reduced as well as the patient having a loss of intrinsic redundancy due to a central auditory lesion, the result would be a break down in comprehension.

Filetered speech reduces the extrinsic redundancy of the speech signal by selectively attenuating portions of its frequency spectrum.

Speech signals can be made low redundant by means of electronic filters, which attenuate parts of the frequency spect The discrimination of filtered speech varies considerably with the type of filters used.i.e., high pass, low pass, or band pass filters, as well as with the verbal material.

Normal persons can manage fairly large reductions in the frequency spectrum of speech signals before any decrease occurs in the discrimination scores. With a low pass filter with cut-off frequency around 800 Hz, or band pass filters with the same rejection of frequencies, the intelligibility of sentences is 70-90% at 35-50 dB sensation level. (Hirsh, 1954; Bocca, 1954; 1955; Linden, 1960; Maspetiol et al, 1964, and Korsan-Bengtsen, 1960, 1970.)

The most important frequencies of speech material such as CVC nonsense syllables and PB-words range from 1500 to 2500 Hz (French and Steinber, 1947; Pollack, 1948; and Hirsh, 1954).

The use of bandpass filters in the low frequency area usuall result in some what high discrimination scores than the low pass filters with in the same frequency range. This as because of a masking effect of the most low frequency sounds in low pass filtered speech (Palva, 1965).

PROCEDURE:

The frequencies above 500 Hz were selectively attenuated at the rate of 18 dB per octave. The unique aspect of this particular test is that the stimulus words were specially chosen from a pool of Michegan CNC words which after filtering remained highly intelligible to a group of normal hearing adults. The rationale for using such stimuli was that they should represent an easy task for persons other than those with central auditory deficiencies. The presentation is done monaurally and the presentation level is 50 dB SL. either the PTA or SRT for subjects with normal hearing sensitivity.

The results obtained with filtered speech test in brain stem lesions vary more than in patients with cortical diseace. Calearo and Antonelli (1968) investigated 24 cases with brain stem lesions, 8 had tumors, and 16 had lesions due to multiple sclorosis, infections or vascular disorders, Of 23 tested with filtered speech, 8 showed a monolateral deficit, and 4 a bilaterally reduced score. Jerger (1964) in 7 patients with brain stem lesions, found 24% difference in the discrimination score between the homo- and contralateral ear for low pass filtered speech.

Metzker (1959) was the first to apply the binaural resynthesis of 2 bands of filtered speech as an index to brain stem pathology. A list of 41 two-syllable German Phonetically balanced words were simultaneously passed througha low pass band (500 to 800 Hz) and high pass band (1815 to 2500 Hz) filter at intensities which were preset for maximum intelligibility for each pass band. The presentation was done 3 times. Initially, the binaural signal was presented so that the right ear received only the high frequency band and left ear received only the low frequency. In second presentation of 41 words in which both frequency bands were presented to both the ears in a diotic manner. The third presentation involved the repetition of the initial test procedure. Normal test results were reflected by relatively fewer errors in the third presentation than in the first. The author's examples implied that the number of errors in the diotic (second presentation) and second binaural presentation(third presentation) were approximately the same. In contrast pathologic results were reflected by a high number of errors in the 2 binaural presentations, and an improvement under diotic stimulation.

Metzker felt that, his test procedure was sensitive to lesions of the brain stem affecting the auditory pathways and to the generalized atrophy of the central auditory nervous system due to aging (presbycusis). Unilateral cortical auditory pathology should not result in abnormal test results due to the normal auditory cortex's ability to receive sufficient synthysis from the intact brain stem.

Hiyashi, Ohta, and Morimoto, (966) and Ohta, Hiyashi, and Morimoto (1967) used Metzker's principle utilizing bands of 300 to 600 Hz and 1200-2400 Hz with nonsense syllables serving as the signals on 78 cases. These researchers reported that individuals afflicted with sensorineural hearingloss could successfully resynthysize the binaurally presented material. It was therefore concluded that the test could be used in the assessment of both brain stem and cortical pathology in the presence of peripheral hearingloss.

Linden (1964) utilized a similar test of binaural fusion with a low pass band of 560 to 715 Hz and a high pass band of 16 to 2200 Hz. When the binaural resynthysis test was presented to subjects with various central pathologies, the ability to resynthysize speech was reduced to the same percentage value as the intelligibility of filtered speech presented monaurally.

DICHOTIC BINAURAL FUSION TEST

Smith and Resnick (1972) published preliminary results from the "Dichotic binaural fusion test" (DBF Test). This was based upon Metzker's principle and primarily designed to differentiate brain stem from temporal lobe pathologies. The Dichotic Binaural Fusion test materials consisted of three 50-word consonant-nucleus-consonant type (CNC) listspresented over bands of 360 to 890 Hz and 1750 to 2220 Hz. The test was presented under 3 conditions. The first condition consisted of a dichotic presentation of the low band signal to one ear and high bend to the other. The second condition consisted of a diotic presentation where both bands were presented to both ears simultaneously. The third condition, consisted of another dichotic presentation similar to first condtion, except that the low band was presented to the ear which originally received the high band signal and vice versa. It was found in normal hearing bilateral sensorineural hearinglosses and those with temporal lobe lesions scored similarly under all three conditions. However, in the ease of confirmed brain stem pathology there was a significant enhancement in the diotic condition over atleast one of the dichotic conditions.

Feldman (1964, 1967) presented dissimilar three syllabic words at high intensity levels simultaneously to both ears. Young normal subjects achieved 100% discrimination score in both ears in this dichotic listening condition. Patients with diffuse central lesions had decreased discrimination bilateral without any difference between the ears. In local lesions of central hearing pathways perception by ipsilateral ear was reduced when the brain stem was injured, while patients with lesions above the inferior colliculus achieved only a reduced score for the contralateral ear.

Palva and Jokinen (1975) used Metzker's principle in their test. They tested over 2000 patients with a resynthysis of filtered speech procedure. It involves the presentation of 2 bands of filtered words. The band widths were 480 to 720 Hz and 1800 to 2400 Hz. Each seperate band yielded a discrimination score of approximately 15 to 20% . However, when the baads was presented simultaneously, in either a binaural or monaural mo the discrimination score typically increased to about 80% in normal hearing young subjects. The test words were presented at 50 dB SL.

There are 3 discrimination scores, The first score was obtained by presenting both bands to the right ear. The second score resulted from the same 2 bands being presented to the left ear. The third score resulted from the dichotic presentation of the filtered speech bands (the low frequency band is presented to right ear, and the &igh frequency band presented to the left ear). The scores were reported in the following manner.

$$\frac{\text{Right ear}}{\text{Left Ear}}\text{Binanral}$$

In cases of brain stem pathology, assymytry in the monaural test was found in either the contralateral or ipsilateral ear combined with poor binaural discrimination, or poor discrimination scores under all three modes of presentation. It was reasoned that the binaural score should be a significant factor in distinguishing a central from a brain stem central auditory disorder. If brain stem lesions occur in areas peripheral to those regions responsible for binaural hearing, the binaural score should be reduced to the same level as that of the poorer ear. However, the binaural discrimination score should be relatively high in lesions involving the auditory cortex because normal fusion occurs in the intact brain stem and may be successfully integrated by the nondiseased hemisphere.

TIME COMPRESSED SPEECH TEST

Jerger (1960) noted that because of the complexity and neural redundency of the central nervous system, measures of retrocochlear pathology require stimuli of complex nature. Calearo and Lazzaroni (1957) and de Quiros (1964) recognised this problem and consequently employed time-compressed speech signals as a measure for evaluating lesions in the central auditory nervous system. Calearo and Lazzaroni pointed out that the time compression reduced the external temporal redundan of the normal speech signals, thereby increasing the difficulty processing task by the internally redundant central nervous system. Unfortunatley Calearo and Lazzaroni (1957) and de Quiros (1964) were not well described and even the normal data were not provided for clinical use.

Early interest in the study of time-altered speech was made possible by the development of the tape recorder. By employing the tape recorder, investigators like Fletcher (1929) were ablefto record a message and subsequently play back the message at a faster or slower speed than was originally recorded. This fast playback procedure enabled the investigator to retain control of certain proportional relationships inherent in the original isgnal. Unfortunatley the fast/slow play back procedures resulted in undesirable shifts in the frequency charecteristics of the recorded signal.

Garvey (1953) employed a chop-slice procedure in order to overcome the problem of the frequency shifts associated with the fast/slow playback technique. In this procedure, certain segments of the recorded signals were manually cut from the recording and the retained samples were spliced back together. In this way they could vary the temporal nature of the signal without undue distortion of the frequency characteristics of th(signal w±%hen=6as originally recorded. In addition, the investigator was able to delete and retain selected segments of the signal and to systematically vary the temporal length of these segments. The procedure has been used frequently when specific control of the deleted or retained samples was necessory (Beasley and Shriner, 1973, Schuckers, 1973).

Fairbanks (1954) developed electromechanical time compressor/expander in order to overcome the problems associated with the fast/slow playback technique and chop-slice procedures. Investigators could record a signal and subsequently delete and retain samples of the signal automatically using the above instrument. Further the retained samples were electromechanically 'spliced' back together such that the end product was a recorded version of the original recording, which was some specific percentage shorter or compressed or,longer or expanded than the original. The principles of the Fairbank's compressor were subsequently employed by Lee (1972), who developed an inexpensive and portable compressor/expander which employed a small tape recorder and a mini computer.

Current interest in the clinical application of time compressed speech dates to a study by Luterman, Welsh, and Melrose (1966) followed by a study by Sticht and Gray (1969) who presented the CID W-22 word lists to normal hearing and sensorineural hearing impaired young and aged adult listeners They concluded that their results indicated that time-altered spee&h, as they employed it did not effectively differentiate normal listeners from persons with sensorineural hearing impairments.

One of the major difficulties in the recent plethora of development of 'tests' for auditory processing problems has been the lack of normative studies for purposes of determining validity and reliability (Willeford, 1976).

Beasley et al., (1972) presented the Rintlemann and Jetty (1974) recorded version of Form B of the Northwestern university auditory test number 6 (NU-6) to 96 normal hearing young adults at sensation levels of 8, 16, 24 and 34 dB. Using Fairbanks device, the four lists of Form B were time-compressed 0%, to 70% in 10% steps and presented to the listeners in an experimental design employing counterbalancing procedure. The average percentage correct responses increased as a function of increasing sensation level and decreasing percentage of time compression* There was a dramatic drop in intelligibility at 70% time compression. The articulation functions across sensation levels ranged from 2% to 3.5% per dB, and these were similar to the articulation functions obtained by Rintlemann and Jetty (1974) on the unmodified versions of the NU-6 (Form B). In a study by Beasley and Forman (1972), the same stimuli were presented to a different group of normal hearing young adults at 40 dB

SL. There was a slight but a non-significant increase in percentage of correct scores obtained at 40 dB SL, compared to those obtained at 32 dB SL. Moreover, the difference appeared to increase in prominence as the listening task increased in difficulty, i.e., as the percentage of time compression increased.

Nikam et al., (1976) presented the Beasley et al (1972) stimuli to 144 nomal hearing English speakers/listeners whose native languages were either Spanish or Indi-Dravidian. The Spanish speaker/listeners had higher average scores than the Indo-Dravidian speaker/listeners. Further the articulati functions for both groups were less steep (6.8 to 2.35%) than that found for the normal hearing English/speaker listeners b Beasley et al (1972) (2.0% to 3.5%/dB). Nevertheless, the authors did suggest that the results could be used, with caution when it was necessory to employ a measure of speech discrimination clinically with speaker/listeners whose native language was Spanish or Indo-Dravidian.

Calearo and Antonelli (1968) studied the effect of time compressed speech in patients with brain-stem lesions and ;' found a decrease in discrimination in 14 out of 23 cases. The loss was only unilateral.

By administration of barbiturates to young subjects Antonelli and Calearo (1968) found a significant decrease in perception of time compressed speech, probably as a result of depression of the reticular formation in the brain stem. Dru such as scopolamine and atropine had no such effect on the results of the test.

MASKING LEVEL DIFFERENCE

A number of laboratories have devoted much time and effort to determine to what extent various auditory stimuli delivered to one ear or both ears simultaneously or almost simultaneously One such phenomenon is called masking. In recent years it has become clear that the auditory system will use one of the two different processing modes-monaural and binaural systems - under the condition of masking depending upon the interaural configuration of signal and masking (Mc Fadden).

Masking level difference (BED) can be defined as the difference (advantage) in masked threshold between dichotically presented stimuli and signals that are presented monotically {or diotically). It can also be reffered as binaural unmasking as binaural release from masking or as the binarual masking level difference (BMLD).

Masking is the process by which the detectibility of one sound the signals is impaired by the presence of another sound, the masker; the effectiveness of a masker and consequently the amount of signal level necessory to be "Just detectable" in a constant masking noise is highly dependent on whether the presentation is monoaural/binaural and whether it i diotic/dichotic. Dichotic presentation permits binaural audiory analysis which can result in detection of signal.

If a target tone is presented to one ear and then covered with noise in the same ear, the noise will mask out the tone if the proper intensity relationships exhist. If the tone and noise are left in the fixed relationship in the first ear and additional noise is presented to the other ear which is 180 degrees out of phase with a noise already being used to mask the target tone, the target tone becomes more audible, It appears as if some form of neural cancellation out of phase of the out of phase noises has taken place.

Licklider (1948) in psychoacoustic laboratory at Harward university while attempting to improve the speech communication over headphone systems of pilots in presence of background aircraft noise, reversed the phase of the signal in the two ears. There was improvement in the reception of the signal when noise and signal were in different phase relationships at the two ears. Thus if One earphone diaphragm moves outward causing a rarifaction, the diaphragm of the opposite earphone moves inward causing condensation. This improvement was called "Masking level Difference".

Hirsh (1948) used a sinusoid wave as signal instead of speech which allowed him to control precisely the frequency content of the signal.

According to Gebhandt and Goldstein (1972) the detectabili of a binaural signal in a masking noise is dependent upon the interaural phase relationships of both the signal and the maske The well documented improvement in threshold which accompanies the manipulation of the phase parameter has been termed the MLD. It is assumed that this unmasking effect is due to an interaction between the target signal and the noise component in the frequency region surrounding the signal.

Hafter(1971) described the MLD is a measure of improvement in detection that occur whenever dichotic cues are added either to signal or to a masker. It is the difference in dB between the signal to noise ratio.: necessory for detection of a diotic signal in diotic masker and the s/N ratio necessori for the particular condition being tested.

Mc Fadden and Passomen (1974) states MLD is an improvement in detection performance for some dichotic listening condition as compared with monotic/diotic listening.

In binaural masking experiments, one may reverse the phase of the masking signal or that of the signal masked in either ear which makes room for number of experimental combinations. For bravity and clarity, we will adopt a short hand to show the relationships among the stimuli and ears.

N = Noise, S - Signal, π = to indicate a phase reversal at one ear relative to the other.

0 = Two signals/Noise in the same phase.

m = to indicate that the noise/signal is monaural.

N_m S_m = Noise and signal both in the same ear (monaural).

N_o S_o = Noise and signal both in phase at the ears.

N_π- S_π = Noise and signal both reversed in phase at one ear relative to the other.

N_o S_m =Noise in phase and signal monaural."

N_π S_m = Noise reversed in phase and signal monaural.

N_o S_π = Noise in phase, signal reversed in phase.

N_π S_o = Noise is reversed in phase signal in phase.

The size of the MLD varies from as large as about 15 dB for the $S N_o$ condition. (Green and Henning 1969). to as little as 0 dB; depending upon a variety of parameters. It is an universal finding that the MLD becomes larger as the spectrum level of the masking noise is increased, especially when the noise is presented to both ears (N) at the same level

The largest MLDs are obtained when either the signal ($S_\pi N_o$ or the noise ($S_o N_\pi$) is opposite in phase at the two ears.

MLD is largest for low frequencies-about 15 dB for 250 Hz and decreases for higher frequencies until a constant of about 3 dB is maintained about 1500-2000 Hz.

MLD is never negative and they never go zero (Yost and Neilson, 1977). MLD for binaural condition is zero and these binaural condition which yield no MLD are ometimes used as the referral condtion for defining MLD rather than N S condition

CLINICAL VALUE OF MLD:

The tonal MLD clinical studies (Noffsinger, 1972; 1975, Olsen et al, 1976; Quaranta and Cervellera, 1975) began in 1971. Recently speech MLD has been extensively used among the clinical population by various researchers like Schuchman Antonelli, etc. Since the value of tonal MLD decreases as the frequency increases from 500 Hz greater interest has been shown in measuring MLD for speech by using spondee stimuli than monosyllables.

MLD IN NORMALS: Dierecks and Jefferess (1962) pointed out 3 conditions that produce the poorest detection are $N_m S_m$

$N_\pi S_\pi$ and $N_o S_o$. These are used as reference in MLD studied The best detection is obtained in the anti-phasic condition. The general size of the antiphasic MLD is about 15 dB at low frequencies, decreasing in size through the mid-frequency range.

Zerlin (1966) concluded that MLD increases with interaural delay time in a manner similar to that for analogous interaural phase difference.

Mulligan (1967) reported a study which demonstrated that only a narrow band around the frequency of the test tone is effective in producing the MLDs were obtained with a Medium band noide (3100 Hz wide) a narrow band noise (1600 Hz wide) and a medium band noise with a hole in it although a critical bandwidth wide and centred at the test tone frequency, When set at equal spectral levels the first, second noises produced equal MLD in spite of the different overall levels. The third noise produces much smaller MLDs . He concluded that the MLD depends upon the relative levels, phase and correlation of the paired critical bands of two ears.

Quaranta, Cossero and Cervellera (1974) investigated the clinical value of tonal MLD among 184 subjects including 20 normals. They found an-average MLD of 8.2 dB with a range of 7 to 9.3 dB.

Quaranta and Cervellera (1973) studied MLD in various kinds of hearing loss cases and normals and found a MLD value of 8.2 dB in normals which was taken as reference and the result of the pathological group were compared with that of the normals

MLD IN BRAIN STEM LESION CASES: Noffsinger (1976) determined MLD for 500 Hz tone as well as spondees. He measured the threshold for 500 Hz tones presented to both ears in phase in the presence of narrow band noise. The noise was centered at 500 Hz at 80 dB SPL. The tones were then put out of phase by 180 degree and a second masked thresold was determined. The difference between the two thresholds is MLD and normals had a shift of 11 dB and these patients had shift of less than 6dB The MLD value for speech was also measured in the similar fashj and normals had a value of 9 dB whereas brain stem lesion case: the MLD value of less than 4 and sometimes 0.

Olsen Noffsinger (1977) studied 12 brain stem lesions and found that tonal (500Hz) MLD was about 2 dB smaller than those of normal group.

Olsen,Noffsinger and Carhart (1976) have reported that the average MLD in 12 central nervous system disorders patients was 9.8 in $S_{\pi}N_{0}$ and 7.3 in $S_{o}N_{\pi}$ and MLD for 500 Hz and for , spondeed was 5.0 for S_{π} N_{0} and 3.8 for S_{o} N_{π}.

Quaranta, Cervellera and Cassoro (1974) found average MLD to be 6 dB and the range is from 2 to 10 dB in 29 cases of central nervous system.

Thus the tonal MLD may be used as a test for the diagnosis of central auditory lesions but only in normally hearing patient Indeed in subjects with SN hearing loss the tonal MLD loses its diagnostic value because lesions of peripheral auditory system disrupt binaural release from masking.

BRAIN STEM EVOKE RESPONSE AUDIOMETRY

(BERA)

The chronology of man's efforts to evaluate the human sensory system is certainly not of recent origin. However, there has been sufficient technological advance to permit more sophisticated assessment of a number of human sensory function; It has been the intent of those working with the hearing impaired child or adult to evolve an electrophysiologic procedure which would yield objective, clinical information about the status of sensory systems.

Although many procedures have been advanced, none has achieved universal acceptance. For example, galvanic skin response audiometry was thought by some to provide a solution to objective measurement. From 1960 to 1970, interest focused on contributions from cortical. evoked responses to tonal and other acoustic stimuli. A significant increase in instrument sophistication and the amount of useful data which could be obtained was experienced.

With in the wider field of electric response audiometry (ERA) the technique known as brain stem evoked response audiometry (BERA) has been found to be particularly useful in recent years. BERA is a completely safe and non-traumatic technique. This can be done by non-medical staff as BERA doesnot require any form of surgery in comparison with electrocochleography, The responses may be used as objective means of assessing hearing acuity and are affected by sedation. They may be also used for neuro-otological diagnosis.

In 1967 Sohmer and Feinmeser of Jersalem, recorded the eighth nerver action potential (AP) from and active electrode placed on ear lobe. A response of 0.5 was evoked by a click of 115 dB SPL. Jewett (1970) conducted experiments in cats and showed that the early neurogenic responses thus obtained were the result of potentials generated by several levels of the auditory pathway.

Comparitive studies in animals and man were done in 1971 by Jewett and Williston indicated that the first of these potentials (N_1) is generated at Cochlear nerve. Lev and Sohmer (1972) reached the conclusion that the wave sequence was produced by the cochlear nerve (N_1) the Cochlear nucleus (N_2), the Superior olivary complex (N_3) and the inferior colliculus (N_4 and N_5).

Sohmer (1972) proposed an anatomical correlation for the series of neurogenic responses typical of the brain stem.

N_5 The inferior colliculus mainly activated by crossed projections

All the responses in brainstem evoked responses occur in first eight mili seconds following the presentation of the stimulus. These peaks (vertex positive) seperated by approximately one mili second are labelled with Roman numbers I through VI (Jewett, 1970). The first 6 components are clearly detectable and labelled (Don et al, 1979) and the clearest wave is V. This is traceable near threshold values of the click stimulus (Hecox and Galambor, 1974).

INSTRUMENTATION: Basically the equipment consists of one part which record the responses (electrodes, amplifiers, filters, averager, display and permanent recording device) and a seperate part which provides the necessory sounds to evoke the response (an audiometer which feeds the sounds to eveke the response a transducer-example a loudspeaker earphoneor bone conductory). One also has to consider the enviornment in which the testing is performed and any useful peices of auxilliary equipment needed for checking the apparatus.

Test enviroment: The subject is best seated in a relaxed position which will minimise any myogenic activity particularly that of the neck muscles, which may generate electrical arteface Active children must be sedated and usually testing is done in a darkened room.

Stimulus generation: BSER can only be satisfactorily obtained at present by using a very brief stimulus with sharp o bursts are being used to obtain BSER.

Stimulus repetition rate: It is advisable to use a stimulus repetition rate of 50/sec. When BSER is to be employed as a neuro-otological tool, it is essential to use 2000 stimuli.

Stimulus transducer: According to Thornton (1975) an anechoic test chamber is essential if loudspeakers are used.

Masking Noise: The apparatus has the provision for the application of masking noise to the non-test ear if monoaural information is required. Wideband masking is required as clicks contain a wide spectrum of frequencies.

Recording equipment: Surface electrodes are needed which are placed on to the scalp and mastoid or neck of the subject, Any high quality EEG electrodes may be used. It is obviously an advantage to obtain the best possible contact between electrode and skin.

Filter setting: The high pass filter is commonly used with a 100-500 Hz cut off frequency.

Recording side of equipment must contain electrode amplifiers, filters, the averager, monitor oscilloscope, and artefact rejection facilities. Output can be recorded permanently using permanent recording circuit (Giblan and Ruben 1978).

CLINICAL PROCEDURE: The target and comparison electrodes are usually placed at the vertex and earlobe respectively with a ground electrode at the forehead. The subject can be awake or asleep since the BSER response is essentially unaffected by sleep stage and most drugs. Sedatives like trimeprazine, promathazine, chloropromazine can be used in young children (Burian, 1975).

It is necessory to start the test with loud stimulus such as 80 dB HL sothat the BSER can be obtained clearly. The stimulus intensity is then reduced in regular steps bo cause the BSER to diminish. The level at which BSER diminishes is considered as the threshold or near threshold of the subject.

Rise and decay time of the stimuli should be rapid i.e. 0.1 m.sec with a duration of 0.1 m.sec stimuli are presented between 2.5 and 10 times per second.

The most identifiable response in BSER is the fifth wave (N_V) which is usually merger with the fourth wave (N_{IV}). The N_V response occurs with a latency of about 6-7 m.sec in adults and 7.6 to 8.6 m.sec. in babies. It can usually be identified after only a few hundred stimuli have been delivered.

CLINICAL APPLICATION OF BSER:

This can be divided in to two,

(i) To estimate acuity,

(ii) in an attempt of neuro-otological diagnosis.

(i) As a measure of hearing acuity: BSER measures the threshold of the auditory response at the level of inferior colliculus and higher lesions may upset hearing without being detected by BSER methods. The first wave or 6 m.sec. response (N_V or N_{4b}) to a click or high frequency tone pip is an excellent audiometric indicator. Davis and Hirsch (1975) used 4800 Hz tone pop to detect the auditory threshold which showed the threshold detection at or below 10 dB SL. According to Suzuki,(1975) Schluman-Galambos and Galambos (1975, 1977). BSER is recordable almost without exception from adults and infants as young as 33 weeks gestational age.

(ii) BSER in Neuro-otological Diagnosis:

BSER provide an interesting electrophysiological correlate of auditory development. Since BSER are obtained by a non-invasive technique, they may be recorded from human neonates without fear of any legal or ethical problems. Hecox and Galambos (1974) described the development of BSER in human subjects and have shown haw the wave form alters during the first few weeks of life. Salamy and Mc Kean (1976) conducted a similar study.

Schulman, Galambos and Galambos (1975) found reliable results of BSER in 24 premature human infants.

Starr, Amlie, Martin and Sanders (1977) assessed the BSER responses in 42 infants ranging in gestational age of 25-44 weeks, and found the latencies of the various potential components decreased with maturation. The effects of brain ste and cochlear disorders on BSER were noted in several. abnormal infants.

The application of all these techniques could permit an objective definition of both normal and abnormal sensory process in newborn infants.

MULTIPLE SCLOROSIS: Multiple sclorosis or disseminated sclorosis is a fairly common disorder affecting mainly young adults. The clinical picture is remarkable for its variation the speed of progression varies from a few weeks to many years, In these cases deafness is rare.

According to a study done by Stockard and Stockard, Scharbrough (1977) 14 out of 40 suspected multiple sclorosis patients had abnormal BSER results.

Robinson and Rudge (1975) in their study twenty two out of thirty patients (multiple sclorosis) showed an abnormal delay of the later waves of the BSER. They managed to get clear readings after averaging only 512 responses using a click stimulus and filters 0.2 sec to 2.5 KHz.

Halliday, Mc Donald and Mushin (1972) have shown a latency delay of the visual evoked response in cases of multiple sclorosis.

Robinson and Rudge (1977) believe that pairs of clicks stimuli 5 m.sec apart, presented at a fast repetition rate stress the auditory system and make the abnormality of the V wave marked in multiple sclorosis.

Selter and Brackmann (1977) reported that 46 percent of the tumor group gave poorly developed BSER waveforms and the N_V was unrecordable and unrecognisable. They noted that

54 percent of the tumor patients in their series had a recordable N_V wave on stimulating the affected ear but this wave often showed a latency.delay when compared to N_V produced on stimulating the normal ear.

Kaga, Yagi, and Hanamura (1976) reported the abnormal results of BSER in a patient with deafness due to brain stem tumor. Right BSER showd waves I, III, IV, V and left BSER showed only wave I at 85 dB clicks.

Thornton (1974) showed an abnormality of the first wave (N_I) when recorded from the ipsilateral side of the head using binaural stimulation and suggested that careful examination of the trace might indicate that the stimulus entering only from the normal contralateral ear was travelling unhindered up the brain stem. He postulated that by comparing the recordings using bilateral and monaural stimulation, it may be possible further to localize the site of dysfunction.

Selters and Brackmann (1977) measured the time elapsing between the N_{III} and N_V peaks and found significant delays only in those patients with large (over 3 cm diameter) tumors, This may prove to be a useful means of predicting tumor size.

Starr end Achor (1975) and Starr and Hamilton (1976) have reported BSER findings in patients with various midbrain tumors. They found that BSER waveform could usually be identified to the level of the site of dysfunction.

For instance with tumors above the superior olivary complex the N_I, N_{II} , N_{III} were identified but N_{IV} , N_V were absent.

Star and Achor (1975) have used BSER to assess brain death in 20 cases. They found that typically only the first wave N_I was obtainable.

SWINGING SPEECH TEST

If a verbal material is periodically switched from one ear to the other, sothat each ear receives half of the message. The stimuli alternate between the subject's two ears every 300 mili seconds, and presented at a sensation level of 30 dB. This test is not very sensitive from the diagnostic view point, however when youngsters have difficulty performing successfully on one or more of the tests, they often become frustrated and can have their confidence restored by doing well on this test.

Bocca and Calearo (1963) used this as a diagnostic technique. The procedure has been varied sothat the message oscillations range from 2 to 40 alternations per second.

Normal subjects can perform this test with no decrease in ability to discriminate simple and meaningful material which is spoken in normal fashion for any rate of oscillation.

Bocca (1961, 1963) demonstrated that normal subjects will achieve discrimination score of 90-100% at any switching rate. The same results are also obtained in patients with isolated lesions of the auditory cortex (Bocca and Calearo, 1963).

While in patients with lesions in the brain stem, the discrimination curve falls abruptly at a switching rate of 3-8 alterations per second (Calearo and Antonelli, 1968). Nine out of 22 patients with brain stem lesions scored low in the swinging speech test, while others achieved a normal score

This finding in brain stem lesions is explained by a disturbance in the fusion of two seperate monaural messages at the level of the crossing of the auditory pathways.

Cherry and Taylor (1954) found this 'dip' in normals at a switching rate around 4 intervals per second., and they attributed this reduction in discrimination score to a mental delay due to switch in attention from one ear to the other. At higher interruptions rates discrimination was again normal,

The combination of this test with filtered speech measures may be useful in helpfng to seperate brain stem lesions from those in the cortex.

SPEECH WITH ALTERNATING MASKING INDEX

(SWAMI)

Jerger (1964) has experimented a technique where words are presented simultaneously to both ears. At the same time a masking noise, with an intensity level of 20 dB greater than the presentation level of the words is alternated between the 2 ears at the rate of one oscillation per second. The performance of each is adversely influenced by the noise under monaural listening conditions but little deficit in intelligibility of the testmaterial is noted by normals when the stimuli are presented binaurally. As with the swinging or switched message procedure this binaural test appears promising as a means of identifying lesions in the lower brain stem where binaural summation is apparently accomplished.

INTERRUPTED SPEECH

Speech can be periodically interrupted by an electronic switch, which causes amplitude-modulations of the speech waves. In this way parts of the speech message are cancelled. The effect of periodically interrupted speech on discrimination has been investigated in normals by among others, Miller and Licklider (1950), Bocca (1958), Calearo and Antonelli (1963) and Teatini (1970). The discrimination was found to depend on the number of interruptions per second, as well as the ratio between the duration of the periods of speech and that of the intervals. When the interruption rate is increased from x 1 to 10,000 the discrimination score is increased from around 50% to 85% at 10 interruptions per second. Any further increase in the interruption rate has only little effect on the score. Teatini (1970) found some what higher scores at 10 interruptions per second, probably because sentences were used as test material instead of PB-words, which suffer very quickly by various forms of distortion.

Periodically interrupted verbal material has been employed with success in identifying lesions of the brain stem (Bocca and Calearo, 1955).

- There was reduced performance with interrupted speech in brain stem lesion cases, where one or both ears showed a poor discrimination score. (Bocca 1963, 1967), Calearo and Antonelli (1968).

When voiced stimuli are interrupted with silent periods which appear alternately In equivalent duration patterns and ratios, they also have the effect of differentially reducing discrimination in the ear contralateral to the lesion site in brain stem disorders.

Jerger (1970) reported similar results as that of Bocca et al., (1963), (1967). He used varying speech-time fractions with synthetic sentences.

BINAURAL SUMMATION TEST

Vyasamurthy (1980) gave an objective method for measuring binaural summation.

Binaural hearing is better than monaural hearing by 6 dB at 35 dB S.L. or more (Hirsh, 1952). This improvement is attributed to binaural summation which takes place at the level of brain stem. Binaural summation or fusion is considered specific to the brain stem not only because many, decus sations occur at this level but also because many contralateral efferent impulses originate here which activate or inhibit peripheral exitability (Bocca and calearo, 1963). Thus one of the most promising audiological techniques for identifying brain stem function is the measurement of binaural summation.

There were three experiments. In first experiment 2 impedence audiometers were used. Ipsilateral acoustic reflex threshold for right and left ears at 1000 Hz were found out independently and in next step, 1000 Hz tone was presented binaurally at previously determined acoustic reflex thresholds and the balance meter needle deflection was noted. The experiment was repeated at 2000 Hz.

In second experiment instead of 2 impedence bridges, one impedence bridge and a portable audiometer was used, and the experiment was conducted in similar lines.

- In third experiment instead of a single frequency, ears were stimulated simultaneously with the tones of different frequency rather than one. All the experiments were conducted on normal subjects.

Results: During binaural stimulation the deflection of the balance meter needle was greater than during monaural stimulation which indicates the binaural summation. Increase in the magnitude of deflection csn be expected only when the loudness of the stimuli increases.

This seems to be a promising technique for detecting brain stem lesion as one of the most promising audiological techniques for exploring brain stem function is the measurement of binaural summation. It can be expected that in subjects with brain stem lesion binaural summation may be absent. This test is to be administered to confirmed brain stem lesions cases in order to findout the validity of the test.

Note; As reflex for crossed stimulation is expected to be absent in brain stem lesions, binaural summation test will have to be administered using two impedence bridges with fecilities for presenting the tones through the probe(H i.e. the impedenee bridges should have provision for ipsilateral reflex measurements)

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