EFFECT OF REPETITION RATE ON AUDITORY BRAINSTEM RESPONSE IN ADULTS AND ELDERLY

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May - 2003

Dedicated to Lord Jesus,

Dear Parents

and

all those whom I like the most

CERTIFICATE

This is to certify that this Dissertation entitled **"EFFECT OF REPETITION RATE ON AUTITORY BRAINSTEM RESPONSE IN ADULTS AND ELDERLY"** is a bonafide work in part fulfillment for the Master's degree (Speech and Hearing) of the student (Register No. MSHM0111).

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This is to certify that this Dissertation entitled **"EFFECT OF REPETITION RATE ON AUTITORY BRAINSTEM RESPONSE IN ADULTS AND ELDERLY"** has been prepared under my supervision and guidance. It is also certified that this Dissertation has not been submitted earlier in any other University for the award of any Diploma or Degree.

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DECLARATION

This Dissertation entitled **"EFFECT OF REPETITION RATE ON AUTITORY BRAINSTEM RESPONSE IN ADULTS AND ELDERLY"** is the result of my own study under the guidance of **Mr. Animesh Barman** Lecturer, Department of Audiology, All India Institute of Speech and Hearing, Mysore and not been submitted earlier in any other University for the award of any Diploma or Degree.

Mysore,

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INTRODUCTION

The auditory evoked potentials are the electrical responses of the nervous system to auditory stimuli (Stapells, Picton, Abalo, Read & Smith, 1985). One of the auditory evoked potentials is the Auditory Brainstem Response (ABR) has emerged as an important clinical tool with its increased diagnostic dimensions. ABRs are widely used for threshold estimation and neuro diagnosis. The latencies of the waves are the characteristics used to qualify the normalcy of the potentials (Fowler & Noffsinger, 1983). The ABR can provide objective and quantifiable information in the otoneurologic evaluation of the patient with suspected cochlear, retrocochlear or central nervous system pathology (Galambos & Hecox, 1978; Stockard, Stockard & Sharbrough, 1977; cited in Gerling & Fintzo-Hieber, 1983; Rowe, 1981).

Utilising ABR to its maximum potential is primarily an exercise in identifying response patterns and knowing which values fall within the range of normal variation and which values have diagnostic significance for peripheral / brainstem dysfunctions (Thornton, 1975; Stockard, Stockard & Sharbrough, 1977; cited in Gerling & Finitzo-Hieber, 1983).

The waves I-V Inter Peak Latency (IPL) and V/I amplitude ratio and interaural latency difference in latency measures are common ABR parameters for determining central dysfunction. Of these, the I-V IPL is more frequently utilised due to the multiple factors that affect the V/I amplitude ratio (Stockard, Stockard & Sharbrough, 1977; cited in Gerling & Finitzo-Hieber, 1983).

The pattern of hearing loss might affect the I-V interpeak latency and V/I amplitude ratio. Yet the interpeak intervals provide some of the most compelling information to differentiate between retrocochlear and cochlear pathologies, and among sites of retrocochlear lesions (Musiek & Lee, 1995).

Interaural latency differences are not necessarily the most sensitive detectors of retrocochlear group, nor are equally sensitive across pathologies (Musiek, Johnson, Gollegly, Josey & Glasscock, 1989, cited in Durrant & Ferraro, 1999). Still, no parameter by itself can be expected to provide adequate sensitivity in all cases (Musiek & Lee, 1995).

The frequency composition of the stimulus is another consideration in the latency of the brainstem potentials. A click is a broad frequency stimulus, but the effective frequencies for stimulating the cochlea depend on the resonance peaks of the transducer, the intensity level of the stimulus and the pure tone thresholds of the subject. In subjects with high frequency hearing loss, elimination of the basal fibers that have the shortest latency responses results in action potentials that are generated more apically and therefore, later than in normal subjects (Aran, Darrouzet & Erre, 1975; Elberling & Salomon, 1976, cited in Fowler & Noffsinger, 1983). Thus, a high frequency hearing loss can result in latencies that are longer than normal.

Whereas Suresha (2001) reported that in subjects with sloping configuration hearing loss, wave I was maximally delayed giving rise to reduced interwave intervals (I-III, III-V & I-V at 80 dBnHL) and wave I had steeper L-1 function than wave III and wave V resulting in reduction in interwave intervals as the level was reduced. The

slope tend to increase as the severity increased. Keith and Greville (1987) and Kirsh, Thornton, Buckard and Halpin (1992) have also seen the similar effect.

The stimulus rate is also seem to have a significant effect on ABR latency. With the increase in click rate, the absolute and interpeak latencies increases in normal hearing adults (Don, Allen & Starr, 1977). The stimulus rate has more pronounced influence on ABR latency for premature infants than adults (Stockard, Stockard & Coen, 1983; Cox, 1985; cited in Hall, 1992).

The absolute and interpeak latency increases in normal hearing adults with the increase in repetition rates and the shift is independent of click intensity (Don, Allen & Starr, 1977). Harkin (1981, cited in Fowler & Noffsinger, 1983) found no difference in latency values at high stimulus rates for young versus elderly adults, but amplitude reduced in the elderly group.

Negligible latency changes for wave V were noted for repetition rates between 2/sec and 20/sec (Salamy, McKean & Buda, 1975, cited in Fowler & Noffsinger, 1983; Pratt & Sohmer, 1976; Zollner, Karnahl & Stange, 1976). A rate of 50/sec in comparison to 10/sec however prolongs the latency of wave V by 0.2-0.4 msec (Hyde, Stephens & Thornton, 1976; Zollner, Karnahl & Stange, 1976; Don, Allen & Starr, 1977).

The effect of repetition rate on wave I latency is less clear than is the effect on wave V latency. The click-elicited wave I latency does not vary with repetition rate

(Jewett & Williston, 1971; Yoshie, 1973, Thornton & Coleman, 1975 cited in Don, Allen & Starr, 1977; Pratt & Sohmer, 1976; Hyde, Stephens & Thornton, 1976).

Pratt and Sohmer, 1976; Chiappa, 1979; Stockard, Stockard, Westmoreland and Corfits, 1979; cited in Gerling & Finitzo-Hieber, 1983 found that as repetition rate increases above 20/sec, the latencies of waves III and V increase and waveform morphology changes in normal hearing subjects without neurologic abnormality. Disparities in the literature exist regarding whether the amplitude of waves I, III, and V decreases as repetition rate increases (Pratt & Sohmer, 1976; Rowe, 1978; Chiappa, 1979, cited in Campbell & Abbas, 1987; Paludetti, Maurizi & Ottaviani, 1983) which is reported to be highly variable.

The influence of hearing loss on repetition rate effects has not been clearly established Campbell & Abbas, 1987. The presence and degree of hearing loss can affect the latencies of ABR waveforms at low repetition rates and the results are influenced by degree of hearing loss Coats & Martin, 1977 Gerling and Finitzo-Hieber (1983) reported that shifts in wave V latency were significantly shorter for subjects with hearing loss than for normal hearing subjects.

Fowler and Noffsinger (1983) and Zollner and Eibach (1981, cited in Hall, 1992) reported the amount of wave V latency shift to be similar in normal and cochlear - impaired populations. Wave V amplitude was significantly greater for the cochlear group than for the retrocochlear group for all repetition rates (9.7, 39.7, 49.7 and 59.7/sec.

Of late, higher repetition rate has been extensively used in the identification of neural abnormality. Though the effects of increased repetition rate in the presence of neurologic abnormality have not been clearly established, it has been well documented that at low repetition rates (< 20/sec), prolongation of wave V latency or absence of waveform can be indicative of neurologic abnormality (Selters & Brackmann, 1977; Clemis & McGee, 1979). It has also been documented that large shifts of wave V latency / disappearance of wave V when repetition rate is increased may also indicate otoneurologic abnormality (Daly, Roeser, Aung & Daly, 1977; Zollner & Eibach, 1981, cited in Campbell & Abbas, 1987; Gerling & Finitzo-Heiber, 1983; Musiek & Gollegly, 1985; Pratt, Ben- David, Peled, Podoshin & Scharf 1981, cited in Campbell & Abbas, 1987) and may be sensitive than ABR measures at low repetition rates. Fowler and Noffsinger (1983) found abnormal latency shifts / disappearance of waves at very rapid stimulus rates in peripheral and central nervous system pathology, including VIII nerve tumours.

It is sometimes the case that responses appearing to be reasonably normal at click rates of 10-20/sec will show some pathologic degradation at high click rates, suggesting retrocochlear pathology (Shanon, Gold & Himelfarb, 1981; Zollner & Eibach, 1981, cited in Campbell & Abbas, 1987). Both cochlear and VIII nerve / brainstem damage can impose latency delays on the waves, thus a cochlear hearing loss confounds the interpretation of latency delays in the brainstem responses (Fowler & Noffsinger, 1983). Lightfoot (1992) used rate induced latency shift (RLS) measurements to identify acoustic neuroma using rates of 11.1 / sec to 80.1 /sec. He demonstrated a sensitivity of 100% and specificity of 97.9% for the same.

Stockard (1977), Galambos (1980), Hecox and Cone (1981), cited in Gerling and Finitzo-Hieber (1983) have shown that increasing the stimulus rate and determining peak latency shifts is of value in identifying the presence of a demyelinating disesase, anoxic-ischemic encephalopathy, rumour and other brainstem abnormalities. More subtle abnormalities may be detected, which are missed at low stimulus rates, this appears to be a rare occurrence. The basis of this controversy may be related to both the decrease in waveform resolution associated with high stimulus rates and the paucity of information on a large patient population regarding the incidence of stimulus abnormality (Rowe, 1981).

Thomsen, Terkildsen & Osterhammel (1978) suggested that normal and neurally impaired subjects evidence the same degree of shifts for variable repetition rate changes. The role of repetition rate in the diagnosis of normal, cochlear impaired and neurally impaired auditory systems, therefore is unknown.

NEED FOR THE STUDY :

Disparities in literature exist regarding whether the amplitude of waves I, III, and V decrease as repetition rate increases (Pratt & Sohmer, 1976; Rowe, 1978; Chiappa, 1979, cited in Campbell & Abbas, 1987; Paludetti, Maurizi & Ottaviani, 1983). However it is evident that variable repetition rate has a significant effect on ABR waves. Many researchers have reported the use of repetition rate to study the neural abnormality especially in adults. There is hardly any study on effect of repetition rate on ABR in adults and elderly normals and individuals with sloping sensorineural hearing loss, which is most commonly seen in elderly either due to presbycusis or any other neural involvement.

Several researches have also been carried out to investigate the age related changes on ABR waves with the repetition rate (Stockard & Coen, 1980, Laksy, 1984,

cited in Campbell & Abbas, 1987; Hall, 1992, Schwartz, Morris & Jacobson, 1993). But all these studies were mainly done either in infants (pre and post term babies) or in adults. Very less or no information is available as to how the stimulus rate affects the older population especially with respect to adults.

It is a well known fact that neural degeneration occurs due to aging. Hence there is no doubt that this could definitely affect the overall ABR response. Giddiness and imbalance is another common symptom, which is seen in elderly people, which can occur either due to normal physiological changes or due to space occupying lesions. Thus an attempt needs to be made to know the variation in ABR as a consequence of normal physiological process due to aging. The lack of knowledge of this fact can mislead a person to suspect a space occupying lesion.

It is also noticed that the electrophysiological results tends to vary, especially across race. Thus it is always advisable to carry out studies to establish the norm for a specific population.

AIM OF THE STUDY :

1. To obtain the
    a) absolute latency and amplitude of ABR waves in different age groups of individuals with normal hearing and sloping sensori neural hearing loss at different rates.
    b) latency - intensity function at different repetition rates for different ABR waves.
    c) interwave intervals for different repetition rates across the age groups.
2. To study the effect of repetition rate on ABR across the age groups.
3. To find out the age at which different parameters of ABR show more variations.

REVIEW OF LITERATURE

Auditory brainstem electric response measures are used widely in the diagnosis of lesion in the auditory pathways caudal to the cortex (Sohmer & Feinmesser, 1967; Jewett 1970, cited in Fowler & Noffsinger, 1983). There are several factors that can affect the ABR waveform. They are non pathologic subject characters which include age, gender, body temperature, state of arousal, attention and effects of drugs and stimulus factors, such as frequency, duration, intensity, polarity, rate and acquisition factors which include analysis time, electrodes, amplification filtering and signal averaging (Hall, 1992). These factors excert profound and often interrelated effects on ABR measurement.

Thornton and Coleman (1975, cited in Don, Allen & Starr, 1977) confirms the observation that stimulus rate has a significant effect on both amplitude and latency of ABR components.

Rate effects are a product of the interactions among a variety of subjects characteristics (like age, body temperature and drugs) and stimulus parameters (such as intensity and duration). Rate may interact also with neuropathology (Hall, 1992).

EFFECT OF REPETITION RATE IN NORMAL ADULTS :

Jewett, Romano and Williston (1970), Jewett and Williston (1971, cited in Schwartz & Berry, 1985) and numerous investigators have described the effect of stimulus rate on ABR in normal hearing adults. They found that stimulus repetition rates upto approximately 20/sec have little effect on ABR, but above this level, ABR

latency generally increases and amplitude decreases as rate increases. These changes are different for each wave component. Wave V amplitude appears to show less decrement with increasing rate (8-10/Sec - 80-90/Sec) than earlier components and also wave VI. At higher rate, amplitude for wave V has typically decreased about 10-30% relative to original amplitudes whereas wave I decreases to about 50% of its original amplitude (A clinical implication of this is that for threshold estimation, higher stimulus rates permit collection of largest quantity of data in the smallest test time).

Don, Allen and Starr (1977) and Gerling (1989) have reported a wave V latency shift by 0.9 msec when click repetition rate was increased from 10/sec to 100/sec in normal hearing adults (ages 18-34).

Van Olphen, Rodenburg, and Verwey (1979) observed that the latency of all ABR components increase by a magnitude of approximately 0.4 msec as repetition rate increases from 10 to 80 Hz .

Yagi and Kaga (1979), Gerling and Finitzo-Heiber (1983) and Gerling (1989) have reported somewhat greater latency prolongations for later waves than earlier waves and found a wave V latency shift of 0.4-0.6 msec at repetition rates from 20 - 80 clicks / sec in normal subjects. Because of this variability, Gerling and Finitzo-Heiber (1983) have defined criterion for an abnormally large shift of wave V latency as greater than 3 standard deviations above the mean (>1.04 msec), for repetition rates of20and90/sec.

Terkildsen, Osterhammel and Huis in't veld (1975) and Zollner, Karnahl and Strange (1976) found wave I latency shifts of 0.4 - 0.5 msec over the same range of rates, although few authors (Hyde, Stephens & Thornton, 1976; Jewett & Williston, 1971, cited in Hall, 1992) have reported no rate effect for wave I.

Buchwald and Huang (1975, cited in Hall, 1992), Fowler and Noffsiger (1983) found that the effect of rate on wave I falls within an intermediate position (about 0.23msec at 5-90/sec) in normal adults. Difficulty in confident identification of wave I and precise determination of latency might have contributed to these discrepancies.Because both peripheral and central ABR components are similarly affected by rate, interwave latencies generally do not vary significantly as a function of rate.

Don, Allen and Starr (1977) & Fowler and Noffsinger (1983) have reported that ABR components I and V usually do not become indistinct with increased rate in normal subjects, but waves II, III and IV may disappear at higher stimulus rates (80-100/sec).

Harkins (1981, cited in Fowler and Noffsinger, 1983) found no difference in latency values at high stimulus rates for young (mean age 25 years) versus elderly (mean age 71 years) adults, but amplitude tended to be reduced in the elderly group.

The rate also interacts with intensity levels. There are controversial results found regarding this. Don, Allen and Starr (1977) & Fujikawa and Weber (1977) found that average amount of wave V latency shift with rate increases to 80/sec is

equivalent to the latency change observed when stimulus intensity is decreased by 15-25dB. Don Allen and Starr (1977) also observed that there is a decrease in the latency of wave as the intensity of the click increases from 30 to 60 dB sensation level.

Gerling and Finitzo-Hieber (1983) studied the effect of stimulus rate from 10 to 20, 50, and 90 clicks per second at 60dBnHL in normal adults (20-35 years). There was an increase in latency of wave V and overall decrease in amplitude as stimulus rate increased from 10 - 90/sec. The difference between the wave V latency means for rates of 20 and 90/sec at 60dBnHL for all subjects was 0.61 msec with a standard deviation of 0.14 msec and a range in scores of 0.24 - 0.96 msec. All wave V latencies were significantly different from each other except for 10-20/sec comparison. He also studied the effect of intensity on the wave V latency shift from 20 - 90/sec for two subject groups. The first group was tested at 30, 60 and 70dBnHL, and the second group at 40, 60 and 70dBnHL. The results showed the greatest shift of latency between means was 0.11 msec with no detectable trend over the four intensities. No significant intensity effect was found for either group.

Most researchers have identified a definite and orderly relationship, where the latency of a given wave is progressively extended as rate is increased, with the later waves being extended in latency more than preceding waves. Fujikawa and Weber (1977) Tietze and Gobsch (1980), Paludetti, Maurizi, and Ottaviani (1983), Lasky (1984, cited in Lightfoot, 1992) have found that the relationship between latency prolongation and stimulus rates are approximately linear.

ABR, REPETITION RATE AND DIFFERENT AGE GROUPS

Infants and children :

There is a direct relationship between maturity of the CNS and the effect of rate on ABR. The stimulus rate has a more pronounced influence on ABR (Hall, 1992).

In the normal infant, increasing click rate between 17.1/sec and 57.1/sec creates an average wave V latency shift of 0.58 msec, representing a 0.28 msec prolongation than that seen in adults. The estimated wave V latency shift in the newborn is approximately 0.145 msec per lOHz increase in click rate (Schwartz, Morris & Jacobson, 1993).

The stimulus rate has a more pronounced influence on ABR latency for premature than term neonates, for younger children (under the age 18 months) than older children and for older children (upto age 13 years) than adults (Fujikawa & Weber, 1977; Despland & Galambos, 1980, cited in Hall, 1992)

Despland and Galambos (1980, cited in Hall, 1992) stated that the slope of the latency versus rate function declined from about 270 µsec / decade of rate in the 30 weeks gestational age per term infant to about 110 (µsec / decade in the term infant. These slopes are both considerably steeper than the linear latency versus rate slope in adults (approximately 35 to 40 µsec / decade in rate).

Lasky and Rupert (1982) found no ABR latency difference for 40 weeks term infants between stimulus rates 3/sec versus 10/sec. Preliminary data for 32 weeks

infants, suggested that wave V latencies were less for a 5/sec than for 10/sec stimulus rate.

Laksy (1984, cited in Hall, 1992) studied the relationship between stimulus rate and intensity for neonates versus adults. Data from normal neonates between ages of 38 and 42 weeks were collected using clicks of alternating polarity at 3 intensities (40,60 and 80 dB) using repetition rates (11.3, 51.3 & 91.3/sec). Neonates showed greater latency increase with increasing rate. The latency versus rate slope is steeper for the 60 and 80dB intensity levels than at 40 dB. The rate effect is greatest for wave V. This results in a combined effect of young age and rate on the wave I-V interval.

The general neurophysiologic basic for these age - rate -latency interpretation i.e. prolonged neural transmission in younger subjects is due to incomplete myelinization and reduced synaptic efficiency (Hecox, 1975; Pratt, Ben-David, Peled, Podoshin & Scharf, 1981; Lasky, 1984, cited in Hall, 1992). Hence slow rates may be necessary to obtain age independent ABRs.

Rate related ABR findings in cochlear pathology :

Coats and Martin (1977) have reported that the presence and degree of hearing loss can affect the latencies of ABR waveforms at low repetition rates and the results have been influenced by the degree of hearing loss.

The interpeak intervals and latency-intensity functions are the common parameters which account for the differences between normals and subjects with cochlear pathology. If interpeak intervals are reasonably symmetric and within norms,

it is safe to consider the lesion to be cochlear regardless of absolute latency values. If recruitment effect is incomplete, the latency-intensity function is expected to converge toward the normal function (Durrant & Ferraro, 1999). Stockard, Stockard, Westmoreland, Corfits (1979,cited in Campbell & Abbas, 1987) reported that the I-III and I-V IPL decreases when intensity decreases from 70-30dBSPL, with latency shifts as large as 0.73 msec occurring for the I-V IPL. The III-V IPL shows a much smaller decrease with intensity. The decrease in the I-III and I-V IPLs with intensity decreases reflects the change in peak latency of wave I.

Rosenhall, Bjorkman, Pedersen and Kail (1985, cited in Silman & Silverman, 1997) observed absence of an age effect on the brainstem auditory evoked potential interwave latencies. Rowe (1978, cited in Silman & Silverman, 1997) reported that the peak latencies and the I-III interpeak latency increased with age as shown by their comparision of young (17-33 years) and older (51-74 years) adults. Elberling and Parbo (1987) showed an increase in interwave interval I-V with age of 0.2-0.3msec over the range of 20-80 years.

There is a controversy regarding the effect of high frequency hearing impairment on interwave (I-V) latency interval of ABR. Some investigators demonstrated no change in I-V interwave interval (IWI) values with high frequency hearing loss (Rosenhamer, Lindstrom & Lundborg, 1981; Abramovich,1986, cited in Hall, 1992; Eggermont, Don & Brackmann, 1980). Rosenhamer, Lindstrom and Lundborg (1981) recorded the I-V and III-V IWI in 110 ears with coehlear hearing loss of various audiometric configuration and etiologies. In 77 subjects with high frequency hearing loss, the changes in I-V and III-V IWI were found to be

insignificant. Keith and Greville (1987) observed unaltered I-V IWI in their subjects with high frequency loss.

On the contrary a few investigators reported a significant decrease in the interwave latency difference in patients with high frequency sensory impairment (Coats & Martin, 1977; Sturzebecher, Kevanishvili, Werbs, Meyer & Schmidt, 1985). Evaluating thirty seven cochlear impaired subjects with sloping hearing loss, Sturzebecher, Kevanishvili, Werbs, Meyer and Schmidt (1985) reported that the I-V interwave interval reduced as stimulus intensity increased. Coats and Martin (1977) simultaneously recorded EcochG and ABR and found that the interwave latency difference between wave N l and wave V was reduced in subjects with high frequency hearing loss. The reason attributed for this differential effect was that the usual major components of wave I were absent because of pathology in the high frequency region and the wave I was comprised of only later components from lower frequency regions leading to reduction in amplitude. Wave V, less dependent on the basal region was less affected except at intensities approaching threshold.

The hypothesis that the wave latencies are determined not only by the neural generators but by the area of activation in the cochlea too were supported by Gorga, Reiland and Beauchaine (1985). They observed a steep L-1 function for the wave V. They attributed this to be the basal spread of excitation at high intensity.

There are differences in the slope of latency intensity (L-I) function between normal and cochlear impaired ears. That is the wave V latency in the cochlear impaired ears may have not effectively achieved asymptotic value at the stimulus

intensity employed and have reported that slope of the L-I series is steeper in patients with high frequency hearing loss than normal hearing.

The L-I function for wave V has a steep slope i.e., latency values are prolonged at low intensities and become normal values at high intensities. This L-I function is most characteristic of flat/mild-moderate sloping cochlear hearing impairment. Subjects with significant hearing impairment often demonstrate a L-I function which is two legged (Galambos & Hecox, 1978, cited in Silman & Silverman, 1997). The average value of L-I slope in persons with significant cochlear impairment may be similar to that for normal hearing persons. Since the function is two-legged-one leg with a steep slope followed by a leg with a shallow slope and the slope is determined on the basis of latencies at a high intensity (where slope is steep) and at low intensity (where slope is shallow), subjects with hearing impairment which is precipitously sloping above l000 Hz may demonstrate a L-I function that is shifted upward of that in normal hearing persons (Stapells, Picton, Abalo, Read & Smith, 1985). In such cases, brainstem auditory evoked potential (BAEP) threshold may be obtained at normal threshold levels (although the latency shift will be prolonged), reflecting the contribution of intact nerve fibers from the apical end of the basilar membrane. The peak latency of wave V never approaches values seen in normal hearing persons, since the response is always dominated by apical fibers. As intensity increases there is a basalward shift in the fibers dominating in the response, but intensity never reaches a level sufficient to stimulate the basal fibers.

Steep intensity-latency slopes and normal ABR at low sensation levels(SLs) have been considered as an indication of recruitment in cochlear damaged ears (Galambos & Hecox, 1978 , cited in Silman & Silverman, 1997).

Don and Eggermont (1978) have found that at low intensity levels, latency is greatly delayed because only more apical (1000-2000Hz) cochlear regions contribute to the response. Higher intensity levels involve the region of 4000Hz and higher frequencies, and these frequencies are represented at more basal portions of the cochlea which are activated with less travelling time along the basilar membrane. Therefore latency decreases sharply.

Zollner and Eibach (1981, cited in Campbell & Abbas, 1987), Fowler and Noffsinger (1983) reported no significant differences in wave V latency shifts between groups of hearing impaired and normal hearing subjects as the repetition rate is increased.

The average amount of wave V latency shift for the poorer ears of the cochlear group was similar to the amount of wave V shift reported for normal hearing adults (Don, Allen & Starr, 1977; Rowe, 1978; Chiappa, 1979; Pratt, Ben-David & Paled, 1981; Lasky, 1984, cited in Campbell & Abbas, 1987).

Rate related ABR findings in retrocochlear group :

Increased stimulation rate is suggested by some as an effective technique for detecting subtle auditory neuropathology (Don, Allen & Starr, 1977; Stockard, Stockard & Sharbrough, 1978, cited in Gerling & Finitzo-Hieber, 1983).

The effects of increased repetition rate in the presence of neurologic abnormality have not been clearly established. It has been well documented that, at low repetition rates (<20/sec), prolongation of wave V latency or the absence of

waveforms can be indicative of otoneurologic abnormality (Selters & Brackmann, 1977; Clemis & McGee, 1979).

Stimulus parameters such as repetition rate may help to differentiate between the effects of cochlear and VIII nerve / brainstem lesions on the brainstem potentials (Fowler & Noffsinger, 1983).

It has been suggested that large shifts of wave V latency or the disappearance of wave V when repetition rate is increased may also indicate otoneurologic abnormality (Daly, Roeser, Aung & Daly, 1977; Musiek & Gollegly, 1985; Zollner & Eibach, 1981, cited in Campbell & Abbas, 1987; Gerling & Finitzo-Hieber, 1983) and may be more sensitive than ABR measures at low repetition rates (Stockard, Stockard & Sharbrough, 1977; Shanon, Gold & Himelfarb, 1981, cited in Campbell & Abbas, 1987; Gerling & Finitzo-Hieber, 1983).

Yagi and Kaga (1979), Daly, Roeser, Aung and Daly (1977, cited in Campbell and Abbas, 1987), Paludetti, Maurizi and Ottaviani (1983) revealed abnormal shifts of wave V latency or disappearance of wave forms as repetition rate increased for persons who had a confirmed lesion affecting the auditory pathway, while other case reports did not (Thomsen, Terkildsen & Osterhammel, 1978; Pratt, Ben-David & Peled, 1981; Hecox, Cone & Blaw, 1981, cited in Campbell and Abbas, 1987).

Selters and Brackmann (1977) and House and Brakmann (1977, cited in Lightfoot 1992) have reported the absence of ABR wave V in the presence of wave I in cases of acoustic neuroma.

The total absence of a recorded ABR may be of diagnostic value but only if the stimulus is presented at an intensity greater than a certain minimum level relative to the hearing thresholds at the higher audiometric frequencies (Lightfoot, 1992). The definition of this minimum level has not been widely reported, but Lightfoot (1992) found that only 1% of tumour free patients had an absent ABR when the click intensity was 80dBnHL or more (max 105 dBnHL). When the ABR is used as a screening test, however, a patient with an absent ABR must be considered as having failed the screen regardless of his audiometric status. This does not imply that he has a retrocochelar disease but rather that one has not been excluded & further tests are necessary.

There are a number of ways in which fast repetition rates have been used in otoneurological diagnosis. Conventional inter peak latency (IPL) measurements have been used with the ABR conducted at high rates, revealing abnormalities not evident at low rates in patients with multiple sclerosis (Stockard & Rossiter, 1977, Cited in Lightfoot, 1992).

Yagi and Kaga (1979), Hecox, Cone and Blaw (1981, cited in Gerling and Finitzo-Hieber, 1983) and Paludetti, Maurizi and Ottaviani (1983) have reported that the disappearance of wave V at high rates when present at low rates has been taken as evidence of neurological dysfunction.

Greater attention has been paid to the rate induced shift of wave V (RLS V). Abnormally high values of RLS V have been recorded in patients with acoustic neuromatas (Josey, 1985 cited in Lightfoot, 1992 & Campbell & Abbas, 1987) and

other neurological diseases (Hecox, Cone & Blaw, 1981, Schaefer, Gerling, Finitzo-Hieber & Freeman, 1983). This form of measurement appears to have the advantage of being immune to the effects of stimulus intensity (Thornton & Coleman, 1975, cited in Gerling & Finitzo-Hieber,1983; Zollner, Karnahl & Strange, 1976; Don, Allen & Starr, 1977; Stockard, Stockard, Westmoreland, 1979,cited in Lightfoot,1992) and cochlear hearing loss (Fowler and Noffsinger, 1983; Campbell & Abbas, 1987). The RLS V is influenced by subject age, however with greater shifts being recorded at the extremes of age spectrum (Fujikawa & Weber, 1977; Despland & Galambos, 1980; Picton, Stapells & Campbell, 1981, cited in Lightfoot, 1992).

Whilst observing abnormal rate effect measurements in patients with neurological disease, Chiappa (1980), Elidan, Sohmer,Gafni and Kahana (1976, cited in Lightfoot, 1992) and Campbell & Abbas (1987) concluded that they were unhelpful, identifying only those patients who were already found abnormal by low-rate measurers. Musiek and Gollegly (1985,cited in Lightfoot, 1992) concluded that those using ABR must await a major study on repetition rate and VIII nerve lesion to provide more definitive evidence to its use.

Gerling and Finitzo-Hieber (1983) studied the effect of increasing stimulus rate on ABR in normal subjects and compared this to 221 patients referred for otoneurologic evaluation. Out of 221, 90 patients with impaired auditory sensitivity demonstrated significantly less wave V latency shift than either 131 patients with normal auditory sensitivity / the normal subjects. Sixteen of 131 normal hearing patients / 12%, had wave V latency shifts that exceeded 1.04msec criterion. Seven of the 90 hearing-impaired patients / 8%, also demonstrated prolonged wave V latency

shifts despite the reduced stimulus rate effects. The authors concluded that a high stimulus rate contributes to the diagnosis of brainstem pathology.

Campbell and Abbas (1987) recorded ABRs in two groups of adult subjects with asymmetric SNHL using clicks at repetition rates of 9.7, 39.7, 49.7, 59.7/sec. One group was composed of 8 patients (cochlear group) and one group was composed of 8 patients with surgically confirmed acoustic neuroma in the ear with poorer hearing sensitivity (retrocochlear group). Detection of wave V at different repetition rates was not significantly different between the two groups. Average wave V latency shift was not significantly different between the two groups as repetition rate increased from 9.7 /sec to 39.7/sec, but was significantly greater for the retrocochlear group as repetition rate increased from 9.7 /sec- 49.7/sec & 59.7 / sec.

PHYSIOLOGIC BASES OF RATE EFFECTS

Several investigators have speculated on possible neurophysiologic mechanisms underlying the effect of increased rate on ABR latency versus amplitude. The physiologic explanation given for overall rate effect is a cumulative neural fatigue and adaptation, and incomplete recovery involving hair-cell-cochlear-nerve junctions and also subsequent synaptic transmission. By this theory, effect of rate would be additive as the number of synapses increased from wave I through wave V (Hall, 1992).

Thornton and Coleman (1975, cited in Gerling & Finitzo-Hieber, 1983) presented data supporting a hypothetical model in which adaptation due to high stimulus rates occurred from auditory nerve through rostral brainstem in normal

subjects. The neurophysiologic mechanisms considered responsible for observed latency shifts with increased rate when both peripheral and central auditory systems are intact include a change in cochlear receptor function (Don, Allen & Starr, 1977), the refractory period of neural elements, and a decrease in synaptic efficacy (Pratt & Sohmer, 1976).

In pathologic conditions, these mechanisms are probably altered resulting in the observed prolonged latency shifts and / or absence of the ABR when stimulus rate is increased (Thornton & Coleman, 1975; Pratt & Sohmer, 1976; Yagi & Kaga, 1979; Pratt, Ben-David, Peled, Podoshin & Scharf,1981, cited in Gerling & Finitzo-Hieber, 1983).

Despland and Galambos (1980, cited in Gerling & Finitzo-Hieber, 1983) have stated that the underlying rationale for rate studies is that in the presence of intracranial pathology, auditory pathways are more likely incapable of conducting neural impulses at high rather than low stimulus rates.

According to a few authors, amplitude is less affected than latency. Terkildsen, Osterhammel and Huis in't veld (1975), Pratt and Sohmer (1976) and Suzuki, Kobayashi, & Takagi (1986, cited in Hall, 1992) have theorized that adaptation may not be precisely uniform for all neurons and this would result in dysynchronization of this response and prolonged latency. Temporal summation would remain adequate for amplitude summation.

According to various investigators (Davis, & Hirsh, 1976, Klein, 1983, Suzuki, Hirai & Horiuchi, 1977, Klein, 1983; Suzuki, Kobayashi & Takagi, 1985, cited in Hall, 1992) the ABR consists of two major spectral components - a slow component (energy at frequencies of 100 HZ and below) and a fast component (energy at frequencies in the regions of 500 and 900 HZ). This dual nature of ABR is appreciated by spectral analysis. The ABR is a slow wave on which fast components (Waves I through VII) are superimposed. There is a physiologically based distinction in the effects of stimulus rate, intensity and frequency on these slow-versus-fast ABR components.

Suzuki, Kobayashi, and Takagi (1986, cited in Hall, 1992) recorded ABRs for stimulus rates of 8 / sec to 90.9/sec and performed power spectral analysis, and then digitally separated the ABR waveforms into a slow component (0-400HZ) & a fast component (400-1500 HZ). Slow-component amplitude was relatively constant across this range of stimulus rates, whereas amplitude of ABR waves I through V (fast component) decreased. Latency of each component increased with rate. Slow component amplitude, which did decrease very slightly with increasing rate, paradoxically showed an amplitude increase at a rate of 40 HZ. According to these authors, the differential effect of rapid stimulus rate on ABR latency (an increase) versus amplitude (essentially no change) reported by others may be explained by this dual nature of the ABR.

It can be highlighted from the above review that one can expect latency and amplitude variation of ABR waves with the repetition rate. These variation also can be more at older age group than the younger age. Studies done on these have shown

differences in latency and amplitude in infants versus adults. Thus similar studies are required to be done for adults and older group without having any gap between the age group. Hence, the present study was aimed for the same.

METHOD

To accomplish the aims following method was planned.

A. SUBJECTS

A total of thirty individuals with sensorf neural hearing loss were considered for the study. They served as the experimental group (Group II). Age matched thirty normal hearing individuals served as the control group (Group I).

Subjects of both experimental and control group were then classified into three groups based on their age as 30-40, 40-50 and 50-65 years and each subgroup had 10 subjects.

The subjects were selected on the basis of following criteria.

Group I (Control group)

1. Pure tone thresholds of within 15dBHL in the frequency range of 250Hz to 8000Hz in octaves.
2. Normal middle ear function : 'A' type tympanogram with acoustic reflexes at normal level.
3. No history of otological symptoms (ear ache, discharge, tinnitus or hearing loss).
4. No history of neurological symptoms.

Group II (Experimental group)

1. Sloping sensori-neural hearing loss with pure tone thresholds of 16dBHL - 55dBHL at octave frequencies of 500Hz, lOOOHz, 2000Hz, 4000Hz and 8000Hz or at least elevated threshold at 4000Hz and 8000Hz. Individuals who had pure

tone threshold with a slope of 5-12dB octave toward high frequency / frequency above 500Hz were considered to have sloping loss (Adapted from Carhart, 1945 and Lloyd & Kaplan, 1978; cited in Silman & Silverman, 1997).

2. No middle ear pathology i.e., all of them had 'A' type tympanogram with present or elevated reflexes.
3. No signs or indications of rectro cochlear pathology.
4. Negative history of psychological problems.
5. No health problem at the time of testing.

B. INSTRUMENTATION

The following instruments were used for the study.

a. A calibrated two-channel diagnostic audiometer (0B822/922) with TDH-39P earphone and B-71 bone vibrator was used to obtain the pure tone thresholds.
b. A calibrated immittance meter (GSI-33 V.2) was used to assess the middle ear status.
c. ABR was recorded using Nicolet Bravo auditory evoked potential system.

C. TEST ENVIRONMENT

The tests were carried out in a room with ambient noise within the permissible level as recommended by ANSI (1977,cited in Silman & Silverman, 1997).

The test room was air conditioned to maintain a comfortable temperature and the subjects were made to sit comfortably on a chair. The lighting in the room was adequate.

D. TEST PROCEDURE

A detailed case history was taken from all the subjects (both experimental and control group) to obtain information regarding their problem or to know whether they had any problem related to hearing or neurological symptoms. Those who did not meet the above mentioned criteria from both the experimental and control group were not considered for further study.

Those who had passed the criteria on case history were taken for the pure tone audiometry. The frequencies tested were 250Hz to 8000Hz in octave intervals for air conduction and from 250Hz to 4000Hz for bone conduction using modified Hughson and Westlake method (Carhart & Jerger, 1959, cited in Silman & Silverman, 1997).

The subjects who had normal hearing in the control group and sloping sensori neural hearing loss within 55dBHL in the experimental group, then underwent immittance testing. Those who had 'A' or 'As' type tympanogram with presence or elevated reflex were either considered for control or experimental group.

ABR TESTING

a. Instructions

The subjects were instructed to 'sit comfortably and relax' on a chair facing away from the instrument. They were instructed to avoid extraneous movements of head, neck and limbs during testing.

b. Electrode placement

The electrode sites were cleaned using skin preparing paste. Adequate amount of conduction material and a piece of plaster were used to stick the silver chloride disc type electrodes.

The non-inverting electrode was placed on vertex (Cz), inverting electrodes were placed on the mastoid of right (A2) and left ear (Al) with common electrode (A) on the forehead (Fz). It was ensured that the electrode impedance was within 5KΩat each site and the inter electrode impedance was within 2KΩ. TDH-39P earphones were then placed without dislodging the electrodes.

The parameters used to record ABR are seen in Table 1.

Table 1 : Shows the parameters used for ABR recording

General set-up	Amplifier set-up	Channel-1	Channel-2
Test: AEP	Sensitivity	50 μV	50μv
No. of channels 2	Band pass filter	Low frequency: l00Hz	Low frequency:l00Hz
		High frequency: 3000Hz	High frequency: 3000Hz
	Notch	Off	Off
	Artifact	On	On
	Montage	Cz/Al	Cz/A2

1,500 rarefaction clicks were presented through TDH-39P supra aural head phones. Inorder to study the effect of different intensities and repetition rate on ABR across the three age groups, the ipsilateral ABR waveforms for clicks were recorded

at three intensities (90dBnHL, 80dBnHL, 60dBnHL) for the four repetition rates (11.1/sec, 30.1/sec, 65.1/sec & 90.1/sec).

The latency, amplitude and interwave intervals were noted for all the three experimental and control groups and also at different repetition rates and intensities.

Analysis

The data collected were subjected to statistical analysis. Univariate analysis of variance was carried out to compare the latencies and amplitude obtained for each wave at different intensities and different repetition rates, for both normal hearing and subjects with sensori neural hearing loss. To know the main effect Duncan's post hoc test was carried out.

RESULTS

The objective of the study was to find the effect of repetition rate on ABR in different age groups with normal hearing and individuals with sloping sensori-neural hearing loss. To accomplish the objective of the study, ABR was recorded from normal hearing subjects and subjects with sloping sensori-neural hearing loss (SNHL) in the age group of 30-40, 40-50 and 50-65 years. The ABR was recorded at three intensities (90dBnHL, 80dBnHL, and 60dBnHL) for the four repetition rates (11.1/sec, 30.1/sec, 65.1/sec & 90.1/sec). The waveform at each intensity level and at each repetition rate was analysed interms of absolute latency of waves I, III, V and amplitude values for I, III, and V peaks. The latency-intensity functions were derived for absolute latency at all repetition rates for all the groups. The inter wave intervals (I - II, III-V &I-V) were noted for all subjects at all repetition rates at 80dBnHL.

The obtained data was then subjected to the statistical analysis using the statistical package SPSS, version 10.0.

The means (M) and Standard Deviation (SD) for absolute latency and amplitude of waves I, III and V, were obtained and tabulated at all repetition rates and at all intensities for both normal and subjects with sensori-neural hearing loss.

To compare the latencies and amplitude obtained for each wave at different intensities and different repetition rates, for both normal hearing and subjects with sensori-neural hearing loss, univariate analysis of variance was carried out.

1. A. Absolute latency of wave I

Table 2 shows the mean latency and standard deviations of wave I in normals at four repetition rates for three groups. It is evident from the table that the latencies are prolonged as repetition rate increases in normals. The same trend is observed across 3 age groups. The latency increase is much noticed in group III at 11.1./sec compared to other groups. Analysis of variance showed a significant difference at 0.002 level (F=5.648) for all the age groups.

Table 2 : Depicts the mean (M) and Standard Deviation (SD) for wave I latency and amplitude at different repetition rate (RR) for normals and subjects with sensorineural hearing loss (SNHL) at 80dBnHL.

Subjects	RR	Latency				Amplitude			
		Normals		SNHL		Normals		SNHL	
		M	SD	M	SD	M	SD	M	SD
I group	11.1	1.72	0.084	1.80	0.14	0.25	0.061	0.11	0.036
(30-40 years)	30.1	1.83	0.080	1.96	0.18	0.16	0.035	0.12	0.043
	65.1	1.88	0.074	2.11	0.026	0.12	0.029	0.10	0.026
	90.1	1.98	0.077	2.21	0.014	0.063	0.015	0.18	0.070
11 group	11.1	1.72	0.12	1.91	0.18	0.17	0.052	0.14	0.060
(40-50 years)	30.1	1.84	0.129	1.99	0.32	0.15	0.057	0.15	0.064
	65.1	1.94	0.166	2.03	0.35	0.11	0.062	0.085	0.035
	90.1	2.0	0.65	-	-	0.19	0.098	-	-
III group	11.1	1.91	0.51	1.96	0.30	0.17	0.017	0.21	0.064
(50-65 years)	30.1	1.94	0.14	1.98	-	0.16	0.014	0.14	-
	65.1	-		-	-			-	-
	90.1	-	-	-	-	-	-	-	-

Table 3 : Duncan's post-hoc test results for wave I latency at 80dBnHL at all repetition rates for normal subjects (N = Number of ears).

Point	N	Sub set for alpha = 0.05	
		1	2
11.1	23	1.76	
30.1	24	1.83	
65.1	20	1.92	
90.1	20		2.12

Duncan's Post Hoc test (Table 3) revealed that the latency at 11.1, 30.1 and 65.1/sec was significantly shorter than that of 90.1/sec. The latencies linearly increased across the four repetition rates. It can be noted that the latencies increased within the subjects with the increase in repetition rate and also across the 3 age groups for the same repetition rate.

The difference in mean latencies between the 11.1 and 90.1/sec repetition rates in normal subjects are approximately 0.26 msec, 0.28 msec and disappearance of wave I at higher repetition rates is seen in 30-40, 40-50 and 50-65 age groups respectively. The latency shift is more in the older age group than in younger adults.

Inspection of the table 2 indicates that, even in subjects with sensorineural hearing loss the same trend was noticed as seen in normal subjects, i.e., the latencies are prolonged with respect to increase in repetition rate. It is evident that at higher rates, the I peak latency is absent in II and III group. ANOVA revealed statistically significant difference at 0.003 level (F=5.698).

Table 4 : Duncan's post hoc test results for wave I latency at 80dBnHL at all repetition rates for subjects with sensorineural hearing loss.

Point	N	Subset for alpha = 0.05	
		1	2
11.1	25	1.87	
30.1	26	1.98	
65.1	25	2.08	
90.1	20		2.42

Duncan's post hoc test (Table 4) showed that, the latency was significantly different at 90.1/sec rate compared to other rates.

In sensorineural hearing loss subjects, the differences in mean latencies between the minimum and maximum repetition are approximately 0.41 msec in group I and disappearance of wave I at higher repetition rates is observed in group II and III. Older group seem to have more latency shift than the young adults.

2. Amplitude of wave I

It is also evident from the table 2 that in normal subjects as the repetition rate increases, the amplitude values decreases. This decrease in amplitude is more as age increases. ANOVA showed a statistically significant difference at 0.000 level (F = 9.079) within the subjects and across the groups, but the Duncan's post hoc test (Table 5) revealed that the subjects had significantly different value at 11.1 /sec compared to that of other repetition rates.

Table 5 : Duncan's post hoc test results for wave I amplitude at 80dBnHLat different repetition rates for normal subjects.

Point	N	Subset for alpha = 0.05	
		1	2
11.1	23		0.20
30.1	24	.16	
65.1	20	.11	
90.1	20	.11	

In sensorineural hearing loss subjects, the amplitude values at 11.1, 30.1 and 65.1/sec repetition rate was almost same in group 1 but increased at 90.1/sec. In group II, the amplitude values was almost same in slower repetition rates but highly reduced at higher repetition rates. Group III had higher amplitude compared to II and I group. ANOVA revealed a significant difference at 0.051 level (F = 2.856).

Table 6 : Duncan's post hoc test results for wave I amplitude at 80dBnHL at different repetition rates for subjects with sensorineural hearing loss.

Point	N	Subset for alpha = 0.05	
		1	2
65.1	30	0.097	
30.1	25	0.14	0.14
11.1	26	0.15	0.15
90.1	20		0.19

Duncan's post hoc test (Table 6) showed that there was no significant difference in amplitude at 11.1 and 30.1/sec. But the significant difference in amplitude was seen between 65.1 and 90.1/sec rates.

3. Absolute latency of wave III

From the Table 7, it can be seen that, in normals the wave III latency increased across the four repetition rates in all the 3 groups. The shift in latency is almost same at 11.1 and 30.1/sec in all the 3 age groups. But at higher repetition rates, the latency increase is more pronounced for II and III group compared to group I. ANOVA showed a statistical difference at 0.000 level (F = 46.49) at different age groups for all the repetition rates.

Table 7 : Depicts the means (M) and Standard Deviation (SD) of wave III latency and amplitude at different repetition rate for normakand subjects with sensorineural hearing loss at 80dBnHL.

Subjects	RR	Latency				Amplitude			
		Normals		SNHL		Normals		SNHL	
		M	SD	M	SD	M	SD	M	SD
1 group	11.1	3.72	0.097	3.71	0.14	0.30	0.11	0.25	0.074
(30-40 years)	30.1	3.80	0.15	3.83	0.12	0.20	0.10	0.28	0.087
	65.1	3.80	0.19	3.89	0.12	0.16	0.042	0.21	0.092
	90.1	4.04	0.10	4.12	0.080	0.13	0.056	0.23	0.13
II group	11.1	3.72	0.10	3.98	0.43	0.26	0.12	0.26	0.13
(40-50 years)	30.1	3.95	0.087	4.04	0.41	027	0.13	0.20	0.11
	65.1	4.04	0.15	4.03	0.38	0.15	0.087	0.25	0.078
	90.1	4.13	0.12	4.16	0.21	0.20	0.060	0.13	0.127
III group	11.1	3.85	0.18	4.00	0.17	0.17	0.069	0.24	0.097
(50-65 years)	30.1	3.88	0.17	4.07	0.20	0.18	0.064	0.18	0.097
	65.1	4.05	0.15	4.31	0.41	0.13	0.034	0.14	0.058
	90.1	4.23	0.15	4.46	0.37	0.14	0.040	0.15	0.045

Table 8 : Duncan's post hoc test results for wave III latency at 80dBnHL at different repetition rates for normal subjects.

Point	N	Subset for alpha = 0.05			
		1	2	3	4
11.1	31	3.76			
30.1	30		3.89		
65.1	30			4.04	
90.1	23				4.16

Duncan's post hoc test (Table 8) showed that there was a significant difference in latency across the rates.

The shift in wave III mean latency in normal subjects in the age range of 30-40, 40-50 and 50-65 years between two repetition rates are approximately 0.32 msec, 0.32 msec and 0.38 msec respectively. The difference is more in the older age group than in the younger adults.

Table 9 : Duncan's post hoc test results for wave III latency at 80dBnHL at all repetition rates for subjects with sensori-neural hearing loss.

Point	N	Subset for alpha = .05	
		1	2
11.1	28	3.89	
30.1	26	3.96	
65.1	15		4.06
90.1	12		4.17

Table 7 shows that subjects with sensori-neural hearing loss also have an increase in latency across all the age groups. This increase in latency is comparatively

less in group I compared to II and III group. Overall there was a increase in latency at higher repetition rate in group **III.** ANOVA showed a significant effect at 0.040 level (F = 2.905), but Duncan's post hoc test (Table 9), showed significant latency shift between lower (11.1 and 30.1/sec) and higher repetition rate (65.1 and 90.1/sec). However, the mean latency shift was higher between 65.1 /sec to 90.1/sec rates than 11.1/sec and 30.1/sec.

The difference in mean latencies between two repetition rates in normal subjects are approximately 0.41 msec, 0.18 msec and 0.46 msec in 30-40, 40-50 and 50-65 age groups respectively. The difference was more pronounced in I and III group compared to II group.

4. Amplitude of wave III

Inspection of Table 7 reveals that in normal subjects the amplitude value decreases across different rates for all the three groups. Compared to low repetition rates (11.1, 30.1/sec) the reduction in amplitude was more at higher repetition rates. It is also evident that the amplitude reduction is more at group III compared to I and II group. ANOVA showed a significant variation within the subjects and across the groups at 0.000 level (F = 7.215).

Table 10 : Duncan's post hoc test results for wave III amplitude at 80dBnHL at different repetition rates for normal subjects.

Point	N	Subset for alpha = 0.05	
		1	2
11.1	31		0.22
30.1	30		0.24
65.1	30	0.15	
90.1	23	0.16	

The Duncan's post hoc test (Table 10) revealed that the amplitude values at two repetition rates (11.1 and 30.1/sec) were significantly different than that of 65.1 and 90.1/sec. But there was no significant difference between 11.1 and 30.1/sec and 65.1 and 90.1/sec repetition rates.

It can be noted that in subjects with sensorineural hearing loss, the amplitude values were almost same across the rates in I and II group. But in group III, the amplitude was relatively good at 11.1 and 30.1/sec rate but reduced at higher repetition rates. ANOVA showed that there was no significant difference between amplitude values across different rates and across subjects and across groups.

Table 11 : Duncan's post hoc test results for wave III amplitude at 80dBnHL at all repetition rates for subject with sensorineural hearing loss.

Point	N	Subset for alpha = 0.05
11.1	28	0.25
30.1	26	0.22
65.1	15	.20
90.1	14	0.19

Duncan's post hoc test (Table 11) revealed that there was no significant difference in amplitude at different rates across the age groups.

5. Absolute latency of wave V

In the table 12 it can be seen that, in all the 3 normal subject groups, there is a linear increase in latency as the repetition rate increases.

It is also evident from the table that as the age increases, the latency also increases even at lesser repetition rates. ANOVA showed that the difference was significant at 0.000 level (F = 35.515).

Table 12 : **Depicts the mean (M) and Standard Deviation (SD) for wave V latency and amplitude value at different repetition rate for normals and subjects with sensorineural hearing loss at 80dBnHL.**

Subjects	RR	Latency				Amplitude			
		Normals		SNHL		Normals		SNHL	
		M	SD	M	SD	M	SD	M	SD
I group	11.1	5.52	0.17	5.62	0.11	0.45	0.15	0.54	0.20
(30-40 years)	30.1	5.64	0.16	5.72	0.15	0.39	0.085	0.45	0.15
	65.1	5.82	0.13	5.94	0.13	0.36	0.088	0.30	0.055
	90.1	6.03	0.15	6.03	0.15	0.32	0.089	0.28	0.11
II group	11.1	5.63	0.21	5.76	0.48	0.46	0.22	0.49	0.25
(40-50 years)	30.1	5.73	0.20	5.99	0.56	0.39	0.199	0.37	0.17
	65.1	5.98	0.167	6.29	0.58	0.367	0.164	0.24	0.14
	90.1	6.11	0.18	6.52	0.61	0.29	0.17	0.23	0.10
III group	11.1	5.74	0.17	5.96	0.24	0.40	0.16	0.52	0.23
(50-65 years)	30.1	5.90	0.22	6.10	0.27	0.35	0.13	0.36	0.17
	65.1	6.10	0.26	6.37	0.33	0.26	0.064	0.31	0.18
	90.1	6.28	0.21	6.58	0.33	0.25	0.09	0.22	0.14

Table 13 : Duncan's post hoc test results for wave V latency at 80dBnHL at all the repetition rates for normal subjects.

Point	N	Subset for alpha = 0.05			
		1	2	3	4
11.1	31	5.66			
30.1	32		5.79		
65.1	32			6.01	
90.1	32				6.15

The Duncan's post hoc test (Table 13) revealed that the latency values were significantly different at each repetition rate across the groups. The shift in **wave** V mean latency between 11.1 and 90.1/sec rates in normal subjects are approximately 0.51 msec, 0.48 msec and 0.54 msec in the age range of 30-40, 40-50 and 50-65 years respectively.

Inspection of the table 12 shows that in subjects with sensorineural hearing loss, there is a general trend seen i.e., there is an increase in latency as repetition rate increases across the age groups. This latency shift is less observed in group I compared to II and III group wherein the increase is relatively more. ANOVA revealed a main effect at 0.000 level (F = 12.705).

Table 14 : Duncan's post hoc test results for wave V latency at 80dBnHL at all repetition rates for subjects with sensorineural hearing loss.

Point	N	Subset for alpha = 0.05	
		1	2
11.1	32	5.75	
30.1	32	5.92	
65.1	30		6.17
90.1	30		6.37

Duncan's post hoc test (Table 14) showed that there was a significant difference in latency seen across the age groups at slower repetition rates (11.1 and 30.1/sec) compared to higher repetition rates.

In subjects with sloping sensorineural hearing loss the shift of the wave V latency between two repetition rates are approximately 0.41 msec, 0.76 msec and 0.62 msec in the age range of 30-40, 40-50 and 50-65 years respectively. Greater shift was noticed in older age group.

6. Amplitude of wave V

Table 12 reveals that in normal subjects the amplitude values reduced across the repetition rates. There is not much difference across the age groups, but amplitude values were reduced in II and III group at higher repetition rates. ANOVA showed that the amplitude values are statistically different at 0.000 level (F = 6.888) across rates.

Table 15 : Duncan's post hoc test results for wave V amplitude at 80dBnHL at all repetition rates for normal subjects.

Point	N	Subset for alpha = 0.05		
		1	2	3
11.1	31			0.4406
30.1	32		.3797	
65.1	32	.3269		
90.1	32	.2869		

From the table 12, it can be observed that, sensorineural hearing loss subjects had higher amplitude values at slower repetition rates compared to that of higher repetition rates across the age groups. ANOVA showed that there was a statistically significant difference in amplitude at 0.000 level (F = 16.63).

Table 16 : Duncan's post hoc test results for wave V amplitude at 80dBnHL at alt repetition rates for subjects with sensori neural hearing loss.

Point	N	Subset for alpha - 0.05		
		1	2	3
11.1	32			.52
30.1	32		0.39	
65.1	32	0.24		
90.1	30	0.28		

Duncan's post hoc test revealed statistically different value for amplitude at all rates, but showed no significant difference at 65.1 and 90.1/sec rates in both normals and subjects with sensorineural hearing loss.

B. Latency - Intensity functions (L-I function)

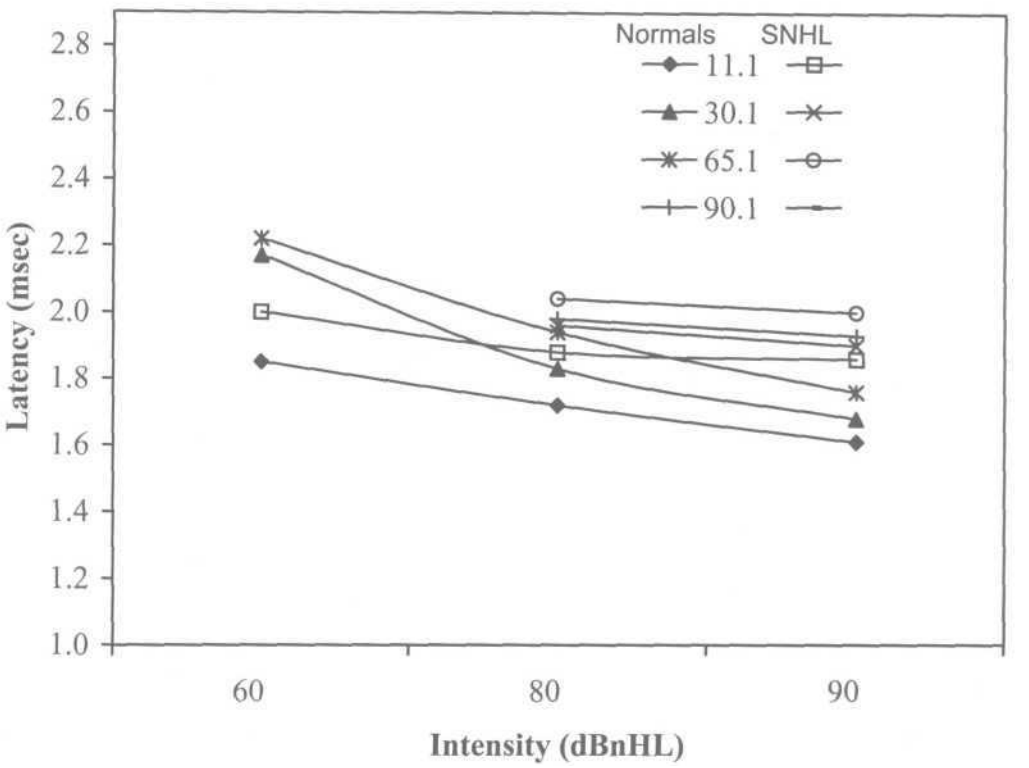
1. L-I function for waves I, III and V

To study the effect of intensity and repetition rate on ABR parameters, the latency-intensity functions were plotted for the waves I, III and V at different repetition rates for normals and subjects with sensorineural hearing loss in the age range of 30-40, 40-50 and 50-65 years respectively.

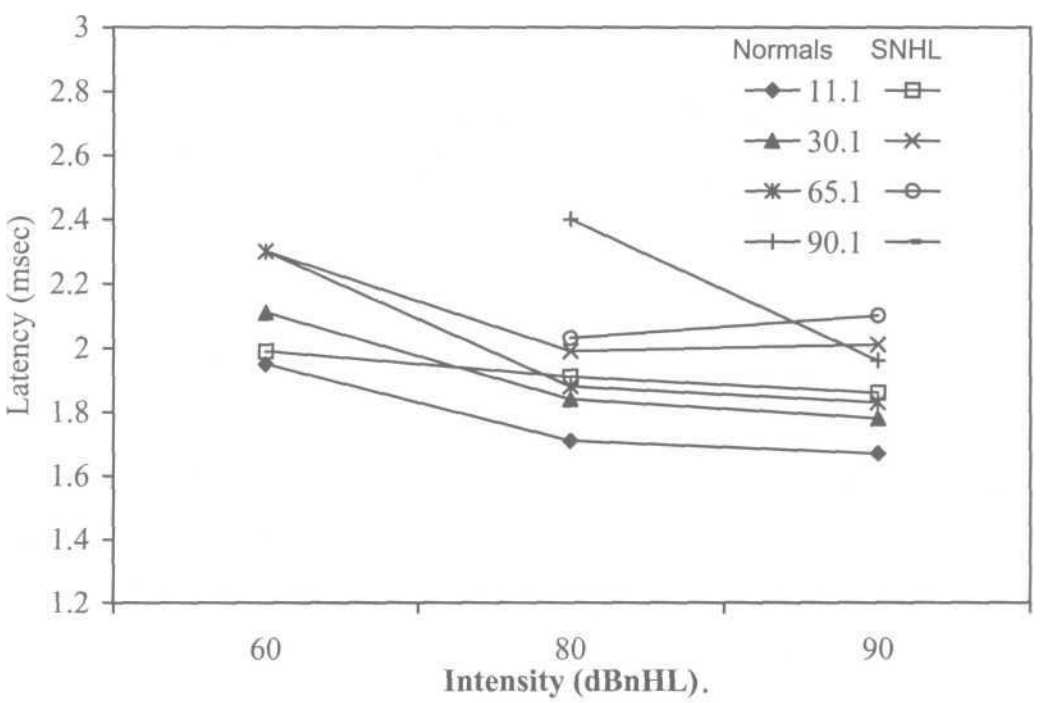
It can be observed from the graphs (1-9) that the latency values of normals fell well below the subjects with sensorineural hearing loss at all repetition rates.

It is also evident that the latency shift is more at higher repetition rates in the low intensity range of 60-80 dBnHL compared to 80-90 dBnHL in both normals and subjects with sensorineural hearing loss for all age groups.

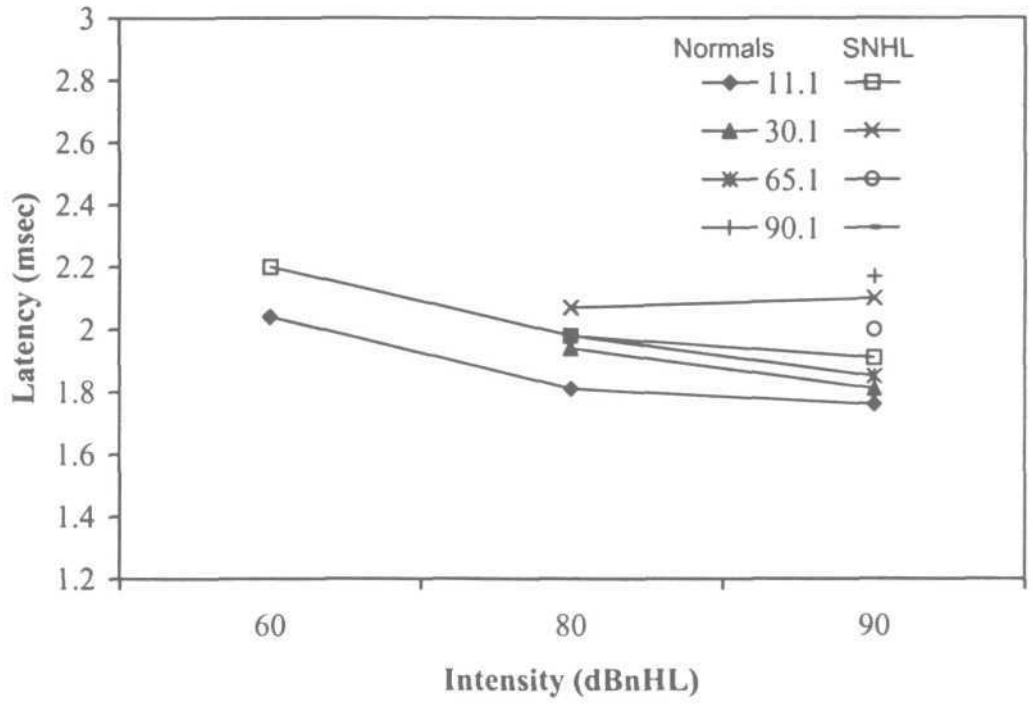
The slope is slightly steeper i.e., more shift is seen in latency in subjects with sensorineural hearing loss compared to normals.



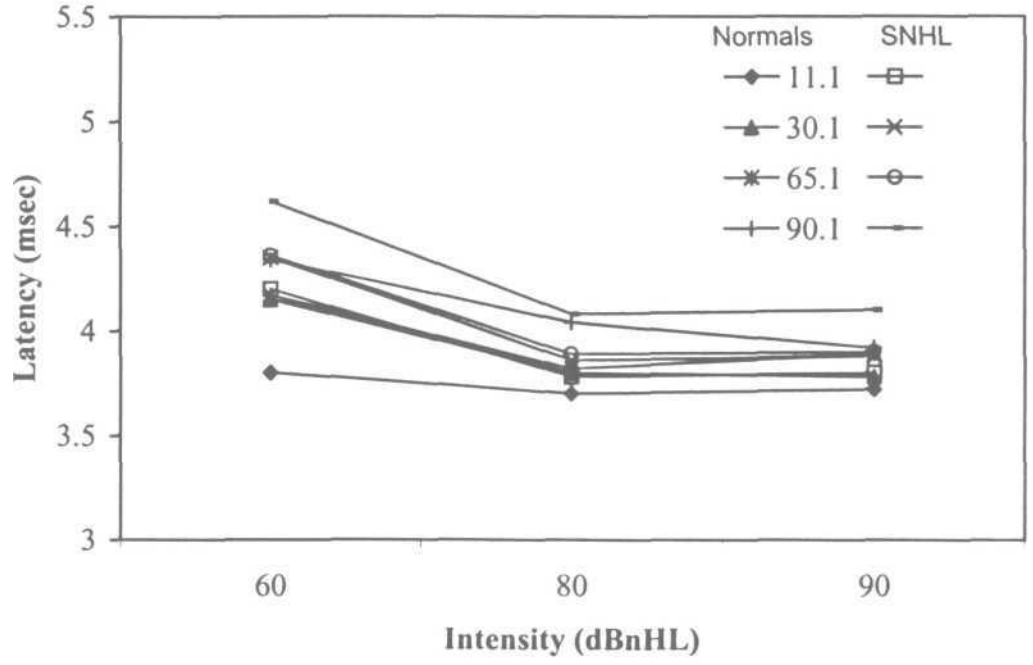
Graph-1 : Showing the latency-intensity function for wave-I at different repetition rate (RR) for normals and subjects with sensorineural hearing loss (SNHL) in the age range of 30-40 years.



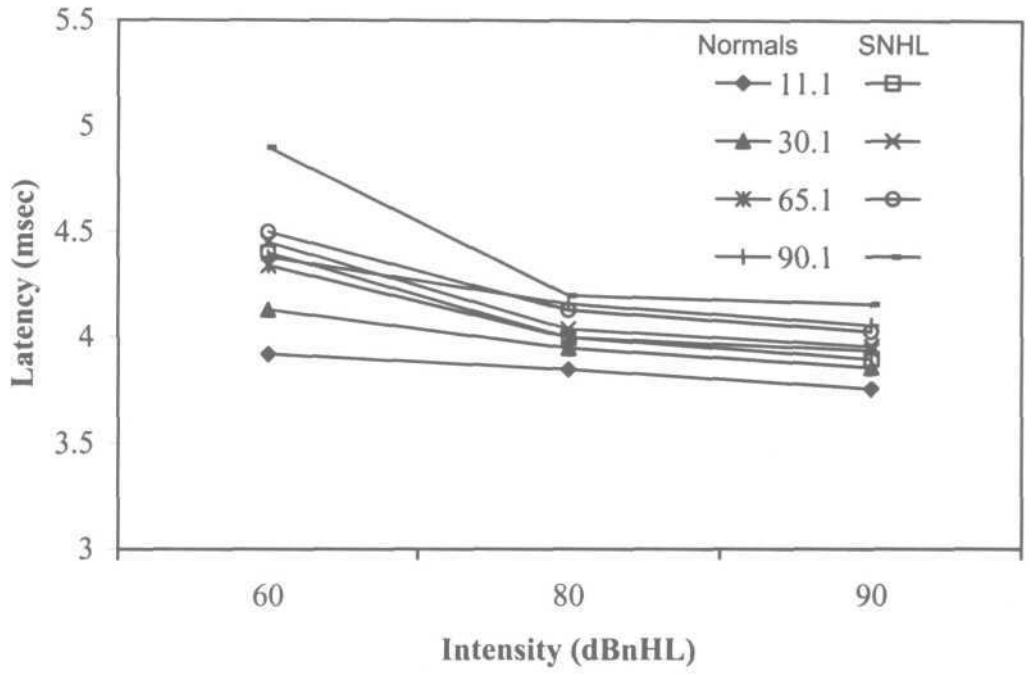
Graph-2 : Showing the latency-intensity function for wave-I at different repetition rate (RR) for normals and subjects with sensorineural hearing loss (SNHL) in the age range of 40-50 years.



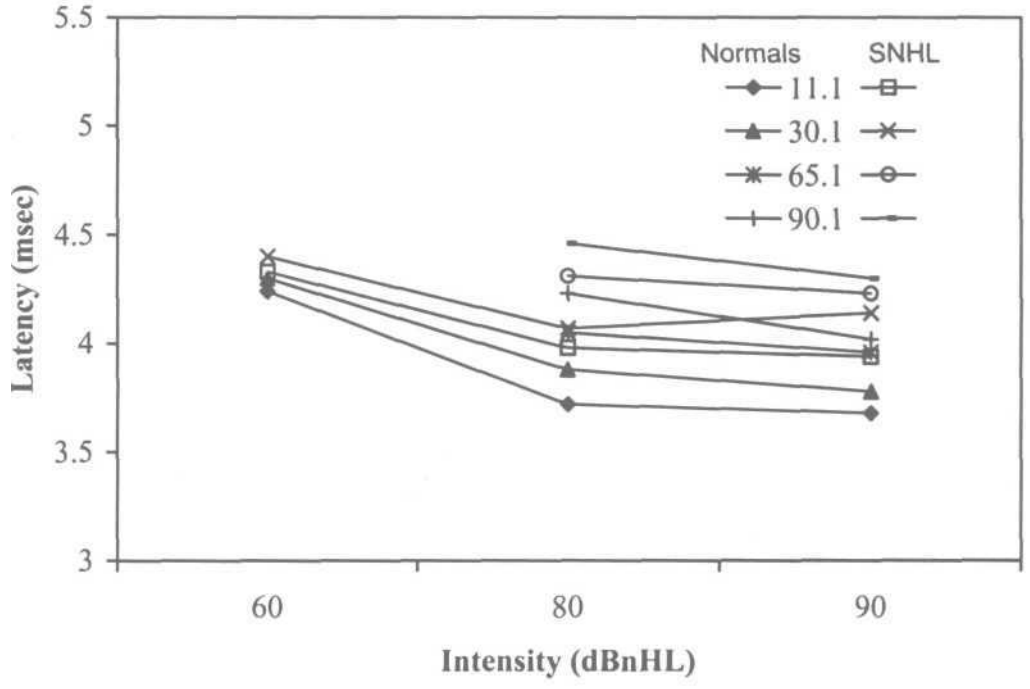
Graph-3 : Showing the latency-intensity function for wave-I at different repetition rate (RR) for normals and subjects with sensorineural hearing loss (SNHL) in the age range of 50-65 years.



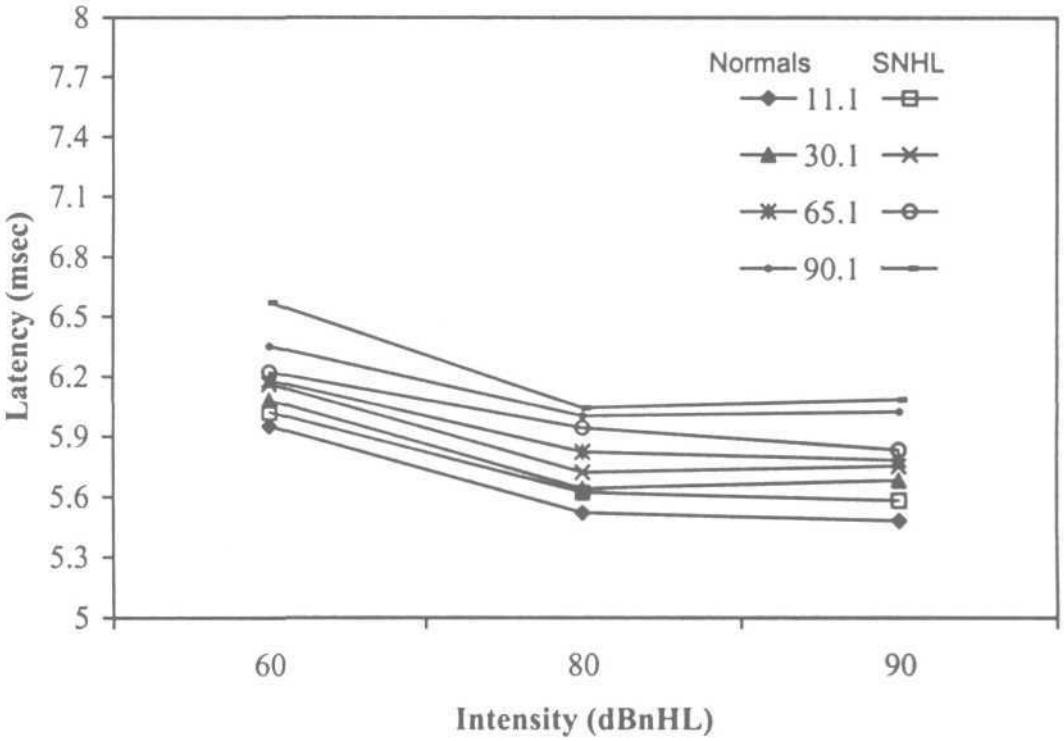
Graph-4 : Showing the latency-intensity function for wave-Ill at different repetition rate (RR) for normals and subjects with sensorineural hearing loss (SNHL) in the age range of 30-40 years.



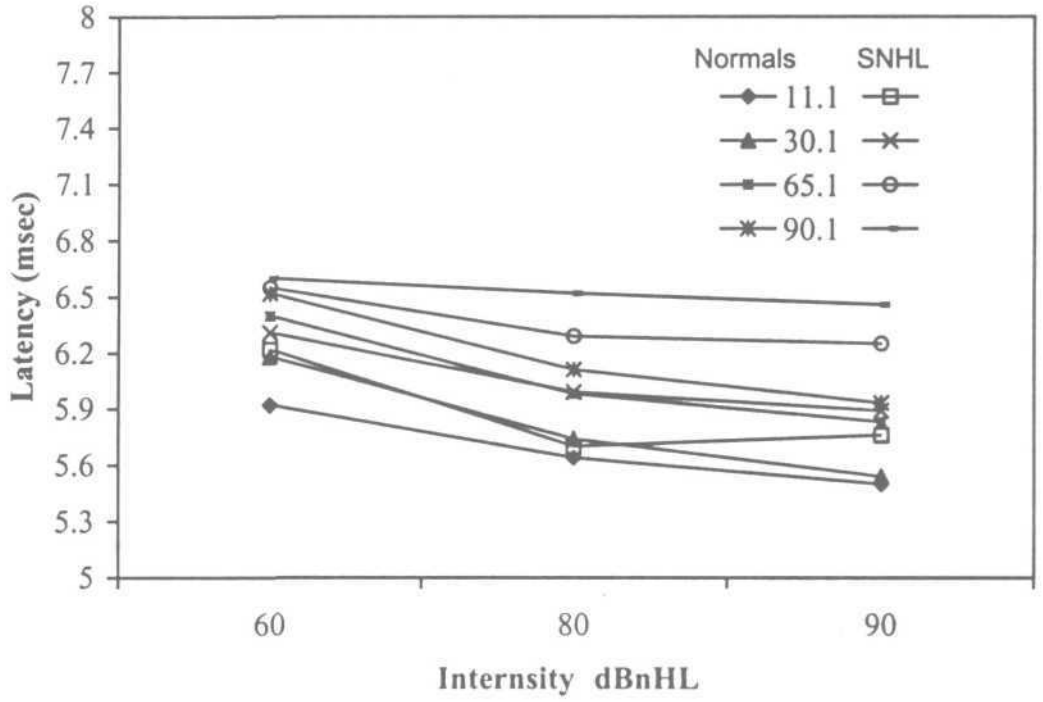
Graph-5 : Showing the latency-intensity function for wave-Ill at different repetition rate (RR) for normals and subjects with sensorineural hearing loss (SNHL) in the age range of 40-50 years.



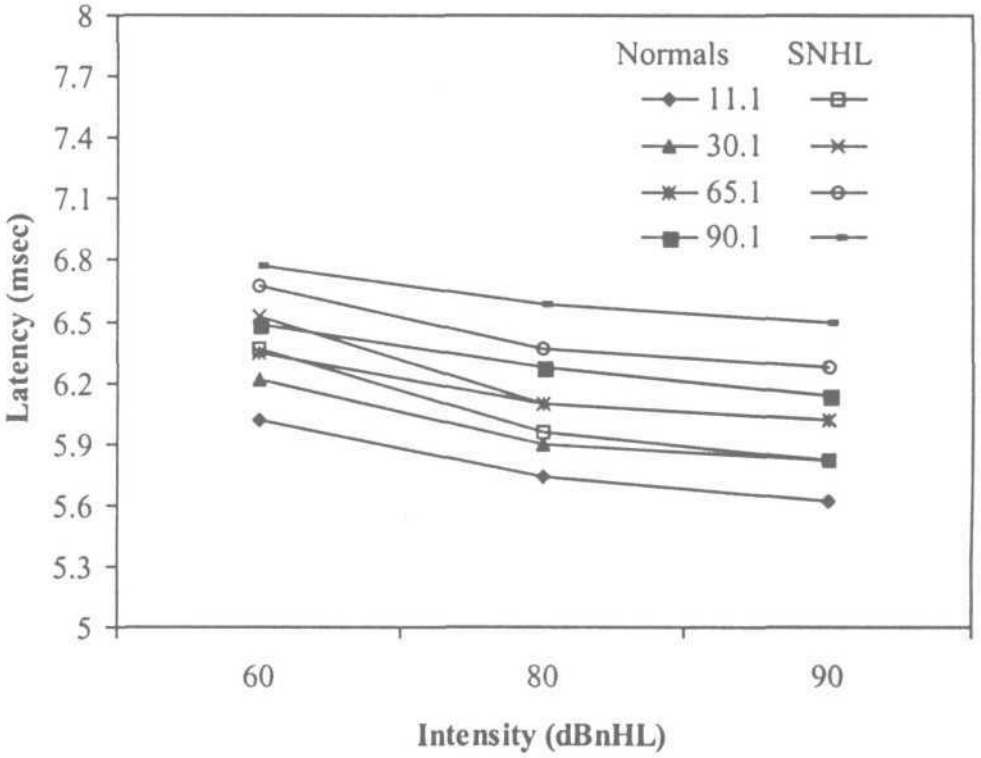
Graph-6 : Showing the latency-intensity function for wave-Ill at different repetition rate (RR) for normals and subjects with sensorineural hearing loss (SNHL) in the age range of 50-65 years.



Graph-7: Showing the latency-intensity function for wave-V at different repetition rate (RR) for normals and subjects with sensorineural hearing loss (SNHL) in the age range of 30-40 years.



Graph-8 : Showing the latency-intensity function for wave-V at different repetition rate (RR) for normals and subjects with sensorineural hearing loss (SNHL) in the age range of 40-50 years.



Graph-9: Showing the latency-intensity function for wave-V at different repetition rate (RR) for normals and subjects with sensorineural hearing loss (SNHL) in the age range of 50-65 years.

It is evident that as the repetition rate increases, the latency shift also increases and the shift in latency is negligible in the intensity range of 80-90 dBnHL.

C. Interwave Intervals (IWI's): I - III, III-V and I-V

The mean values of IWI's I-III, III-V and I-V for normals and subjects with sensorineural hearing loss across different age groups at all repetition rates are shown in table 17.

Table 17 : Depicts the mean values ofinterwave intervals at 80dBnHL for normals and subjects with sensori neural hearing loss at all repetition rates.

Subjects	RR	I-III		III-V		I-V	
		Normals	SNHL	Normals	SNHL	Normals	SNHL
		Means	Means	Means	Means	Means	Means
Group I (30-40 years)	11.1	2	1.91	1.8	1.91	3.8	3.82
	30.1	1.97	1.87	1.84	1.89	3.81	3.76
	65.1	1.86	1.78	2.14	1.93	4	3.71
	90.1	2.14	2.06	1.91	1.99	4.05	3.82
Group II (40-50 years)	11.1	2.14	2.09	1.78	1.76	3.92	3.85
	30.1	2.11	2.05	1.78	1.95	3.89	4
	65.1	2.16	2.1	1.94	2.16	4.1	4.26
	90.1	1.76	-	1.95	2.49	3. 71	-
Group III (50-65 years)	11.1	1.74	2.07	2.02	1.98	3.76	4.05
	30.1	1.94	2.09	2.02	2.03	3.96	4.12
	65.1	-		2.05	2.06	-	-
	90.1	-	-	2.05	-	-	-

In table 17, it can be observed that, the interwave latency difference is reduced in subjects with sensory neural hearing loss for both I-V and I-III in comparison to normals for group I. III-V IWI didn't show any specific pattern.

The I—III and I-V peak latency showed a tendency to increase with age at same repetition rate. In the older group especially, sensory neural hearing loss cases showed maximum I-V IWI.

DISCUSSION

The absolute latency of waves

The results of the present study has clearly shown the differential effect of repetition rate on ABR in normal adults and subjects with sloping sensorineural hearing loss.

In subjects with normal hearing and sensorineural hearing loss, the latencies of waves I, III and V increased with the increase in repetition rate with in the subjects and also across the age groups for same repetition rate.

The neurophysiological mechanisms responsible for observed latency shifts with increased rate in normals is due to cumulative neural fatigue and adaptation, and incomplete recovery involving hair-cell-cochlear-nerve junction and also subsequent synaptic transmission. The effect of rate would be additive as the number of synapses increases from wave I through wave V (Hall, 1992). Latency shifts seen with increase in rate in normals may also be due to a change in cochlear receptor function (Don, Allen & Starr, 1977), the refractory period of neural elements, and decrease in synaptic efficacy (Pratt & Sohmer, 1976) due to which conduction rate decreases and there is increase in latency.

In pathological conditions, these mechanisms are altered which results in the observed prolonged latency shifts and / or absence of the ABR waves when stimulus rate is increased (Yagi & Kaga 1979; Pratt, Ben-David, Peled, Podoshin & Scharf, 1981, cited in Gerling & Finitzo-Hieber, 1983).

The increase in latency with the increase in rate is comparatively more in older subjects in both normals and subjects with sensorineural hearing loss.

The possible reason for greater latency shift in elderly is that there is a tendency to reduce conduction rate due to the physiological changes takes place in elderly resulted due to lack of myelinization (Yakolev & Lecours, 1957,cited in Fujikawa &Weber,1977). There is also a possibility of reduction in number of nerve fibers available. This deterioration can be seen as a decrement in brain weight (Bondareff,1959 cited in Fujikawa & Weber, 1977) a deminution in cell size (Feldman & Peters, 1975, cited in Fujikawa & Weber, 1977) and a reduction in cell count (Yakolev & Lecours, 1957 cited in Fujikawa & Weber, 1977). Based on the observations we can conclude that there is a reduction in conduction rate in both group II and III, which is relatively greater in group III.

In normals and subjects with sensorineural hearing loss, there is an increase in latency across the same age group and across repetition rate. This is because there is a tendency to reduce conduction rate especially at higher repetition rate due to physiological changes (Yakolev & Lecours, 1957 cited in Fujikawa & Weber, 1977).

The present study has shown difference in latency shift between normals and subjects with sensorineural hearing loss whereas several investigators (Don, Allen & Starr, 1977; Rowe, 1978; Chiappa, 1979; Pratt, Ben-David & Paled, 1981; Zollner & Eibach, 1981; Fowler & Noffsinger, 1983 & Lasky, 1984, cited in Gerling & Finitzo. Hieber, 1983) have reported no significant differences in wave V latency shits

between groups of hearing impaired and normal hearing subjects as repetition rate is increased.

The latency shift between 11.1 to 90.1/sec repetition rate is lesser for wave I than wave III and V. In the present study the latency shift is approximately 0.2 msec to 0.3 msec for wave I, 0.3 msec to 0.4 msec for wave III and 0.5 msec to 0.6 msec for wave V in normal subjects. Whereas these shifts were more in subjects with sensorineural hearing loss which is approximately 0.4 msec or more for wave I, 0.4 to 0.5 msec for wave III and .6 msec to 0.8 msec for wave V. The greater latency shift for higher waves is mainly due to the cumulative neural fatigue and adaptation, incomplete recovery of hair-cell-cochlear-nerve-junction and also subsequent nerve transmission which is greater for higher waves (Hall, 1992).

Yagi and Kaga (1979), Gerling and Finitzo-Heiber (1982), Gerling (1989) have also reported greater shift in latency for later waves than for earlier waves and they observed a wave V latency shift of 0.4 - 0.6 msec. Where as Van Olphen, Rodenburg and Verwey (1979) reported of approximately 0.4 msec latency shift for all ABR components.

Terkildsen, Osterhammel and Huis in't veld (1975), Zollner, Karnahl and Strange (1976) reported a wave I latency shift of 0.4 to 0.5 msec which was much greater than the shift seen in this study in normals but similar latency shift is seen in subjects with SN hearing loss. However, Hyde, Stephens and Thornton (1976); Jewett and Williston (1971, cited in Schwartz & Beery, 1985) have not reported such changes in wave I.

The latency shift is seen to be more for higher repetition rates above 30.1/sec. But shift is negligible below 30.1 / sec repetition rates. Jewett, Romano and Williston (1970), Jewett and Williston (1971, cited in Schwartz & Berry, 1985) have also not observed any effect on ABR in normal adults for the stimulus upto repetition rates of 20/ sec and above this they have observed gradual increase in latency. Gerling and Finitzo-Hieber (1983) also observed less shift of wave V till 20/ sec stimulus rate.

Amplitude values

In subjects with normal hearing and sensorineural hearing loss, the amplitude of wave I & III reduced with the increase in repetition rate within the subjects and in elderly adults.

One possible explanation for this finding is the phenomenon related to refractoriness and reduced efficiency at the synaptic junction and increased neural asynchrony which is more prominent at higher repetition rates (Thornton & Coleman, 1975, cited in Fujikawa & Weber, 1977). Whereas the V amplitude shows less decrement with increasing rate than earlier components. These results are supported by Jewett and Romano and Williston (1970) and Jewett, Williston (1971, cited in Schwartz & Berry, 1985) who have found that wave V amplitude is affected minimally at relatively high rates of presentation.

Subjects in the older group has shown greater amplitude reduction than younger adults. This is because of the physiological changes (neural) leading to number of neuron available for transduction and lack of synchronization with age resulted in more reduction in amplitude (Thornton and Coleman, 1975, cited in

Gerling & Finitzo-Hieber, 1983) and also could be due to loss of myelinization (Yakolev & Lecours, 1957, cited in Fujikawa & Weber, 1977). Another possibility is that it could be due to the neural fatigue and adaptation (Hall, 1992). The reduction in amplitude with rate and age seen in this study are in agreement with that of Harkins 1981, cited in Fowler and Noffsinger, 1983, who has found reduced amplitude in the elderly group.

There is a disappearance of wave I at higher repetition rate and this is seen across all the three age groups. This is in agreement with Lightfoot (1992) who also reported of disappearance of ABR waves in tumour free patients.

Jewett, Romano and Williston (1970), Jewett and Williston, 1971; cited in Schwartz & Berry, 1985, have also seen a similar effect on ABR waves with the increase in rates. They have observed 50% reduction in amplitude for wave I but typically less reduction in amplitude for wave V which is approximately 10-30% of the original amplitude seen at lower rates. Thus, this significant reduction in amplitude along with the deterioration of morphology at higher rate would have made it difficult to identify the waves especially wave I.

Disappearance of wave I was also seen in subjects with SN hearing loss in group II and III. This is expected as the wave I is more vulnerable to get affected by high frequency SN hearing loss (Silman & Silverman, 1997). This is because the wave I is thought to be maximally contributed by the basal part of the cochlea due to it's shortest latency (Coats & Martin,1977). Thus the disappearance of wave I in

Group II and Group III may be due to hearing loss and may not be solely due to neurological changes.

Latency and Amplitude

In general the latency shift was seen more for wave III and V and reduced amplitude for wave III which was more in Group II and Group III. Whereas it was less for wave I. This is in par with the findings of Don, Allen and Starr (1977), Fowler and Noffsinger (1983) that wave II, III and IV are more vulnerable to rate effect. Whereas Harkins (1981, cited in Fowler & Noffsinger, 1983) found no differences in latency values at high stimulus rates for young adults versus elderly and the reduced amplitude is seen in the elderly group. This variation was noticed for the elderly group with a mean age of 71 years. Fujikawa and Weber (1977), Despland and Galambos (1980), Picton, Stapells and Campbell (1981); cited in Lightfoot, 1992, have reported a rate latency shift of wave V is influenced by subject age and greater shifts was noticed at the extremes of age spectrum.

However in the present study a greater shift in latency and reduced amplitude is seen for individuals with age above 40 years for later waves. However in the literature several researchers have reported similar shift in latency and amplitude after 70 years of age. This suggests that there could be a tendency of early neural degeneration in Indian Population.

Latency-Intensity functions

In normal subjects there is not much difference in latency for waves I, III and V at the intensity range of 80-90 dBnHL. But there is more shift noticed between the 60-80 dBnHL intensity range. This is because in normals latency reaches saturation at

around 80dBnHL (Hall, 1992). Thus with the increase in intensity there will be not much change in latency.

At low intensity levels, latency is greatly delayed because only more apical (1000-2000Hz) cochlear regions contribute to the response. Higher intensity levels involve the region of 4000 Hz and higher frequencies, and these frequencies are represented at more basal portions of the cochlea which are activated with less travelling time along the basilar membrane. Therefore latency decreases sharply (Don, Eggermont, 1978). Don, Allen and Starr (1977) also seen the reduction in wave V latency with the increasing intensity.

It is also observed that as the repetition rate increases, the latency shift also increase rapidly. This increase in latency seen at higher repetition rates is because of the decreased efficiency of synaptic junction and reduction in neural firing rate (Terkildsen, Osterhammel & Huis in't Veld, 1975; Thornton & Coleman, 1975, cited in Fujikawa & Weber, 1977). Pratt and Sohmer (1976) related the phenomenon to refractoriness and a decreased efficiency at the synaptic junction,which could be more pronounced at lower intensities.

In subjects with sensori neural hearing loss the shift in latency is more than the normals. In pathological condition, the mechanism is probably altered resulting in the more latency shifts (Pratt & Sohmer, 1976; Yagi & Kaga, 1979). This variation also could be due to some amount of neural involvement in older age group resulting in more shift in latency. Additional shift also could be due to the interactive effect of age, rate, intensity and pathological condition. Coats and Martin, 1977 and Hall, 1992,

also reports of a similar effect in sensorineural hearing loss cases. Whereas Don, Allen and Starr (1977) could not observe any specific trend of latency shift with the intensity variation.

Interwave Intervals

In subjects with normal hearing the I—III and I-V IWI's was comparatively greater compared to subjects with sensori-neural hearing loss. In subjects with sensori neural hearing loss, the I—III and I-V IWI was slightly less in group I. This is because hearing impairment has a greater effect on the latency of wave I than wave III and V, i.e., latency of wave I prolonged more than that of waves III and V, thus reducing the IWI for 1 -III and I-V IWI (Silman & Silverman, 1997). These results are in agreement with the results of previous investigations by Coats and Martin (1977) and Struzebecher, Kevanishvili, Webs, Mayer and Schmidt (1985) and Suresha(2001)

However, inter-wave-interval for I-III, and I-V was more in case of group II and III especially in subjects with sensorineural hearing loss. This also suggests that there could be normal physiological changes associated with nerve due to aging brought this changes with the rate.

Elberling and Parbo (1987), Rowe (1978,cited in Silman & Silverman, 1997) also have seen the similar increase in IWI (IPL) with the age. However, Rosenhall, Bjorkman, Pedersen and Kall (1985, cited in Silman & Silverman, 1997) did not observe such variations.

At higher repetition rates the I-III IWI's are even more prolonged in both groups. This is because at higher repetition rates there is reduced synaptic efficiency (Pratt & Sohiner, 1976). This is more effective towards higher peaks resulting in prolongation of I-III IWI. In the older age group, there is a prolongation of I-V IWI, which also suggest nerve involvement.

SUMMARY AND CONCLUSION

The effects of increasing stimulus repetition rate on the ABR have been investigated in normals, hearing impaired subjects with neurologic abnormality (Chiappa, 1979, cited in Gerling & Finitzo-Hieber, 1983). It is found that as repetition rate increases above 20/sec, the latencies of waves III and V increases and waveform morphology changes. Disparities in literature exists regarding whether the amplitude of waves I, III and V decreases as repetition rate increases (Chiappa, 1979; Rowe, 1978, cited in Gerling & Finitzo-Hieber, 1983). Repetition rate also interacts with age. Few studies have shown no difference in latency values at high stimulus rates for young versus elderly adults but amplitude reduced in the elderly group. The influence of hearing loss on repetition rate effects has not been clearly established. Few studies have reported no significant differences in wave V latency shifts between groups of hearing impaired and normal hearing subjects as repetition rate increased. Hence the present study was designed to investigate the effect of repetition rate in normals and subjects with SNHL in adults and elderly adults.

Thus the present study was taken

1 .To obtain the

a. Absolute latency and amplitude of waves in different age groups of individuals with normal hearing and sloping sensori neural hearing loss at different rates.

b. Latency - Intensity function at different repetition rates.

c. Interwave intervals for different repetition rates across the age groups.

2. To study the effect of repitition rate on ABR across the age groups.

3. To find out the age at which different parameters of ABR show more variations.

For this purpose ABR was recorded for click stimuli across ages (30-40, 40-50 & 50-65 years) for 30 normals and 30 subjects with sloping SNHL across repetition rates (11.1, 30.1, 65.1 and 90.1/sec) and at different intensities (90dBnHL, 80dBnHL & 60 dBnHL). One-way ANOVA was carried out to analyse the data collected.

Results of the study indicated that:

1. In subjects with normal hearing and sloping sensorineural hearing loss the latencies of waves I, III and V increased with the increase in repetition rate within the subjects and across age groups for the same repetition rate.
2. Increase in latency is comparatively greater especially for later peaks in older subjects in both normals and subjects with sensorineural hearing loss.
3. There is a difference in latency shift between normals and subjects with SNHL across rates.
4. Greater latency prolongations for later waves than for earlier waves is seen in both the groups.
5. Amplitude of waves I and III reduced with the increase in repetition rate across age groups, whereas the amplitude of wave V showed less decrement with increasing rate.
6. Reduction in amplitude is more in subjects with SNHL compared to normals.
7. The latency-intensity function shift is more at higher repetition rates in the low intensity range of 60-80 dBnHL in both normals and subjects with SNHL.
8. In subjects with SNHL, the L-I functions are steeper than normal.
9. The interwave latency is reduced in subjects with SNHL for both I-V in I-III IWI for younger group.

10. In subjects with sensorineural hearing loss, the older age groups showed maximum I-V interwave intervals.

Thus, it can be concluded that one can expect shift in latency and decreased amplitude for higher repetition rates and this effect will be greater at lower intensity and also in the older age group. The approximate latency shift of wave V can be 0.5 msec to 0.6 mesc in normals and 0.6 msec to 0.8 msec in subjects with sensorineural hearing loss when rate is increased from 11.1/sec to 90.1/sec. From the results obtained it also may be concluded that one can expect more variation in later waves in latency as early as 40's or at least by early 50's.

Implication

The present study gives an insight into how the latency varies across age, rate, and intensity in Indian population, which would definitely help one to differentiate abnormal neural involvement from the normal physiological changes taking place due to aging. This study also adds more information to the literature carried out in this regard. It also gives an idea to the future researchers to carry out similar studies on cases with space occupying lesions and compare the results obtained from the current study to assess the sensitivity of ABR.

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