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The Effects of Age and Hearing Impairment on the Acoustic Reflex-Decay.

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THE EFFECTS OF AGE AND HEARING IMPAIRMENT ON THE ACOUSTIC REFLEX DECAY

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ABSTRACT

Information is lacking on the measurement of the acoustic reflex decay for normal hearing individuals of different age groups, and also for cochlear type pathologies. This study compared the results of acoustic reflex decay measures on normal hearing and hearing impaired subjects for three different age categories.

Thirty normal hearing individuals and 30 patients with a cochlear type hearing impairment served as subjects. Each group of thirty subjects were divided equally into three age categories: young (15-34), middle (35-54), and old (55-74).

Each subject was tested for hearing threshold, reflex threshold and reflex decay at four frequencies: 500, 1000, 2000, and 4000 Hz. An immediate test-retest procedure was performed for the reflex threshold and reflex decay measurements.

The Madsen Electronics Impedance Meter, Model ZO-61, was used to obtain the acoustic reflex measurements. A Beckman, Type R, Dynograph Recorder was used to obtain a graphic representation of the reflex. The

amplitude of the reflex decay was measured in millimeters from the recording paper at eight time intervals over a 60 second stimulation period. The amplitude measures were converted into percent decay scores.

The reflex decay measures illustrated that the normal and pathological ears responded in a very similar fashion to sustained acoustic stimulation. The mean scores for the two hearing groups, combining ages, frequencies, and presentations showed little reflex decay over the 60 second stimulation period.

Age did not appear to have a significant effect on the percent of reflex decay. Mean scores for the different age groups were quite similar for both normal and pathological subjects. It was observed that the amplitude of the reflex response generally decreased with age.

Reflex decay measurements were statistically different for the four test frequencies measured. The frequency of 500 Hz showed practically no reflex decay during the stimulation period. The test frequencies of 1000 and 4000 Hz showed more decay than 500 Hz but less than 50% during the stimulation period. The frequency of 2000 Hz showed only a 54% decay over the stimulation

period. The present results substantiate reports in the literature that little reflex decay is shown for 500 and 1000 Hz but do not support previous findings of marked decay at 2000 and 4000 Hz. Other literature has been published which indicated that retro-cochlear type lesions produced an extremely rapid reflex decay even at 500 Hz.

Test-retest results for reflex decay were considered to be clinically reliable.

The present results point out that reflex decay measures did not differentiate between normal ears and ears with cochlear pathology. However, reflex decay measures may prove to be helpful in differentiating normal ears, and ears with cochlear pathology from ears with retro-cochlear type lesions.

CHAPTER I

INTRODUCTION

During the past forty years a great deal of research has been accomplished with regard to the middle ear musculature. More recently greater attention has been paid to the activity of these muscles as measured by the acoustic reflex, or sometimes termed relative impedance measures. The technique of obtaining reflex measures has been improved in an attempt to differentiate types of ear pathologies.

In 1946, Metz, using the acoustic reflex as an indicator, demonstrated that this method had potential for differentiating conductive hearing impairments from sensory neural type pathologies. Since Metz's original experiments a significant amount of work has been accomplished to improve and refine the means of measuring the acoustic reflex, as well as the various factors influencing the reflex.

The majority of subsequent studies have concerned themselves with measurement and identification of the

reflex thresholds. Other parameters of the reflex that have been investigated include latency, amplitude, amplitude and phase, response to pure tones of varying frequencies and intensities, response to noise, and decay of the reflex. However, there are several aspects of these parameters that have not been well-defined.

Initially, the reflex measurements were designed to differentiate conductive pathology from normal ears and those with sensory neural pathology. The presence of the reflex ruled out a conductive impairment. The presence of the reflex at sensation levels lower than those found in normals was believed to indicate recruitment, which is considered to be indicative of cochlear pathology.

The more recent studies tend to indicate that some of the other parameters of the acoustic reflex may also be helpful in differentiating ear pathologies. For example, Anderson, Barr and Wedenberg (1969) found a very rapid amount of decay in patients with confirmed VIII nerve tumors. However, there does not appear to be any significant amount of evidence which defines the normal amount of acoustic reflex decay.

Therefore, it appears that a knowledge of the normal or average amount of decay in normal ears would lend comparative information. A recent study by Beedle (1970) suggests that there might be a difference in acoustic reflex studies for various age groups with normal hearing. The difference observed was in the magnitude of the acoustic reflex response at increasing levels above reflex threshold. Subjects under 50 years of age showed larger reflex changes than did subjects over 50 years of age as the SL re: reflex threshold increased.

The purpose of this study is to investigate and define the various parameters of the acoustic reflex in terms of its decay. It is believed that more information is needed concerning the decay phenomena observed in normal hearing subjects so that any deviations observed in pathological conditions will be more meaningful.

This study was carried out by measuring the acoustic reflex and its rate of decay on a number of subjects with normal hearing. More specifically the subjects were divided into three different age groups to determine if age was a significant factor or variable.

In order to add further information to that of the 30 normal hearing subjects, a population of 30 known pathological ears was also investigated. The selected pathological group demonstrated audiologic signs of cochlear pathology.

The specific experimental questions are presented at the end of Chapter II.

CHAPTER II

REVIEW OF THE LITERATURE

The first portion of the following section describes the anatomy and physiology of the middle ear mechanism. The second area discusses the measurement of the acoustic reflex. The third portion describes the various parameters of the acoustic reflex. The fourth part reviews the many applications of the acoustic reflex measurement in a clinical setting. In the final portion the experimental questions are set forth.

Anatomy of the Middle Ear

The middle ear or tympanic cavity is an irregular, laterally compressed, space lying within the temporal bone. The air which fills the cavity is provided via the nasal part of the pharynx and the Eustachian tube. The cavity houses the chain of movable bones which serve to convey sound vibrations impinging on the tympanic membrane to the internal ear.

The cavity can be described as a container with four sides, a roof, and a floor. Measurements of the

cavity indicate that both the vertical and antero-posterior diameters are about 15mm. Distances in the transverse directions are about 6mm above to 4mm below, while directly opposite the membrane it is only about 2mm. The total volume of the cavity is said to be about 2cc (S.S. Stevens, 1965).

The Membranous or Lateral Wall is formed primarily by the tympanic membrane and partly by the ring of bone housing the membrane.

The Labyrinthic or Medial Wall is vertical in direction with a dimension of 6mm in length and about 8mm in width. The characteristics of the medial wall, which serve to separate the middle ear from the labyrinth, include: the oval window, round window, promontory, and the facial canal prominence (Aqueduct of Falopius).

The Anterior Wall is wider above than below and extends to about 4mm from the floor. The anterior wall contains small channels housing fine nerves and vessels from the carotid plexus and from the carotid artery. In the upper portion of the wall is the orifice for both the tensor tympanic muscle and the Eustachian tube. The semicanal is a cylindrical canal housing the tensor

tympani muscle. It lies beneath the tegmen tympani and above the Eustachian tube. It extends to the medial wall and rests directly above the oval window. The lateral wall and floor of the semicanal is formed by the septum canalis musculotubarii. It also ends above the oval window, expanding slightly and curving laterally to form a type of pulley over which the tendon of the muscle passes.

The Posterior Wall or Mastoid is wider above than below and presents three particular structures, one of which is more important in terms of the middle ear musculature: entrance to the antrum, pyramidal eminence, and fossa incudis. The pyramidal eminence is located behind the oval window and in front of the vertical portion of the facial canal; it contains the stapedius muscle. A small aperture from the summit permits the exit of the stapedial tendon. The pyramidal cavity traverses downward and backward but in front of the facial canal which sends a twig from the facial nerve to the stapedius muscle.

The Tegmental Wall or Roof forms the upper wall of the tympanic cavity and also a part of the floor of the middle cranial fossa. It lies on the anterior

surface of the petrous portion of the temporal bone. It also serves to cover the semicanal of the tensor tympani.

The Jugular Wall or Floor consists of a thin plate of bone and separates the cavity from the jugular fossa. The floor lies about 2.5-3mm lower than the inferior rim of the tympanic membrane. Near the medial wall an opening allows for the passage of the tympanic branch of the glossopharyngeal nerve.

Muscles of the Tympanic Cavity

The tensor tympani muscle and the tube connecting the tympanic cavity with the pharynx were first described by Eustachius in 1564. Varolius, in 1591, first described accurately the second tympanic muscle, the stapedius (Wever and Lawrence, 1954).

The tensor tympani, originating in the cartilaginous portion of the Eustachian tube, runs a course parallel and above the tube until it emerges from its canal where the tendon makes a turn around a small hook-like process on the promontory; it then moves laterally and attaches to the manubrium. Contraction of this muscle serves to pull the membrane inward and thus increase its

tension. The mean length of four human specimens measured 25mm. The cross-sectional area in two human specimens measured 4.8 and 6.9 sq. mm (Wever and Lawrence, 1954).

The stapedius originates within the lumen of the pyramidal eminence of the posterior wall, the tendon emerges from the orifice at the apex and passes forward to insert into the posterior surface of the stapes neck. Contraction of this muscle acts to pull the stapes head backward causing the footplate to rotate on a horizontal axis drawn through its center. An average length of this muscle on three human specimens measured 6.3mm with a cross section of 4.9 sq. mm (Wever and Lawrence, 1954).

A branch from the mandibular division of the trigeminal or fifth cranial nerve supplies the tensor tympani muscle. The stapedial nerve branches off from the facial nerve in the upper part of the third segment of the facial canal. The nerve passes through a minute bony canal into the cavity of the pyramidal eminence and supplies the stapedial muscle (Wever and Lawrence, 1954).

There have been several hypotheses formulated as to the function of the middle ear muscles. These theories

have been referred to by some authors as: 1, the intensity control theory; 2, the frequency selection theory; 3, the fixation theory; and 4, the labyrinthine pressure theory. Wever and Lawrence (1954) have examined the various theories and have drawn the following conclusions:

> There seems little question that the tympanic muscles contribute to the strength and rigidity of the ossicular mechanism. Anyone who has severed both the tensor and stapedius tendons is impressed by the extreme fragility then found in the mechanism. Manipulations that formerly could easily be withstood will now cause serious damage, as best shown in an impairment of cochlear potentials. The fixation theory therefore can be accepted along with the protection theory in the explanation of tympanic muscle functions....The muscular action is a simple reflex and the degree of contraction is not under voluntary control.

Acoustic Reflex

Hensen was the first to observe middle ear muscle reflexes in response to acoustic stimuli. Hensen, as well as Pollak in 1886, viewed primarily the reflex of the tensor tympani. It was in 1913 that Kato demonstrated acoustic reflex contractions not only of the tensor tympani, but also of the stapedius (Jepsen, as cited in Jerger, 1963).

The reflex arc of the tympanic muscles has been described by several investigators. A brief description follows the accompanying outline in Figure 1.

> The cochlear nerve constitutes the afferent part of the reflex arc. The trophic centers for the first neuron in the auditory path are the bipolar cells of the spiral ganglion in the spiral canal of the modiolus. The central axons from the spiral ganglion enter the brain stem together with the vestibular nerve lateral to the facial nerve in the groove below the brachium of the pons and continue to the primary auditory centers, the ventral and dorsal nuclei of the cochlear nerve, which constitute the trophic centers for the second neuron and are situated in the pons. Fibers from the ventral cochlear nucleus cross those from the opposite side and together with the latter form the trapezoid body. In the lateral part of the trapezoid body in the anterior part of the reticular formation lies the superior olivary nucleus, which is presumed to be connected through the medial longitudinal fasciculus and the superior olivary peduncle with various nuclei of the cranial nerves - among others, the trigeminal and facial nuclei (Jepsen, cited in Jerger, 1963).

Methods and Measurements of Acoustic Reflex

Luscher (1929) was the first to observe contractions of the stapedius muscle in man. The only method available at this time was by direct observation, supplemented with the aid of a microscope. Most of these observations

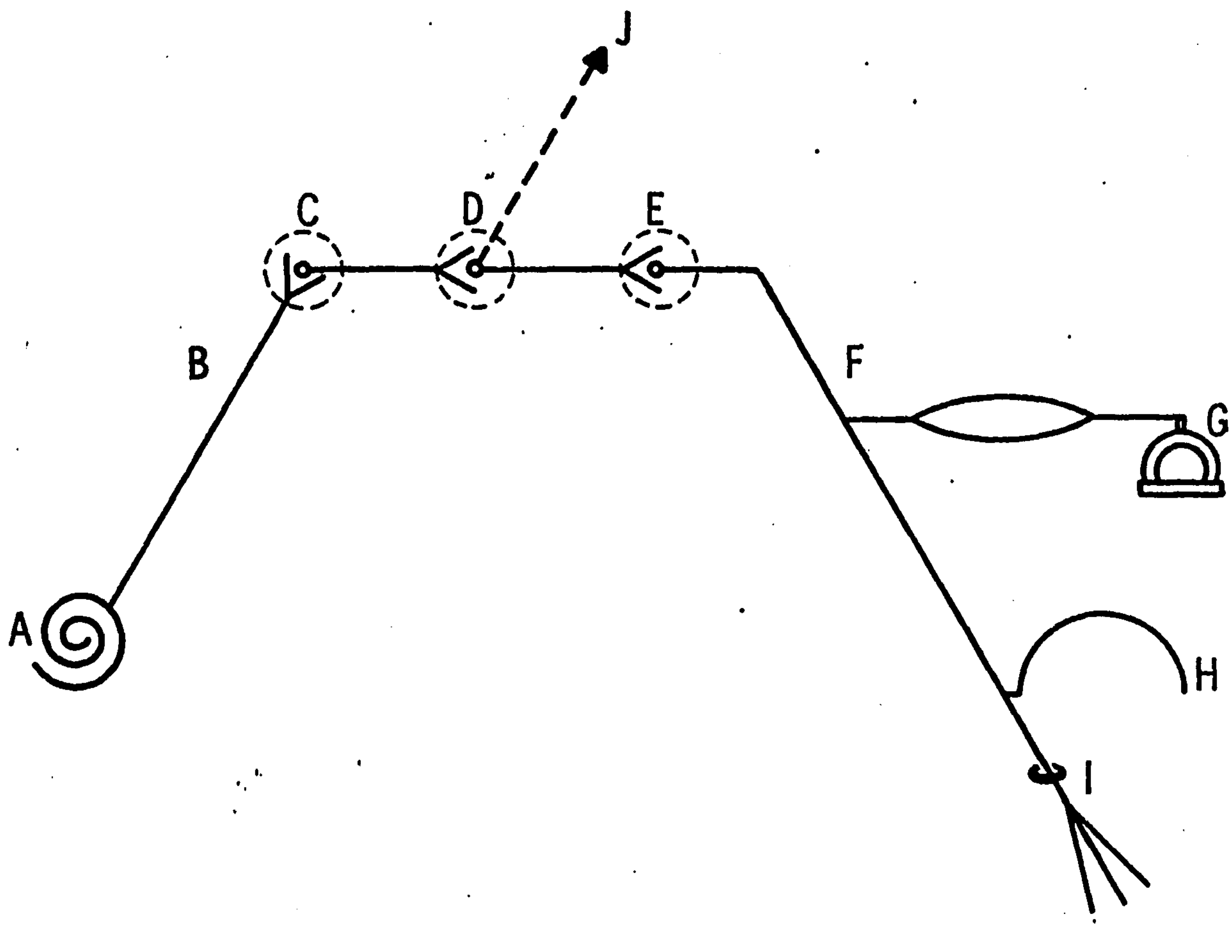

Figure 1. Diagram of presumed course of acoustic stapedius reflex arc: A, cochlea; B, cochlear nerve; C, primary auditory centers; D, superior olivary nucleus; E, facial motor nucleus; F, facial nerve; G, stapedius muscle and stapes; H, chorda tympani; I, stylomastoid foramen; J, to temporal lobe (Jepsen, cited in Jerger, 1963).

took place on pathological ears. A perforation of the tympanic membrane was necessary in order to view the muscle. Some of the studies were carried out during surgery.

Lindsay et al. (1936) used pure tone stimuli from an audiometer while he observed the stapedius reflex through a perforation of the tympanic membrane. In general the threshold was found to be 65 - 85dB above the threshold of hearing.

Electromyographic recordings have been made by recording action potentials from the tympanic muscles (Perlman and Case, 1939; Fisch and Schulthess, 1963). Both threshold measurements and latency studies have been performed using electromyography (Djupesland, 1965).

Impedance Measurements

Perhaps the most widely used method of measuring the acoustic reflex comes under the heading of relative impedance measures. Zwislocki (1961) discusses the acoustic impedance in terms of stiffness, mass, and resistance. Stiffness of the middle ear system predominates for the low frequencies while mass predominates for the high frequencies. By measuring the

ratio of the reflected and incident waves an impedance measure is derived. It is believed that this impedance expresses the acoustic properties of the middle ear and is affected by pathological conditions. The stiffness and resistance factors can be increased by stapes ankylosis or adhesions. A positional disturbance of the ossicles increases the mass component. Stiffness and resistance can be reduced by a discontinuity of the ossicular chain. It has been found that the contraction of the middle ear muscles will result in an impedance change. Therefore, it has become a common method to observe an impedance change by eliciting the contraction of the stapedial muscle with intense acoustic stimuli. The resulting change in impedance can then be expressed as the acoustic stapedial reflex.

In order to measure the acoustic impedance, two types of devices have been designed--the mechano-acoustic measuring bridge and the electro-acoustic measuring device.

The mechanical bridge consists primarily of a brass tube, a telephone diaphragm, and a variable acoustic resistor. The accompanying diagram in Figure 2 illustrates the various parts of the bridge. The diaphragm (M)

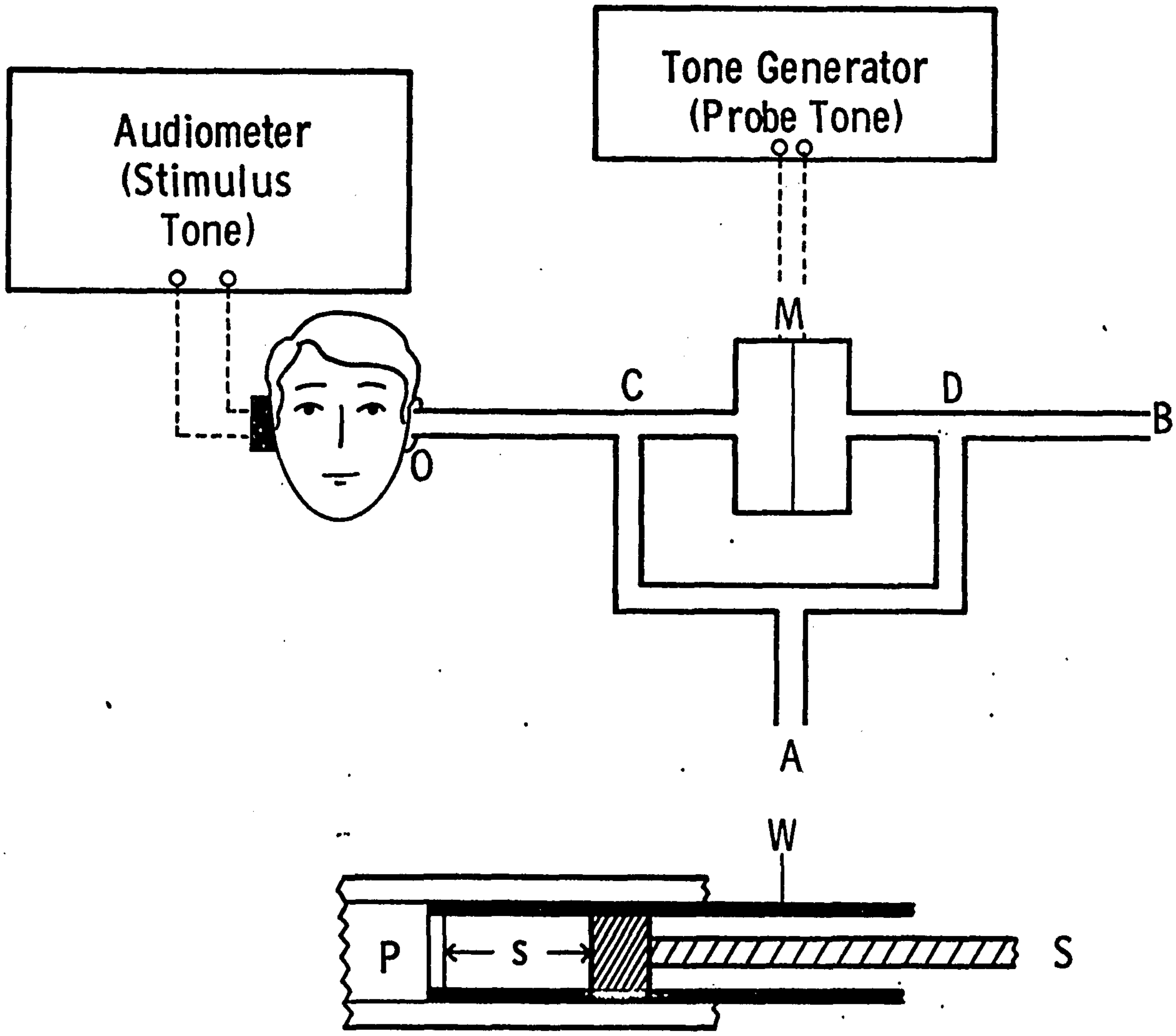

Figure 2. The acoustic measuring bridge, audiometer for stimulus tone, and tone generator for test tone. At the bottom is the right end piece of the acoustic bridge with the variable acoustic resistor shown on an enlarged scale.

which is connected to the tone generator produces a stimulus through both ends of the brass tube.

One end of the tube (O) is inserted and sealed into the subject's external auditory canal, the other end (B) houses the variable resistor. Two tubes (C and D), which are connected on either side of the diaphragm, lead from the main tube to a single auscultation tube in order for the examiner to monitor the signal.

The probe tone meets a resistance at the tympanic membrane of the ear. The comparison resistance consists of a felt disk (P) which is fixed in the end of a tube (W) and inserted into the main tube (B). A metal piston (S) is inserted into tube (W) and thus the length of the air column (s) between the felt disk and the piston may be varied.

An olive attached to (O) is then inserted into the external auditory canal. Modeling wax with a layer of vaseline is placed around the end of the olive being inserted into the canal to insure a snug fit.

Once the connection between the bridge and olive has been made the test tone is switched on. The variable comparison resistor is then adjusted until

a balance has been reached. The balancing of the tone is monitored through the auscultation tube. Balance is reached when the tone becomes inaudible, or nearly so, to the examiner. The adjustment of the piston influences the phase of the tone being produced into tube (B) as well as through tube (D). When the tones originating through tube C and D have reached the point of being opposite in phase the tone being monitored through tube A is canceled out. It is immaterial whether or not the subject can hear the tone.

Once the balance has been obtained an acoustic stimulation is introduced to the contralateral ear. The stimulus tone elicits the bilateral stapedius contraction, resulting in a change of the acoustic impedance at the tympanic membrane of the ear connected to the bridge. The impedance change is evidenced by a change of the test tone from inaudible or minimal to audible. The impedance change produced by the acoustic reflex, begins shortly after the onset of the stimulus tone. On the cessation of the stimulus tone, the test tone decreases in intensity, usually to the former minimum, which indicates that balance has been reattained.

The electro-acoustic impedance meter illustrated in Figure 3 is the type that was used in this study. It consists of a telephone (D) and a microphone (C), which are connected to the external canal by two small rubber tubes ending in the probe unit. The probe unit is fitted with a plastic foam cuff around the inner end to ensure an air-tight closure of the ear canal. Thus the ear canal is converted into a hermetically sealed space, the tympanic membrane serving as one end and the probe unit serving as the other end. The change of impedance of the membrane can then be determined. The change in impedance is of value in that it reflects the displacement and changes in tension of the ear drum brought about by the contraction of the stapedius muscle.

This change in impedance is measured in the following manner: The telephone, producing a 220 Hz test tone, serves to establish a certain preset sound level in the ear-canal space (65dB HL). The sound level obtained depends exclusively on the impedance of the space, this being dominated by variations in the impedance of the tympanic membrane and the middle ear structures. The sound is partially reflected by the tympanic membrane and

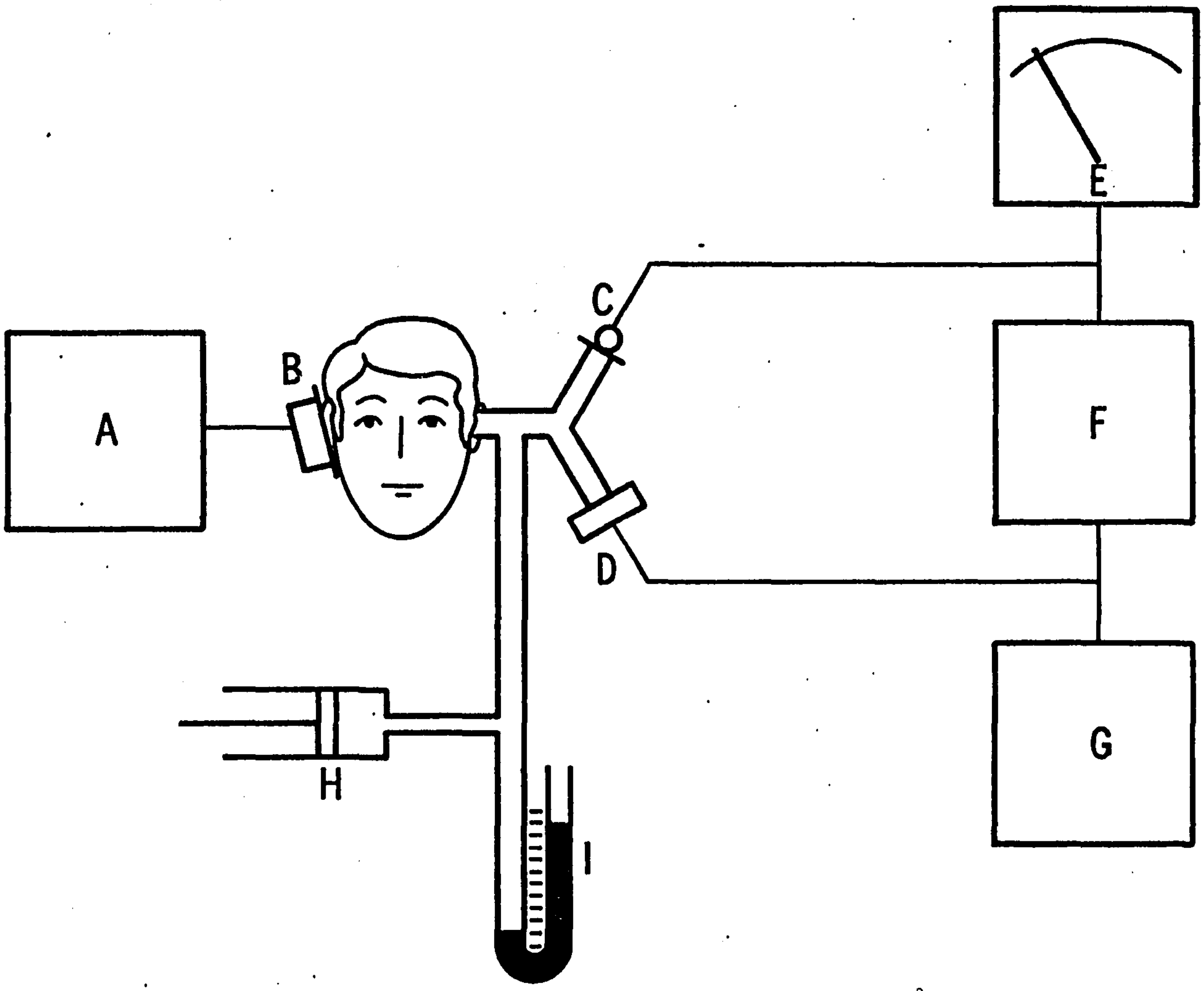

Figure 3. Principle of electroacoustic impedance measuring bridge: A-B, audiometer and earphone for stimulus tone; C-D, microphone and telephone for test tone; E, indicating meter; F, phase and amplitude control; G, tone generator for test tone; H, pump for variation of pressure in meatus; I, manometer (Jepsen, illustrated in Jerger, 1963).

a second tube conveys it back to the microphone. This signal is counterbalanced to a zero state by means of a current from the 220 Hz sound generator (G), passing through components that control phase and amplitude (F). The degree of counterbalancing obtained is read on a vacuum tube voltmeter. The reflected signal gives a visual deflection in arbitrary units on an indicating meter (E), or may be automatically read on a strip chart recorder.

Once the null has been established the acoustic reflex measurement may be obtained. An acoustic stimulus, usually a pure tone from an audiometer (A), is presented through an earphone (B) to the contralateral ear in order to elicit the stapedial contraction. Upon contraction of the stapedius the tympanic membrane will undergo a change in tension and position, thus creating a difference in impedance to the 220 Hz probe tone. The impedance change of the membrane will cause a change in the intensity of the probe tone as it is being monitored by the microphone. This intensity change will be reflected as a visual deflection on the meter or on the recorder.

A pressure system comprising a pump (H) and a manometer (I) is also connected by flexible tubing to the insert probe unit. The pump is used to vary the air pressure in the ear canal to levels above and below atmospheric pressure. By means of this system in conjunction with the section for acoustic impedance measurements, the pressures in the middle and external ear can be equalized and may be read directly on the manometer in mm water.

Parameters of Acoustic Reflex

Three parameters of the acoustic reflex which have been investigated are: threshold, latency, and decay. Of these three, threshold measurements have been the most numerous. The most common method of stimulation has been the use of pure tone stimuli. The general practice is to determine: 1, Threshold, the minimal intensity level of a pure tone necessary to elicit the stapedial reflex; 2, Latency, the time period between onset of the stimulus and onset of the contraction; and 3, Decay, the reduction, measured in percent, of the observable reflex during continuous stimulation over a

specified period of time.

Threshold

The threshold for the acoustic reflex has been defined as that level (in dB above the threshold of hearing in the stimulated ear) which is just capable of inducing a reflex contraction sufficient to be recognized by a change in the impedance of the tympanic membrane (Jepsen, as cited in Jerger, 1963).

Some of the interesting observations concerning the acoustic reflex threshold are presented in the following statements. "The sensitivity, defined as intensity required for ten per cent of maximum impedance change, is found to be almost parallel to the threshold of audibility, with a difference of about 80dB for contralateral stimulation" (Møller, 1962). "It is seen that the ipsilateral stimulation almost always requires smaller intensity to cause the same impedance change, which means that the sensitivity is higher to an ipsilateral stimulus" (Møller, 1961).

Upon stimulation of one ear with an audiometer at unspecified frequencies and intensities Potter observed

the contraction of the stapedius muscle in the contralateral ear. "It was found that this curve followed closely the one for bone conduction but placed at a lower level" (Potter, 1936).

Lindsay et al. (1936) discuss 25 patients whose stapedius muscle could be observed. Their results indicate that the contraction was observed when the intensity of the stimulating tone was about 65dB stronger than the threshold of hearing. They were impressed with the relation between hearing threshold and contraction threshold.

Jepsen (1951) reports the mean values for reflex thresholds of 49 subjects or 98 ears. The frequencies studied were 250, 500, 1000, 2000, and 4000 Hz. In a few cases, reflexes were obtained for frequencies 125 and 8000 Hz. The threshold curve was found to lie about 70-80dB HL, with the lowest thresholds at 1000-2000 Hz.

Using an acoustic bridge as an indicator, Metz (1952) studied reflex thresholds. In normal hearing subjects the reflex was found to be elicited by a sound intensity of 70-90dB, and most readily at 1000-2000 Hz. In otosclerotic patients the acoustic reflex could not be elicited. The HL threshold value for eliciting

contraction of the stapedial muscles in patients with impairment of hearing, assumed to be of a sensory neural type, is the same as that of persons with normal hearing. Reflex could not be obtained on two patients with verified cerebellar pontine angle tumors.

In summary, it has been found by various methods that the acoustic reflex generally occurs at the same intensity levels (65-90dB) for normal hearing persons and persons with a cochlear hearing impairment. Less sound pressure is usually required for the mid frequencies (1000 and 2000 Hz) than for the lower frequencies (250 and 500 Hz) and higher frequencies (4000 and 8000 Hz).

Latency

Several investigators have reported the latency of the stapedius muscle reflex in animals (Wersäll, 1958; Eliasson, and Gisselsson, 1955; Metz, 1951; Møller, 1958). Metz (1951), using an acoustic impedance measuring system or Schuster bridge, noticed that the latency decreases with increasing intensity of the tone from

about 150 msecs at 80dB to 50 and 40 msecs at 90 and 100dB, respectively.[1]

Perlman and Case (1939) found the latent period to be about 10.5 msecs for a "strong tone" of 1000 Hz. Their measures were determined by placing an electrode directly on the stapedius tendon and measuring action currents.

Møller (1958), using an acoustic impedance measuring device, studied the latency of the acoustic reflex in eight normal hearing adults. Two tones were used for stimulation, 500 and 1500 Hz. The maximum and minimum latent time obtained was 130 and 25 msecs, with latency decreasing as stimulus was increased.

Lilly (1964) supports the above findings in his statement that there is an inverse relationship for the latency of maximum impedance and the level of noise.

The observed difference between the latency measures by electromyography and relative impedance are due primarily to the measuring system itself. With the electrode placed directly on the muscle, it is expected

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[1]Metz does not give the reference level for the stimulating intensities that he used.

that this method would produce a shorter latency than one which depends upon an effect on the ossicular chain and tympanic membrane, plus the measuring apparatus before the result is recorded.

Reflex Decay

According to Wersäll (1958), Luscher and Kato observed the fatiguing condition of the stapedius muscle in man and termed it "reflex deafness."[2] The sustained contraction was observed upon intense, continuous acoustic stimulation. Later, irregular, clonic jerks decreasing in height were observed. Finally, the resting state of the muscle was observed even though the stimulation was still present. The decay usually took place after 30-70 seconds. Apparently Luscher was using high frequency tones (2734-6889 Hz). He also reported that a different tone presented simultaneously with the primary tone could elicit a new contraction following the relaxation to the

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[2]It will be noticed here and in other portions of this descriptive section that the terminology used in reference to reflex decay is not consistent. The term fatigue was used in many of the earlier studies but has since been discarded in place of the term decay. The present use of the term decay was operationally defined on page 21.

primary tone. Of particular interest is his observation that if the reflex diminished with the continuous sounds so that the muscle relaxed completely, recovery of the reflex contraction to its full extent occurred only after two-three minutes or more.

Metz (1946, 1951) also showed that the stapedial contraction relaxed slowly and gradually. He found that the contraction could be maintained for, at most, 20-30 seconds. In some cases the muscles relaxed instantaneously. However, Metz's investigations differed from Luscher's in that after a short interruption of the stimulus following the fatigued phase, a full initial contraction was evident. It was also shown that a second tone can elicit a contraction of original strength while in the presence of the primary tone; therefore, the relaxation could not have depended upon muscular fatigue. Kobrak, Lindsay, and Perlman (1941) reported similar findings from direct observation of the stapedius tendon in man.

Wersäll (1958) has described the fatigability of the tympanic muscles in animals (rabbits and cats) using varying procedures: length of stimulation; differing frequencies; and use of a secondary tone in the presence

of a primary tone. In general he found that more fatigue occurred more rapidly as intensity and frequency were increased. Wersäll also found a difference in the fatigability of the two middle ear muscles, the tensor tympani being the more easily fatigued. He stated that this difference precludes the cochlea as the only site of the fatigue. However, it should be pointed out that these experiments were carried out with animals whose tensors contract upon acoustic stimulation, whereas in man this is most often not the case.

Using human subjects and an electro-acoustic measuring device, Gjaevenes and Sohoel (1962) have arrived at the following conclusion: An impedance shift caused by adding a secondary tone to the primary tone is not dependent on the frequency difference between the two tones. An impedance shift attributed to the reactivation of the stapedius muscle can be brought about by superimposing an identical tone.

The difference in amount of fatigue for high (3000 Hz) and low (500 Hz) frequencies has been shown by Johansson et al. (1967). The low pitch tones did not evidence any appreciable decay for the 50 normal-hearing subjects. Forty (40) of 50 subjects showed ten per cent

or less relative deflection for a ten-second presentation of 500 Hz. No one showed more than 50 per cent deflection. For 3000 Hz the range was quite random. At least eight subjects showed 90-100 per cent relative decline in a ten-second period, with 20 of 50 subjects showing 50 per cent or more relative decline in contraction.

Anderson, Barr, and Wedenberg (1969) noted that while using a 10 sec. tone at 10dB above reflex threshold, no decay was observed for frequencies of 500 and 1000 Hz, but there was significant decay for frequencies of 2000 and 4000 Hz. These authors present graphs showing the "half life" of the responses at 2000 and 4000 Hz to be at 14 and 7 seconds, respectively, in a group of 50 normal ears. They studied 17 patients with tumors affecting the acoustic nerve. The results of the reflex measurements showed that the reflex threshold was pathologically elevated in all 17 cases, in seven cases so much that the reflex could not be elicited even at maximum available sound stimulus (120dB HL). In the ten cases where the reflex threshold was obtained there was yet another interesting feature in the reflex

response, namely an abnormally rapid decay on prolonged stimulation. As has been shown earlier, there is normally no measurable reflex decay for the frequencies 500 and 1000 Hz. For the tumor group there was a marked reflex decay. The response amplitude for these frequencies was halved in about three seconds. None of the subjects, at any of the test frequencies, demonstrated a"half-life" time period longer than five seconds.

Lilly (1964) reported that there was no evidence of adaptation to a ten second burst of noise after the acoustic impedance had reached a maximum change.

In summary, the amount of acoustic reflex decay appears to be a function of the frequency and intensity of the stimulating tone. With the use of noise and low frequency stimulation practically no decay is observed. Reflex decay is observed at 2000 Hz in normal hearing subjects and the amount increases directly with frequency. The condition or state of the auditory system seems to have its effect upon the amount of reflex decay. Patients with acoustic nerve tumors evidence rapid decay at the lower frequencies in which decay usually is not present. A description of the

acoustic reflex decay in cochlear pathologies is one purpose of the present study. The cause of the reflex decay is not fully explained. An acoustic reflex can be reobtained from a superimposed tone of identical frequency to the primary tone, which produced an initial decay.

Clinical Application of Acoustic Reflex

The use of the acoustic reflex as a clinical diagnostic tool has yet to be fully investigated. As mentioned earlier, one of the primary reasons for determining the impedance of the middle ear is to aid in diagnosis of differing types of ear pathology.

In 1946, Metz published the results of a study in which he made absolute measures of impedance on a number of normal and pathological ears. He concluded that impedance measures could be used in the diagnosis of conductive impairments. However, because of the technical difficulties and the overlapping of results Metz felt that perhaps an electro-acoustic device could be designed which would aid in solving the technical difficulties and thus

lend more information to the differential diagnosis of ear pathology. An important observation to come out of his study was that a muscle reflex could not be elicited from any of the ears with conductive impairments.

A comparison between results obtained with a mechanical bridge and an electro-acoustic bridge emphasized the uncertainties involved in such measurements and that absolute figures of the impedance are of little diagnostic value (Terkildsen, Scott Nielsen, 1960; Burke, Herer, and McPerson, 1970).

With the use of an acoustic bridge Feldman (1963) concluded that this instrument was useful as a clinical tool in differentiating between conductive and sensory neural losses. The absolute impedance measures provided information that helped to differentiate between a variety of conductive impairments.

Other investigators in later years have published results which disagree with Feldman. Nixon and Glorig (1964) found that the variability of acoustic impedance measures between thirteen normal hearing subjects was too great. They suggested that with increased instrument precision and improved test environment that the results of such a study could be improved.

Zwislocki, in 1966, felt that the absolute impedance measures yielded too great an individual variance between different types of conductive pathologies and was not ready to be used for routine clinical testing.

This idea was upheld by Bicknell and Morgan (1968). They measured the acoustic impedance on a group of otosclerotic ears and a group of normals. The overlap was very large for the two groups. Their conclusions were that absolute impedance measurements, as measured with the Zwislocki acoustic bridge, have extremely limited clinical value and that instruments designed to measure small changes in impedance are of more use in clinical practice.

Feldman and Djupesland (1971) made a comparative study between the Zwislocki Acoustic Bridge (mechanical) and the Madsen, Z070 Electroacoustic Bridge on 11 normal hearing subjects. Both compliance and absolute impedance values at the eardrum were derived with each instrument. Test-retest reliability was shown to be extremely high for each instrument and the correlation between instruments was similarly high. It was stressed, however, that these findings related only to a normal

population where the resistance component of impedance is a relatively stable factor that contributes minimally to the total impedance measured at the eardrum.

In 1971, Brooks concluded, after testing children as young as 12 months, that the electro-acoustic impedance measuring bridge is a practicable, reliable and clinically useful method of examining the middle ear function in children.

Conductive Losses

In patients manifesting a hearing loss the existence of the acoustic reflex implies an intact middle ear system to the level of the crura of the indicator ear, while the absence of the acoustic reflex suggests middle ear pathology of the indicator ear (Feldman, 1967). Such a generalized statement does not always hold true. Changes in the acoustic impedance of the ear elicited by acoustic stimulation does not prove that the middle ear is functioning normally. For example, acoustically elicited impedance changes have been observed in ears which subsequently revealed a middle ear lesion (Djupesland, 1969; Lilly, Mills, and Kos 1969). Neither does a failure to elicit impedance changes in an ear by acoustic stimulation always indicate a pathological

condition of the middle ear. Damage to the reflex arc or to a middle ear lesion on the contralateral side preventing sufficient acoustic stimulation may also lead to a negative acoustic reflex (Klockhoff, 1961; Djupesland, 1964, 1969; and Greisen and Rasmussen, 1970).

Anderson and Barr (1966) compared the reflex studies of two groups of subjects with conductive hearing impairments (fixation and interruption). The fixation group demonstrated "recruitment" in both the Fowler Test and on acoustic reflex studies. The fixation group showed a decrease between the Hearing Level threshold and reflex threshold - thus implying recruitment. Their study has shown that certain types of conductive impairments do yield acoustic reflexes and are associated with an increased slope of the loudness function - a "conductive recruitment."

As another means of eliciting an impedance change, both electrical and tactile stimulation have been used (Metz, 1946; Jepsen, 1955; Klockhoff and Anderson, 1959; and Djupesland, 1964). These changes have been shown to be the result of the stapedius muscle alone (Jepsen, 1955; Klockhoff, 1961; and Djupesland, 1969). Contraction

of the tensor tympani has been shown to occur by directing a puff of air to the orbital region. This usually results in a generalized startle reaction and can be of benefit to reveal that the tensor is functional (Klockhoff, 1961; Klockhoff and Anderson, 1960).

Contraction of both the stapedius and tensor tympani can be elicited by lifting the upper eyelids. Djupesland (1969) concluded that if tactile stimulation does not lead to impedance changes a middle ear lesion is present. He also feels that the information obtained when middle ear pressure is measured, and the impedance changes recorded upon acoustic stimulation and lifting of the eyelids, can contribute to a more specific identification of the nature of the middle ear lesion.

Sensory Neural Hearing Loss (Cochlear)

Hood (1969) states that "it is now a well established fact that the occurrence of loudness recruitment is constantly associated with and indeed restricted to disorders such as Meniere's disease which affect the hair cells of Corti's organ and is characteristically absent in deafness due to structural damage of the cochlear

nerve fibers." Thus he has defined a substantial difference between cochlear and retro-cochlear pathology -- the phenomena of loudness recruitment. It is due to this phenomena that the acoustic reflex has been used as a means of identifying cochlear pathologies. Metz (1946, 1952) concluded that loudness recruitment of an impaired ear is indicated if the acoustic reflex can be elicited at a reduced sensation level.

Other authors (Thomsen, 1955; Møller, 1961; Jepsen, 1963; Feldman, 1964; and Lamb, et al., 1968) have also drawn the conclusion that the acoustic reflex is directly related to the loudness of the stimulus sound. This conclusion was reached by comparing the results of the Alternate Binaural Loudness Balance test and the results of the acoustic reflex. From these studies one is led to believe that the acoustic reflex obtained at a reduced sensation level is indicative of loudness recruitment, and by definition, indicative of cochlear pathology.

More recently studies have shown, however, that patients with a pure conductive loss for the ear receiving the stimulating tone have also exhibited acoustic reflexes at reduced sensation levels (Anderson and

Barr, 1966; McRobert, 1968).

Beedle (1970) was unable to show a significant relationship between the loudness growth in a group of patients with known Meniere's disease and a group of normals. Beedle reasoned that since the acoustic reflex occurs at or near the same intensity level for both normals and pathological ears, the elicitation of the reflex could be directly related to loudness. He also assumed that the growth of the acoustic reflex is contingent upon the loudness of the stimulus. His result showed that the acoustic reflex growth was much larger and more rapid for the normals than the subjects who had loudness recruitment.

Lidén (1969) has recently reported the results of a clinical and experimental study using the stapedius muscle reflex as an objective recruitment test. On the human subjects he proposed a classification of three profiles from the results obtained.

Reflex Profile I: If the stapedial reflex can be elicited at the same sound level as in normal subjects and if the span between hearing threshold and reflex threshold is diminished, recruitment phenomenon is

considered to be present.

Reflex Profile II: No recruitment is indicated if an elevated stapedial reflex with a normal span between hearing threshold and reflex threshold is observed.

Reflex Profile III: This profile is characterized by a pathologically elevated reflex threshold and a diminished span between hearing threshold and reflex threshold.

Of the 52 patients with Meniere's disease, 75 per cent belonged to reflex profile I. The remaining 25 per cent were in profile III. Of the 30 ears of 15 patients with athetosis, 29 ears demonstrated a raised reflex threshold. All of the athetotics were classed either as reflex profile II or III. Five of nine subjects with acoustic tumors were classed as reflex profile II.

The experimental portion of the study compared the tone thresholds and reflex thresholds of cats before and after they were subjected to noise exposure. The intra-aural reflex thresholds were not changed by the induced sensory neural hearing loss. The reflex measurements post trauma were classed as reflex profile I, and

Lidén feels justified in stating that recruitment indicated by the stapedius reflex test is synonomous with cochlear injury. Histologically, there was extensive damage to the outer hair cells but practically none to the inner hair cells.

Pseudohypoacusis

Jepsen was the first to publish information indicating that the acoustic reflex could be used to identify patients exhibiting pseudohypoacusis (1953). According to Lamb and Peterson (1967) when an acoustic reflex can be elicited at a lower level than the voluntary pure tone threshold there can be little doubt that some degree of pseudohypoacusis is present. Jepsen (cited in Jerger, 1963) believes the acoustic reflex measurement can be an excellent tool in detecting so-called pseudohypoacusis, due to the fact that the reflex arc occurs at the mid brain level and does not require higher cortical function (Thomsen, 1955b).

Facial Paralysis

The use of the acoustic reflex can be of some

benefit in the topical diagnosis of facial palsy. Jepsen (cited in Klockhoff, 1961) stated that a stapedius reflex test increased the possibility of localizing a lesion to the infrastapedial or suprastapedial portion of the facial nerve. Generally, if a reflex is present, the lesion involving the facial palsy is believed to be peripheral to the stapedial branch of the facial nerve. If a stapedial reflex is not elicited there is more evidence that the lesion is central to the stapedial branch. In the absence of a stapedial reflex, the tensor reflex test can be used to add further information toward the diagnosis. If air-jet stimulation to the orbital region fails to elicit a tensor response, a definite conclusion as to the location of the lesion still can not be made. However, if the tensor reflex can be elicited as in normal ears, it will be possible to infer to greater assurance that a stapedius reflex has been abolished by a supra stapedial facial nerve lesion. These findings are supported in articles by Thomsen (1955a), Lindstrom and Liden (1963), and Lidén, Peterson, and Harford (1970).

Sensory Neural Hearing Loss (Retro-Cochlear)

The use of acoustic reflex measurements in the differential diagnosis of retro-cochlear lesions is extremely limited. Perhaps one reason for the lack of measurements is the patient population, which is itself limited. Patients exhibiting VIII nerve lesions are relatively few in number.

In some of the early work with acoustic reflex studies, patients with VIII nerve tumors did not yield acoustic reflex thresholds (Metz, 1952).

Anderson et al. (1969) revealed some interesting results while studying the "reflex decay" of the acoustic reflex in 12 patients with a confirmed VIII nerve tumor and 5 patients with a posterior fossa tumor affecting the acoustic nerve. There were primarily two important features of the responses obtained from these patients: (1) an elevated reflex threshold, and (2) very rapid decay of the reflex. To elaborate, in 7 of the 15 patients the reflex could not be elicited at the maximum intensity available, 120dB HL. In ten of the patients where a reflex could be elicited, there was an abnormally rapid decay during a ten-second presentation of the

stimulating tone. In comparison, Anderson also tested 15 normal hearing subjects, who showed virtually no decay for the same period of time for the frequencies 500 and 1000 Hz. There was evidence of slight decay at the higher frequencies -- 2000 and 4000 Hz. Anderson has not published any results of the tests performed on a large number of patients examined who were referred for possible VIII nerve deficits.

Alberti and Kristensen (1970) have reported similar findings on a patient with known brain stem disease. Using a 1000 Hz tone at 10dB SL re: reflex threshold the examiners measured the amount of reflex decay exhibited by the patient. At 4.5 seconds the reflex recording had reached a "half-life" point or 50% of the initial maximum contraction.

Another technique which has employed the stapedius muscle reflex in oto-neurological examinations of brain stem tumors depends on not only contralateral stimulation but homolateral stimulation as well (Greisen and Rasmussen, 1970). In two patients the contralateral stimulation produced no response, while homolateral stimulation resulted in normal reactions. The examiners interpreted these results to indicate an interruption of the reflex

arc of the stapedius muscle at a point within the brain stem, between the cochlear nuclei on the one side and the facial nucleus on the other side.

Test for Recessive Genes for Deafness

Two methods, Bèkésy audiometry and stapedius reflex measurement, were used by Anderson and Wedenberg (1968) in an attempt to identify carriers of genes for recessive deafness. The study consisted of 30 parental pairs with normal hearing and a strong indication of genetic deafness; they had 74 children, 47 of them with severe genetic hearing impairments or total deafness. The results of the study showed two peculiarities: (1) small but distinct dips in the middle frequency range of the parent's hearing threshold and (2) abnormally high thresholds for the acoustically elicited stapedius reflex. The authors feel that the stapedius reflex test is in several respects more reliably evaluated than the hearing threshold test. Most evidence to date has shown that the reflex threshold is obtainable within 70-90 dB HL. Even for those individuals exhibiting exogenous defects in hearing (age and noise) a reflex is

usually obtainable at comparable levels -- resulting in the classification of recruitment. Only a few acquired defects are known to elevate the reflex threshold (e.g., acoustic tumors and certain viral infections) and then invariably, in connection with elevation of the hearing threshold.

From the preceding review of the literature it can be seen that there are many avenues of acoustic reflex measurements yet to be more fully investigated. The question arises as to what type of behavior does the sensory neural loss, primarily cochlear in origin, display on the acoustic reflex decay? There has not appeared in the literature any data on this particular question.

This information should be helpful in differentiating types of ear pathology. Previous information shows that conductive type losses generally do not yield acoustic reflexes; while patients with sensory neural losses often yield a reflex with the threshold being closer to the auditory threshold than that shown by normals (normals 70-90dB SL, sensory neural 30-50dB SL). What can be done to separate the sensory neural losses into the category of cochlear and retro-cochlear? There is

controversy that Alternate Binaural Loudness Balance (ABLB) is not as efficient as some individuals believe (Jerger, cited in Hood, 1969). Anderson (1969) has published data on retro-cochlear lesions showing an elevated acoustic reflex threshold and rapid decay, while normals show practically no decay for acoustic reflex, especially for low frequencies. It must also be kept in mind that normals and cochlear losses exhibit the same reflex thresholds with reference to Hearing Level. Perhaps the decay pattern of the cochlear and retro-cochlear lesions, as measured by acoustic reflex, could be another method of differentiating them.

The ABLB is applicable only when one ear is essentially normal or at least 20-40dB better than the poorer ear. There is often a problem of differentiating a bilateral, moderate-severe hearing loss due to inadequate masking problems. The acoustic reflex can help to determine: (1) if there is a conductive component or not by being able to elicit a reflex, (2) the pattern of threshold will help to shed light on retro-cochlear or a cochlear problem, and (3) the pattern of acoustic reflex decay may possibly be an even better diagnostic indicator.

With the above points in mind the following questions have been formulated.

Experimental Questions

1. Is there a significant difference in the acoustic reflex threshold for a group of normal subjects and a group of subjects exhibiting a hearing loss attributable to cochlear pathology?
2. Is there a significant difference in the acoustic reflex decay for a group of normal hearing subjects and a group of subjects exhibiting a hearing loss attributable to cochlear pathology?
3. Is there a significant difference in the acoustic reflex decay for subjects of different age groups with normal hearing.
4. Is there a significant difference in the acoustic reflex decay for subjects of different age groups with hearing impairment attributable to cochlear pathology?

5. Is there a significant difference in the acoustic reflex decay at different stimulus frequencies for the normal hearing subjects and those with a cochlear pathology?
6. Is there a significant difference between an initial measurement of acoustic reflex decay and a repeat measurement?

CHAPTER III

SUBJECTS, EQUIPMENT, AND PROCEDURES

This chapter includes a detailed description of the criteria for subject selection, the equipment employed, and the testing procedure.

Subjects

Two groups of 30 subjects each comprised the experimental sample for this investigation. Both groups (normals and pathologicals) were sub-divided into ten subjects in each of three age categories: young (15-34), middle (35-54), and old (55-74).

The criteria for the normal group was as follows:

1. No history of ear surgery; no active ear pathology.
2. Bilateral air conduction thresholds no poorer than 15dB HL re; the 1964 ISO standard at the four frequencies to be tested, 500, 1000, 2000, and 4000 Hz. The thresholds for the 55-74 year old normal hearing individuals were comparable to those shown by Glorig and Nixon (1960), and

Glorig and Davis (1961), and Corso (1959). The bone conduction thresholds were within ± 10dB of air conduction thresholds.

3. Reflex thresholds for the four test frequencies no poorer than 95dB HL.

4. Reflex recordings adequately stable to allow for necessary measurements. The recording had to be relatively free from such influencing factors as vascular interferences, respiration, and other types of physical movement that might cause a change in the impedance recording.

The pathological group was drawn from the records of the Louisiana State University Medical Center's Hearing Clinic and Tulane Speech and Hearing Clinic. The established criteria for the pathological group was as follows:

1. A unilateral or bilateral, sensory neural hearing impairment, cochlear in nature based on audiological evaluation. No previous ear surgery.

2. A hearing loss in the test ear of no less than 30dB HL and no greater than 75dB HL at 500, 1000, 2000, and 4000 Hz. Bone conduction must agree with air conduction within ± 10dB.

3. Reflex thresholds for the four frequencies no poorer than 95dB HL.
4. Reflex recordings adequately stable to allow for necessary measurements.

Equipment

Hearing threshold tests were performed on all subjects in an IAC sound suite, Model 404 TCL, using a Beltone 14CX audiometer fitted with TDH-39 earphones. Periodic calibration checks were made on the audiometer throughout the study with a Bruel and Kjaer Sound Level Meter and Octave Band Filter (Type 1613 and 2203) and 6cc coupler (Type 4152) and microphone (B&K 4132). The same audiometer was employed to perform bone conduction thresholds.

A block diagram of the equipment used in the acoustic reflex measurements is presented in Figure 4.

The Madsen Electronics Impedance Meter, Model ZO-61, was used to obtain the acoustic reflex measurements. This equipment was fully described in a previous section.

The reflex-eliciting pure tones were delivered from a Hewlett-Packard Audio Oscillator, Model 200 ABR. The signal frequency was monitored and checked by a Hewlett-Packard Electronic Counter, Model H22 5211B. The pure

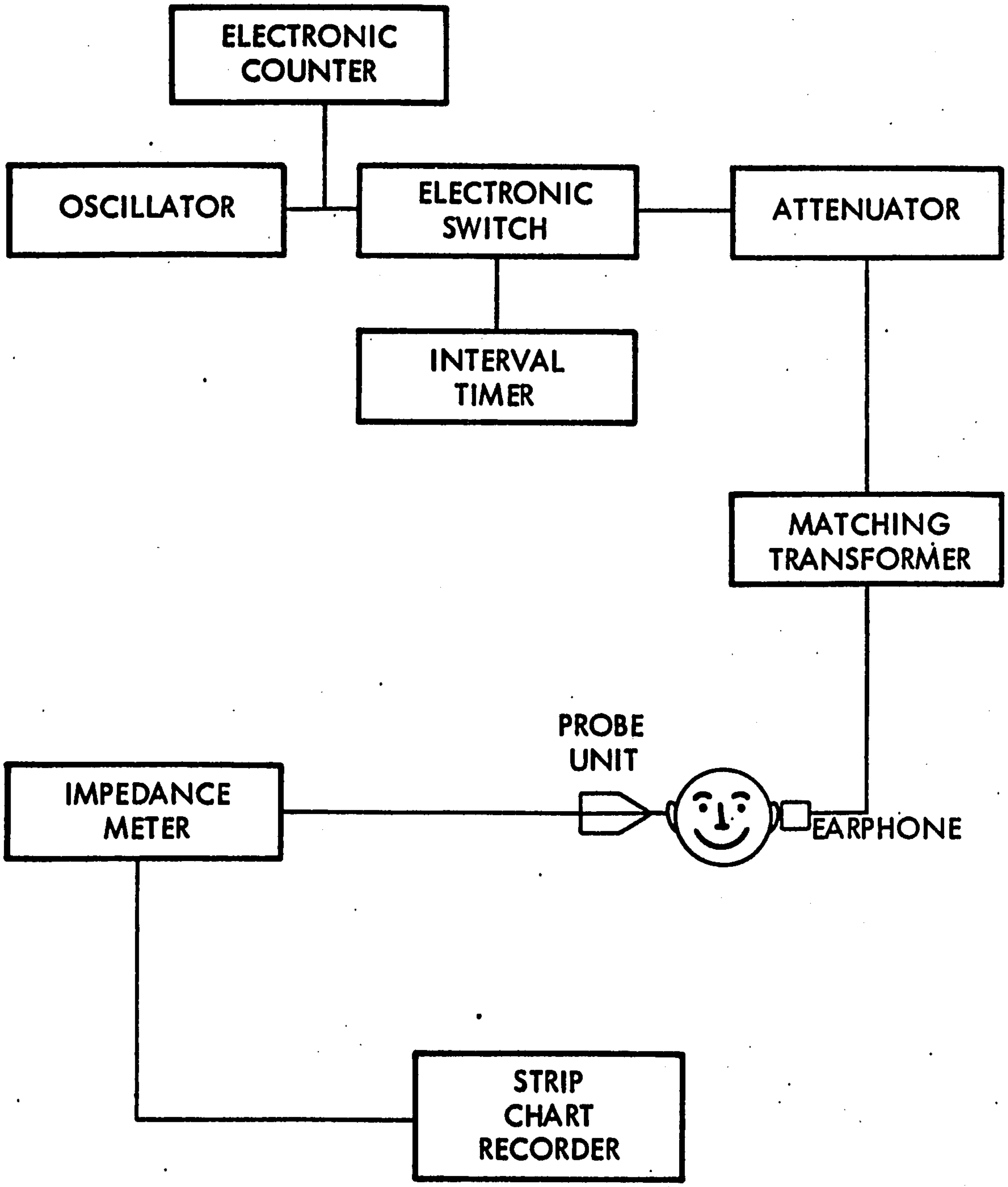

Figure 4. Block diagram of equipment

tone signal was routed through a Grason-Stadler Electronic Switch, Model 829 E and associated Grason-Stadler Interval Timer, Model 471-1, and Grason-Stadler Power Supply, 471-2, in order to activate the signal and to control the rise-decay time of the signal.

From the timer and switch the stimulating tone was routed through a Hewlett-Packard Attenuator, M-350-CS and an impedance matching transformer (United Transformer Co., Type L5 33) before it was delivered to the TDH-39 earphone.

The acoustic output of the earphone and attenuator linearity was checked with the B&K sound level meter and 6cc coupler.

The pure tones used to elicit the acoustic reflex thresholds had a rise-decay time of 25 msecs and a duration of 1000 msecs. The pure tone signal for the acoustic reflex decay had the same rise-decay time, but the duration depended upon the criteria subsequently described. The rise-decay time and the 1000 msec duration were checked with a Tektronix, Type 564, Storage Oscilloscope.

During the acoustic reflex measurements the stimulating pure tone signals were manually activated and terminated

at the interval timer.

The probe tone of 220 Hz from the Madsen Electronics Impedance Meter was checked with the Hewlett-Packard Electronic Counter to ensure its specified frequency. The acoustic output was measured with the B&K Sound Level Meter at the beginning and end of the study.

The manometer was checked and calibrated with the use of a "U" tube manometer filled with water.

The output of the impedance meter was led to a Beckman, Type R, Dynograph Recorder in order to obtain a graphic representation of the reflex. The recorder pen, pre-amplifier, and amplifier were reset and calibrated for each subject. The pre-amp was set to 20mv/cm, the amplifier to X1 mv/cm, and the pen was set to 4. The heat sensitivity for the reflex recorder pen and the time marker were adjusted to obtain markings that were clearly discernible. The paper speed was 1 cm/second.

Procedure

Initially, all subjects received a pure tone air conduction hearing test to determine the hearing thresholds for the four frequencies to be studied. The old age normals and the pathological subjects received bone conduction

tests in addition to the air conduction tests. Upon completion of the hearing threshold tests the subject was moved to a quiet room for the acoustic reflex measurements. Since the acoustic reflex level is usually reached only above 70dB HL the ambient noise in the experimental room was considered to have a negligible effect on the measurements.

Prior to the reflex measurements the subjects were instructed as to the nature of the test and were asked to remain quiet and as still as possible during the procedure.

The non-test, or probe ear, was examined to rule out the presence of excessive cerumen. If such existed it was removed with a cotton swab. A foam plastic cuff of the appropriate size was selected and placed on the tip of the Madsen probe unit. A small amount of lubricant was placed on the cuff to facilitate an air-tight fit as well as for comfort in the probe ear. The earphone was placed on the test ear.

The seal of the probe unit was checked by applying a manometric pressure of ± 200 mm (water). If the manometric indicator needle showed leakage by a change in its

reading, the cuff was repositioned or replaced until an air-tight seal was obtained.

Once the seal had been assured the manometric pressure was returned to zero. The impedance meter sensitivity was set to the highest level which permitted a stable recording. The amplitude and phase of the probe tone was adjusted until a null had been established. The null was indicated by the smallest obtainable reading on either the Impedance Meter (10/100 meter deflection), or on the strip chart recorder. Reflex thresholds were then determined and recorded as described in the following paragraphs.

The order of frequency presentation was 4000, 2000, 1000, and 500 Hz. Beginning with a stimulus level of 70dB HL at 4000 Hz, the stimulating tone was increased in 2dB steps until a threshold was established. If a reflex was obtained at 70dB, the tone was decreased to 60dB and presented again in increasing steps of 2dB until a threshold was obtained. The criteria set for identifying the reflex threshold was as follows:

1. The Dynograph Recorder had to show an initial upward deflection within one second following the onset of the acoustic stimulus as indicated

by the event marker of the recorder.

2. The minimally detectable upward deflection had to be noticeably different from the preceding random pen fluctuations.

The intensity level of the reflex threshold was recorded on the subjects data sheet in decibels Sound Pressure Level (SPL) re: .0002 dynes/cm^2. By subtracting the 1964 ISO decibel level required to establish normal hearing threshold from the SPL for each frequency, the individuals reflex threshold re: Hearing Level (HL) ISO was obtained. By subtracting the individual's hearing threshold for each frequency from the reflex threshold HL of the same frequency, the reflex threshold could be reported in Sensation Level (SL) re: Hearing Threshold. For an example, to obtain these measures for a 4000 Hz tone the following results might have been achieved:

Reflex Threshold in SPL	88.0 dB
Minus ISO for 4000 Hz	-9.0 dB
Reflex Threshold HL=	79.0 dB
Minus Hearing Threshold	-0.0 dB
Reflex Threshold in SL=	79.0 dB

Upon determination of each reflex threshold, reflex decay measures for that frequency were obtained. The null balance was readjusted as necessary. The intensity

level of the stimulating tone was 10dB SL re: reflex threshold for that frequency. Duration of the stimulating tone for the reflex decay measures was determined by one of the following criteria:

1. Until the amplitude of the reflex recording returned to the pre-test baseline on the recorder.

2. Until a maximum of one minute had been reached.

By allowing the reflex to decay to base line, a specific time measure could be made from two specified points--stimulus onset and termination.

There were three reasons for choosing a maximum stimulating period of one minute. Previous investigations (Anderson et al. 1969) have shown that decay takes place within one minute if it is going to show any measurable decay. Second, the one minute allowed for necessary observations and measurements and a longer period would not yield any additional information. Third, temporary threshold shift and acoustic trauma should be avoided by limiting the period of intense stimulation.

Upon completion of the first reflex threshold and decay measurement at each frequency the same procedure

and frequency order was repeated. Harris, (1953) has shown typical threshold recovery curves following pure tone stimulation for various time periods and intensity levels. For example, he reports threshold recovery for a 1000 Hz tone, following a one minute presentation of a fatiguing tone of 750 Hz at 120dB SPL, to take 30 seconds. Since the time period and/or intensity of the stimulating tones used in this study were less than those mentioned above, it was felt that a two minute recovery period between the continuous test stimuli was sufficient to allow for any temporary threshold shift.

The amplitude of the reflex decay was measured in millimeters from the recording paper at eight time intervals: 2,5,10,15,20,30,45, and 60 seconds. It was believed that these time intervals would yield results representative of the over-all 60 second stimulation period. The total test time for each subject was approximately an hour and a half.

CHAPTER IV

RESULTS AND DISCUSSION

The purpose of this study was to compare data on acoustic reflex decay for normal hearing subjects and subjects exhibiting a cochlear type hearing impairment. This chapter presents the results and discussion of the study.

Hearing threshold, acoustic reflex threshold, and acoustic reflex decay measurements were made on all subjects. A summary of the raw data is presented in Appendix A. All the raw data sheets include: the subject's identification number; hearing status; age category; the results of the first and second presentations; the frequencies tested; the amplitude of the acoustic reflex in millimeters at eight time intervals; the acoustic reflex threshold in Sound Pressure Level, Hearing Level, and Sensation Level; and the last column gives the subject's hearing threshold for the experimental ear.

The results of the study were analyzed as three series of four-way analysis of variance. The first series analyzed auditory thresholds, the second analyzed reflex thresholds in SPL, HL, and SL, and the third analyzed reflex decay

at seven time intervals. The method employed consisted of a split-plot arrangement of treatments in a completely randomized design, where the whole plot was a two by three factorial (two types of hearing, Normal and Pathological; by three age levels, young, middle age, and old); with ten subjects per combination of hearing and age. The split-plot was composed of a four by two factorial (four frequencies, 4000, 2000, 1000, and 500 Hz; by two presentations). Least Significant Differences were used to explore the differences among the means within those variables containing more than two levels. The sources of variation with their appropriate degrees of freedom can be viewed in Table 2. Two of the three "three factor" and the "four factor" interactions were pooled with Error B as they were assumed to be of minor importance. Means were adjusted for disproportionate number of observations resulting from an inability to obtain reflex thresholds at some frequencies on various subjects (Harvey, 1960). It was found that 4000 Hz, particularly, did not always yield reflex thresholds even for normals. This finding is consistent with a recent study by Jerger (1972). Jerger states that the absence of a reflex at 4000 Hz need not have pathological significance.

Hearing Threshold

The mean pure tone air conduction hearing thresholds for normal and pathological subjects divided into three age categories, for four test frequencies, are presented in Table 1. The means for the normal and pathological subjects for the four test frequencies are plotted in Figure 5.

Table 1

Mean Pure Tone Air Conduction Hearing Thresholds for Normal and Pathological Ears for the Three Age Groups and the Four Test Frequencies

	Normal Ears				Pathological Ears			
	Frequency							
	500	1000	2000	4000	500	1000	2000	4000
Young	0.0	-1.0	-5.0	3.5	40.5	48.5	55.0	56.0
Middle	0.0	1.0	2.0	8.5	51.5	58.0	56.0	64.5
Old	11.5	10.5	12.0	28.5	35.5	39.0	47.5	59.0

The pathological subjects show at least a 40dB or greater impairment than the normal subjects across the four test frequencies. The 40dB difference between normal and pathological ears is maintained for the young and middle

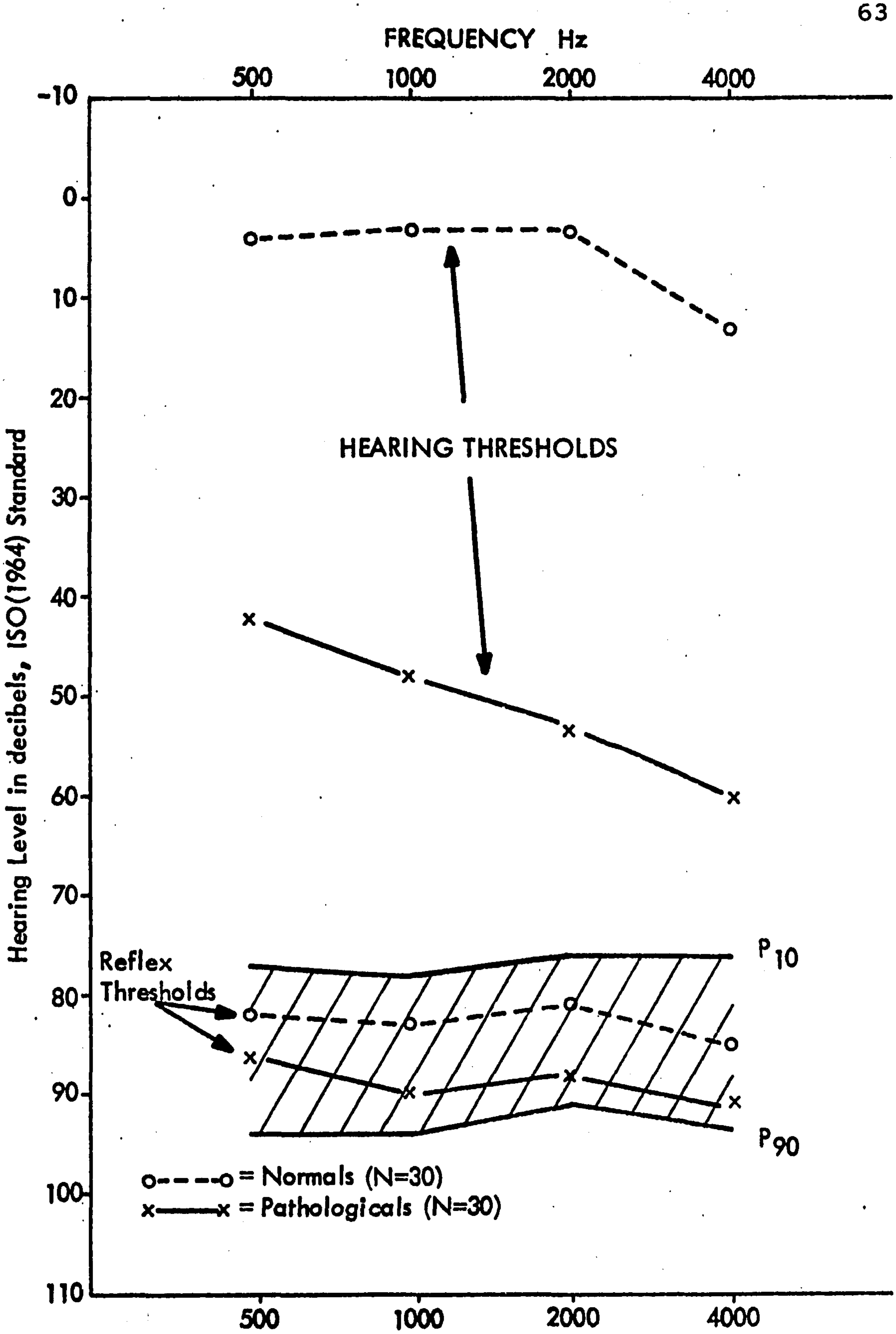

Figure 5. Mean Hearing Thresholds and Reflex Thresholds for Normals and Pathologicals.

age groups. However, the difference between normal and pathological ears for the old age groups is less than 40dB.

The analysis of variance for the hearing thresholds is presented in Table 2. The analysis indicates that there is a significant difference at the .01 level of confidence between the normal and pathological subjects. The pathological subjects, as expected, required more intensity in order to establish hearing threshold.

Table 2

Analysis of Variance for Hearing Thresholds

Source of Variation	df	Mean Square	F Value
Total	432		
Hearing	1	182073.21	474.56**
Age	2	1541.28	4.02*
Hearing x Age	2	5840.95	15.22**
Error A	52	383.67	
Frequency	3	2187.09	33.55**
Time	1	6.45	0.09
Time x Freq.	3	5.65	0.08
Hearing x Freq.	3	591.29	9.07**
Hearing x Time	1	13.77	0.21
Hearing x Time x Freq.	3	12.12	0.18
Age x Freq.	6	229.98	3.52**
Age x Time	2	2.61	0.04
Age x Time x Freq.	6	2.46	0.03
Error B	347	65.18	

**$p < .01$

*$p < .05$

The group means for hearing threshold by age, combining normal and pathological ears are presented in Table 3.

Table 3

Mean Hearing Thresholds by Age, Combining Normal and Pathological Ears

Young	Middle	Old
23.9	29.5	29.7

LSD .05 = 4.65

The results indicate that as age increases the intensity level required to reach threshold also increases. Additional analysis through the use of Least Significant Difference (LSD) indicates that the younger age subjects required significantly less intensity to establish threshold than did either of the two older age groups.

The interaction between hearing and age, combining frequency, indicates that the old age normal hearing subjects differed significantly from the young and middle age normal hearing subjects, as revealed in Table 4. The normal subjects show a direct relationship between age and hearing threshold. This result is consistent with other studies (Corso 1958, Glorig and Nixon 1960).

Table 4

Mean Hearing Thresholds by Age for Normal and Pathological Ears Combining Frequency

	Young	Middle	Old
Normals	.6	2.8	15.6
Pathologicals	50.0	57.3	45.2

LSD .05 = 6.55

One interesting observation regarding the significant interaction between hearing and age in the pathological subjects was that the old age group demonstrated less hearing impairment than the young and middle age groups. This finding suggests that there is not a direct relationship between hearing thresholds and age for the pathological ears in this study. This particular result also appears to contribute to the significant effects found in answer to the experimental questions relative to reflex threshold and decay to be discussed later.

The mean hearing thresholds for the four test frequencies, combining normals and pathologicals, are presented in Table 5.

Table 5

Mean Hearing Thresholds for Frequency
Combining Normal and Pathological Ears

Frequency			
500	1000	2000	4000
23.2	25.7	27.7	34.2
	LSD .05 = 3.32		

The frequency of 4000 Hz required significantly more intensity to establish threshold than did the other three test frequencies.

The significant interaction of hearing by frequency, combining age, demonstrates that hearing thresholds differ by frequency between the two groups. The normal ears showed no difference between the three lower frequencies, while the pathological ears demonstrated approximately a 5dB difference per octave between these frequencies. It can be seen from Figure 5 and Table 6 that 4000 Hz required significantly greater intensity than did the lower frequencies within each group.

Table 6

Mean Hearing Thresholds by Frequency for Normal and Pathological Ears Combining Age

	Frequency			
	500	1000	2000	4000
Normals	3.8	3.5	3.0	13.5
Pathologicals	42.5	48.5	52.8	59.8
		LSD .05 = 4.23		

The significant interaction between frequency and age highlights the general relationship that greater intensity is required to obtain threshold for the higher frequencies as age increases. It must be remembered in viewing the mean hearing thresholds for frequency by age in Table 7 that the data combine the normal and pathological subjects. While it can be expected for persons to show poorer thresholds with advancing age in normal ears, the same statement is not necessarily true for pathological ears as illustrated in Table 1. The abnormal condition present in the pathological ears is apparently dependent on factors other than age, thus explaining some of the present exceptions to the trend.

Table 7

Mean Hearing Thresholds for Frequency by Age, Combining Normal and Pathological Ears

	Frequency			
Age	500	1000	2000	4000
Young	20.2	23.7	25.0	29.7
Middle	25.7	29.5	29.0	36.5
Old	23.5	24.7	29.7	43.7

LSD .05 = 5.02

To summarize, a significant difference was demonstrated between the two groups of subjects for hearing threshold. For normal ears, as age increased hearing decreased and it decreased with an increase in frequency. For the pathological subjects in this study hearing thresholds and age did not yield a direct consistent relationship. However, hearing and frequency, for the pathological subjects, did show a direct relationship; as frequency increased hearing thresholds decreased.

Acoustic Reflex Thresholds

This section presents the results and discussion in answer to the first experimental question.

Question 1

Is there a significant difference in the acoustic reflex threshold for a group of normal hearing subjects and a group of subjects exhibiting a hearing loss attributable to cochlear pathology?

Measurements for reflex thresholds were interpreted by three methods: Sound Pressure Level (SPL), Hearing Level (HL), and Sensation Level (SL).

Reflex threshold measured in SPL utilized an absolute reference value of .0002 dynes/cm.[2] When the reflex threshold was measured in HL the relative reference was average hearing thresholds established for normal hearing subjects at individual frequencies re: the 1964 ISO Standard (Newby, 1972). The reference for reflex thresholds measured in SL was the individual subject's hearing thresholds at each test frequency. The adjusted mean reflex thresholds for the normal and pathological subjects for these three measures are presented in Table 8.

Table 8

Adjusted Mean Reflex Thresholds Measured in Sound Pressure Level, Hearing Level, and in Sensation Level for Normal and Pathological Subjects

Reference	Normal	Pathological
SPL	91.8	98.8
HL	83.1	89.7
SL	77.2	40.2

According to the analysis of variance in Table 9, there is a significant difference between the normal and pathological subjects for each of the three measurement methods. The adjusted means show that it required more intensity to establish reflex threshold in SPL and HL for the pathological subjects than it did for the normal subjects. When reflex thresholds were viewed in terms of SL the reverse relationship was evident. The normal subjects demonstrated a much larger range (77.2dB) between hearing threshold and reflex threshold than did the pathological subjects (40.2dB).

Table 9

Analysis of Variance for Acoustic Reflex Thresholds Measured in Sound Pressure Level (SPL), Hearing Level (HL), and Sensation Level (SL)

		F Values		
Source	df	SPL	HL	SL
Total	432			
Hearing	1	16.71**	15.24**	304.73**
Age	2	2.97*	3.39*	6.23**
Hearing x Age	2	3.80*	4.36*	4.34*
Error A	52			
Frequency	3	31.57**	16.29**	16.26**
Time	1	10.65**	13.26**	4.05*
Time x Freq.	3	1.78	3.56*	0.82
Hrg. x Freq.	3	7.13**	4.05**	5.86**
Hrg. x Time	1	0.10	1.09	0.03
Hrg. x Time x Freq.	3	0.07	0.87	0.02
Age x Freq.	6	2.19*	1.61	4.71**
Age x Time	2	0.21	0.92	0.16
Age x Time x Freq.	6	0.17	0.52	0.09
Error B	347			

**$p < .01$
*$p < .05$

The significant F ratios associated with these measurements provide an affirmative answer to the first experimental question:

> <u>There is a significant difference in the acoustic reflex thresholds for a group of normal hearing subjects and a group of hearing impaired subjects.</u>

In support of the above conclusion the following discussion of the results is offered.

Although the difference between normal and pathological subjects for acoustic reflex thresholds was statistically significant by all methods, reflex threshold levels reported in SPL or HL alone provide the examiner with little information of clinical importance. Reflex thresholds should preferably be reported in SL by frequency to be clinically meaningful.

The range of reflex thresholds obtained by Peterson and Lidén (1970) for normal hearing subjects is illustrated in Figure 5. Both hearing groups of the present study fall within the P10 - P90 range reported by the above investigators. Jerger (1972) states that 95 percent of normal reflexes will fall within a 30dB range (70-100dB HL). Due to the wide variance in reflex thresholds that has been reported for normals, and because of the relatively small differences found between normal and pathological subjects in this study it is not possible to classify these subjects as "normal hearing" or "hearing impaired" based solely on their level of reflex threshold.

The significant differences in reflex thresholds between frequencies vary depending on whether the reflex is measured in SPL or HL. The adjusted means for the four frequencies measured in SPL and HL are presented in Table 10. Reflex thresholds measured in SPL, combining normal and pathological subjects, shows that 1000 Hz and 2000 Hz required significantly less intensity than did 500 Hz and 4000 Hz. A similar observation has been reported previously for the thresholds of hearing when measurements are based on the same reference scale. This same relationship for frequency is not evident when reflex thresholds are measured in HL due to the different SPL's required to establish hearing threshold for the different frequencies. The difference for reflex thresholds in HL between frequencies is a finding to be noted, because it has potential importance in terms of measuring reflex decay. This point will be explained in a subsequent discussion. The significant hearing by frequency interaction simply reflects the trend for frequency that occurred in the main effects, viz. that the differences between the two groups of subjects were not similar at all frequencies.

Table 10

Adjusted Mean Reflex Thresholds for Four Frequencies in SPL and HL, Combining Normal and Pathological Subjects

	Frequency			
Reference	500	1000	2000	4000
SPL	95.8	93.3	93.8	98.6
HL	84.8	86.8	85.3	88.9

SPL LSD .05 = 1.17 HL LSD .05 = 1.32

Age was a significant factor when reflex thresholds were measured in SPL and HL. Combining normal and pathological ears, the old age subjects required less intensity to establish reflex threshold (92.9dB SPL, 83.7dB HL) than in the young (94.8dB SPL, 86.0dB HL) and middle (98.3dB SPL, 89.5dB HL) age groups. The old age subject's lower reflex thresholds possibly reflect the difference in hearing thresholds for the pathological subjects. As the intensity levels for hearing threshold increase, reflex thresholds also require greater intensity (Jerger, 1972). This explanation is supported by examining the significant interaction for age when the normal and pathological subjects are compared. The mean reflex thresholds in SPL and HL for normal and pathological

subjects are presented in Table 11. The old age pathological subjects do not follow the pattern that is present for the normal hearing age groups or the young and middle age pathological subjects.

Table 11

Mean Reflex Thresholds in SPL and HL for Normal and Pathological Subjects by Age

	Age		
	Young	Middle	Old
SPL			
Normals	91.5	91.7	92.3
Pathologicals	98.1	104.1	93.1
HL			
Normals	82.7	82.9	83.5
Pathologicals	89.3	95.3	83.6

SPL, LSD .05 = 5.88 HL, LSD .05 = 5.84

The old age pathological subjects required lower intensity levels to establish reflex threshold for SPL and HL than was found for the young or middle age pathological subjects, but significant differences were found only in comparison to the middle age pathological subjects. The young pathological subjects showed reflex thresholds that were also

significantly lower in comparison to the middle age pathological subjects. However, it is doubtful that these threshold differences by age represent any clinical importance because of the variance reported for reflex thresholds. There was no significant difference between the three age groups of normal hearing subjects for either measure. There were statistically significant differences between the normal and pathological young and middle age groups, but not the old age groups. Again this reflects the importance of hearing thresholds. There was less difference between hearing thresholds for the old age groups than for the young and middle age groups.

The main effect of time, or difference between presentation one and presentation two, revealed a statistically significant difference for reflex thresholds in SPL, HL, and SL. However, the differences were extremely small in terms of decibels (2dB) and are not considered to be clinically important. When the range for normal reflex thresholds is reported to be approximately 20-30dB, a mean difference of 2dB between two tests is negligible. This small difference would tend to support the observation that reflex threshold measures are quite

reliable (Djupesland, Flottorp, and Winther 1967 , Jerger 1972).

The significant age by frequency interaction for SPL showed no particular trend. The largest difference between any two group means was 6dB, and this is not considered to be of clinical significance.

As shown in Table 8 there was a significant difference between the normal and pathological subjects when reflex thresholds were measured in SL. Such thresholds can be visualized by comparing the reflex thresholds with the hearing thresholds in Figure 5. There is a much larger range between these thresholds for normals than for pathologicals. The reduced range for pathological ears has been interpreted to reflect recruitment, a phenomenon associated with a cochlear type hearing impairment (Metz 1952, Jepsen 1963). Measurement of acoustic reflex threshold in SL has become a common clinical procedure in determining the cochlear status of sensory neural hearing loss (Jerger 1972).

Age was shown to be a significant factor in the analysis of variance for reflex thresholds in SL. The young age subjects, combining normal and pathological

ears, showed a higher SL (62.2dB) than did the middle age (60.0dB) and old age subjects (54.0dB). This finding is in support of others that show a decrease in SL with an increase in age. (Jepsen 1963, Jerger 1972). This age difference is a potentially important factor and raises the question: Can an older person with normal hearing for his age be classed as pathological due to a lowered SL? In answer, it must be remembered that a certain amount of reduced SL can be expected due to aging, because as age increases hearing threshold requires greater intensity. In viewing the mean reflex thresholds in SL for normal and pathological subjects by age in Table 12, it is seen that the old age normals demonstrated a significantly lower SL than the young and middle age normals; yet, the old age normal subjects' SL was significantly higher than any of the pathological groups'. There was no difference between age groups for the pathological subjects, which suggests that the pathological condition masks the effects of age. If these SL's can be used as a general trend then it can be expected that old age normals will demonstrate noticeably different SL's from pathological ears.

Table 12

Mean Reflex Thresholds in SL for Hearing by Age

	Age		
	Young	Middle	Old
Normals	83.3	80.2	68.2
Pathologicals	41.1	40.1	40.5
LSD .05 = 6.87			

The adjusted mean reflex thresholds in SL for frequency, combining normal and pathological subjects are presented in Table 13.

Table 13

Adjusted Mean Reflex Thresholds in SL for Frequency Combining Normal and Pathological Subjects

Frequency			
500	1000	2000	4000
61.6	61.0	57.5	54.6
LSD .05 = 2.05			

The general conclusion to be drawn from this table shows that as frequency increased the reflex threshold in SL decreased.

The mean reflex thresholds in SL for hearing by frequency in Table 14 points out that higher frequencies demonstrated lower SL's, and that pathological subjects had much lower SL's than did normal subjects.

Table 14

Mean Reflex Thresholds in SL for Normal and Pathological Subjects by Frequency

	Frequency			
	500	1000	2000	3000
Normals	78.8	79.5	78.6	71.9
Pathologicals	44.3	42.6	36.6	37.7
LSD	.05 =	2.91		

The means for the age by frequency interaction in Table 15 suggests that the SL's for reflex thresholds decreased as age and frequency increased. A generalization to be considered here is that reflex thresholds in SL are affected less at lower frequencies by age and hearing impairment than at higher frequencies.

Table 15

Mean Reflex Thresholds in SL for Age by Frequency Combining Normal and Pathological Subjects

	Frequency			
Age	500	1000	2000	4000
Young	62.8	64.9	62.7	61.7
Middle	63.7	63.3	62.5	67.4
Old	60.0	58.9	53.7	48.2
	LSD .05 = 3.56			

In summary, there are definite differences between normal and pathological subjects for reflex thresholds when measured in SPL, HL, or SL.

For SPL: reflex thresholds increase in intensity as hearing thresholds increase in intensity; For normals as age increases reflex thresholds increase, the same is not shown for the pathological subjects in this study; Reflex thresholds for different frequencies appear to be dependent on age and hearing loss, the mid-frequencies were affected less by age and hearing loss; Although there was a statistical difference for time, reflex threshold measures are considered to be clinically reliable.

For HL: reflex thresholds increased as intensity to obtain hearing threshold increased; The trend is for reflex threshold to increase as age increased; Reflex thresholds were lowest for 500 Hz and highest for 4000 Hz, showing a trend to increase as frequency increased; Although test-retest results were significant they are considered to be of little clinical consequence.

For SL: The pathological subjects showed a significantly reduced range between hearing threshold and reflex threshold; normal subjects showed a decrease in reflex thresholds as age increased, pathological subjects did not reveal an age effect; The reflex thresholds in SL generally decreased as frequency increased; Although the test-retest results were significantly different they are considered to be adequately stable.

The following section presents the results and discussion of the remaining five experimental questions.

Reflex Decay Measurements

Question 2

Is there a significant difference in the acoustic reflex decay for a group of normal hearing subjects and

a group of subjects exhibiting a hearing loss attributable to cochlear pathology?

The mean curves for the reflex decay measurements for normal and pathological subjects over the 60 second stimulation period are presented in Figure 6 with the amplitude of response measured in millimeters. The normal ears showed a stronger reflex but both groups showed approximately the same amount of decay over time. Although these measures show absolute differences between the two groups, the primary purpose was to observe percent decay over time. In order to achieve this and to compare data from this study with previous studies the amplitude of response was converted from millimeters to a percent score.

The response at 2 seconds was considered to be the maximum response. Percentage scores were determined by dividing the amplitude at each of seven time intervals by the amplitude at two seconds. These intervals were 5, 10, 15, 20, 30, 45, and 60 seconds. For example, if the amplitude at 10 seconds was 10mm. and the amplitude at two seconds was 15mm. it would yield 10/15= .66; 1.00 - .66=.34% decay.

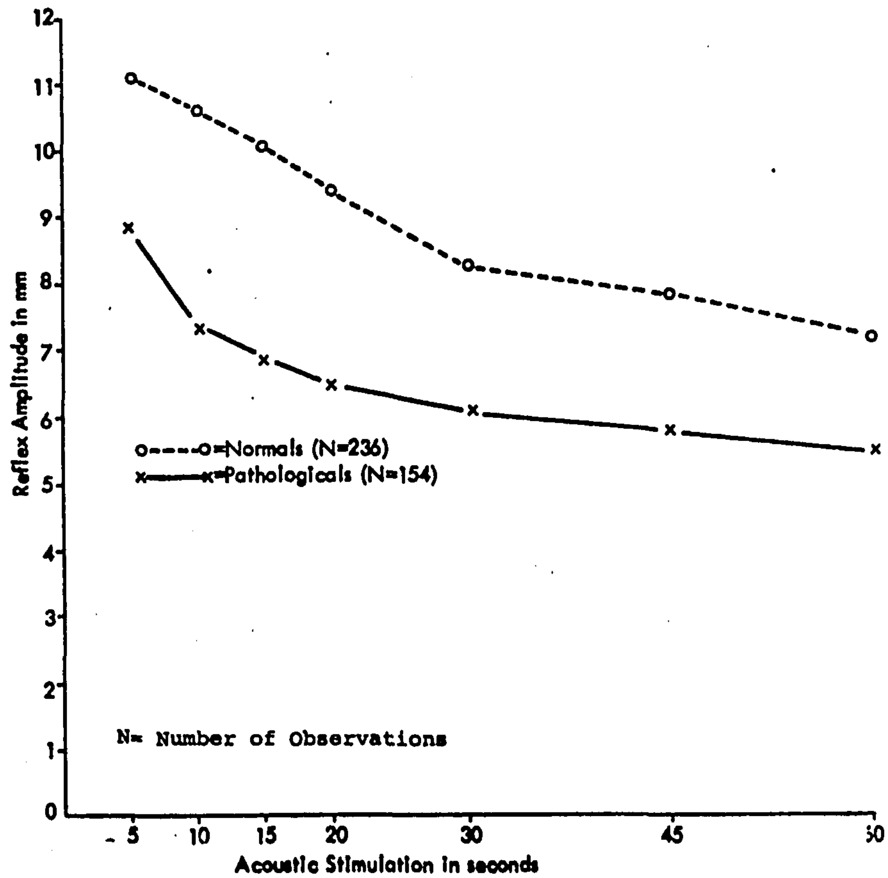

Figure 6. Mean Reflex Decay for Normals and Pathologicals for combined ages, frequencies, and presentations.

The two second maximum response was chosen based on knowledge of the latency period of the reflex and empirical observation of the initial maximum amplitude. It was assumed that maximum contraction would occur within a two second period from stimulus onset. When the amplitude of the response was greater at a later point in time, as it sometimes was, it was interpreted to reflect the variability of the reflex measure and not truly representative of maximum contraction.

The adjusted mean percent of reflex decay for normal and pathological subjects at the selected time intervals is presented in Table 16. The negative percent scores that appear in this table are due to the criteria used for determining the percent score. In cases where the amplitude at a later time exceeded that of two seconds the measure for that specific time appears as a negative percent. For example, if the amplitude at two seconds was 10mm. and the amplitude at ten seconds was 12mm. it would yield 12/10 = 1.2; 1.00 - 1.2 = -.20%.

A reflex decay recording for a young normal ear stimulated with a 2000 Hz tone is presented in Figure 7. Note how the amplitude spikes at various time points.

These extremes are not considered to represent actual maximum contraction but are considered artifacts due to an unknown source or sources. Measurement of such spike points would yield negative percentage scores. Although the recording is not atypical, most of the recordings did not yield such wide fluctuations.

Table 16

Adjusted Mean Percent Reflex Decay for Normal and Pathological Subjects Combining Age, Frequency and Presentations

Time Period in Seconds	5	10	15	20	30	45	60
Normals	-.05	-.01	.06	.14	.20	.27	.31
Pathologicals	-.03	.09	.17	.22	.25	.30	.29

The adjusted mean percent of reflex decay is presented graphically in Figure 8 and shows very little difference between normal and pathological subjects. An analysis of variance (Table 17) was carried out comparing the two groups at each of the selected time intervals. The analysis showed no significant differences between normal and pathological subjects at any of the time intervals.

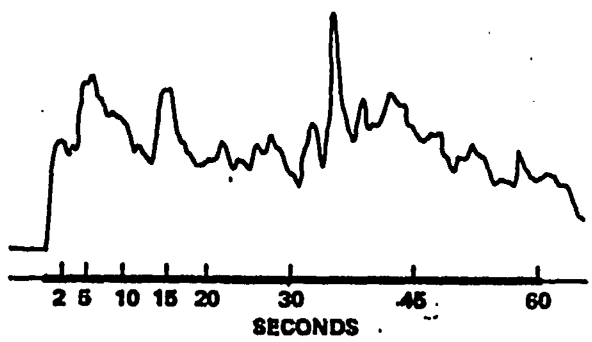

Figure 7. A Reflex Decay Recording for a Young Normal Ear Stimulated with a 2000 Hz Tone for 60 Seconds.

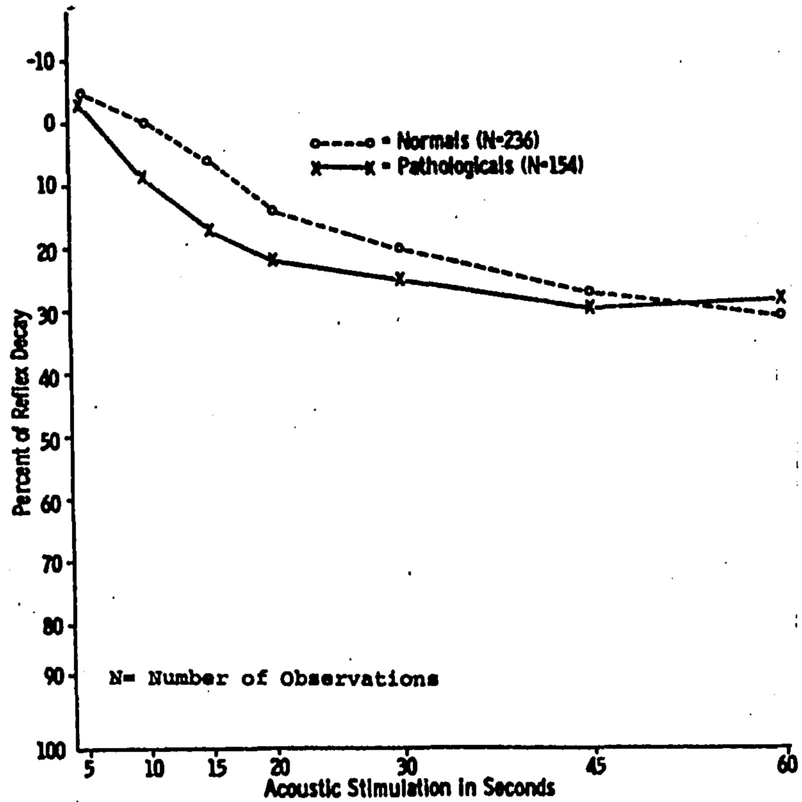

Figure 8. Adjusted Mean Percent of Reflex Decay for Normals and Pathologicals for Combined Age, Frequency, and Presentations.

Table 17

Analysis of Variance for Percent of Acoustic Reflex Decay
For Seven Selected Time Intervals

		F Values						
Source	df	05	10	15	20	30	45	60
Total	389							
Hearing	1	< 1	< 1	< 1	< 1	< 1	< 1	1.22
Age	2	1.15	< 1	< 1	< 1	< 1	< 1	< 1
Hearing x Age	2	< 1	< 1	< 1	< 1	< 1	< 1	1.06
Error A	52							
Frequency	3	3.79*	4.28**	5.65**	11.17**	5.24**	16.03**	10.22**
Time	1	3.64	0.194	0.173	1.642	0.027	3.682	.263
Time x Freq.	3	1.58	1.29	0.710	0.242	1.025	.727	1.043
Hrg. x Freq.	3	0.09	0.403	0.075	0.131	0.001	.120	.035
Hrg. x Time	1	0.18	0.029	0.133	0.036	0.063	.256	.380
Hrg. x Time x Freq.	3	0.09	0.435	0.231	0.095	0.032	.199	.339
Age x Freq.	6	3.56**	1.689	2.107	3.00**	2.579*	2.582*	1.788
Age x Time	2	3.05*	3.19*	1.917	0.271	2.110	2.492	2.823
Age x Time x Freq.	6	1.90	3.11**	1.667	1.291	2.463*	3.21**	2.807*
Error B	304							

**p < .01
*p < .05

As shown in Figure 8 the normal subjects revealed a slightly less rapid decay for the first 20 seconds; but as time progressed the curve for the normals crossed below that for the pathological subjects. The mean decay curves in this study are not consistent with the findings of Anderson, et al. (1969) who showed significantly more decay in their normal hearing subjects. Their findings will be discussed when considering reflex decay at different frequencies. Although the present study points out no difference between normal and pathological subjects, clinical usefulness of this information depends on an interpretation by frequency, as will be done in answer to experimental Question 5.

Because the analysis showed no significant differences between normal and pathological subjects at any of the time intervals the answer to experimental question two is negative.

There is no significant difference in the acoustic decay for a group of normal hearing subjects and a group of hearing impaired subjects.

Experimental Question 3 and Question 4 deals with differences between age categories for normal and pathological subjects and therefore are presented together.

Question 3

Is there a significant difference in the acoustic reflex decay for subjects of different age groups with normal hearing?

Question 4

Is there a significant difference in the acoustic reflex decay for subjects of different age groups with a hearing impairment due to cochlear pathology?

The mean percent of acoustic reflex decay for normal and pathological subjects by age groups for the seven time intervals is presented in Table 18. The same data is presented in graphic form in Figure 9 for normal subjects and Figure 10 for pathological subjects.

The analysis of variance (Table 17) did not yield significant F ratios for the different age groups at any of the selected time intervals for either normal or pathological subjects. In viewing Figure 9 it is obvious that there is no difference between the curves for the normal young, middle and old age groups. In Figure 10

Table 18

Mean Percent of Reflex Decay for
Normal and Pathological Subjects
by Age, Combining Frequency and Presentations

	Seconds						
	5	10	15	20	30	45	60
Normals							
Age							
Young	.01	.04	.10	.18	.25	.28	.29
Middle	-.14	-.05	.04	.11	.19	.32	.35
Old	-.01	-.01	.05	.18	.18	.21	.32
Pathologicals							
Age							
Young	.06	.17	.22	.26	.30	.35	.41
Middle	.02	.17	.27	.32	.34	.37	.38
Old	-.02	.03	.08	.11	.19	.22	.20

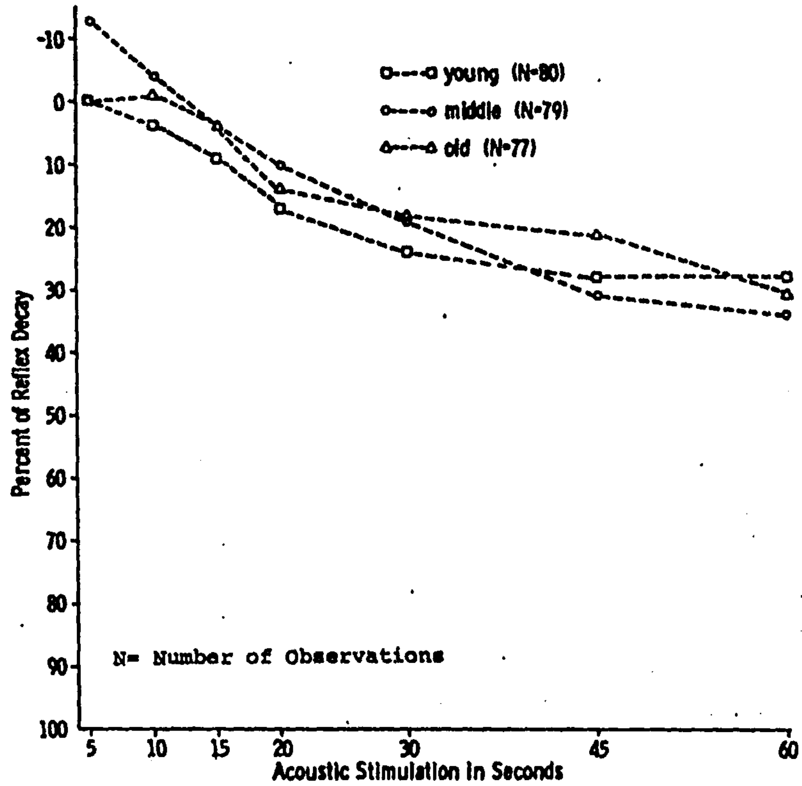

Figure 9. Mean Percent of Reflex Decay for Normals for Three Age Groups, Combining Frequency and Presentations.

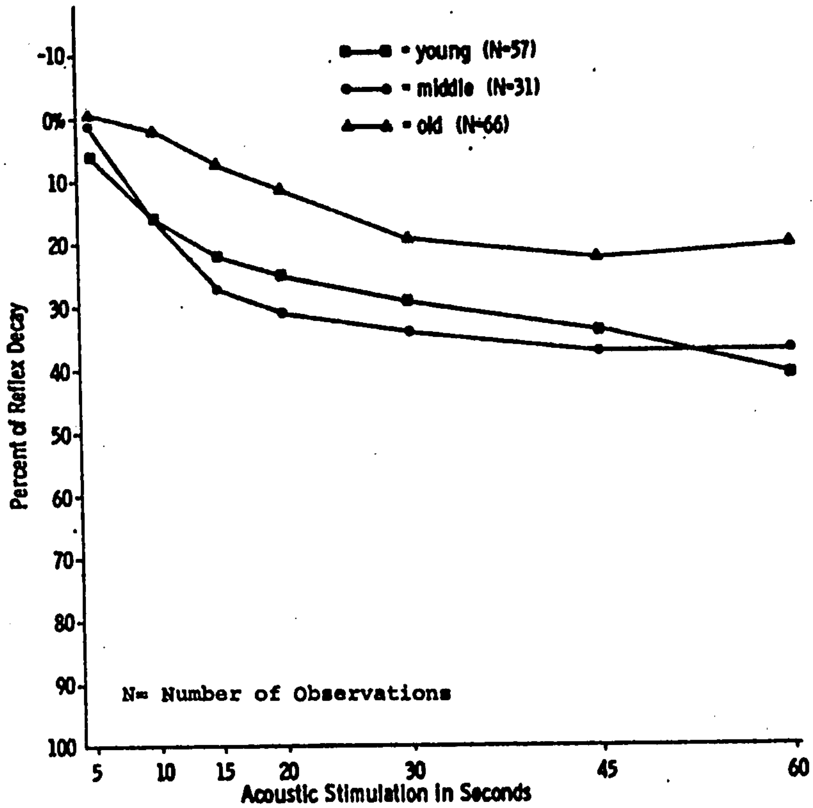

Figure 10. Mean Percent of Reflex Decay for Pathologicals for Three Age Groups, Combining Frequency and Presentations.

the pathological young and middle age groups tend to show slightly more reflex decay than does the old age group. It is possible that this trend is attributable to the lesser degree of hearing impairment present in the old age group. Mean hearing threshold for the old age pathological subjects was better than the mean threshold for either of the two younger age groups.

For lack of significant F ratios, Questions 3 and 4 are answered in the negative: <u>There is not a significant difference in the acoustic reflex decay for different age groups for either normal hearing subjects or for hearing impaired subjects</u>.

<u>Question 5</u>

Is there a significant difference in the acoustic reflex decay at different stimulus frequencies for the normal hearing subjects and those with a hearing impairment?

The adjusted mean percent of reflex decay for the four frequencies tested, combining normal and pathological subjects is presented in Table 19 and Figure 11.

The analysis of variance (Table 17) yielded significant F values for frequency at each of the seven time

Table 19

Adjusted Mean Percent of Reflex Decay for Frequency Combining Normal and Pathological Subjects, Age, and Presentations

	Interval in Seconds						
Frequency	5	10	15	20	30	45	60
500	−.09	−.06	−.03	−.01	.02	.03	.07
1000	.03	.05	.10	.16	.22	.27	.26
2000	.11	.20	.27	.35	.44	.49	.54
4000	−.24	−.02	.13	.20	.22	.35	.31
LSD .05=	.18	.15	.14	.11	.19	.12	.15

intervals. All of the time intervals yielded F ratios significant at the .01 level of confidence except at 5 seconds where the significance level was .05.

In viewing the data in Table 19 and Figure 11, two things should be considered: 1. The total amount of decay within each frequency, and 2. The amount of decay between frequencies.

The frequency of 500 Hz shows the least amount of decay (7%) over time, while 2000 Hz shows the most decay (54%). The frequencies of 1000 and 4000 Hz show significantly more decay than 500 Hz, and significantly less

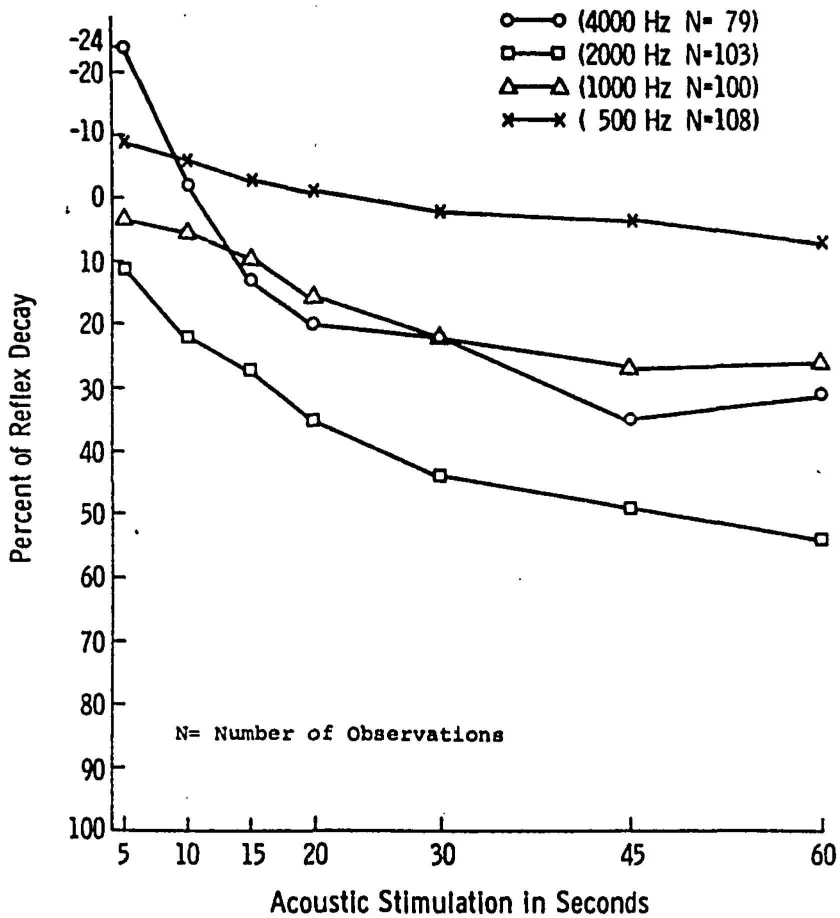

Figure 11. Adjusted Mean Percent of Reflex Decay for Four Frequencies, Combining Normals and Pathologicals, Age and Presentations.

than 2000 Hz, but do not show a significant difference between each other.

Beyond the 10 second measurement point, 500 Hz clearly demonstrates its difference from the other frequencies by showing only minimal decay. Likewise, 2000 Hz clearly stands out from the other frequencies showing the most decay as time progresses. This result is somewhat unexpected. Previous results (Anderson, et al. 1959; Djupesland 1967) have shown that the most decay for normal subjects is observed for 4000 Hz, and that the amount of decay decreased as frequency decreased.

The greatest amount of decay for 2000 Hz in the present study cannot be attributed to differences in hearing, normal vs. pathological, because the same frequency relationship is observed for both groups as shown in Figure 12. There was not a significant F ratio for the hearing by frequency interaction, which suggests that although there is a difference between frequencies, there is no difference between normal and pathological subjects. This can be seen by comparing the curves in Figure 12. The two groups at 500 Hz show almost

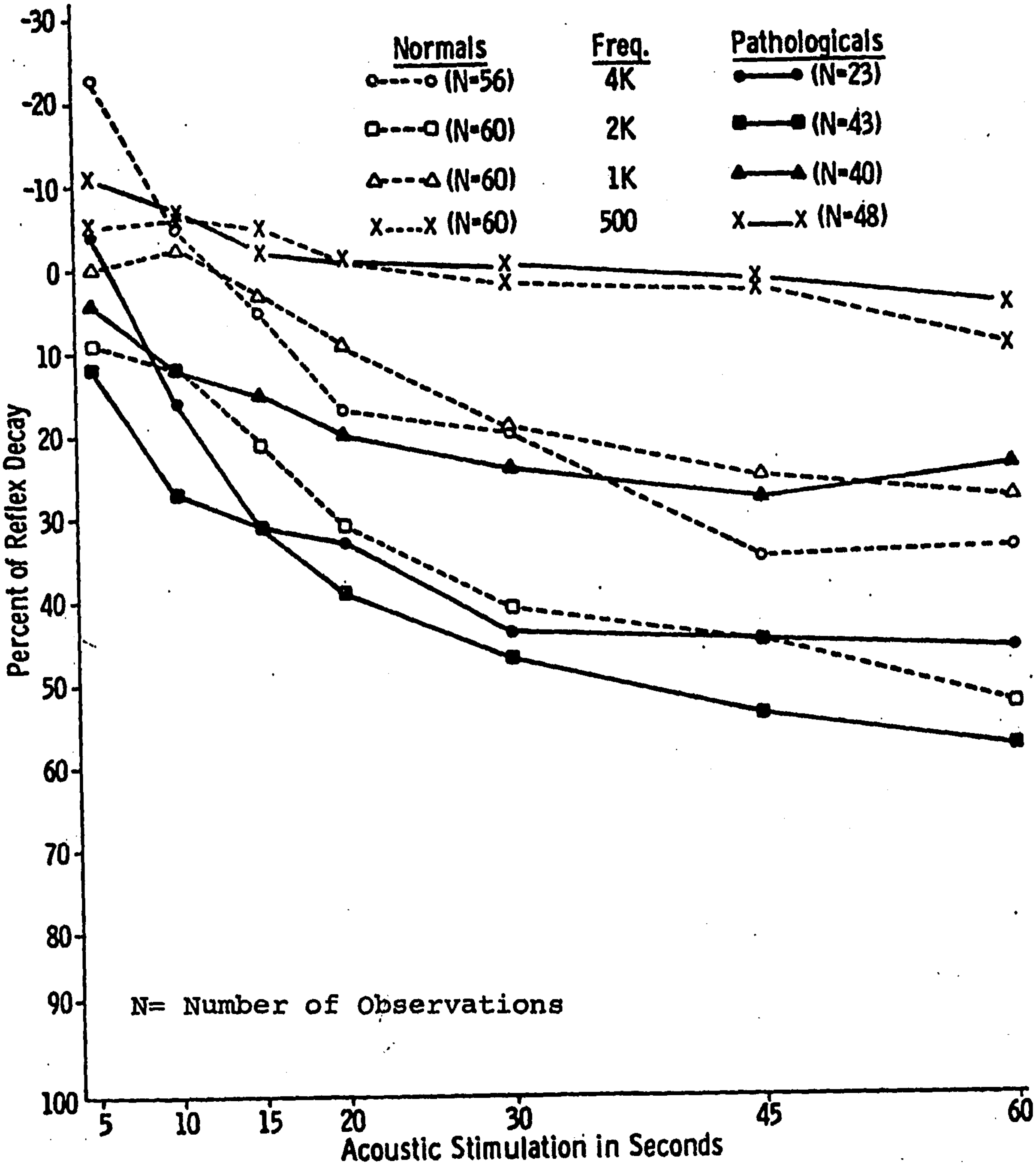

Figure 12. Mean Percent of Reflex Decay for Normals and Pathologicals for Four Frequencies, Combining Ages and Presentations.

identical curves. The other frequencies show slight variation between the two groups. It should be noted that 4000 Hz shows the most variation between normal and pathological subjects in comparison to other frequencies. This variation may reflect the aberrant behavior observed with reflex threshold measurements at this frequency. Because 4000 Hz frequently does not produce any measurable reflex thresholds for normal or pathological subjects (Jerger, 1972) the usefulness of this frequency for reflex decay measures should be questioned.

The answer to Question 5 is positive.

There is a significant difference in the acoustic reflex decay at different stimulus frequencies for normal hearing and hearing impaired subjects.

The answer to Question 5 appears to provide the most important information for clinical purposes. The review of the literature indicates that very little information had been published regarding reflex decay measurements. The principle work dealing with the topic was that of Anderson et al. 1969. Their results for 50 normal ears showed no reduction in reflex decay within the 10 second stimulation period for the lower

frequencies of 500 and 1000 Hz. However, they reported the median "half-life" (50% decay) of the responses at 2000 and 4000 Hz to be 14 and 7 seconds, respectively. The "half-life" at 14 seconds must be questioned since the stimulation time was reported to be 10 seconds. Their "half-life" at 2000 Hz appears as a "projected" result and not based on actual measurement. These authors illustrated the decay as a straight line function which fails to reflect the variability observed in this study.

The present study supports the finding of minimal decay for the lower frequencies, but definitely differs from Anderson et al. 1969 for the higher frequencies. During the first 10 seconds of stimulation the normal hearing subjects show no decay for 500, 1000, or 4000 Hz, and show only 12% decay for 2000 Hz. The pathological subjects generally show more decay than normal subjects in the first 15-20 seconds, but do not reach the 50% or "half-life" point reported by Anderson. Only one frequency ever reached a 50% decay. This was observed for 2000 Hz for the pathological subjects, but only after approximately 40 seconds of stimulation.

Anderson, et al. reported an excessively rapid reflex decay for acoustic tumor patients. Their patients showed a "half-life" occurring at 4 seconds for the lower frequencies of 500 and 1000 Hz. These authors suggest that this finding would help to differentiate an ear with an VIII nerve tumor, showing little or no hearing loss, from a normal ear, but not from ears exhibiting other types of sensory neural pathology.

There was not a clear pattern present for the age by frequency interaction for reflex decay. It was noted that the interaction of age by time by frequency was statistically significant at four time intervals. However, this interaction did not yield an interpretation of clinical significance. The greatest effect on the three factor interaction was obviously due to frequency since the main effects of age and time failed to reveal significant differences individually.

The present study shows that normal ears and ears with cochlear pathology react alike on reflex decay measurements. Therefore, reflex decay could possibly be helpful in differentiating not only between normal ears and retro-cochlear lesions, but also between cochlear

and retro-cochlear lesions.

To summarize, of the four frequencies studied, 500 Hz would appear to yield the most definitive information for differential diagnosis for the following reasons: 1. Age appears to have less effect on 500 Hz than on higher frequencies; 2. Hearing loss appears to affect the higher frequencies more than 500 Hz; 3. Reflex thresholds are more easily obtained at 500 Hz than at higher frequencies; 4. Less reflex decay was observed for 500 Hz than for higher frequencies for both normal ears and ears with cochlear pathology; and, 5. Very rapid decay has been reported in the literature at 500 Hz for retro-cochlear lesions.

<u>Question 6</u>

Is there a significant difference between an initial measurement of acoustic reflex decay and a repeat measurement?

The mean percent of reflex decay for presentations one and two for normal and pathological subjects are presented in Table 20.

The analysis of variance in Table 17 does not reveal a significant F ratio for Time (first vs. second presentation). The mean percent of reflex decay for the two

Table 20

Mean Percent of Reflex Decay for Presentation One and Presentation Two, for Normal and Pathological Subjects, Combining Age and Frequency

	Seconds						
	5	10	15	20	30	45	60
Normals							
First	.05	.00	.04	.11	.20	.21	.28
Second	-.10	-.01	.08	.17	.21	.33	.35
Pathologicals							
First	.00	.08	.14	.17	.23	.23	.26
Second	.04	.14	.20	.24	.29	.37	.37

presentations for normal and pathological subjects is illustrated in Figure 13. The graph shows a slight variation between the two presentations for both normal and pathological subjects. Djupesland et al. (1967) reported reproducible results in most cases when measuring the duration of the impedance changes during continuous stimulation with pure tones. The above investigators allowed a 24 hour period between tests while the present study allowed approximately 10 minutes between the initial test and the repeat measurement. The present study indicates

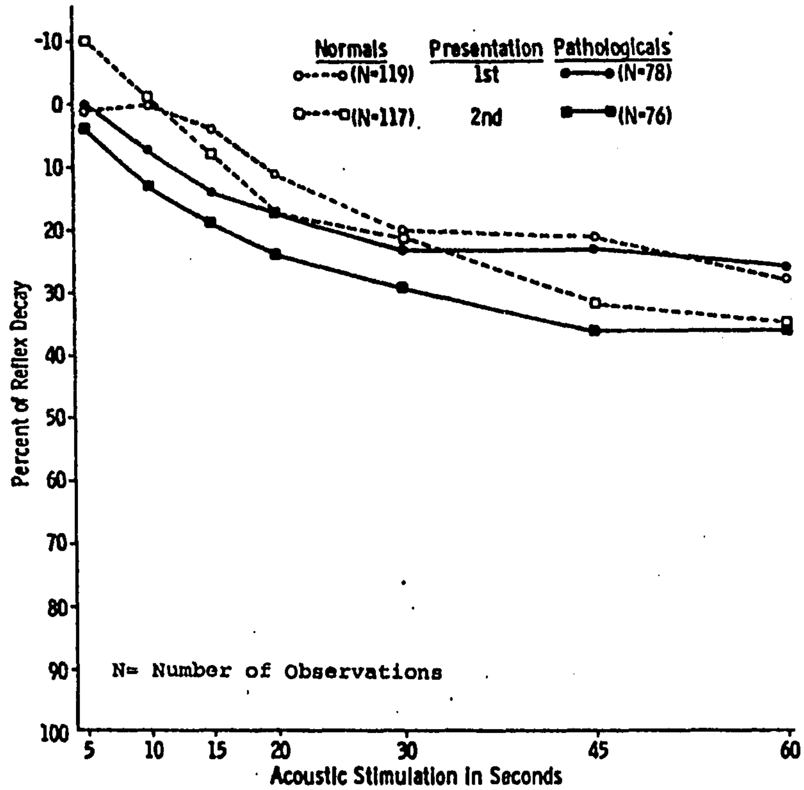

Figure 13. Mean Percent of Reflex Decay for Normals and Pathologicals for Two Presentations, Combining Age and Frequency.

that reflex decay is a measure that is stable and repeatable and therefore Question 6 is answered negatively.

<u>There is no significant difference between an initial measurement of acoustic reflex decay and a repeat measurement</u>.

CHAPTER V

SUMMARY AND CONLCUSIONS

Summary

The purpose of the present study was to compare the results of acoustic reflex decay measures on three different age groups of normal hearing subjects and subjects with a hearing impairment attributed to cochlear pathology.

To date little information has been published concerning the clinical usefulness of the reflex decay measure. The major work on reflex decay by Anderson et al. (1969) did not provide results for cochlear pathology nor for different age subjects.

In the present study a total of 60 subjects were tested. The 30 normal and 30 pathological subjects were sub-divided into three age groups: young 15-34, middle 35-54, and old 55-74. Each subject was tested for hearing threshold, reflex threshold, and reflex decay at four frequencies, 500, 1000, 2000, and 4000 Hz. An immediate

test-retest procedure was performed for the reflex threshold and reflex decay measurements for all subjects at four test frequencies. A limit of 95dB hearing level was established as the maximum for obtaining a reflex threshold in order that decay measurements could be made at 10dB sensation level re: reflex threshold. The acoustic stimulation for the decay measurement remained on for one minute, or, until the response amplitude had decayed to the pre-test baseline. All results were permanently recorded on a strip chart recorder.

The following questions were asked in the experimental design:

1. Is there a significant difference in the acoustic reflex threshold for a group of normal hearing subjects and a group of subjects exhibiting a hearing loss attributable to cochlear pathology?
2. Is there a significant difference in the acoustic reflex decay for a group of normal hearing subjects and a group of subjects exhibiting a hearing loss attributable to cochlear pathology?
3. Is there a significant difference in the acoustic reflex decay for subjects of different age

groups with normal hearing?

4. Is there a significant difference in the acoustic reflex decay for subjects of different age groups with a hearing impairment due to cochlear pathology?
5. Is there a significant difference in the acoustic reflex decay at different stimulus frequencies for the normal hearing subjects and those with a hearing impairment?
6. Is there a significant difference between an initial measurement of acoustic reflex decay and a repeat measurement?

Results of the various measures were examined through statistical treatment using the analysis of variance procedure.

Answers to the experimental questions are as follows:

1. There is a significant difference in the acoustic reflex threshold measured in SPL, HL, and SL for a group of normal hearing subjects and a group of hearing impaired subjects.

2. Normal hearing and hearing impaired subjects showed similar results for acoustic reflex decay measures.
3. Normal hearing subjects of different ages showed no differences for acoustic reflex decay measures.
4. Hearing impaired subjects of different ages showed no differences for acoustic reflex decay measures.
5. There were significant differences between the four test frequencies for acoustic reflex decay for both normal and hearing impaired subjects.
6. The results indicate that the initial and repeat reflex decay measurement were not considered to be significantly different.

Conclusions

The hearing thresholds and acoustic reflex thresholds demonstrated that there was a difference between the normal and pathological subjects in this study. The pathological subjects required more intensity to establish hearing threshold than did the normal subjects. The reflex thresholds in SL showed a significantly decreased range for the pathological subjects, indicating the presence of recruitment, or a cochlear type impairment.

The normal and pathological ears in this study did not differ significantly in the way they reacted to sustained acoustic stimulation. The reflex decay measures illustrated that as long as the ear was able to respond to the sustained stimulus the normal and pathological ears responded in a very similar fashion.

Age was a factor when measuring hearing threshold and reflex threshold; as age increased the intensity level required to establish hearing threshold increased; as age increased the sensation level of the reflex threshold decreased. Age did not show any significant effects on reflex decay measurements.

Frequency was a factor in measures of hearing threshold, reflex threshold, and reflex decay. As frequency increased the intensity level for hearing threshold increased. As frequency increased the intensity level for reflex threshold in sensation level decreased. As frequency increased the percent of reflex decay increased. Reflex decay measures for different frequencies did not differentiate between normal ears and pathological ears with a cochlear impairment; however, such measures may be helpful in differentiating normal ears, and ears with cochlear

pathology from retro-cochlear type lesions.

Differences in test-retest for reflex threshold and reflex decay were of small magnitude and they both were therefore considered to be clinically unimportant.

The present study has served to identify several areas for further investigation. Studies should be done:

1. To further evaluate the differences observed between frequencies for reflex decay.
2. To investigate the significance of response amplitude between normal and pathological ears, and between different age groups.
3. To develop a standardized procedure for obtaining reflex decay in terms of the intensity, duration, and frequency of the stimulating tone.
4. To develop a standard procedure for recording reflex decay.
5. To explain the physiological basis of reflex decay.
6. To investigate the relationship of presbycusis and reflex thresholds in SL particularly at higher frequencies.

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APPENDIX A

RAW DATA SUMMARY SHEETS

The information contained in the raw data summary sheets has been placed in coded columns and computer typed for accuracy.

The coded columns are explained as follows:

SUBJ: the individual subjects number. It should be noted that the numbers repeat from 1-10, because there were 10 subjects in each of 2 hearing groups and 3 age groups.

HEAR: N represents normal hearing subjects.
P represents pathological subjects.

AGE: Y represents young age subject.
M represents middle age subject.
O represents old age subject.

PRES: 1 represents Presentation One
2 represents Presentation Two

FREQ: 4K represents 4000 Hz
2K represents 2000 Hz
1K represents 1000 Hz
.5K represents 500 Hz

The amplitude of the sustained reflex obtained from the graphic recorder is presented in millimeters at eight selected time intervals.

Reflex thresholds were measured in decibels with three references. These are presented in the columns under Reflex Level IN. SPL = Sound Pressure Level

HL = Hearing Level

SL = Sensation Level

The final column gives the hearing threshold in decibels re: HL ISO 1964 for the experimental ear. HT - Hearing Threshold.

APPENDIX A
RAW DATA SUMMARY SHEET

SUBJ	HEAR	AGE	PRES	FREQ	*---- REFLEX AMPLITUDE IN MILLIMETERS * TIME INTERVAL IN SECONDS * 2	5	10	15	20	30	45	60* ----*	REFLEX LEVEL IN * SPL	HL	SL *	HT
1	N	Y	1	4K	13.0	7.0	4.0	3.5	3.0	1.0	0.0	0.0	90.0	81.0	76.0	5.0
1	N	Y	1	2K	14.5	10.5	8.5	7.5	8.5	8.0	6.0	4.5	83.5	75.0	85.0	-10.0
1	N	Y	1	1K	14.0	11.5	11.5	10.0	10.0	11.0	8.5	7.5	77.5	71.0	81.0	-10.0
1	N	Y	1	.5K	5.0	5.0	5.0	5.0	6.0	8.0	8.0	10.5	74.0	63.0	68.0	-5.0
1	N	Y	2	4K	23.0	12.0	8.0	7.0	9.5	6.0	4.0	2.5	82.0	73.0	68.0	
1	N	Y	2	2K	8.0	5.0	4.5	3.0	2.0	2.5	1.5	1.5	81.5	73.0	83.0	
1	N	Y	2	1K	10.5	7.5	11.0	10.0	6.5	9.0	12.0	14.5	75.5	69.0	79.0	
1	N	Y	2	.5K	13.0	13.0	11.5	11.5	12.0	14.0	15.5	17.5	78.0	67.0	72.0	
2	N	Y	1	4K	18.0	15.5	14.5	13.0	12.5	7.5	5.0	4.0	88.0	79.0	79.0	0.0
2	N	Y	1	2K	10.5	8.0	7.0	7.0	6.5	7.5	8.5	8.5	87.5	79.0	84.0	-5.0
2	N	Y	1	1K	10.0	8.5	8.0	7.5	7.0	7.0	5.0	6.0	89.5	83.0	93.0	-10.0
2	N	Y	1	.5K	16.5	15.0	11.5	11.5	12.0	15.5	13.5	12.5	88.0	77.0	97.0	-20.0
2	N	Y	2	4K	10.0	9.0	6.0	5.0	2.5	1.0	1.0	0.0	94.0	85.0	85.0	
2	N	Y	2	2K	9.0	8.5	8.0	8.0	6.0	4.0	4.0	3.0	93.5	85.0	90.0	
2	N	Y	2	1K	9.5	8.0	9.0	11.0	11.0	9.0	7.5	7.0	93.5	87.0	97.0	
2	N	Y	2	.5K	11.0	10.0	8.0	8.0	8.0	10.0	9.0	6.5	86.0	75.0	95.0	
3	N	Y	1	4K	13.0	11.5	10.0	6.0	3.0	1.0	1.5	2.0	94.0	85.0	80.0	5.0
3	N	Y	1	2K	17.0	17.0	16.0	15.0	14.5	14.0	13.5	12.0	103.5	95.0	100.0	-5.0
3	N	Y	1	1K	8.0	7.0	6.5	5.5	4.5	5.5	2.5	3.5	97.5	91.0	91.0	0.0
3	N	Y	1	.5K	10.0	10.0	8.5	7.5	7.0	7.0	6.0	7.0	102.0	91.0	86.0	5.0
3	N	Y	2	4K	10.0	9.5	9.0	7.5	7.0	6.0	5.5	5.5	100.0	91.0	86.0	
3	N	Y	2	2K	9.5	9.5	9.0	8.0	8.0	8.0	9.0	8.0	103.5	95.0	100.0	
3	N	Y	2	1K	9.0	8.5	8.0	6.5	6.0	5.0	5.0	6.0	101.5	95.0	95.0	
3	N	Y	2	.5K	7.5	5.0	5.0	4.0	4.0	3.0	3.0	3.0	102.0	91.0	86.0	

APPENDIX A

RAW DATA SUMMARY SHEET

SUBJ	HEAR	AGE	PRES	FREQ	*---- REFLEX AMPLITUDE IN MILLIMETERS / TIME INTERVAL IN SECONDS 2	5	10	15	20	30	45	60 ----*	* REFLEX LEVEL IN SPL	HL	SL *	HT
4	N	Y	1	4K	12.5	12.0	7.5	7.5	8.0	6.5	9.0	6.0	102.0	93.0	78.0	15.0
4	N	Y	1	2K	34.0	30.0	30.0	31.0	23.0	26.5	28.0	21.5	93.5	85.0	90.0	-5.0
4	N	Y	1	1K	20.0	18.0	18.0	17.0	18.0	19.5	20.0	16.0	101.5	95.0	95.0	0.0
4	N	Y	1	.5K	13.0	17.0	17.0	19.0	21.0	16.0	16.0	12.0	106.0	95.0	95.0	0.0
4	N	Y	2	4K	15.0	28.0	13.0	15.0	17.0	11.5	6.0	8.0	104.0	95.0	80.0	
4	N	Y	2	2K	33.5	33.5	33.0	28.0	22.0	22.0	22.0	15.0	89.5	81.0	86.0	
4	N	Y	2	1K	18.0	31.5	32.0	31.0	32.5	25.0	19.0	25.0	101.5	95.0	95.0	
4	N	Y	2	.5K	20.0	25.0	30.0	19.0	20.5	10.0	20.0	14.0	104.0	93.0	93.0	
5	N	Y	1	4K	5.0	4.5	4.0	4.0	4.5	3.0	2.0	2.0	100.0	91.0	96.0	-5.0
5	N	Y	1	2K	13.0	16.0	15.5	16.0	14.5	11.5	10.0	9.0	91.5	83.0	83.0	0.0
5	N	Y	1	1K	8.0	12.5	12.0	12.0	12.0	10.5	9.0	8.5	95.5	89.0	84.0	5.0
5	N	Y	1	.5K	13.5	14.0	15.0	16.5	14.0	16.0	14.5	17.0	94.0	84.0	74.0	10.0
5	N	Y	2	4K	7.5	8.0	2.0	3.0	3.0	1.5	1.0	1.5	104.0	95.0	100.0	
5	N	Y	2	2K	12.0	14.0	14.5	11.5	10.0	7.0	5.0	4.0	91.5	83.0	83.0	
5	N	Y	2	1K	14.0	15.5	18.0	17.5	17.5	14.5	14.5	15.5	95.5	89.0	84.0	
5	N	Y	2	.5K	15.0	16.0	15.0	15.5	16.5	16.5	16.5	17.0	98.0	87.0	77.0	
6	N	Y	1	4K	2.5	4.0	11.0	2.5	2.0	1.0	1.5	3.0	96.0	87.0	77.0	10.0
6	N	Y	1	2K	18.0	16.0	10.0	12.5	8.0	8.0	6.0	4.5	81.5	73.0	73.0	0.0
6	N	Y	1	1K	15.0	18.0	10.0	14.0	7.0	6.0	3.5	5.5	77.5	71.0	66.0	5.0
6	N	Y	1	.5K	13.5	18.5	17.5	23.0	20.0	20.0	17.5	15.0	88.0	77.0	72.0	5.0
6	N	Y	2	4K	5.0	3.5	0.5	0.0	0.0	0.0	0.0	0.0	88.0	79.0	69.0	
6	N	Y	2	2K	19.0	20.5	16.5	11.5	12.5	9.0	7.5	8.5	83.5	75.0	75.0	
6	N	Y	2	1K	25.0	26.0	25.0	16.5	14.5	12.5	18.0	13.0	83.5	77.0	72.0	
6	N	Y	2	.5K	25.0	18.0	12.0	15.0	14.0	11.5	13.5	8.5	88.0	77.0	72.0	

APPENDIX A
RAW DATA SUMMARY SHEET

SUBJ	HEAR	AGE	PRES	FREQ	*---- REFLEX AMPLITUDE IN MILLIMETERS							-----*	REFLEX LEVEL IN *			
					TIME INTERVAL IN SECONDS											
					2	5	10	15	20	30	45	60	SPL	HL	SL	HT
7	N	Y	1	4K	7.0	7.5	7.5	7.0	7.0	6.5	15.0	17.0	88.0	79.0	79.0	0.0
7	N	Y	1	2K	13.0	16.0	16.5	19.0	10.5	13.5	18.5	12.0	87.5	79.0	84.0	-5.0
7	N	Y	1	1K	25.0	17.5	32.5	32.5	26.0	22.0	24.0	24.0	91.5	85.0	85.0	0.0
7	N	Y	1	.5K	23.5	33.5	33.0	33.0	31.5	30.5	22.5	32.0	94.0	83.0	93.0	-10.0
7	N	Y	2	4K	6.5	9.0	9.0	8.5	3.5	3.5	1.0	3.0	92.0	83.0	83.0	
7	N	Y	2	2K	33.5	31.5	21.5	24.0	32.5	11.0	11.5	15.5	91.5	83.0	88.0	
7	N	Y	2	1K	33.5	33.5	33.0	20.0	33.0	15.0	15.0	22.0	83.5	77.0	77.0	
7	N	Y	2	.5K	30.0	33.0	33.0	25.5	24.0	29.0	23.0	18.0	94.0	83.0	93.0	
8	N	Y	1	4K	10.0	7.5	7.0	6.5	5.0	5.5	3.5	2.5	90.0	81.0	76.0	5.0
8	N	Y	1	2K	10.5	10.5	11.5	11.0	9.0	8.0	9.0	10.5	81.5	73.0	83.0	-10.0
8	N	Y	1	1K	12.0	14.0	14.5	14.5	16.0	15.0	14.5	15.0	87.5	81.0	81.0	0.0
8	N	Y	1	.5K	6.0	7.0	9.0	10.5	10.5	10.0	9.5	8.0	92.0	81.0	76.0	5.0
8	N	Y	2	4K	15.0	11.0	7.0	7.5	7.0	4.5	4.5	4.5	96.0	87.0	82.0	
8	N	Y	2	2K	10.5	10.0	9.0	8.5	7.0	7.0	7.0	6.0	79.5	71.0	81.0	
8	N	Y	2	1K	11.0	11.5	12.0	12.0	12.5	11.0	10.5	10.0	87.5	81.0	81.0	
8	N	Y	2	.5K	7.5	6.5	6.5	6.5	6.5	7.0	7.0	8.0	96.0	85.0	80.0	
9	N	Y	1	4K	20.0	9.0	6.5	9.0	7.5	7.0	8.5	7.5	96.0	87.0	92.0	-5.0
9	N	Y	1	2K	21.0	26.0	18.0	19.0	16.5	16.5	18.0	16.0	95.5	87.0	97.0	-10.0
9	N	Y	1	1K	20.0	21.5	26.0	24.0	23.0	20.5	20.0	14.0	97.5	91.0	96.0	-5.0
9	N	Y	1	.5K	25.0	28.5	28.5	26.5	24.5	30.5	29.5	23.0	100.0	89.0	84.0	5.0
9	N	Y	2	4K	15.5	9.0	9.0	14.0	9.5	1.5	1.0	0.0	96.0	87.0	92.0	
9	N	Y	2	2K	27.5	22.0	17.5	20.0	16.5	14.0	17.0	8.0	97.5	89.0	99.0	
9	N	Y	2	1K	20.0	25.5	23.5	24.5	20.0	18.5	14.0	12.0	97.5	91.0	96.0	
9	N	Y	2	.5K	17.0	22.0	22.5	25.0	26.0	25.0	24.0	24.0	98.0	87.0	82.0	

APPENDIX A
RAW DATA SUMMARY SHEET

SUBJ	HEAR	AGE	PRES	FREQ	*---- REFLEX AMPLITUDE IN MILLIMETERS / TIME INTERVAL IN SECONDS 2	5	10	15	20	30	45	-----* 60*	REFLEX LEVEL IN * SPL	HL	SL *	HT
10	N	Y	1	4K	5.5	4.0	8.5	12.5	6.0	5.0	3.0	8.0	88.0	79.0	74.0	5.0
10	N	Y	1	2K	18.0	9.5	9.5	8.5	13.0	19.0	10.0	10.0	87.5	79.0	79.0	0.0
10	N	Y	1	1K	21.0	22.5	20.0	25.5	20.5	19.0	23.5	21.5	81.5	75.0	70.0	5.0
10	N	Y	1	.5K	24.0	26.0	21.5	26.5	25.0	21.5	22.0	19.0	80.0	69.0	64.0	5.0
10	N	Y	2	4K	21.0	14.0	12.5	8.0	8.0	7.0	10.0	11.5	94.0	85.0	80.0	
10	N	Y	2	2K	33.5	30.5	26.0	29.0	17.0	17.0	18.5	16.5	89.5	81.0	81.0	
10	N	Y	2	1K	27.5	25.0	21.5	20.0	23.0	32.0	25.0	28.5	81.5	75.0	70.0	
10	N	Y	2	.5K	17.5	19.0	18.0	20.5	20.5	19.0	12.0	12.5	80.0	69.0	64.0	
1	N	M	1	4K	2.5	6.0	2.5	3.0	5.0	1.0	0.0	0.0	102.0	93.0	78.0	15.0
1	N	M	1	2K	10.0	8.0	15.5	8.0	9.0	5.0	6.5	5.0	93.5	85.0	80.0	5.0
1	N	M	1	1K	17.5	13.0	19.0	15.0	15.0	11.0	8.5	8.0	95.5	89.0	89.0	0.0
1	N	M	1	.5K	16.0	15.0	16.5	17.0	15.0	14.0	16.0	11.0	94.0	83.0	83.0	0.0
1	N	M	2	4K	0.5	6.5	4.5	4.0	3.0	6.0	3.0	4.0	104.0	95.0	80.0	
1	N	M	2	2K	5.0	5.0	9.0	9.0	6.5	4.0	2.0	0.0	97.5	89.0	84.0	
1	N	M	2	1K	14.5	12.0	11.5	8.0	7.0	3.5	6.5	1.5	95.5	89.0	89.0	
1	N	M	2	.5K	11.0	11.0	10.5	12.0	10.5	10.0	9.5	7.0	94.0	83.0	83.0	
2	N	M	1	4K	2.5	3.5	2.5	3.0	3.5	3.0	3.5	3.0	100.0	91.0	76.0	15.0
2	N	M	1	2K	11.0	12.0	12.5	11.0	10.0	9.0	9.0	8.0	93.5	85.0	80.0	5.0
2	N	M	1	1K	16.0	17.5	22.0	20.5	21.5	19.0	18.0	17.0	89.5	83.0	83.0	0.0
2	N	M	1	.5K	13.5	18.0	19.0	19.0	19.0	19.5	21.0	22.0	90.0	79.0	99.0	-20.0
2	N	M	2	4K	6.0	7.0	6.0	5.5	4.5	3.0	3.0	2.0	100.0	91.0	76.0	
2	N	M	2	2K	10.0	11.0	10.0	9.0	8.0	7.0	5.5	8.0	93.5	85.0	80.0	
2	N	M	2	1K	16.5	16.5	19.5	20.0	17.0	17.5	16.0	15.0	89.5	83.0	83.0	
2	N	M	2	.5K	13.0	17.0	19.5	18.5	19.0	18.5	14.0	5.0	90.0	79.0	99.0	

APPENDIX A
RAW DATA SUMMARY SHEET

SUBJ	HEAR	AGE	PRES	FREQ	REFLEX AMPLITUDE IN MILLIMETERS / TIME INTERVAL IN SECONDS: 2	5	10	15	20	30	45	60	REFLEX LEVEL IN: SPL	HL	SL	HT
3	N	M	1	4K	4.5	6.5	6.0	7.0	7.0	5.5	3.0	1.5	98.0	89.0	79.0	10.0
3	N	M	1	2K	11.0	9.0	6.0	6.0	6.5	5.5	6.0	4.0	93.5	85.0	80.0	5.0
3	N	M	1	1K	12.0	13.5	13.0	12.0	10.5	11.5	6.0	4.0	93.5	87.0	82.0	5.0
3	N	M	1	.5K	14.0	13.5	15.0	18.0	17.5	14.0	13.0	11.5	98.0	87.0	82.0	5.0
3	N	M	2	4K	2.5	9.0	6.0	3.5	3.0	3.5	3.5	3.5	102.0	93.0	83.0	
3	N	M	2	2K	8.0	7.0	8.0	6.5	6.5	6.0	5.5	5.5	93.5	85.0	80.0	
3	N	M	2	1K	10.5	12.0	11.0	9.5	9.0	8.0	6.5	6.0	97.5	91.0	86.0	
3	N	M	2	.5K	14.0	16.5	17.0	15.5	14.0	13.0	13.5	12.0	96.0	85.0	80.0	
4	N	M	1	4K	6.5	4.0	5.0	5.5	4.0	2.5	3.0	2.5	86.0	77.0	72.0	5.0
4	N	M	1	2K	11.5	9.0	9.0	7.5	7.5	6.5	5.5	4.5	89.5	81.0	76.0	5.0
4	N	M	1	1K	19.0	12.0	12.5	12.5	14.0	10.0	12.5	11.0	81.5	75.0	70.0	5.0
4	N	M	1	.5K	12.0	11.0	11.0	11.5	11.5	10.0	8.0	8.5	84.0	73.0	63.0	10.0
4	N	M	2	4K	5.0	6.0	6.5	6.0	6.0	5.0	4.5	5.0	84.0	75.0	70.0	
4	N	M	2	2K	14.0	9.0	11.5	10.5	10.5	8.0	8.0	6.5	91.5	83.0	78.0	
4	N	M	2	1K	21.0	16.0	16.5	15.0	15.0	15.0	13.0	12.0	83.5	77.0	72.0	
4	N	M	2	.5K	10.0	10.5	10.5	9.0	10.0	12.0	11.5	10.5	82.0	71.0	61.0	
5	N	M	1	4K	3.5	5.0	5.0	5.0	3.5	3.0	3.5	4.0	76.0	67.0	77.0	-10.0
5	N	M	1	2K	10.0	9.0	10.5	7.5	10.5	7.0	7.5	7.0	85.5	77.0	82.0	-5.0
5	N	M	1	1K	11.0	10.0	19.0	12.0	13.0	10.5	11.0	9.5	81.5	75.0	75.0	0.0
5	N	M	1	.5K	10.0	14.5	12.5	10.0	10.0	7.5	8.0	10.0	84.0	73.0	78.0	-5.0
5	N	M	2	4K	12.5	9.0	9.5	7.0	9.0	4.5	4.5	4.5	80.0	71.0	81.0	
5	N	M	2	2K	8.5	6.0	6.5	8.0	8.0	2.5	1.0	0.0	83.5	75.0	80.0	
5	N	M	2	1K	20.5	16.5	20.5	16.0	15.5	13.0	12.0	20.0	83.5	77.0	77.0	
5	N	M	2	.5K	7.5	10.0	10.0	15.0	9.5	7.0	7.0	10.5	82.0	71.0	76.0	

APPENDIX A

RAW DATA SUMMARY SHEET

SUBJ	HEAR	AGE	PRES	FREQ	REFLEX AMPLITUDE IN MILLIMETERS — TIME INTERVAL IN SECONDS: .2	5	10	15	20	30	45	60	REFLEX LEVEL IN: SPL	HL	SL	HT
6	N	M	1	4K	9.0	7.0	6.0	5.5	4.5	3.5	2.0	2.0	92.0	83.0	73.0	10.0
6	N	M	1	2K	28.0	18.5	19.0	17.5	17.0	16.5	15.5	13.5	87.5	79.0	74.0	5.0
6	N	M	1	1K	33.0	33.0	33.0	33.0	27.0	26.0	17.0	14.5	87.5	81.0	86.0	-5.0
6	N	M	1	.5K	11.5	10.5	10.0	11.0	10.0	10.0	8.5	7.0	94.0	83.0	88.0	-5.0
6	N	M	2	4K	7.0	6.5	4.5	4.0	4.0	3.0	3.0	3.0	100.0	91.0	81.0	
6	N	M	2	2K	22.0	25.0	16.0	15.5	14.0	13.5	9.0	7.5	89.5	81.0	76.0	
6	N	M	2	1K	13.5	14.0	13.5	13.0	12.5	10.0	8.0	5.5	91.5	85.0	90.0	
6	N	M	2	.5K	12.0	10.5	10.0	10.0	10.0	9.0	9.5	8.5	92.0	81.0	86.0	
7	N	M	1	4K	6.5	7.0	6.0	6.0	6.5	4.0	4.0	2.5	76.0	67.0	72.0	-5.0
7	N	M	1	2K	21.0	16.5	19.0	16.0	14.5	12.5	9.0	8.0	87.5	79.0	84.0	-5.0
7	N	M	1	1K	22.5	20.0	21.0	20.5	21.0	18.5	16.5	14.0	91.5	85.0	90.0	-5.0
7	N	M	1	.5K	17.0	13.5	13.0	13.5	13.5	10.5	10.5	13.0	94.0	83.0	88.0	-5.0
7	N	M	2	4K	11.0	6.5	4.0	4.0	2.0	1.0	2.0	1.0	84.0	75.0	80.0	
7	N	M	2	2K	24.5	21.0	17.0	15.0	14.0	8.5	8.5	7.0	87.5	79.0	84.0	
7	N	M	2	1K	22.0	20.0	21.0	22.0	22.5	19.0	17.5	18.0	91.5	85.0	90.0	
7	N	M	2	.5K	20.0	17.0	15.5	14.0	14.0	15.0	12.5	14.0	98.0	87.0	92.0	
8	N	M	1	4K	19.5	11.0	7.5	10.0	10.5	7.5	6.0	5.0	92.0	83.0	63.0	20.0
8	N	M	1	2K	28.0	18.5	12.5	14.0	10.5	8.5	9.5	11.0	93.5	85.0	80.0	5.0
8	N	M	1	1K	10.0	11.0	10.0	10.0	13.0	8.5	8.0	6.5	87.5	81.0	81.0	0.0
8	N	M	1	.5K	27.0	20.0	18.0	17.0	16.5	16.5	19.0	16.5	98.0	87.0	87.0	0.0
8	N	M	2	4K	13.0	8.0	7.5	6.0	6.5	5.5	7.0	5.0	92.0	83.0	63.0	
8	N	M	2	2K	18.0	10.5	10.0	6.5	5.5	3.5	5.0	6.0	93.5	85.0	80.0	
8	N	M	2	1K	12.0	14.0	16.5	16.5	12.5	12.0	10.0	16.0	91.5	85.0	85.0	
8	N	M	2	.5K	13.0	13.5	13.0	12.5	13.0	10.5	11.0	11.5	100.0	89.0	89.0	

APPENDIX A

RAW DATA SUMMARY SHEET

S U B J	H E A R	A G E	P R E S	F R E Q	*---- REFLEX AMPLITUDE IN MILLIMETERS							-----*	REFLEX LEVEL IN *			H T
					TIME INTERVAL IN SECONDS											
					* 2	5	10	15	20	30	45	60*	S P L	H L	S L *	
9	N	M	1	4K	5.5	5.5	4.5	4.0	3.5	1.5	2.5	3.0	96.0	87.0	77.0	10.0
9	N	M	1	2K	8.5	8.0	8.0	6.0	5.5	4.0	4.0	4.0	95.5	87.0	87.0	0.0
9	N	M	1	1K	11.0	11.0	9.0	4.5	3.0	2.5	2.0	2.0	93.5	87.0	87.0	0.0
9	N	M	1	.5K	8.0	8.0	6.0	4.5	4.0	2.5	3.5	2.5	96.0	85.0	80.0	5.0
9	N	M	2	4K	4.0	3.0	2.0	0.0	0.0	0.0	0.0	0.0	100.0	91.0	81.0	
9	N	M	2	2K	8.5	5.0	3.5	3.0	1.5	2.5	1.5	0.5	99.5	91.0	91.0	
9	N	M	2	1K	9.0	10.0	9.5	7.0	7.5	4.5	5.0	4.0	93.5	87.0	87.0	
9	N	M	2	.5K	7.0	6.0	4.5	6.0	4.5	3.0	4.0	3.5	96.0	85.0	80.0	
10	N	M	1	4K	3.5	3.0	3.0	2.5	2.5	2.0	0.0	0.0	100.0	91.0	76.0	15.0
10	N	M	1	2K	21.0	11.0	10.0	6.5	6.0	5.5	4.0	4.0	87.5	79.0	79.0	0.0
10	N	M	1	1K	22.0	21.5	19.5	15.5	13.5	8.0	5.0	5.0	91.5	85.0	75.0	10.0
10	N	M	1	.5K	17.0	14.0	12.0	15.0	14.5	13.0	14.0	10.0	98.0	87.0	72.0	15.0
10	N	M	2	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
10	N	M	2	2K	8.5	5.5	4.0	3.5	2.0	2.0	2.0	2.0	87.5	79.0	79.0	
10	N	M	2	1K	15.0	16.0	12.0	7.5	7.0	4.5	3.5	2.5	91.5	85.0	75.0	
10	N	M	2	.5K	7.0	8.0	7.0	7.0	6.5	6.0	6.0	5.0	96.0	85.0	70.0	
1	N	O	1	4K	5.0	5.0	5.0	4.0	4.0	4.0	3.5	4.0	94.0	85.0	75.0	10.0
1	N	O	1	2K	7.0	6.5	6.0	6.0	5.0	5.0	4.5	5.0	91.5	83.0	73.0	10.0
1	N	O	1	1K	7.0	6.5	5.5	5.5	5.5	5.5	5.0	4.5	89.5	83.0	68.0	15.0
1	N	O	1	.5K	4.0	4.5	4.5	4.0	4.0	3.0	3.0	2.5	94.0	83.0	83.0	0.0
1	N	O	2	4K	5.5	5.5	5.0	4.0	3.5	3.0	1.0	1.5	96.0	87.0	77.0	
1	N	O	2	2K	7.0	6.5	5.5	4.5	4.0	3.0	3.0	2.0	91.5	83.0	73.0	
1	N	O	2	1K	6.0	5.0	5.0	4.5	3.5	2.5	1.0	2.0	89.5	83.0	68.0	
1	N	O	2	.5K	7.0	6.5	6.5	4.5	4.5	4.5	4.0	3.5	96.0	85.0	85.0	

APPENDIX A
RAW DATA SUMMARY SHEET

SUBJ	HEAR	AGE	PRES	FREQ	REFLEX AMPLITUDE IN MILLIMETERS — TIME INTERVAL IN SECONDS: 2	5	10	15	20	30	45	60	REFLEX LEVEL IN: SPL	HL	SL	HT
2	N	0	1	4K	3.5	3.5	3.5	3.5	3.0	2.5	2.0	1.0	102.0	93.0	53.0	40.0
2	N	0	1	2K	6.0	6.5	7.0	6.0	5.0	4.0	4.0	4.0	95.5	87.0	67.0	20.0
2	N	0	1	1K	4.0	5.0	5.0	5.0	5.0	4.0	3.5	4.0	95.5	89.0	69.0	20.0
2	N	0	1	.5K	4.5	4.5	5.0	5.0	4.5	4.0	4.0	4.5	102.0	91.0	76.0	15.0
2	N	0	2	4K	3.5	3.5	2.5	2.0	2.0	2.0	0.5	0.0	104.0	95.0	55.0	
2	N	0	2	2K	6.0	6.0	6.0	5.5	5.0	5.0	4.0	3.0	95.5	87.0	67.0	
2	N	0	2	1K	4.5	5.0	5.5	5.5	5.0	5.5	6.5	5.5	97.5	91.0	71.0	
2	N	0	2	.5K	2.0	3.0	3.5	3.5	3.0	3.5	3.0	2.0	104.0	93.0	78.0	
3	N	0	1	4K	3.0	3.0	3.0	3.0	3.0	3.0	3.5	3.5	98.0	89.0	54.0	35.0
3	N	0	1	2K	7.5	7.5	8.0	8.0	7.5	6.5	6.0	5.0	97.5	89.0	89.0	0.0
3	N	0	1	1K	5.5	5.5	8.0	7.5	6.0	7.0	8.5	4.0	95.5	89.0	89.0	0.0
3	N	0	1	.5K	5.0	5.0	6.5	6.0	6.0	6.5	6.5	6.0	106.0	95.0	85.0	10.0
3	N	0	2	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
3	N	0	2	2K	7.0	6.0	5.0	5.0	3.5	3.0	3.0	3.5	99.5	91.0	91.0	
3	N	0	2	1K	3.0	3.5	4.0	4.0	4.0	3.5	3.0	2.0	95.5	89.0	89.0	
3	N	0	2	.5K	3.0	3.0	5.0	4.0	4.0	3.5	2.5	1.5	106.0	95.0	85.0	
4	N	0	1	4K	4.0	2.5	3.0	3.0	2.0	1.0	4.5	5.0	78.0	69.0	64.0	5.0
4	N	0	1	2K	10.0	7.0	6.5	6.0	6.0	5.0	5.0	5.0	79.5	71.0	61.0	10.0
4	N	0	1	1K	11.0	11.0	11.0	11.0	10.5	10.5	10.0	6.0	83.5	77.0	82.0	-5.0
4	N	0	1	.5K	6.5	6.5	6.5	7.0	7.0	7.0	7.0	7.0	90.0	79.0	79.0	0.0
4	N	0	2	4K	3.0	3.5	3.5	4.5	4.5	4.0	3.0	2.0	88.0	79.0	74.0	
4	N	0	2	2K	8.0	6.5	6.0	6.0	5.5	4.0	2.5	1.5	81.5	73.0	63.0	
4	N	0	2	1K	8.5	8.0	8.5	9.0	9.0	7.0	5.0	4.5	83.5	77.0	82.0	
4	N	0	2	.5K	5.0	5.5	6.0	6.5	6.0	6.5	7.0	6.0	92.0	81.0	81.0	

APPENDIX A
RAW DATA SUMMARY SHEET

SUBJ	HEAR	AGE	PRES	FREQ	REFLEX AMPLITUDE IN MILLIMETERS — TIME INTERVAL IN SECONDS: 2	5	10	15	20	30	45	60	REFLEX LEVEL IN: SPL	HL	SL	HT
5	N	0	1	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	108.0	99.0	64.0	35.0
5	N	0	1	2K	21.5	19.0	18.5	18.0	16.0	13.5	12.0	10.0	87.5	79.0	69.0	10.0
5	N	0	1	1K	23.5	24.0	22.5	22.5	20.5	18.5	18.0	16.0	83.5	77.0	77.0	0.0
5	N	0	1	.5K	18.0	20.5	22.0	21.0	22.0	21.0	20.0	19.0	102.0	91.0	81.0	10.0
5	N	0	2	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	114.0	105.0	70.0	
5	N	0	2	2K	21.0	18.5	17.0	16.0	14.0	12.5	11.5	9.0	87.5	79.0	69.0	
5	N	0	2	1K	18.5	16.5	15.0	13.0	13.0	11.0	10.0	8.0	81.5	75.0	75.0	
5	N	0	2	.5K	18.5	19.5	20.0	20.0	19.5	18.5	18.5	17.0	102.0	91.0	81.0	
6	N	0	1	4K	4.0	4.5	3.5	3.0	2.0	1.5	1.0	1.0	100.0	91.0	46.0	45.0
6	N	0	1	2K	6.0	8.5	8.5	7.5	5.5	4.0	3.5	3.0	91.5	83.0	48.0	35.0
6	N	0	1	1K	4.0	4.0	4.0	4.0	2.0	1.0	2.0	2.0	91.5	85.0	50.0	35.0
6	N	0	1	.5K	4.0	4.0	4.0	3.0	2.5	2.5	2.5	2.5	100.0	89.0	64.0	25.0
6	N	0	2	4K	3.0	3.5	2.5	1.0	0.5	0.0	0.0	0.0	100.0	91.0	46.0	
6	N	0	2	2K	5.5	6.5	6.5	4.0	3.0	2.0	2.0	1.0	91.5	83.0	48.0	
6	N	0	2	1K	6.0	5.5	4.5	3.5	3.0	0.0	0.0	0.0	89.5	83.0	48.0	
6	N	0	2	.5K	7.0	7.0	6.5	6.0	5.0	4.5	4.0	4.0	102.0	91.0	66.0	
7	N	0	1	4K	2.0	3.0	3.5	4.0	4.0	5.0	3.5	4.0	104.0	95.0	45.0	50.0
7	N	0	1	2K	4.0	4.0	3.0	2.0	2.0	0.0	0.0	0.0	87.5	79.0	69.0	10.0
7	N	0	1	1K	4.5	4.5	5.0	5.0	4.5	5.5	6.0	5.5	95.5	89.0	74.0	15.0
7	N	0	1	.5K	5.5	6.0	5.5	6.0	5.5	5.0	6.0	6.0	106.0	95.0	65.0	30.0
7	N	0	2	4K	1.5	1.5	1.0	1.0	1.0	1.5	1.0	1.0	102.0	93.0	43.0	
7	N	0	2	2K	3.0	4.5	4.0	2.0	2.0	2.0	0.0	0.0	91.5	83.0	73.0	
7	N	0	2	1K	2.0	2.0	2.0	1.5	1.5	0.5	1.0	2.0	93.5	87.0	72.0	
7	N	0	2	.5K	1.5	2.0	2.5	2.0	1.0	1.0	1.5	1.0	102.0	91.0	61.0	

APPENDIX A
RAW DATA SUMMARY SHEET

SUBJ	HEAR	AGE	PRES	FREQ	*---- REFLEX AMPLITUDE IN MILLIMETERS ------* TIME INTERVAL IN SECONDS 2	5	10	15	20	30	45	60*	REFLEX LEVEL IN * SPL	HL	SL *	HT
8	N	O	1	4K	5.0	3.5	3.0	4.0	2.0	2.0	3.5	2.5	80.0	71.0	71.0	0.0
8	N	O	1	2K	7.0	6.0	6.0	5.0	4.5	3.5	3.0	3.0	83.5	75.0	70.0	5.0
8	N	O	1	1K	6.0	4.0	4.0	3.5	5.0	3.0	4.0	3.0	77.5	71.0	61.0	10.0
8	N	O	1	.5K	5.0	3.5	5.0	4.5	5.0	4.0	7.0	5.0	76.0	65.0	50.0	15.0
8	N	O	2	4K	9.0	7.5	6.0	6.0	6.0	5.0	4.5	4.5	86.0	77.0	77.0	
8	N	O	2	2K	11.5	10.0	10.0	8.5	7.5	6.5	6.0	6.0	89.5	81.0	76.0	
8	N	O	2	1K	4.0	4.5	4.5	4.0	3.5	4.0	3.0	4.5	81.5	75.0	65.0	
8	N	O	2	.5K	4.5	6.0	5.5	4.0	4.0	4.0	4.0	4.0	82.0	71.0	56.0	
9	N	O	1	4K	5.0	6.0	6.5	6.5	6.5	8.0	8.5	1.5	84.0	75.0	40.0	35.0
9	N	O	1	2K	5.0	6.0	8.0	10.0	8.0	9.0	9.0	6.0	91.5	83.0	73.0	10.0
9	N	O	1	1K	6.0	6.0	6.0	6.5	7.0	7.0	6.5	5.5	93.5	87.0	82.0	5.0
9	N	O	1	.5K	6.5	9.0	9.5	10.0	11.5	13.5	12.0	13.0	96.0	85.0	80.0	5.0
9	N	O	2	4K	5.0	5.0	5.0	4.0	4.5	5.0	6.0	5.0	92.0	83.0	48.0	
9	N	O	2	2K	4.0	2.5	3.0	2.5	2.0	3.0	2.5	3.0	93.5	85.0	75.0	
9	N	O	2	1K	5.5	5.5	8.5	8.0	6.5	8.0	8.0	7.5	95.5	89.0	84.0	
9	N	O	2	.5K	6.0	5.5	5.5	6.5	7.0	8.0	6.0	5.5	98.0	87.0	82.0	
10	N	O	1	4K	7.5	6.5	4.5	7.0	5.0	5.0	4.5	3.0	90.0	81.0	51.0	30.0
10	N	O	1	2K	13.0	11.5	9.0	10.0	7.5	6.5	10.5	7.0	83.5	75.0	65.0	10.0
10	N	O	1	1K	9.0	7.0	7.5	11.0	6.0	5.5	5.5	5.0	79.5	73.0	63.0	10.0
10	N	O	1	.5K	5.5	4.5	4.0	3.5	4.0	4.0	8.5	4.0	80.0	69.0	64.0	5.0
10	N	O	2	4K	7.0	6.5	6.0	5.0	4.5	4.0	3.0	3.5	90.0	81.0	51.0	
10	N	O	2	2K	11.0	6.0	6.0	5.0	3.0	1.5	2.0	2.0	79.5	71.0	61.0	
10	N	O	2	1K	11.5	9.0	5.5	6.0	4.5	9.5	7.0	5.0	77.5	71.0	61.0	
10	N	O	2	.5K	8.5	9.5	9.5	8.5	7.0	7.0	5.5	6.5	86.0	75.0	70.0	

APPENDIX A
RAW DATA SUMMARY SHEET

SUBJ	HEAR	AGE	PRES	FREQ	REFLEX AMPLITUDE IN MILLIMETERS — TIME INTERVAL IN SECONDS: 2	5	10	15	20	30	45	60	REFLEX LEVEL IN: SPL	HL	SL	HT
1	P	Y	1	4K	21.5	21.0	14.0	16.0	16.0	8.0	7.5	2.5	102.0	93.0	33.0	60.0
1	P	Y	1	2K	30.0	25.0	22.0	21.0	15.0	16.5	15.5	12.5	101.5	93.0	48.0	45.0
1	P	Y	1	1K	33.5	33.5	33.0	25.5	25.5	24.5	23.5	23.5	95.5	89.0	39.0	50.0
1	P	Y	1	.5K	15.0	10.0	10.0	12.5	12.5	12.5	15.0	12.0	94.0	83.0	43.0	40.0
1	P	Y	2	4K	15.5	10.0	5.0	3.5	7.0	5.0	5.0	0.0	104.0	95.0	35.0	
1	P	Y	2	2K	12.5	6.0	2.5	5.0	11.0	7.0	7.0	5.0	99.5	91.0	46.0	
1	P	Y	2	1K	34.0	30.0	28.0	26.0	26.0	25.0	24.0	24.0	97.5	91.0	41.0	
1	P	Y	2	.5K	13.0	9.0	8.0	7.0	4.0	4.0	4.0	4.0	90.0	79.0	39.0	
2	P	Y	1	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75.0
2	P	Y	1	2K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75.0
2	P	Y	1	1K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	65.0
2	P	Y	1	.5K	19.0	33.0	28.0	20.0	34.0	33.5	33.0	32.0	106.0	95.0	50.0	45.0
2	P	Y	2	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
2	P	Y	2	2K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
2	P	Y	2	1K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
2	P	Y	2	.5K	18.0	29.0	31.0	34.0	34.0	31.5	30.0	33.0	104.0	93.0	48.0	
3	P	Y	1	4K	8.5	8.0	4.0	3.0	4.5	3.5	3.0	2.0	74.0	65.0	40.0	25.0
3	P	Y	1	2K	22.5	21.5	18.0	16.0	13.5	13.5	11.5	10.0	83.5	75.0	50.0	25.0
3	P	Y	1	1K	15.0	16.0	13.5	15.0	12.5	10.5	11.5	10.5	85.5	79.0	44.0	35.0
3	P	Y	1	.5K	20.0	19.5	17.0	16.5	16.5	17.0	16.0	15.0	90.0	79.0	29.0	50.0
3	P	Y	2	4K	14.0	11.0	10.5	5.0	5.0	4.0	3.0	3.0	80.0	71.0	46.0	
3	P	Y	2	2K	23.0	21.5	17.0	15.5	15.5	10.5	9.0	8.0	81.5	73.0	48.0	
3	P	Y	2	1K	20.5	19.5	17.5	15.5	15.0	14.0	12.0	11.5	85.5	79.0	44.0	
3	P	Y	2	.5K	19.0	17.0	17.0	15.0	15.0	14.5	14.0	14.0	92.0	81.0	31.0	

APPENDIX A
RAW DATA SUMMARY SHEET

SUBJ	HEAR	AGE	PRES	FREQ	*---- REFLEX AMPLITUDE IN MILLIMETERS -----* TIME INTERVAL IN SECONDS: 2	5	10	15	20	30	45	60*	REFLEX LEVEL IN *: SPL	HL	SL *	HT
4	P	Y	1	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	114.0	105.0	65.0	40.0
4	P	Y	1	2K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	107.5	99.0	44.0	55.0
4	P	Y	1	1K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	103.5	97.0	42.0	55.0
4	P	Y	1	.5K	7.5	9.5	8.0	7.0	8.0	9.0	9.5	8.0	102.0	91.0	61.0	30.0
4	P	Y	2	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	114.0	105.0	65.0	
4	P	Y	2	2K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	107.5	99.0	44.0	
4	P	Y	2	1K	11.0	7.5	8.0	6.0	5.0	6.5	6.0	5.0	101.5	95.0	40.0	
4	P	Y	2	.5K	7.5	9.0	9.0	10.0	9.5	10.5	10.0	10.0	106.0	95.0	65.0	
5	P	Y	1	4K	15.0	12.5	9.0	7.0	3.5	3.5	3.0	6.0	92.0	83.0	18.0	65.0
5	P	Y	1	2K	20.0	18.0	11.0	13.0	6.0	6.0	6.0	5.5	97.5	89.0	39.0	50.0
5	P	Y	1	1K	21.0	14.5	10.5	8.0	8.0	4.5	5.0	6.5	93.5	87.0	52.0	35.0
5	P	Y	1	.5K	16.5	13.0	13.5	11.0	9.5	12.5	10.5	10.5	94.0	83.0	48.0	35.0
5	P	Y	2	4K	23.0	16.5	8.5	7.5	6.5	6.0	5.5	6.5	98.0	89.0	24.0	
5	P	Y	2	2K	19.0	12.0	7.0	6.5	6.5	2.0	1.0	1.5	99.5	91.0	41.0	
5	P	Y	2	1K	19.0	16.0	12.5	7.5	7.5	7.0	7.0	6.0	93.5	87.0	52.0	
5	P	Y	2	.5K	12.5	11.0	8.5	8.0	7.0	6.0	6.5	5.0	92.0	81.0	46.0	
6	P	Y	1	4K	9.5	8.0	6.5	6.0	5.5	3.5	3.0	1.5	98.0	89.0	34.0	55.0
6	P	Y	1	2K	9.0	14.5	9.0	8.5	6.0	3.5	1.5	1.0	87.5	79.0	19.0	60.0
6	P	Y	1	1K	27.0	27.0	22.0	19.5	16.0	16.5	11.0	7.5	91.5	85.0	30.0	55.0
6	P	Y	1	.5K	26.0	18.0	15.5	13.0	13.0	15.0	13.0	10.0	86.0	75.0	40.0	35.0
6	P	Y	2	4K	12.0	8.5	7.0	2.5	3.0	1.5	1.5	2.0	98.0	89.0	34.0	
6	P	Y	2	2K	6.0	7.5	4.5	4.5	2.5	6.5	2.0	3.0	89.5	81.0	21.0	
6	P	Y	2	1K	20.0	18.5	17.0	13.0	11.5	11.5	12.0	8.0	89.5	83.0	28.0	
6	P	Y	2	.5K	28.0	19.5	20.0	25.5	16.0	15.5	16.0	22.0	88.0	77.0	42.0	

APPENDIX A
RAW DATA SUMMARY SHEET

SUBJ	HEAR	AGE	PRES	FREQ	Reflex Amplitude in Millimeters — Time Interval in Seconds: 2	5	10	15	20	30	45	60	Reflex Level in: SPL	HL	SL	HT
7	P	Y	1	4K	3.0	3.0	3.0	2.5	2.5	3.0	4.0	4.0	98.0	89.0	29.0	60.0
7	P	Y	1	2K	13.5	10.0	9.0	8.0	6.0	5.0	5.0	5.0	89.5	81.0	16.0	65.0
7	P	Y	1	1K	9.5	8.0	3.5	3.5	3.5	5.5	4.0	3.5	87.5	81.0	31.0	50.0
7	P	Y	1	.5K	7.5	5.5	6.5	7.5	6.5	6.5	6.0	7.0	88.0	77.0	22.0	55.0
7	P	Y	2	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	114.0	105.0	45.0	
7	P	Y	2	2K	6.0	4.0	2.5	3.5	3.0	3.0	3.0	0.0	91.5	83.0	18.0	
7	P	Y	2	1K	7.0	4.5	5.0	6.5	6.5	5.0	4.5	4.0	85.5	79.0	29.0	
7	P	Y	2	.5K	4.0	4.0	3.5	3.0	3.5	2.5	1.0	0.0	88.0	77.0	22.0	
8	P	Y	1	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	114.0	105.0	65.0	40.0
8	P	Y	1	2K	7.0	9.0	9.5	9.5	9.5	9.5	9.0	6.5	103.5	95.0	50.0	45.0
8	P	Y	1	1K	5.5	4.5	6.5	6.5	6.5	6.5	6.5	6.0	101.5	95.0	55.0	40.0
8	P	Y	1	.5K	5.5	6.0	6.5	6.5	5.5	5.5	6.0	6.0	96.0	85.0	45.0	40.0
8	P	Y	2	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	114.0	105.0	65.0	
8	P	Y	2	2K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	107.5	99.0	54.0	
8	P	Y	2	1K	7.0	8.0	8.0	7.5	8.0	8.0	7.0	7.5	99.5	93.0	53.0	
8	P	Y	2	.5K	8.0	8.5	9.0	9.0	9.0	7.5	8.5	7.0	102.0	91.0	51.0	
9	P	Y	1	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	108.0	99.0	34.0	65.0
9	P	Y	1	2K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	105.5	97.0	27.0	70.0
9	P	Y	1	1K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	105.5	99.0	49.0	50.0
9	P	Y	1	.5K	11.0	14.5	15.0	12.5	11.5	10.5	9.5	6.5	98.0	87.0	37.0	50.0
9	P	Y	2	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	108.0	99.0	34.0	
9	P	Y	2	2K	20.0	15.0	16.5	19.0	14.5	9.5	5.5	5.5	103.5	95.0	25.0	
9	P	Y	2	1K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	107.5	101.0	51.0	
9	P	Y	2	.5K	13.0	15.0	15.5	14.5	14.0	12.5	12.5	11.0	98.0	87.0	37.0	

APPENDIX A

RAW DATA SUMMARY SHEET

SUBJ	HEAR	AGE	PRES	FREQ	*---- REFLEX AMPLITUDE IN MILLIMETERS							-----*	REFLEX LEVEL IN *			
					* TIME INTERVAL IN SECONDS							*	SPL	HL	SL *	HT
					* 2	5	10	15	20	30	45	60*			*	
10	P	Y	1	4K	24.0	25.0	25.0	21.0	19.0	18.0	15.0	8.5	104.0	95.0	20.0	75.0
10	P	Y	1	2K	29.0	31.0	31.5	31.0	30.0	28.0	24.0	20.0	103.5	95.0	35.0	60.0
10	P	Y	1	1K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	105.5	99.0	49.0	50.0
10	P	Y	1	.5K	28.5	28.5	29.0	29.0	27.5	27.0	27.5	26.5	101.0	90.0	65.0	25.0
10	P	Y	2	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	110.0	101.0	26.0	
10	P	Y	2	2K	30.0	30.0	30.0	30.0	29.0	28.0	24.0	27.0	103.5	95.0	35.0	
10	P	Y	2	1K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	107.5	101.0	51.0	
10	P	Y	2	.5K	28.0	27.0	26.5	26.5	25.0	25.0	25.0	24.5	102.0	91.0	66.0	
1	P	M	1	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	65.0
1	P	M	1	2K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	65.0
1	P	M	1	1K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	65.0
1	P	M	1	.5K	8.0	8.5	8.5	8.0	8.0	7.0	7.5	7.0	106.0	95.0	40.0	55.0
1	P	M	2	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
1	P	M	2	2K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
1	P	M	2	1K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
1	P	M	2	.5K	10.5	12.0	11.5	11.5	10.5	12.0	12.5	12.0	106.0	95.0	40.0	
2	P	M	1	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.0
2	P	M	1	2K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0
2	P	M	1	1K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	55.0
2	P	M	1	.5K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	108.0	97.0	37.0	60.0
2	P	M	2	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
2	P	M	2	2K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
2	P	M	2	1K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
2	P	M	2	.5K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

APPENDIX A
RAW DATA SUMMARY SHEET

SUBJ	HEAR	AGE	PRES	FREQ	REFLEX AMPLITUDE IN MILLIMETERS — TIME INTERVAL IN SECONDS: 2	5	10	15	20	30	45	60	REFLEX LEVEL IN: SPL	HL	SL	HT
3	P	M	1	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75.0
3	P	M	1	2K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	107.5	99.0	39.0	60.0
3	P	M	1	1K	5.5	5.0	4.5	4.5	4.0	4.0	5.5	14.5	101.5	95.0	45.0	50.0
3	P	M	1	.5K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	114.0	103.0	73.0	30.0
3	P	M	2	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
3	P	M	2	2K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	111.5	103.0	43.0	
3	P	M	2	1K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	105.5	99.0	49.0	
3	P	M	2	.5K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	114.0	103.0	73.0	
4	P	M	1	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75.0
4	P	M	1	2K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	65.0
4	P	M	1	1K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	111.5	105.0	40.0	65.0
4	P	M	1	.5K	16.0	15.5	15.0	14.0	11.5	15.0	10.5	11.0	96.0	85.0	35.0	50.0
4	P	M	2	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
4	P	M	2	2K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
4	P	M	2	1K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	111.5	105.0	40.0	
4	P	M	2	.5K	22.0	28.0	13.5	16.5	15.0	16.5	19.0	17.5	98.0	87.0	37.0	
5	P	M	1	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	108.0	99.0	39.0	60.0
5	P	M	1	2K	7.0	5.5	5.5	6.5	6.0	8.0	7.0	6.0	99.5	91.0	46.0	45.0
5	P	M	1	1K	6.5	6.5	5.5	6.0	7.0	6.0	6.0	4.0	93.5	87.0	37.0	50.0
5	P	M	1	.5K	5.5	9.0	8.0	6.5	6.5	7.5	8.5	5.5	92.0	81.0	31.0	50.0
5	P	M	2	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	108.0	99.0	39.0	
5	P	M	2	2K	5.0	3.0	2.0	2.5	1.5	0.0	0.0	0.0	99.5	91.0	46.0	
5	P	M	2	1K	9.0	8.5	6.0	5.5	6.0	6.0	2.0	5.5	95.5	89.0	39.0	
5	P	M	2	.5K	5.0	4.5	4.0	4.0	3.0	2.5	2.0	1.0	92.0	81.0	31.0	

APPENDIX A

RAW DATA SUMMARY SHEET

SUBJ	HEAR	AGE	PRES	FREQ	REFLEX AMPLITUDE IN MILLIMETERS — TIME INTERVAL IN SECONDS: 2	5	10	15	20	30	45	60	REFLEX LEVEL IN: SPL	HL	SL	HT
6	P	M	1	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	110.0	101.0	41.0	60.0
6	P	M	1	2K	8.5	5.5	4.5	5.0	4.5	3.0	2.5	2.0	99.5	91.0	26.0	65.0
6	P	M	1	1K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	107.5	101.0	36.0	65.0
6	P	M	1	.5K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	108.0	97.0	37.0	60.0
6	P	M	2	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	114.0	105.0	45.0	
6	P	M	2	2K	8.5	4.0	4.0	4.0	3.5	3.0	2.0	2.0	101.5	93.0	28.0	
6	P	M	2	1K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	107.5	101.0	36.0	
6	P	M	2	.5K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	108.0	97.0	37.0	
7	P	M	1	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75.0
7	P	M	1	2K	3.0	2.5	2.0	2.0	2.0	2.0	2.0	2.0	99.5	91.0	51.0	40.0
7	P	M	1	1K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	105.5	99.0	44.0	55.0
7	P	M	1	.5K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	114.0	103.0	48.0	55.0
7	P	M	2	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
7	P	M	2	2K	2.0	2.0	1.5	1.0	1.0	1.0	1.0	1.0	103.5	95.0	55.0	
7	P	M	2	1K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	109.5	103.0	48.0	
7	P	M	2	.5K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	116.0	105.0	50.0	
8	P	M	1	4K	1.0	1.0	0.5	0.0	0.0	0.0	0.0	0.0	102.0	93.0	38.0	55.0
8	P	M	1	2K	10.0	7.0	4.5	4.5	3.5	3.5	3.0	3.0	97.5	89.0	34.0	55.0
8	P	M	1	1K	9.5	10.0	10.5	10.5	11.0	11.0	10.5	9.0	101.5	95.0	35.0	60.0
8	P	M	1	.5K	3.5	5.0	5.5	6.0	6.0	6.0	6.5	5.0	104.0	93.0	38.0	55.0
8	P	M	2	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	108.0	99.0	44.0	
8	P	M	2	2K	7.0	7.0	3.5	3.0	4.0	3.5	3.0	3.0	99.5	91.0	36.0	
8	P	M	2	1K	4.0	4.5	4.5	4.5	4.0	3.5	3.0	2.0	99.5	93.0	33.0	
8	P	M	2	.5K	0.5	1.0	1.0	0.0	0.0	0.0	0.0	0.0	104.0	93.0	38.0	

APPENDIX A
RAW DATA SUMMARY SHEET

SUBJ	HEAR	AGE	PRES	FREQ	REFLEX AMPLITUDE IN MILLIMETERS — TIME INTERVAL IN SECONDS								REFLEX LEVEL IN			HT
					2	5	10	15	20	30	45	60	SPL	HL	SL	
9	P	M	1	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75.0
9	P	M	1	2K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	105.5	97.0	22.0	75.0
9	P	M	1	1K	11.5	6.0	5.0	5.0	5.0	4.0	4.0	3.5	97.5	91.0	36.0	55.0
9	P	M	1	.5K	9.0	8.0	8.0	8.0	8.0	8.0	8.5	8.5	100.0	89.0	34.0	55.0
9	P	M	2	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
9	P	M	2	2K	5.0	3.0	2.0	2.0	3.0	2.5	2.0	2.0	103.5	95.0	20.0	
9	P	M	2	1K	13.0	6.5	6.0	5.0	4.5	3.5	3.5	3.5	99.5	93.0	38.0	
9	P	M	2	.5K	10.0	9.0	7.0	7.5	6.5	6.0	5.0	6.0	98.0	87.0	32.0	
10	P	M	1	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	70.0
10	P	M	1	2K	5.0	8.0	9.0	7.5	6.0	5.0	5.0	4.5	99.5	91.0	31.0	60.0
10	P	M	1	1K	14.0	13.5	11.5	11.0	10.0	9.0	9.0	8.5	101.5	95.0	35.0	60.0
10	P	M	1	.5K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	110.0	99.0	54.0	45.0
10	P	M	2	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
10	P	M	2	2K	7.5	8.0	3.5	2.0	0.0	0.0	0.0	0.0	101.5	93.0	33.0	
10	P	M	2	1K	16.0	14.0	11.5	11.0	10.5	9.0	8.0	9.0	101.5	95.0	35.0	
10	P	M	2	.5K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	112.0	101.0	56.0	
1	P	O	1	4K	4.0	2.5	1.5	1.5	1.5	1.5	2.0	3.0	90.0	81.0	21.0	60.0
1	P	O	1	2K	7.0	6.0	5.0	3.5	3.0	3.0	2.0	2.0	77.5	69.0	29.0	40.0
1	P	O	1	1K	7.5	6.5	5.0	4.5	4.0	3.5	4.0	5.0	77.5	71.0	36.0	35.0
1	P	O	1	.5K	4.5	2.5	3.0	2.0	2.0	2.0	4.0	3.5	84.0	73.0	48.0	25.0
1	P	O	2	4K	3.0	2.0	1.5	2.0	2.0	3.0	1.0	1.5	96.0	87.0	27.0	
1	P	O	2	2K	8.0	7.0	5.0	4.0	3.5	3.5	4.0	4.0	81.5	73.0	33.0	
1	P	O	2	1K	6.0	5.5	4.0	3.0	3.0	3.5	2.5	2.0	77.5	71.0	36.0	
1	P	O	2	.5K	5.0	4.0	3.5	3.5	3.0	3.0	2.0	1.5	82.0	71.0	46.0	

APPENDIX A

RAW DATA SUMMARY SHEET

S U B J	H E A R	A G E	P R E S	F R E Q	*---- REFLEX AMPLITUDE IN MILLIMETERS ------* TIME INTERVAL IN SECONDS 2	5	10	15	20	30	45	60	REFLEX LEVEL IN * S P L	H L	S L	H T
2	P	0	1	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0
2	P	0	1	2K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	55.0
2	P	0	1	1K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0
2	P	0	1	.5K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	94.0	83.0	58.0	25.0
2	P	0	2	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
2	P	0	2	2K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
2	P	0	2	1K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
2	P	0	2	.5K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
3	P	0	1	4K	3.0	3.0	5.0	2.5	2.5	3.0	3.5	4.5	94.0	85.0	50.0	35.0
3	P	0	1	2K	3.5	2.0	2.0	2.0	2.5	2.5	2.5	3.0	93.5	85.0	50.0	35.0
3	P	0	1	1K	7.5	7.5	6.5	6.0	6.0	5.0	4.5	4.5	101.5	95.0	50.0	45.0
3	P	0	1	.5K	6.0	6.0	6.0	5.5	5.0	4.5	5.0	3.0	102.0	91.0	46.0	45.0
3	P	0	2	4K	2.0	3.0	3.5	3.5	3.0	2.5	3.5	4.5	96.0	87.0	52.0	
3	P	0	2	2K	6.0	3.5	3.5	3.5	3.0	2.5	0.0	0.0	97.5	89.0	54.0	
3	P	0	2	1K	7.0	7.0	7.0	6.5	6.5	5.0	3.0	1.5	101.5	95.0	50.0	
3	P	0	2	.5K	2.5	3.0	3.0	3.5	4.0	3.5	3.5	3.0	102.0	91.0	46.0	
4	P	0	1	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	65.0
4	P	0	1	2K	4.0	4.0	4.0	3.0	2.0	0.0	0.0	0.0	103.5	95.0	30.0	65.0
4	P	0	1	1K	3.5	3.5	4.0	4.0	4.0	4.0	4.0	4.0	93.5	87.0	27.0	60.0
4	P	0	1	.5K	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	94.0	83.0	33.0	50.0
4	P	0	2	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	112.0	103.0	38.0	
4	P	0	2	2K	2.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	97.5	89.0	24.0	
4	P	0	2	1K	3.5	4.0	4.0	6.0	3.0	4.5	3.0	4.0	95.5	89.0	29.0	
4	P	0	2	.5K	2.5	2.5	2.5	2.5	3.0	3.0	3.5	3.5	96.0	85.0	35.0	

APPENDIX A
RAW DATA SUMMARY SHEET

SUBJ	HEAR	AGE	PRES	FREQ	*---- REFLEX AMPLITUDE IN MILLIMETERS / TIME INTERVAL IN SECONDS * 2	5	10	15	20	30	45	60*	REFLEX LEVEL IN * SPL	HL	SL *	HT
5	P	0	1	4K	2.0	3.5	3.0	3.0	3.5	2.0	2.0	2.0	102.0	93.0	43.0	50.0
5	P	0	1	2K	4.0	4.0	4.5	3.5	3.0	1.0	0.5	2.0	93.5	85.0	40.0	45.0
5	P	0	1	1K	6.0	5.5	7.0	6.5	6.0	7.0	8.0	9.5	91.5	85.0	45.0	40.0
5	P	0	1	.5K	4.0	5.0	6.0	6.0	5.5	6.0	3.0	4.0	98.0	87.0	52.0	35.0
5	P	0	2	4K	1.0	1.0	1.5	1.0	1.0	0.0	0.0	0.0	104.0	95.0	45.0	
5	P	0	2	2K	3.5	4.0	4.0	3.0	2.5	2.0	0.0	0.0	95.5	87.0	42.0	
5	P	0	2	1K	5.5	6.0	7.0	6.0	6.0	7.0	7.0	9.0	93.5	87.0	47.0	
5	P	0	2	.5K	4.0	6.0	6.0	6.5	6.0	7.0	9.5	10.5	96.0	85.0	50.0	
6	P	0	1	4K	2.5	4.0	4.0	4.0	3.5	3.5	3.5	2.5	102.0	93.0	28.0	65.0
6	P	0	1	2K	2.0	2.5	2.0	2.5	2.0	1.5	1.5	1.0	93.5	85.0	50.0	35.0
6	P	0	1	1K	4.0	4.5	4.0	4.0	4.0	4.0	3.5	1.5	97.5	91.0	61.0	30.0
6	P	0	1	.5K	2.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0	94.0	83.0	58.0	25.0
6	P	0	2	4K	2.0	2.0	1.5	1.0	1.0	1.0	1.0	0.5	104.0	95.0	30.0	
6	P	0	2	2K	2.5	2.5	2.5	2.0	1.5	2.0	1.5	2.0	91.5	83.0	48.0	
6	P	0	2	1K	3.0	3.5	3.0	3.0	3.0	2.5	2.5	2.5	93.5	87.0	57.0	
6	P	0	2	.5K	2.5	3.5	3.5	3.5	3.5	3.5	3.0	4.5	96.0	85.0	60.0	
7	P	0	1	4K	8.0	6.0	5.5	5.5	5.0	5.0	5.0	5.0	92.0	83.0	13.0	70.0
7	P	0	1	2K	14.0	7.0	6.0	4.0	4.0	5.0	5.0	5.5	85.5	77.0	22.0	55.0
7	P	0	1	1K	15.0	14.0	12.0	13.0	12.0	13.0	13.5	13.0	83.5	77.0	52.0	25.0
7	P	0	1	.5K	4.5	4.5	4.5	4.5	4.5	3.0	3.0	1.5	78.0	67.0	42.0	25.0
7	P	0	2	4K	13.0	5.0	5.0	5.0	4.5	4.5	5.0	5.0	92.0	83.0	13.0	
7	P	0	2	2K	15.0	11.5	11.0	10.5	10.0	9.5	9.5	9.0	87.5	79.0	24.0	
7	P	0	2	1K	15.0	13.5	12.5	12.0	12.0	12.0	12.5	13.0	83.5	77.0	52.0	
7	P	0	2	.5K	11.0	5.0	6.0	5.5	4.0	5.5	5.0	5.5	84.0	73.0	48.0	

APPENDIX A
RAW DATA SUMMARY SHEET

SUBJ	HEAR	AGE	PRES	FREQ	*---- REFLEX AMPLITUDE IN MILLIMETERS TIME INTERVAL IN SECONDS 2	5	10	15	20	30	45	60 -----*	REFLEX LEVEL IN * SPL	HL	SL *	HT
8	P	0	1	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	80.0
8	P	0	1	2K	8.5	3.0	0.0	0.0	0.0	0.0	0.0	0.0	89.5	81.0	31.0	50.0
8	P	0	1	1K	20.0	17.0	8.0	7.0	8.0	3.5	1.5	0.0	87.5	81.0	46.0	35.0
8	P	0	1	.5K	5.0	10.0	5.0	4.5	5.5	3.0	2.0	4.0	80.0	69.0	39.0	30.0
8	P	0	2	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
8	P	0	2	2K	13.0	6.5	4.0	2.0	2.5	1.0	1.5	0.5	89.5	81.0	31.0	
8	P	0	2	1K	22.0	20.5	14.5	15.0	10.0	8.5	4.5	4.5	89.5	83.0	48.0	
8	P	0	2	.5K	9.0	9.0	6.0	5.0	5.0	4.5	4.0	3.5	84.0	73.0	43.0	
9	P	0	1	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	70.0
9	P	0	1	2K	2.5	3.0	4.0	4.0	4.0	2.0	4.5	4.0	101.5	93.0	33.0	60.0
9	P	0	1	1K	3.5	4.0	3.5	4.0	4.5	4.0	4.5	3.5	97.5	91.0	36.0	55.0
9	P	0	1	.5K	3.0	4.0	4.5	4.5	5.0	3.5	4.5	5.0	102.0	91.0	41.0	50.0
9	P	0	2	4K	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
9	P	0	2	2K	2.0	2.0	1.5	2.0	2.5	2.0	2.0	1.0	103.5	95.0	35.0	
9	P	0	2	1K	1.5	2.0	2.5	2.5	1.5	1.0	1.5	2.5	101.5	95.0	40.0	
9	P	0	2	.5K	1.0	2.0	2.5	3.0	3.5	3.5	2.5	2.5	104.0	93.0	43.0	
10	P	0	1	4K	5.0	5.0	3.5	4.0	4.0	4.0	3.0	2.5	92.0	83.0	38.0	45.0
10	P	0	1	2K	5.5	6.5	5.5	4.0	3.0	3.5	2.0	2.0	83.5	75.0	40.0	35.0
10	P	0	1	1K	8.0	9.5	10.0	9.5	9.0	9.5	10.0	11.0	89.5	83.0	48.0	35.0
10	P	0	1	.5K	3.5	5.5	6.0	6.0	7.0	7.0	8.0	8.0	96.0	85.0	40.0	45.0
10	P	0	2	4K	4.5	5.5	4.0	3.0	2.5	2.0	1.0	1.0	96.0	87.0	42.0	
10	P	0	2	2K	9.0	10.5	8.0	6.5	5.5	6.5	5.5	5.0	87.5	79.0	44.0	
10	P	0	2	1K	6.5	7.5	7.0	6.5	7.0	6.5	6.5	6.0	89.5	83.0	48.0	
10	P	0	2	.5K	4.5	6.5	7.0	6.5	6.0	6.0	6.5	6.5	96.0	85.0	40.0	

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Date of Examination:

April 24, 1973