CHAPTER 7

EFFECT OF NONPATHOLOGICAL FACTORS ON BAEP WAVEFORM CHARACTERISTIC

7.1 INTRODUCTION

Since clinical interpretation of Brainstem Auditory Evoked Potential (BAEP) waveforms concerns with their absolute peak latencies, interpeak latencies and amplitudes, one who is attending in any BAEP waveform study should have clear idea bout the factor effects on BAEP waveform characteristics. Age, sex, stimulus variables, etc are some of non pathological factors that can change the absolute peaks latency, interpeak latency and amplitudes of the BAEP waveform components.

From a normal adult subject, a BAEP waveform of usually with seven waves which is a complex waveform with different peak latency and amplitude are recorded. These waves are obtained within 10 msec after the onset of click stimulus. In BAEP waveform the first five waves (I-V) are consistent and found in all normal adult subjects whereas waves VI and VII are variable and are recorded only in some of the stimulated ears.

In this chapters the effect of age and sex on BAEP waveform component of different normal adult subjects which are recorded from their ipsilateral (stimulated ear) and contralateral (non stimulated ear) ears are discussed. The BAEP waveform characteristics at both ears in mixed age and gender studied by various researchers (Stockard et al., 1978, Chiappa et al., 1979, Prasher et al., 1980).
The effect of increasing age after childhood results on prolongation of absolute peak latencies and interpeak latencies of all waves (Rowe, 1978, Jerger et al., 1980, Kjaer, 1980). Females had shorter absolute peak latencies and interpeak latencies than males (Beagle et al., 1978, Rosenhamer et al., 1980, Michalewski et al., 1980). So the effect of increasing age and sex difference on BAEP waveform components of both ears are considerable. These effects as the part of present work are investigated and discussed in detail in next section.

Stimulus variables are another factors that will significantly change the BAEP waveform characteristics. Increasing stimulus rates results in increased absolute peak latencies of all BAEP waveform components (Doble et al., 1980, Squires et al., 1980, Pratt et al., 1981, Gerling et al., 1983). Studies on stimulus rates (Pratt et al., 1981, Stockard et al., 1977) suggest that, increasing stimulus rate above 30 pulse per second will often worsen abnormalities seen at 10/s whereas Chiappa et al (1979) studied higher stimulus rate on various normal and abnormal patients and found that no such results as who were normal at the slower rates but abnormal at the faster rate. In present work various subjects in different age group and sex are selected to study their BAEPs absolute peak latencies and interpeak latencies in different stimulus repetition rates. This work is shown the variations in each waveform components according to increasing the age and sex. This results may be useful in BAEP waveform interpretation in neuroclinical laboratories when investigation on each BAEP waveform components is concerned.

Changes in stimulus intensity can also produce marked changes in the absolute peak latencies and interpeak latencies of all BAEP waveform (Jewett, 1970, Salomon et al., 1971, Picton et al., 1974). Here the increased stimulus intensities with increasing the age in either sex are investigated to demonstrate the amount of absolute peak latency and inter peak latency changes in each age group for each sex. Study of those changes specially in
lower stimulus intensities can be helpful when interpretation of individual peaks are under study.

The last study in this section is about the calculation of BAEP waveform component frequencies. In routine BAEP waveform interpretation usually the values of absolute peak latencies and interpeak latencies are used as the measure of peaks normal or abnormality. These values may exceed by a fraction of point according to the values reported by Stockard et al (1977) and the neurological laboratory or neurophysiologist may fallen to confuse whether that value have to be considered as normal or abnormal peak where as by using the frequency spectrum analysis as the peak variation are shown wider the study of peak variation could be more precisely. In this study the BAEP data are collected from normal and abnormal patients in different age and are presented in frequency spectrum to calculate the level of each peak frequency.

7.2 EFFECT OF AGE AND SEX ON STIMULATED AND NON STIMULATED BAEP WAVEFORM COMPONENTS

The Brainstem Auditory Evoked Potentials (BAEPs) to the ipsilateral (stimulated ear) and contralateral (non stimulated ear) ears of each subjects are is recorded from electrodes placed one at the midvertex (Cz), on the mastoid bones or earlobules and one on the forehead or wrist as ground. The acoustic stimulus used was a click of pulse wave, 100 micro second in duration. The click intensity for this recording was 90 db with a click rate of 20 pulse per second. The differential input from the ipsilateral and contralateral ear is filtered for a band pass of 100-3000 Hz and amplified for a gain $5 \times 10^5$ times. The recorded responses for 10 m sec. after the onset of stimulus is averaged for 2048 clicks in a two channel averager and displayed on a monitor. In this recording atleast two trials for each ear are obtained and superimposed to demonstrate the consistency of the waveform. The most consistent and clearcut waveform are produced with
relaxed or sleeping subjects. This is due to elimination of muscle and movement artifacts. The averaging must be temporarily halted when excessive artifacts are present. The recording was done for fifty three normal adult subjects in different age group and sex with relaxed condition on a bed. The BAEP waveforms from both ear according to the subjects age and sex differences are displayed on the monitor.

7.2.1 Results

The results are obtained from fifty three (28 males and 25 females) normal adult subjects aged from 3 to 85 years. While analysis, the (I-V) recorded datas are grouped according to the patient ages in five different age groups namely 3-19, 20-29, 30-39, 40-49, 50-85 years. From the sample datas, the mean values of absolute peak latencies, interpeak latencies and standard deviation of each group for the ipsilateral and contralateral ears to stimulation in males subjects is studied (Tafti, et al., 1996). From the sample datas, the mean of absolute peak latencies, interpeak latencies and standard deviation of each age group from the ipsilateral and contralateral ears to stimulation ears in both sexes are calculated. The absolute peaks changes according to each group corresponds to ipsilateral and contralateral ears in male subjects are shown in tables 7.1 and 7.2. The corresponding values in females are shown in tables 7.3 and 7.4. Absolute peak latency obtained from the ipsilateral and contralateral ears of male and female subjects increased by increasing the subjects age. Females had shorter absolute peaks latency and interpeak latency than males. The latency of wave V in females were shorter compare to other waves. Waves I, II and V in contralateral ear had prolonged latency in both sexes compare to ipsilateral ear whereas waves III and IV in contralateral ears of both sexes were shorter. It can be seen from the tables that, the latency difference in wave V between the younger and older female subjects were larger in contralateral ear compare to waves I and III whereas in male subjects waves I and V were shorter compare to wave III.
Table 7.1 Absolute peak and inter peak latencies for different age, Males, Ipsilateral ear

<table>
<thead>
<tr>
<th>Waves</th>
<th>3-19 years Mean ± SD</th>
<th>20-29 years Mean ± SD</th>
<th>30-39 years Mean ± SD</th>
<th>40-49 years Mean ± SD</th>
<th>50-85 years Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1.53 ± 0.005</td>
<td>1.58 ± 0.048</td>
<td>1.63 ± 0.011</td>
<td>1.65 ± 0.015</td>
<td>1.83 ± 0.035</td>
</tr>
<tr>
<td>II</td>
<td>2.43 ± 0.044</td>
<td>2.60 ± 0.045</td>
<td>2.61 ± 0.053</td>
<td>2.51 ± 0.032</td>
<td>2.68 ± 0.122</td>
</tr>
<tr>
<td>III</td>
<td>3.54 ± 0.153</td>
<td>3.68 ± 0.068</td>
<td>3.74 ± 0.012</td>
<td>3.86 ± 0.120</td>
<td>3.92 ± 0.038</td>
</tr>
<tr>
<td>IV</td>
<td>4.55 ± 0.123</td>
<td>4.81 ± 0.052</td>
<td>4.72 ± 0.112</td>
<td>4.59 ± 0.025</td>
<td>4.91 ± 0.053</td>
</tr>
<tr>
<td>V</td>
<td>5.46 ± 0.081</td>
<td>5.59 ± 0.021</td>
<td>5.69 ± 0.028</td>
<td>5.74 ± 0.030</td>
<td>5.79 ± 0.072</td>
</tr>
<tr>
<td>I-III</td>
<td>2.01 ± 0.148</td>
<td>2.10 ± 0.020</td>
<td>2.11 ± 0.001</td>
<td>2.21 ± 0.105</td>
<td>2.09 ± 0.003</td>
</tr>
<tr>
<td>II-III</td>
<td>1.11 ± 0.109</td>
<td>1.08 ± 0.023</td>
<td>1.13 ± 0.041</td>
<td>1.35 ± 0.088</td>
<td>1.23 ± 0.084</td>
</tr>
<tr>
<td>III-V</td>
<td>1.92 ± 0.072</td>
<td>1.91 ± 0.047</td>
<td>1.95 ± 0.016</td>
<td>1.88 ± 0.090</td>
<td>1.87 ± 0.05</td>
</tr>
<tr>
<td>I-V</td>
<td>3.93 ± 0.076</td>
<td>4.01 ± 0.027</td>
<td>4.06 ± 0.017</td>
<td>4.09 ± 0.015</td>
<td>3.96 ± 0.039</td>
</tr>
<tr>
<td>III-IV</td>
<td>1.01 ± 0.030</td>
<td>1.13 ± 0.016</td>
<td>0.98 ± 0.100</td>
<td>0.73 ± 0.095</td>
<td>0.99 ± 0.015</td>
</tr>
<tr>
<td>IV-V</td>
<td>0.91 ± 0.042</td>
<td>0.78 ± 0.031</td>
<td>0.97 ± 0.084</td>
<td>1.15 ± 0.005</td>
<td>0.88 ± 0.019</td>
</tr>
</tbody>
</table>

All values in milliseconds
SD = Standard deviation
Table 7.2  Absolute peak and inter peak latencies for different age, Males, Contralateral ear

<table>
<thead>
<tr>
<th>Waves</th>
<th>3-19 years Mean + SD</th>
<th>20-29 years Mean + SD</th>
<th>30-39 years Mean + SD</th>
<th>40-49 years Mean + SD</th>
<th>50-85 years Mean + SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1.70 ± 0.270</td>
<td>1.73 ± 0.134</td>
<td>1.81 ± 0.230</td>
<td>1.79 ± 0.097</td>
<td>1.87 ± 0.150</td>
</tr>
<tr>
<td>II</td>
<td>2.48 ± 0.088</td>
<td>2.73 ± 0.014</td>
<td>2.73 ± 0.076</td>
<td>2.76 ± 0.107</td>
<td>2.86 ± 0.110</td>
</tr>
<tr>
<td>III</td>
<td>3.49 ± 0.128</td>
<td>3.60 ± 0.019</td>
<td>3.66 ± 0.043</td>
<td>3.80 ± 0.072</td>
<td>3.91 ± 0.071</td>
</tr>
<tr>
<td>IV</td>
<td>4.45 ± 0.080</td>
<td>4.80 ± 0.083</td>
<td>4.70 ± 0.083</td>
<td>4.75 ± 0.025</td>
<td>4.74 ± 0.130</td>
</tr>
<tr>
<td>V</td>
<td>5.64 ± 0.094</td>
<td>5.69 ± 0.018</td>
<td>5.82 ± 0.031</td>
<td>5.85 ± 0.055</td>
<td>5.80 ± 0.082</td>
</tr>
<tr>
<td>I-III</td>
<td>1.79 ± 0.142</td>
<td>1.87 ± 0.115</td>
<td>1.85 ± 0.187</td>
<td>2.01 ± 0.025</td>
<td>2.04 ± 0.079</td>
</tr>
<tr>
<td>II-III</td>
<td>1.01 ± 0.040</td>
<td>0.89 ± 0.005</td>
<td>0.93 ± 0.033</td>
<td>1.04 ± 0.035</td>
<td>1.05 ± 0.039</td>
</tr>
<tr>
<td>III-V</td>
<td>2.15 ± 0.034</td>
<td>2.09 ± 0.001</td>
<td>2.16 ± 0.012</td>
<td>2.05 ± 0.017</td>
<td>1.89 ± 0.011</td>
</tr>
<tr>
<td>I-V</td>
<td>3.94 ± 0.176</td>
<td>3.96 ± 0.116</td>
<td>4.01 ± 0.199</td>
<td>4.06 ± 0.042</td>
<td>3.92 ± 0.068</td>
</tr>
<tr>
<td>III-IV</td>
<td>0.96 ± 0.048</td>
<td>1.20 ± 0.064</td>
<td>1.04 ± 0.040</td>
<td>0.95 ± 0.069</td>
<td>0.83 ± 0.059</td>
</tr>
<tr>
<td>IV-V</td>
<td>1.19 ± 0.014</td>
<td>0.89 ± 0.065</td>
<td>1.12 ± 0.053</td>
<td>1.10 ± 0.030</td>
<td>1.06 ± 0.048</td>
</tr>
</tbody>
</table>

All values in milliseconds
SD = Standard deviation
Table 7.3  Absolute peak and inter peak latencies for different age, Females, Ipsilateral ear

<table>
<thead>
<tr>
<th>Waves</th>
<th>3-19 years</th>
<th>20-29 years</th>
<th>30-39 years</th>
<th>40-49 years</th>
<th>50-85 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean + SD</td>
<td>Mean + SD</td>
<td>Mean + SD</td>
<td>Mean + SD</td>
<td>Mean + SD</td>
</tr>
<tr>
<td>I</td>
<td>1.50 ± 0.023</td>
<td>1.54 ± 0.011</td>
<td>1.59 ± 0.011</td>
<td>1.59 ± 0.150</td>
<td>1.64 ± 0.057</td>
</tr>
<tr>
<td>II</td>
<td>2.37 ± 0.111</td>
<td>2.57 ± 0.038</td>
<td>2.52 ± 0.058</td>
<td>2.58 ± 0.019</td>
<td>2.62 ± 0.065</td>
</tr>
<tr>
<td>III</td>
<td>3.53 ± 0.015</td>
<td>3.49 ± 0.080</td>
<td>3.70 ± 0.030</td>
<td>3.67 ± 0.042</td>
<td>3.76 ± 0.015</td>
</tr>
<tr>
<td>IV</td>
<td>4.52 ± 0.127</td>
<td>4.57 ± 0.038</td>
<td>4.83 ± 0.013</td>
<td>4.92 ± 0.023</td>
<td>5.05 ± 0.025</td>
</tr>
<tr>
<td>V</td>
<td>5.36 ± 0.061</td>
<td>5.38 ± 0.038</td>
<td>5.37 ± 0.012</td>
<td>5.47 ± 0.017</td>
<td>5.56 ± 0.021</td>
</tr>
<tr>
<td>I-III</td>
<td>2.03 ± 0.008</td>
<td>1.95 ± 0.069</td>
<td>2.11 ± 0.019</td>
<td>2.08 ± 0.108</td>
<td>2.12 ± 0.042</td>
</tr>
<tr>
<td>II-III</td>
<td>1.16 ± 0.096</td>
<td>0.92 ± 0.042</td>
<td>1.18 ± 0.028</td>
<td>1.09 ± 0.023</td>
<td>1.14 ± 0.050</td>
</tr>
<tr>
<td>III-V</td>
<td>1.83 ± 0.046</td>
<td>1.89 ± 0.042</td>
<td>1.67 ± 0.018</td>
<td>1.30 ± 0.025</td>
<td>1.80 ± 0.006</td>
</tr>
<tr>
<td>I-V</td>
<td>3.86 ± 0.048</td>
<td>3.84 ± 0.027</td>
<td>3.78 ± 0.001</td>
<td>3.88 ± 0.133</td>
<td>3.92 ± 0.036</td>
</tr>
<tr>
<td>III-IV</td>
<td>0.99 ± 0.112</td>
<td>1.08 ± 0.042</td>
<td>1.13 ± 0.017</td>
<td>1.25 ± 0.019</td>
<td>1.29 ± 0.010</td>
</tr>
<tr>
<td>IV-V</td>
<td>0.84 ± 0.066</td>
<td>0.81 ± 0.001</td>
<td>0.54 ± 0.001</td>
<td>0.55 ± 0.006</td>
<td>0.51 ± 0.004</td>
</tr>
</tbody>
</table>

All values in milliseconds
SD = Standard deviation
Table 7.4 Absolute peak and inter peak latencies for different age, Females, Contralateral ear

<table>
<thead>
<tr>
<th>Waves</th>
<th>3-19 years Mean + SD</th>
<th>20-29 years Mean + SD</th>
<th>30-39 years Mean + SD</th>
<th>40-49 years Mean + SD</th>
<th>50-85 years Mean + SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1.63 ± 0.220</td>
<td>1.69 ± 0.200</td>
<td>1.76 ± 0.120</td>
<td>1.72 ± 0.080</td>
<td>1.77 ± 0.109</td>
</tr>
<tr>
<td>II</td>
<td>2.48 ± 0.034</td>
<td>2.58 ± 0.038</td>
<td>2.64 ± 0.137</td>
<td>2.64 ± 0.069</td>
<td>2.67 ± 0.058</td>
</tr>
<tr>
<td>III</td>
<td>3.49 ± 0.026</td>
<td>3.66 ± 0.053</td>
<td>3.58 ± 0.015</td>
<td>3.63 ± 0.088</td>
<td>3.66 ± 0.047</td>
</tr>
<tr>
<td>IV</td>
<td>4.56 ± 0.115</td>
<td>4.71 ± 0.073</td>
<td>4.70 ± 0.058</td>
<td>4.84 ± 0.046</td>
<td>4.98 ± 0.014</td>
</tr>
<tr>
<td>V</td>
<td>5.36 ± 0.038</td>
<td>5.48 ± 0.146</td>
<td>5.45 ± 0.023</td>
<td>5.82 ± 0.018</td>
<td>5.70 ± 0.025</td>
</tr>
<tr>
<td>I-II</td>
<td>1.86 ± 0.194</td>
<td>1.97 ± 0.147</td>
<td>1.82 ± 0.105</td>
<td>1.91 ± 0.008</td>
<td>1.89 ± 0.062</td>
</tr>
<tr>
<td>II-III</td>
<td>1.01 ± 0.008</td>
<td>1.08 ± 0.015</td>
<td>0.94 ± 0.017</td>
<td>0.99 ± 0.019</td>
<td>0.99 ± 0.011</td>
</tr>
<tr>
<td>III-V</td>
<td>1.87 ± 0.012</td>
<td>1.82 ± 0.094</td>
<td>1.87 ± 0.008</td>
<td>2.19 ± 0.016</td>
<td>2.04 ± 0.022</td>
</tr>
<tr>
<td>I-V</td>
<td>3.73 ± 0.182</td>
<td>3.79 ± 0.054</td>
<td>3.69 ± 0.097</td>
<td>4.10 ± 0.024</td>
<td>3.93 ± 0.084</td>
</tr>
<tr>
<td>III-IV</td>
<td>1.07 ± 0.089</td>
<td>1.05 ± 0.020</td>
<td>1.12 ± 0.043</td>
<td>1.19 ± 0.042</td>
<td>1.32 ± 0.033</td>
</tr>
<tr>
<td>IV-V</td>
<td>0.80 ± 0.077</td>
<td>0.77 ± 0.073</td>
<td>0.75 ± 0.035</td>
<td>0.98 ± 0.058</td>
<td>0.72 ± 0.011</td>
</tr>
</tbody>
</table>

All values in milliseconds
SD = Standard deviation
In females the I-III, I-V, III-IV and II-III interpeak in contralateral ear shown shorter mean values than the ipsilateral ears. Whereas in males I-III and III-IV were shorter. The I-III and I-V interpeak latency in ipsilateral and contralateral ears of male and female subjects were increased whereas III-V interpeak latency decreased. III-IV interpeak latency in ipsilateral and contralateral ears of male subjects decreased whereas the corresponding interpeak latency in females increased. II-III interpeak latency in both ears of the male subjects increased whereas in females decreased. III-V and IV-V interpeak latency in both ears of male and female subjects were decreased.

The standard deviation related to absolute peak latency, interpeak latency of each ear correspond to increasing the age and sex are calculated. The mean absolute peak latency and interpeak latency plus one or less than two standard deviation are fallen within the normal limit.

7.2.2 Discussion

From the data obtained at stimulated and non stimulated ears of each normal adult subjects, the absolute peak and interpeak latencies of each ear according to the differences in increasing the age group and sex are calculated. Both males and females at contralateral ear shown an increased absolute peak latency in waves I, II, V compare to the ipsilateral ear. In an study (Stockare et al., 1978) with 50 normal young adult subject (mean age of 28 years) without consideration of their sex, waves II and V had an increased value in the contralateral side compared to ipsilateral side and the values for these peaks were 3.01 ms and 6.00 ms respectively. Whereas in present work the values were 2.60 ms and 5.57 ms in younger (mean age 26.4 years) age group. The latency values for waves III and IV in contralateral ear found to be shorter in present study and the values for these waves in younger adult subject were 3.58 ms, 4.65 ms whereas the values reported by Stockard were 3.89 ms and 5.09 ms. In another study
reported by Starr et al (1982) the mean latency in wave IV was 0.24 ms earlier at ipsilateral versus contralateral ears whereas the value found in this study and by Stockard were 0.16 ms and 0.06 ms later respectively. The II-III interpeak latency in ipsilateral ear show 0.09 ms and the III-V, IV-V interpeak latencies in contralateral ear 0.13 ms and 0.12 ms prolonger than contralateral ear. Stockard reported the values of 0.15 ms, 0.21 ms and 0.19 ms for the mentioned above interpeak latencies. There is a similar report studied by Rosenhamer (1982).

There are various report suggest that by increasing age after childhood, there is an increase in absolute peaks and interpeak latencies of all BAEP waveform component. In an study (Hecox et al., 1974) in human infants and adults, adult subjects had a latency of 5.80 ms for wave V. In another report studied (Jerger et al., 1980) to define the effect of age and sex on the brainstem auditory responses wave V latency in male subject ranged from 5.70 ms in youngest age group to 5.89 ms in the oldest age group. For female subjects, the latency ranged from 5.57 ms for the youngest age group to 5.76 ms for the oldest group. Whereas in present study, in male subjects, the latency of wave V ranged from 5.46 ms in the youngest to 5.79 ms in oldest age group and in female subjects, the latency of wave V ranged from 5.36 ms in youngest age group to 5.56 ms in the oldest age group. In an study by Jerger and Hall, the combined aged group male subjects had the mean latency value of 0.14 ms greater than the females in wave V whereas the combination in present work shown 0.23 ms greater than female subjects. In another study (Salamy et al., 1976) in combined aged group subjects found the peaks latency of 1.57 ms, 2.37 ms, 3.64 ms, 4.82 ms and 5.55 ms for waves I to V whereas in present work the latencies for the same waves were 1.64 ms, 2.56 ms, 3.74 ms, 4.71 ms, 5.65 ms respectively.

By increasing age after childhood (Rowe, 1978) there are increases in interpeak latency of all components. In a group of mixed gender Rowe found a mean I-V interpeak latency of 3.94 ms in young subjects (mean age
25 years) versus 4.00 ms for older subjects (mean age 61.7 years). Kjaer (1980) found a greater difference but in male only and the mean I-V interpeak latency of 4.10 ms in 20-29 years increased to 4.51 ms for the 50-69 years whereas in this study in a group of mixed gender, the mean I-V interpeak latency in younger subjects (mean age 29.3 years) were 3.91 ms versus 3.96 ms for older subjects (mean age 65.3 years) and in male only the I-V interpeak latency value of 4.01 ms for the age group of 20-29 years decreased to 3.69 ms for the age group of 50-85 years. The range of I-III interpeak latency changes for the same age group were 2.10 ms, 2.09 ms and for III-V interpeak latency were 1.91 ms and 1.87 ms.

The standard deviation of absolute peak and interpeak latencies of all subject attend in this study with different ages and sex are calculated. There are reports (Ciganek et al., 1984, Deka, 1994) about the level of standard deviation in BAEP waveform components. According to Deka, when wave I-III interpeak latency values increases by more than 2SD there is a conduction defect between the 8th nerve close to the cochlear and the lower pontine region, if III-V interpeak latency increase by more than 2SD, there is a conduction defect between the lower pons and the mid brain. There is a report (Deka et al., 1987) that discussed the absolute peak latency reported about the absolute peak and interpeak latencies abnormalities in different cases. In present study to compare the obtained data with the values reported by Stockard et al (1977), the standard deviation of BAEP waveform components for all subjects are calculated and found to be within normal limit. So all the results obtained in this study are very much coincident with the previous studies and could be useful in all neurological laboratories.
7.3 EFFECT OF STIMULUS INTENSITIES ON THE BAEP WAVEFORM COMPONENTS OF DIFFERENT AGE GROUP AND SEX

There are values studies (Starr et al., 1975, Galambos et al., 1979, Stockard et al., 1979, Coats et al., 1980, Michalewski et al., 1980, McGee et al., 1982) suggested that, absolute peak and interpeak latencies are increased by decreasing the stimulus intensities. But report about the variation of BAEP waveform components on changes of stimulus intensities according to the different age group and sex are still limited. As it is noted changes in stimulus intensity, change the absolute peak and interpeak latency of all waves but much of this effect is attributed to changes in wave I shape which is a manifestation of activity in two eight nerve neuronal populations. The changes in wave I is due to the fact that it is originates in different section of the cochlear partition (Elberling, 1974). The changes are depend on stimulus intensity, as the base of the cochlear is activated by higher intensities and the apex of the cochlear by lower intensities. Since stimulus intensity have effective changes on the wave I and the effect on the later waves are prominent. The present study is investigating on the effect of stimulus changes on different age and sex to demonstrate the amount of changes in each wave corresponds to each level of stimulus intensity with different age and sex.

7.3.1 Method and Materials in Recording of BAEP Waveform to the Effect of Stimulus Intensities

The BAEPs are recorded from three scalp electrodes placed one at the midvertex (Cz), on the mastoid bone or earlobe according to 10-20 electrode system and the third one on the forehead or wrist as ground. The amplification and filtering are followed according to the procedure used in Section 7.2. The click stimulus of 50, 60, 70, 80 and 90 db are presented monaurally at a rate of 20 pulse per second to the right ear of each subject.
with non stimulated ear masked to 25-30 db difference from the right ear with white noise to prevent cross hearing, threshold level for the click on the right ear is tested while the contralateral ear is being masked. Twenty eight subjects in different age group and sex are selected to define the effect of changes in stimulus intensity on their BAEP waveform characteristics.

7.3.2 Result

Twenty eight normal adult subjects (15 males and 13 females) aged from 11 to 65 years are selected for testing. Non had a history of neurological problem or hearing difficulties and all had the threshold of around 5 db to click stimulus. The recorded datas are grouped according to the age of subjects in 11-19, 20-29, 30-39, 40-49, 50-65 years.

Table 7.5-7.9 are shown the means of absolute peak latency recorded with changes in stimulus intensity from male subjects in different age group and tables 7.10-7.14 are the corresponding mean absolute peak latency in female subjects. The absolute peak latency in BAEP waves are increased by increasing the age (Tafiti et al., 1996) whereas the corresponding values decreased by increasing the stimulus intensities in both male and female of all age groups. Absolute peaks latency changes with stimulus intensity from 90 to 80 db were minimal in all age group and both sexes. Whereas the changes in lower stimulus intensities specially in 70 db were maximal or the peak latency prolonged. For example, the peak latency difference from 90 to 80 db in mixed aged group and both sexes were 0.02 ms, 0.03 ms and 0.04 ms for waves I, III and V respectively whereas the corresponding peak latency difference from 80 to 70 db were 0.26 ms, 0.23 ms and 0.19 ms. Absolute peaks latency in females BAEP with different stimulus intensities were shorter than male in all age groups. The changes in absolute peak latency in each age group corresponds to different stimulus intensities in male subjects are shown in Figures 7.1 to 7.5 and the corresponding peaks latency changes in female subjects are shown in Figures 7.6 to 7.10. The
Table 7.5  Means of absolute peaks latency with different stimulus intensities, right ear, males.

<table>
<thead>
<tr>
<th>Waves</th>
<th>Age group 11-19 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Click Intensities (db)</td>
</tr>
<tr>
<td></td>
<td>90</td>
</tr>
<tr>
<td>Wave I</td>
<td></td>
</tr>
<tr>
<td>20/S 2048 clicks</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>SD</td>
</tr>
<tr>
<td>Wave II</td>
<td></td>
</tr>
<tr>
<td>20/S 2048 clicks</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>SD</td>
</tr>
<tr>
<td>Wave III</td>
<td></td>
</tr>
<tr>
<td>20/S 2048 clicks</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>SD</td>
</tr>
<tr>
<td>Wave IV</td>
<td></td>
</tr>
<tr>
<td>20/S 2048 clicks</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>SD</td>
</tr>
<tr>
<td>Wave V</td>
<td></td>
</tr>
<tr>
<td>20/S 2048 clicks</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>SD</td>
</tr>
</tbody>
</table>

All peaks and SD are in milli seconds
SD = Standard deviation
/S = Pulse per second
Table 7.6  Means of absolute peaks latency with different stimulus intensities, right ear, males.

<table>
<thead>
<tr>
<th>Waves</th>
<th>Click Intensities (db)</th>
<th>Age group 20-29 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>90</td>
<td>80</td>
</tr>
<tr>
<td>Wave I</td>
<td>20/S</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>2048 clicks</td>
<td>SD</td>
</tr>
<tr>
<td>Wave II</td>
<td>20/S</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>2048 clicks</td>
<td>SD</td>
</tr>
<tr>
<td>Wave III</td>
<td>20/S</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>2048 clicks</td>
<td>SD</td>
</tr>
<tr>
<td>Wave IV</td>
<td>20/S</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>2048 clicks</td>
<td>SD</td>
</tr>
<tr>
<td>Wave V</td>
<td>20/S</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>2048 clicks</td>
<td>SD</td>
</tr>
</tbody>
</table>

All peaks and SD are in milli seconds
SD = Standard deviation
/S = Pulse per second
Table 7.7  Means of absolute peaks latency with different stimulus intensities, right ear, males.

<table>
<thead>
<tr>
<th>Waves</th>
<th>Click Intensities (db)</th>
<th>90</th>
<th>80</th>
<th>70</th>
<th>60</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age group 30-39 years</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wave I</td>
<td>20/S 2048 clicks</td>
<td>Mean</td>
<td>1.690</td>
<td>1.680</td>
<td>1.960</td>
<td>2.110</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
<td>0.080</td>
<td>0.070</td>
<td>0.080</td>
<td>0.035</td>
</tr>
<tr>
<td>Wave II</td>
<td>20/S 2048 clicks</td>
<td>Mean</td>
<td>2.640</td>
<td>2.760</td>
<td>2.970</td>
<td>2.740</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
<td>0.210</td>
<td>0.040</td>
<td>0.160</td>
<td>0.180</td>
</tr>
<tr>
<td>Wave III</td>
<td>20/S 2048 clicks</td>
<td>Mean</td>
<td>3.780</td>
<td>3.840</td>
<td>4.100</td>
<td>4.200</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
<td>0.057</td>
<td>0.070</td>
<td>0.030</td>
<td>0.020</td>
</tr>
<tr>
<td>Wave IV</td>
<td>20/S 2048 clicks</td>
<td>Mean</td>
<td>4.940</td>
<td>5.160</td>
<td>5.250</td>
<td>5.520</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
<td>0.130</td>
<td>0.056</td>
<td>0.080</td>
<td>0.070</td>
</tr>
<tr>
<td>Wave V</td>
<td>20/S 2048 clicks</td>
<td>Mean</td>
<td>5.660</td>
<td>5.690</td>
<td>5.910</td>
<td>6.080</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
<td>0.063</td>
<td>0.040</td>
<td>0.049</td>
<td>0.060</td>
</tr>
</tbody>
</table>

All peaks and SD are in milli seconds
SD = Standard deviation
/S = Pulse per second
Table 7.8  Means of absolute peaks latency with different stimulus intensities, right ear, males.

<table>
<thead>
<tr>
<th>Waves</th>
<th>Age group 40-49 years</th>
<th>Click Intensities (db)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>90</td>
</tr>
<tr>
<td>Wave I</td>
<td>20/S 2048 clicks Mean</td>
<td>1.760</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.070</td>
</tr>
<tr>
<td>Wave II</td>
<td>20/S 2048 clicks Mean</td>
<td>3.020</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.050</td>
</tr>
<tr>
<td>Wave III</td>
<td>20/S 2048 clicks Mean</td>
<td>3.880</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.080</td>
</tr>
<tr>
<td>Wave IV</td>
<td>20/S 2048 clicks Mean</td>
<td>5.170</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.100</td>
</tr>
<tr>
<td>Wave V</td>
<td>20/S 2048 clicks Mean</td>
<td>5.780</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.080</td>
</tr>
</tbody>
</table>

All peaks and SD are in milli seconds
SD = Standard deviation
/S = Pulse per second
Table 7.9  Means of absolute peaks latency with different stimulus intensities, right ear, males.

<table>
<thead>
<tr>
<th>Waves</th>
<th>Mean 20/S</th>
<th>SD 20/S</th>
<th>Mean 2048 clicks</th>
<th>SD 2048 clicks</th>
<th>Mean 2048 clicks</th>
<th>SD 2048 clicks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wave I</td>
<td>1.900</td>
<td>0.070</td>
<td>1.940</td>
<td>0.110</td>
<td>2.170</td>
<td>0.060</td>
</tr>
<tr>
<td>Wave II</td>
<td>2.860</td>
<td>0.020</td>
<td>2.960</td>
<td>0.090</td>
<td>3.320</td>
<td>0.077</td>
</tr>
<tr>
<td>Wave III</td>
<td>3.820</td>
<td>0.030</td>
<td>3.820</td>
<td>0.080</td>
<td>4.150</td>
<td>0.020</td>
</tr>
<tr>
<td>Wave IV</td>
<td>4.980</td>
<td>0.090</td>
<td>5.040</td>
<td>0.140</td>
<td>5.140</td>
<td>0.160</td>
</tr>
<tr>
<td>Wave V</td>
<td>5.600</td>
<td>0.090</td>
<td>5.620</td>
<td>0.098</td>
<td>5.870</td>
<td>0.035</td>
</tr>
</tbody>
</table>

All peaks and SD are in milli seconds
SD = Standard deviation
S = Pulse per second
Table 7.10 Means of absolute peaks latency with different stimulus intensities, right ear, females.

<table>
<thead>
<tr>
<th>Waves</th>
<th>Click Intensities (db)</th>
<th>20/S 2048 clicks</th>
<th>20/S 2048 clicks</th>
<th>20/S 2048 clicks</th>
<th>20/S 2048 clicks</th>
<th>20/S 2048 clicks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wave I</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>80</td>
<td>70</td>
<td>60</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Wave II</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wave III</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wave IV</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wave V</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

All peaks and SD are in milli seconds
SD = Standard deviation
/S = Pulse per second
Table 7.11 Means of absolute peaks latency with different stimulus intensities, right ear, females.

<table>
<thead>
<tr>
<th>Waves</th>
<th>Age group 20-29 years</th>
<th>Click Intensities (db)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>90</td>
</tr>
<tr>
<td>Wave I</td>
<td>20/S 2048 clicks Mean</td>
<td>1.510</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.070</td>
</tr>
<tr>
<td>Wave II</td>
<td>20/S 2048 clicks Mean</td>
<td>2.540</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.100</td>
</tr>
<tr>
<td>Wave III</td>
<td>20/S 2048 clicks Mean</td>
<td>3.560</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.040</td>
</tr>
<tr>
<td>Wave IV</td>
<td>20/S 2048 clicks Mean</td>
<td>4.580</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.210</td>
</tr>
<tr>
<td>Wave V</td>
<td>20/S 2048 clicks Mean</td>
<td>5.280</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.060</td>
</tr>
</tbody>
</table>

All peaks and SD are in milli seconds
SD = Standard deviation
/S = Pulse per second
Table 7.12 Means of absolute peaks latency with different stimulus intensities, right ear, females.

<table>
<thead>
<tr>
<th>Waves</th>
<th>Click Intensities (db)</th>
<th>90</th>
<th>80</th>
<th>70</th>
<th>60</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>20/S</td>
<td>20/S</td>
<td>20/S</td>
<td>20/S</td>
<td>20/S</td>
</tr>
<tr>
<td>Wave I</td>
<td>2048 clicks</td>
<td>Mean</td>
<td>1.610</td>
<td>1.590</td>
<td>1.880</td>
<td>2.040</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
<td>0.069</td>
<td>0.098</td>
<td>0.046</td>
<td>0.004</td>
</tr>
<tr>
<td>Wave II</td>
<td>2048 clicks</td>
<td>Mean</td>
<td>2.690</td>
<td>2.580</td>
<td>2.780</td>
<td>2.500</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
<td>0.060</td>
<td>0.034</td>
<td>0.023</td>
<td>0.100</td>
</tr>
<tr>
<td>Wave III</td>
<td>2048 clicks</td>
<td>Mean</td>
<td>3.620</td>
<td>3.620</td>
<td>3.840</td>
<td>3.970</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
<td>0.034</td>
<td>0.080</td>
<td>0.040</td>
<td>0.023</td>
</tr>
<tr>
<td>Wave IV</td>
<td>2048 clicks</td>
<td>Mean</td>
<td>4.880</td>
<td>4.840</td>
<td>4.880</td>
<td>5.090</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
<td>0.020</td>
<td>0.092</td>
<td>0.069</td>
<td>0.040</td>
</tr>
<tr>
<td>Wave V</td>
<td>2048 clicks</td>
<td>Mean</td>
<td>5.350</td>
<td>5.420</td>
<td>5.620</td>
<td>5.690</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
<td>0.072</td>
<td>0.075</td>
<td>0.051</td>
<td>0.052</td>
</tr>
</tbody>
</table>

All peaks and SD are in milli seconds
SD = Standard deviation
/S = Pulse per second
Table 7.13 Means of absolute peaks latency with different stimulus intensities, right ear, females.

<table>
<thead>
<tr>
<th>Waves</th>
<th>Click Intensities (db)</th>
<th>20/4S 2048 clicks</th>
<th>2048 clicks</th>
<th>20/S 2048 clicks</th>
<th>2048 clicks</th>
<th>20/S 2048 clicks</th>
<th>2048 clicks</th>
<th>20/S 2048 clicks</th>
<th>2048 clicks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wave I</td>
<td>Mean</td>
<td>1.730</td>
<td>0.035</td>
<td>2.570</td>
<td>0.042</td>
<td>4.830</td>
<td>0.046</td>
<td>5.490</td>
<td>0.058</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.070</td>
<td>0.028</td>
<td>0.035</td>
<td>0.035</td>
<td>0.060</td>
<td>0.049</td>
<td>0.070</td>
<td>0.058</td>
</tr>
<tr>
<td>Wave II</td>
<td>Mean</td>
<td>1.960</td>
<td>0.042</td>
<td>3.910</td>
<td>0.028</td>
<td>5.140</td>
<td>0.070</td>
<td>5.360</td>
<td>0.080</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>2.270</td>
<td>0.028</td>
<td>3.160</td>
<td>0.028</td>
<td>4.200</td>
<td>0.028</td>
<td>5.080</td>
<td>0.028</td>
</tr>
<tr>
<td>Wave III</td>
<td>Mean</td>
<td>2.290</td>
<td>0.035</td>
<td>4.010</td>
<td>0.035</td>
<td>4.410</td>
<td>0.035</td>
<td>5.020</td>
<td>0.049</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>2.680</td>
<td>0.098</td>
<td>4.010</td>
<td>0.028</td>
<td>4.410</td>
<td>0.035</td>
<td>5.020</td>
<td>0.049</td>
</tr>
<tr>
<td>Wave IV</td>
<td>Mean</td>
<td>2.130</td>
<td>0.028</td>
<td>4.010</td>
<td>0.035</td>
<td>4.010</td>
<td>0.035</td>
<td>5.020</td>
<td>0.049</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>2.680</td>
<td>0.098</td>
<td>4.010</td>
<td>0.028</td>
<td>4.410</td>
<td>0.035</td>
<td>5.020</td>
<td>0.049</td>
</tr>
</tbody>
</table>

Click Intensities (db)

<table>
<thead>
<tr>
<th>Waves</th>
<th>Age group 40-49 years</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wave I</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Wave II</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Wave III</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Wave IV</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Wave V</td>
<td>50</td>
<td></td>
</tr>
</tbody>
</table>

All peaks and SD are in milli seconds.

SD = Standard deviation

/2 = Pulse per second
Table 7.14 Means of absolute peaks latency with different stimulus intensities, right ear, females.

<table>
<thead>
<tr>
<th>Waves</th>
<th>Age group 50-65 years</th>
<th>90</th>
<th>80</th>
<th>70</th>
<th>60</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Click Intensities (db)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wave I</td>
<td>20/S 2048 clicks Mean</td>
<td>1.790</td>
<td>1.840</td>
<td>2.020</td>
<td>2.130</td>
<td>2.330</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.034</td>
<td>0.046</td>
<td>0.034</td>
<td>0.030</td>
<td>0.021</td>
</tr>
<tr>
<td>Wave II</td>
<td>20/S 2048 clicks Mean</td>
<td>2.720</td>
<td>2.730</td>
<td>3.080</td>
<td>2.720</td>
<td>3.270</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.086</td>
<td>0.050</td>
<td>0.092</td>
<td>0.034</td>
<td>0.067</td>
</tr>
<tr>
<td>Wave III</td>
<td>20/S 2048 clicks Mean</td>
<td>3.710</td>
<td>3.740</td>
<td>3.900</td>
<td>3.980</td>
<td>4.110</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.023</td>
<td>0.049</td>
<td>0.010</td>
<td>0.017</td>
<td>0.050</td>
</tr>
<tr>
<td>Wave IV</td>
<td>20/S 2048 clicks Mean</td>
<td>5.070</td>
<td>4.940</td>
<td>4.920</td>
<td>4.930</td>
<td>5.000</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.130</td>
<td>0.100</td>
<td>0.098</td>
<td>0.050</td>
<td>0.115</td>
</tr>
<tr>
<td>Wave V</td>
<td>20/S 2048 clicks Mean</td>
<td>5.440</td>
<td>5.470</td>
<td>5.630</td>
<td>5.620</td>
<td>5.710</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.031</td>
<td>0.087</td>
<td>0.063</td>
<td>0.080</td>
<td>0.014</td>
</tr>
</tbody>
</table>

All peaks and SD are in milli seconds
SD = Standard deviation
/S = Pulse per second
Figure 7.1 Peaks latency changes on effect of stimulus intensity with different age group, right ear, males, 90 db.
Figure 7.3 Peaks latency changes on effect of stimulus intensity with different age group, right ear, males, 70 db
Figure 7.4 Peaks latency changes on effect of stimulus intensity with different age group, right ear, males, 60 db.
Figure 7.5 Peaks latency changes on effect of stimulus intensity with different age group, right ear, males, 50 db
Figure 7.6 Peaks latency changes on effect of stimulus intensity with different age group, right ear, females, 90 db
Figure 7.7 Peaks latency changes on effect of stimulus intensity with different age group, right ear, females, 80 db
Figure 7.8 Peaks latency changes on effect of stimulus intensity with different age group, right ear, females, 70 db
Figure 7.9 Peaks latency changes on effect of stimulus intensity with different age group, right ear, females, 60 db.
Figure 7.10 Peaks latency changes on effect of stimulus intensity with different age group, right ear, females, 50 db.
Figures shown clearly, the absolute latency changes in male and female subjects corresponds to different stimulus intensity and age. Male and females subjects in older age group shown prolonged peak latency compare to younger. Females shown shorter absolute peaks latency than males in different stimulus intensities. Wave V peak latency found to be maximum in the age group of 40-49 years among all others age group whereas waves I and III were maximum in older age group.

Tables 7.15 to 7.19 are shown the means of I-III, III-V and I-V interpeak latency with different stimulus intensity and age group in male and Table 7.20 to 7.24 the corresponding peak latency changes in female subjects. The interpeak latency were decreased by decreasing the stimulus intensities and increasing the age. Females had shorter interpeak latencies than males. Along with mean of absolute peak latency, interpeak latency, the standard deviation of each are also calculated and all lies within the normal level.

7.3.3 Discussion

The effect of stimulus intensities on BAEP waveform components are discussed by various researchers. Hecox et al (1974) reported that wave V at stimulus intensity of 60 db had an absolute peak latency of 6.0 ms. Starr et al (1975) in an study on different stimulus intensities found that BAEP waves I and V at 80 db had the peak latency value of 1.40 ms and 5.40 ms whereas Zimmermann (1987) is reported the value of 5.75 ms for peak latency of wave V. Galambos et al (1979) reported wave V at stimulus intensity of 50 and 60 db had the values of 6.60 ms and 6.20 ms, respectively. In present study in mixed age and gender the wave V at intensities 50 and 60 db shown the values of 5.89 ms and 5.79 ms. Stokard et al (1979) in their study suggested that, a normal 31-years’ woman BAEP waveform components, I and III at 60 db intensity had the latencies of 1.77 ms and 4.35 ms and at 50 db the latencies of 2.07 ms and 4.42 ms.
Table 7.15 Means of Interpeak latency with different stimulus intensities, right ear, males

<table>
<thead>
<tr>
<th>Interpeaks</th>
<th>Age Group 11 - 19 Years</th>
<th>Click Intensities (db)</th>
<th>90</th>
<th>80</th>
<th>70</th>
<th>60</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-III</td>
<td>20/S 2048 clicks</td>
<td>Mean</td>
<td>2.110</td>
<td>2.080</td>
<td>2.080</td>
<td>2.010</td>
<td>1.890</td>
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<td></td>
<td></td>
<td>SD</td>
<td>0.015</td>
<td>0.000</td>
<td>0.010</td>
<td>0.010</td>
<td>0.035</td>
</tr>
<tr>
<td>III-V</td>
<td>20/S 2048 clicks</td>
<td>Mean</td>
<td>1.850</td>
<td>1.870</td>
<td>1.800</td>
<td>1.780</td>
<td>1.780</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
<td>0.005</td>
<td>0.040</td>
<td>0.030</td>
<td>0.025</td>
<td>0.030</td>
</tr>
<tr>
<td>I-V</td>
<td>20/S 2048 clicks</td>
<td>Mean</td>
<td>3.960</td>
<td>3.950</td>
<td>3.880</td>
<td>3.790</td>
<td>3.670</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
<td>0.010</td>
<td>0.040</td>
<td>0.040</td>
<td>0.035</td>
<td>0.065</td>
</tr>
</tbody>
</table>

All interpeaks and SD are in milli seconds.
SD = Standard Deviation
/S = Pulse per second
Table 7.16 Means of Interpeak latency with different stimulus intensities, right ear, males

<table>
<thead>
<tr>
<th>Interpeaks</th>
<th>Age Group 20 - 29 Years</th>
<th>Click Intensities (db)</th>
<th>90</th>
<th>80</th>
<th>70</th>
<th>60</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-III</td>
<td>20/S 2048 clicks</td>
<td>Mean</td>
<td>2.140</td>
<td>2.140</td>
<td>2.100</td>
<td>2.006</td>
<td>1.960</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
<td>0.012</td>
<td>0.019</td>
<td>0.030</td>
<td>0.030</td>
<td>0.013</td>
</tr>
<tr>
<td>III-V</td>
<td>20/S 2048 clicks</td>
<td>Mean</td>
<td>1.840</td>
<td>1.940</td>
<td>1.860</td>
<td>1.830</td>
<td>1.840</td>
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<tr>
<td></td>
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<td>SD</td>
<td>0.023</td>
<td>0.001</td>
<td>0.016</td>
<td>0.030</td>
<td>0.040</td>
</tr>
<tr>
<td>I-V</td>
<td>20/S 2048 clicks</td>
<td>Mean</td>
<td>3.980</td>
<td>4.080</td>
<td>3.960</td>
<td>3.860</td>
<td>3.800</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
<td>0.035</td>
<td>0.020</td>
<td>0.014</td>
<td>0.060</td>
<td>0.053</td>
</tr>
</tbody>
</table>

All interpeaks and SD are in milli seconds.
SD = Standard Deviation
/S = Pulse per second
Table 7.17 Means of Interpeak latency with different stimulus intensities, right ear, males

<table>
<thead>
<tr>
<th>Interpeaks</th>
<th>Age Group 30 - 39 Years</th>
<th>Click Intensities (db)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>90</td>
</tr>
<tr>
<td>I-III</td>
<td>20/S 2048 clicks</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
</tr>
<tr>
<td>III-V</td>
<td>20/S 2048 clicks</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
</tr>
<tr>
<td>I-V</td>
<td>20/S 2048 clicks</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
</tr>
</tbody>
</table>

All interpeaks and SD are in milli seconds.
SD = Standard Deviation
/S = Pulse per second
Table 7.18 Means of Interpeak latency with different stimulus intensities, right ear, males

<table>
<thead>
<tr>
<th>Interpeaks</th>
<th>Age Group 40 - 49 Years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Click Intensities (db)</td>
</tr>
<tr>
<td></td>
<td>90</td>
</tr>
<tr>
<td>I-III</td>
<td></td>
</tr>
<tr>
<td>20/S</td>
<td>Mean</td>
</tr>
<tr>
<td>2048 clicks</td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>0.010</td>
</tr>
<tr>
<td>III-V</td>
<td></td>
</tr>
<tr>
<td>20/S</td>
<td>Mean</td>
</tr>
<tr>
<td>2048 clicks</td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>0.005</td>
</tr>
<tr>
<td>I-V</td>
<td></td>
</tr>
<tr>
<td>20/S</td>
<td>Mean</td>
</tr>
<tr>
<td>2048 clicks</td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>0.010</td>
</tr>
</tbody>
</table>

All interpeaks and SD are in milli seconds.
SD = Standard Deviation
/S = Pulse per second
Table 7.19 Means of Interpeak latency with different stimulus intensities, right ear, males

<table>
<thead>
<tr>
<th>Interpeaks</th>
<th>Age Group 50 - 65 Years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Click Intensities (db)</td>
</tr>
<tr>
<td></td>
<td>90</td>
</tr>
<tr>
<td>I-III</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>SD</td>
</tr>
<tr>
<td>III-V</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>SD</td>
</tr>
<tr>
<td>I-V</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>SD</td>
</tr>
</tbody>
</table>

All interpeaks and SD are in milli seconds.
SD = Standard Deviation
/S = Pulse per second
Table 7.20  Means of Interpeak latency with different stimulus intensities, right ear, females

<table>
<thead>
<tr>
<th>Interpeaks</th>
<th>Click Intensities (db)</th>
<th>Age group 11 - 19 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>90</td>
<td>80</td>
</tr>
<tr>
<td>I - III</td>
<td>20/S 2048 clicks Mean SD</td>
<td>2.040</td>
</tr>
<tr>
<td>III - V</td>
<td>20/S 2048 clicks Mean SD</td>
<td>1.760</td>
</tr>
<tr>
<td>I - V</td>
<td>20/S 2048 clicks Mean SD</td>
<td>3.800</td>
</tr>
</tbody>
</table>

All interpeaks and SD are in milli seconds
SD = Standard deviation
/S = Pulse per second
Table 7.21 Means of Interpeak latency with different stimulus intensities, right ear, females

<table>
<thead>
<tr>
<th>Interpeaks</th>
<th>Age group 20 - 29 years</th>
<th>Click Intensities (db)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>90</td>
</tr>
<tr>
<td>I - III</td>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>20/S 2048 clicks</td>
<td>2.050</td>
</tr>
<tr>
<td>III - V</td>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>20/S 2048 clicks</td>
<td>1.720</td>
</tr>
<tr>
<td>I - V</td>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>20/S 2048 clicks</td>
<td>3.770</td>
</tr>
</tbody>
</table>

All interpeaks and SD are in milli seconds
SD = Standard deviation
/S = Pulse per second
Table 7.22 Means of Interpeak latency with different stimulus intensities, right ear, females

<table>
<thead>
<tr>
<th>Interpeaks</th>
<th>Age group 30 - 39 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Click Intensities (db)</td>
</tr>
<tr>
<td></td>
<td>90</td>
</tr>
<tr>
<td>I - III</td>
<td>20/S</td>
</tr>
<tr>
<td></td>
<td>SD</td>
</tr>
<tr>
<td>III - V</td>
<td>20/S</td>
</tr>
<tr>
<td></td>
<td>SD</td>
</tr>
<tr>
<td>I - V</td>
<td>20/S</td>
</tr>
<tr>
<td></td>
<td>SD</td>
</tr>
</tbody>
</table>

All interpeaks and SD are in milli seconds
SD = Standard deviation
/S = Pulse per second
Table 7.23 Means of Interpeak latency with different stimulus intensities, right ear, females

All interpeaks and SD are in milli seconds
SD = Standard deviation
/S = Pulse per second

<table>
<thead>
<tr>
<th>Interpeaks</th>
<th>Age group 40 - 49 years</th>
<th>Click Intensities (db)</th>
<th>90</th>
<th>80</th>
<th>70</th>
<th>60</th>
<th>50</th>
</tr>
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<tbody>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I - III</td>
<td>20/S 2048 clicks</td>
<td>Mean SD</td>
<td>1.940</td>
<td>2.040</td>
<td>1.850</td>
<td>1.880</td>
<td>1.930</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.007</td>
<td>0.042</td>
<td>0.007</td>
<td>0.005</td>
<td>0.012</td>
</tr>
<tr>
<td>III - V</td>
<td>20/S 2048 clicks</td>
<td>Mean SD</td>
<td>1.820</td>
<td>1.760</td>
<td>1.780</td>
<td>1.750</td>
<td>1.760</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.108</td>
<td>0.042</td>
<td>0.023</td>
<td>0.014</td>
<td>0.100</td>
</tr>
<tr>
<td>I - V</td>
<td>20/S 2048 clicks</td>
<td>Mean SD</td>
<td>3.760</td>
<td>3.760</td>
<td>3.730</td>
<td>3.630</td>
<td>3.690</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.115</td>
<td>0.003</td>
<td>0.016</td>
<td>0.014</td>
<td>0.112</td>
</tr>
</tbody>
</table>
Table 7.24 Means of Interpeak latency with different stimulus intensities, right ear, females

<table>
<thead>
<tr>
<th>Interpeaks</th>
<th>Age group 50 - 65 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Click Intensities (db)</td>
</tr>
<tr>
<td></td>
<td>90</td>
</tr>
<tr>
<td>1 - III</td>
<td>20/S 2048 clicks</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>III - V</td>
<td>20/S 2048 clicks</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>1 - V</td>
<td>20/S 2048 clicks</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

All interpeaks and SD are in milli seconds
SD = Standard deviation
/S = Pulse per second
whereas in this study the same waves at the same age group for the stimulus intensity of 60 db had the values of 2.04 ms and 3.97 ms and for 50 db the values of 2.22 ms and 4.18 ms. In another study (Michalewski et al., 1980) with 20 males and females of mixed age the waves I, II, III, IV and V in male and female subjects shown that by increasing the stimulus intensities from 60 to 80 db all absolute peak latencies are decreased.

The I-III, III-V, I-V inter peak latencies in mixed gender of combined age group at stimulus intensities 50, 60 and 70 db is reported by Stockard et al (1979). The IPLs were increased by increasing the stimulus intensities. The I-III IPL in 25 years man reported by the same author Stockard et al (1979) that the values at 50, 60 and 70 db intensities were 2.48 ms, 2.44 ms, and 2.52 ms whereas in this work the same IPL at the similar intensities with that age group shown the values of 1.96 ms, 2.03 ms, and 2.10 ms, respectively.

The standard deviation calculated for absolute peak and inter peak latencies are more or less same as the values reported by previous workers named in this section. So all the results obtained here are coincident with the studies reported by the previous researchers and can be useful in all neurological laboratories when interpretation of BAEP waveform components in different age group with different stimulus intensities are concerned.

7.4 EFFECT OF STIMULUS REPETITION RATES ON BAEP WAVEFORM COMPONENTS OF DIFFERENT AGE GROUP AND SEX

Since BAEP recording have proven to be an important tool in the evaluation of neurological problems, higher stimulus rate became a power in diagnosis of certain abnormalities that shown normal in routine BAEP waveform interpretation. There are various studies (Starr et al., 1975,
Stockard et al., 1977, Stockard et al., 1977, Sohmer et al., 1974) reported that increasing the stimulus rates to higher level could demonstrate the abnormal latencies and amplitude that could not be presented at a relatively lower rates. But Chiappa et al. (1979) stated that an increase in stimulus rate produces no more diagnostic information that already presented at a lower stimulus rate. The effect of stimulus repetition rate on BAEP waveform latencies are reported (Hyde, 1976, Pratt et al., 1977) that no changes in wave I latency but increments in subsequent BAEP waveform components as a function of increasing click rates whereas the other study (Salamy et al., 1977, Harkins, 1980) suggested that an increase in peak latency of wave I and I-V difference as a function of rate. The I-V interpeak latency is used as common BAEP parameter for determining central dysfunction (Gerling, 1983).

There is a common report (Don et al., 1977, Lenhardt et al., 1981, Stockard et al., 1979, Thornton et al., 1975, Zollener et al., 1976, Ven Olphan et al., 1979) suggested that by increasing the stimulus rate, absolute peak latency of all BAEP waves are increased. Since the effect of stimulus rate on BAEP waveform of subjects in various age and sex are not investigated widely, the present study is arranged to define the changes in the peak latency and interpeak latency of subjects in different age group and sex.

7.4.1 Method and Materials

BAEP recording including electrode placement, amplification, filtering and the number of averaging response are followed as mentioned in section 7.3.1. In this recording, the patients were selected for test all were normal and non had audiological or neurological problem and hearing threshold of each ear to 20 pulse per second is determined. The averaged hearing threshold for all subject was around 10 db. A click stimulus intensity of 90 db at different stimulus rates of 5, 10, 20, 50 and 100 pulse
per second (pps) are presented monaurally to the right ear of each subject when left ear is masked with white noise to prevent cross hearing. The response is recorded for the first 10 ms with the post stimulus average of 2048 clicks and displayed on an oscilloscope. The waveform usually contains of five peaks or waves designated in I to V. The mean peak latencies, interpeak latencies and standard deviations of BAEP waveform that is recorded from each subject with selected stimulus rate in different age group and sex are calculated and compared with the previous results.

7.4.2 Results

In this study twenty seven (15 males and 12 females) normal adult subjects aged from 13 to 58 years are selected in this test. While analysis the recorded datas are grouped according to the age of subjects in 13-19, 20-29, 30-39, 40-49, 50-58 years. The recording were done on right ear only because most subjects felt unconvenient to be tested at both ears. The BAEP waveform components are recorded for each subject in different age and sex to the stimulus rate of 5, 10, 20, 50 and 100 pps for at least two trials. The mean absolute peaks latency, interpeak latency and standard deviation of male subjects are shown in tables 7.25-7.29 and the corresponding values in females are shown in tables 7.30-7.34. From the tables it can be seen that, by increasing the stimulus rates absolute peak latency of all BAEP waveform components are increased both in male and female subjects. These changes at higher stimulus rates were remarkable. For example, absolute peak latency difference for wave I, III and V in the stimulus rates from 10 to 20 pps in mixed aged and gender shown the values of 0.07 ms, 0.06 ms, and 0.07 ms whereas from 20 to 50 pps the values 0.17 ms, 0.17 ms and 0.34 ms respectively. The variation of peaks latency corresponds to increasing the age in males according to stimulus rate changes can be clearly seen in Figures 7.11-7.15 and in females in figures 7.16-7.20. Almost in all stimulus rates, wave I and III peak latency in males and females had maximum changes at age group of 40-49 years and older age. But wave V
Table 7.25 Means of absolute peaks latency with different stimulus repetition rates, right ear, males.

<table>
<thead>
<tr>
<th>Waves</th>
<th>Age group 13-19 years</th>
<th>Click Rates (pulse per second)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Wave I</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>90 db 2048 clicks Mean</td>
<td>1.540</td>
</tr>
<tr>
<td></td>
<td>90 db 2048 clicks SD</td>
<td>0.023</td>
</tr>
<tr>
<td>Wave II</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>90 db 2048 clicks Mean</td>
<td>2.480</td>
</tr>
<tr>
<td></td>
<td>90 db 2048 clicks SD</td>
<td>0.034</td>
</tr>
<tr>
<td>Wave III</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>90 db 2048 clicks Mean</td>
<td>3.580</td>
</tr>
<tr>
<td></td>
<td>90 db 2048 clicks SD</td>
<td>0.017</td>
</tr>
<tr>
<td>Wave IV</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>90 db 2048 clicks Mean</td>
<td>4.660</td>
</tr>
<tr>
<td></td>
<td>90 db 2048 clicks SD</td>
<td>0.046</td>
</tr>
<tr>
<td>Wave V</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>90 db 2048 clicks Mean</td>
<td>5.460</td>
</tr>
<tr>
<td></td>
<td>90 db 2048 clicks SD</td>
<td>0.046</td>
</tr>
</tbody>
</table>

All peaks and SD are in milli seconds
SD = Standard deviation
db = decibel
Table 7.26  Means of absolute peaks latency with different stimulus repetition rates, right ear, males.

<table>
<thead>
<tr>
<th>Waves</th>
<th>Age group 20-29 years</th>
<th>Click Rates (pulse per second)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Wave I</td>
<td>90 db 2048 clicks</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
</tr>
<tr>
<td>Wave II</td>
<td>90 db 2048 clicks</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
</tr>
<tr>
<td>Wave III</td>
<td>90 db 2048 clicks</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
</tr>
<tr>
<td>Wave IV</td>
<td>90 db 2048 clicks</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
</tr>
<tr>
<td>Wave V</td>
<td>90 db 2048 clicks</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
</tr>
</tbody>
</table>

All peaks and SD are in milli seconds
SD = Standard deviation
db = decibel
Table 7.27 Means of absolute peaks latency with different stimulus repetition rates, right ear, males.

<table>
<thead>
<tr>
<th>Waves</th>
<th>Age group 30-39 years</th>
<th>Click Rates (pulse per second)</th>
<th>5</th>
<th>10</th>
<th>20</th>
<th>50</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wave I</td>
<td>90 db 2048 clicks</td>
<td>Mean</td>
<td>1.630</td>
<td>1.730</td>
<td>1.720</td>
<td>1.960</td>
<td>1.990</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
<td>0.086</td>
<td>0.069</td>
<td>0.063</td>
<td>0.054</td>
<td>0.046</td>
</tr>
<tr>
<td>Wave II</td>
<td>90 db 2048 clicks</td>
<td>Mean</td>
<td>2.500</td>
<td>2.620</td>
<td>2.600</td>
<td>2.850</td>
<td>2.970</td>
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<tr>
<td></td>
<td></td>
<td>SD</td>
<td>0.023</td>
<td>0.080</td>
<td>0.011</td>
<td>0.040</td>
<td>0.093</td>
</tr>
<tr>
<td>Wave III</td>
<td>90 db 2048 clicks</td>
<td>Mean</td>
<td>3.600</td>
<td>3.710</td>
<td>3.700</td>
<td>3.920</td>
<td>4.110</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
<td>0.098</td>
<td>0.034</td>
<td>0.090</td>
<td>0.040</td>
<td>0.057</td>
</tr>
<tr>
<td>Wave IV</td>
<td>90 db 2048 clicks</td>
<td>Mean</td>
<td>4.600</td>
<td>4.660</td>
<td>4.720</td>
<td>4.890</td>
<td>4.890</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
<td>0.098</td>
<td>0.050</td>
<td>0.027</td>
<td>0.013</td>
<td>0.097</td>
</tr>
<tr>
<td>Wave V</td>
<td>90 db 2048 clicks</td>
<td>Mean</td>
<td>5.550</td>
<td>5.570</td>
<td>5.600</td>
<td>6.070</td>
<td>6.020</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
<td>0.046</td>
<td>0.017</td>
<td>0.053</td>
<td>0.080</td>
<td>0.063</td>
</tr>
</tbody>
</table>

All peaks and SD are in milli seconds
SD = Standard deviation
db = decibel
Table 7.28 Means of absolute peaks latency with different stimulus repetition rates, right ear, males.

<table>
<thead>
<tr>
<th>Waves</th>
<th>Age group 40-49 years</th>
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<tbody>
<tr>
<td></td>
<td>Click Rates (pulse per second)</td>
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<tr>
<td></td>
<td>Wave I</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wave II</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wave III</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wave IV</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wave V</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

All peaks and SD are in milli seconds
SD = Standard deviation
db = decibel
Table 7.29 Means of absolute peaks latency with different stimulus repetition rates, right ear, males.

<table>
<thead>
<tr>
<th>Waves</th>
<th>Age group 50-58 years</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Click Rates (pulse per second)</td>
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<td>5</td>
</tr>
<tr>
<td>Wave I</td>
<td>90 db 2048 clicks</td>
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<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Wave II</td>
<td>90 db 2048 clicks</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Wave III</td>
<td>90 db 2048 clicks</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Wave IV</td>
<td>90 db 2048 clicks</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Wave V</td>
<td>90 db 2048 clicks</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

All peaks and SD are in milli seconds
SD = Standard deviation
db = decibel
Table 7.30  Means of absolute peaks latency with different stimulus repetition rates, right ear, females.

<table>
<thead>
<tr>
<th>Waves</th>
<th>Age group 13-19 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Click Rates (pulse per second)</td>
</tr>
<tr>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Wave I</td>
<td>90 db 2048 clicks</td>
</tr>
<tr>
<td></td>
<td>SD</td>
</tr>
<tr>
<td>Wave II</td>
<td>90 db 2048 clicks</td>
</tr>
<tr>
<td></td>
<td>SD</td>
</tr>
<tr>
<td>Wave III</td>
<td>90 db 2048 clicks</td>
</tr>
<tr>
<td></td>
<td>SD</td>
</tr>
<tr>
<td>Wave IV</td>
<td>90 db 2048 clicks</td>
</tr>
<tr>
<td></td>
<td>SD</td>
</tr>
<tr>
<td>Wave V</td>
<td>90 db 2048 clicks</td>
</tr>
<tr>
<td></td>
<td>SD</td>
</tr>
</tbody>
</table>

All peaks and SD are in milli seconds
SD = Standard deviation
db = decibel
Table 7.31 Means of absolute peaks latency with different stimulus repetition rates, right ear, females.

<table>
<thead>
<tr>
<th>Waves</th>
<th>Age group 20-29 years</th>
<th>Click Rates (pulse per second)</th>
<th>5</th>
<th>10</th>
<th>20</th>
<th>50</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wave I</td>
<td>90 db 2048 clicks</td>
<td>Mean SD</td>
<td>1.510</td>
<td>1.570</td>
<td>1.610</td>
<td>1.790</td>
<td>1.780</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mean SD</td>
<td>0.063</td>
<td>0.063</td>
<td>0.034</td>
<td>0.040</td>
<td>0.069</td>
</tr>
<tr>
<td>Wave II</td>
<td>90 db 2048 clicks</td>
<td>Mean SD</td>
<td>2.480</td>
<td>2.560</td>
<td>2.590</td>
<td>2.680</td>
<td>2.750</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mean SD</td>
<td>0.046</td>
<td>0.014</td>
<td>0.056</td>
<td>0.069</td>
<td>0.071</td>
</tr>
<tr>
<td>Wave III</td>
<td>90 db 2048 clicks</td>
<td>Mean SD</td>
<td>3.470</td>
<td>3.580</td>
<td>3.580</td>
<td>3.690</td>
<td>3.760</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mean SD</td>
<td>0.028</td>
<td>0.014</td>
<td>0.040</td>
<td>0.017</td>
<td>0.092</td>
</tr>
<tr>
<td>Wave IV</td>
<td>90 db 2048 clicks</td>
<td>Mean SD</td>
<td>4.520</td>
<td>4.500</td>
<td>4.660</td>
<td>4.560</td>
<td>4.480</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mean SD</td>
<td>0.069</td>
<td>0.069</td>
<td>0.080</td>
<td>0.110</td>
<td>0.180</td>
</tr>
<tr>
<td>Wave V</td>
<td>90 db 2048 clicks</td>
<td>Mean SD</td>
<td>5.280</td>
<td>5.100</td>
<td>5.440</td>
<td>5.790</td>
<td>5.460</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mean SD</td>
<td>0.023</td>
<td>0.120</td>
<td>0.051</td>
<td>0.060</td>
<td>0.130</td>
</tr>
</tbody>
</table>

All peaks and SD are in milli seconds
SD = Standard deviation
db = decibel
Table 7.32 Means of absolute peaks latency with different stimulus repetition rates, right ear, females.

<table>
<thead>
<tr>
<th>Waves</th>
<th>Age group 30-39 years</th>
<th>Click Rates (pulse per second)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Wave I</td>
<td>90 db 2048 clicks</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
</tr>
<tr>
<td>Wave II</td>
<td>90 db 2048 clicks</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
</tr>
<tr>
<td>Wave III</td>
<td>90 db 2048 clicks</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
</tr>
<tr>
<td>Wave IV</td>
<td>90 db 2048 clicks</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
</tr>
<tr>
<td>Wave V</td>
<td>90 db 2048 clicks</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
</tr>
</tbody>
</table>

All peaks and SD are in milli seconds
SD = Standard deviation
db = decibel
Table 7.33  Means of absolute peaks latency with different stimulus repetition rates, right ear, females.

<table>
<thead>
<tr>
<th>Waves</th>
<th>Age group 40-49 years</th>
<th>Click Rates (pulse per second)</th>
<th>5</th>
<th>10</th>
<th>20</th>
<th>50</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wave I</td>
<td>90 db 2048 clicks</td>
<td>Mean SD</td>
<td>1.750</td>
<td>0.042</td>
<td>1.620</td>
<td>0.040</td>
<td>1.820</td>
</tr>
<tr>
<td>Wave II</td>
<td>90 db 2048 clicks</td>
<td>Mean SD</td>
<td>2.260</td>
<td>0.130</td>
<td>2.200</td>
<td>0.150</td>
<td>2.320</td>
</tr>
<tr>
<td>Wave III</td>
<td>90 db 2048 clicks</td>
<td>Mean SD</td>
<td>3.400</td>
<td>0.049</td>
<td>3.480</td>
<td>0.052</td>
<td>3.690</td>
</tr>
<tr>
<td>Wave IV</td>
<td>90 db 2048 clicks</td>
<td>Mean SD</td>
<td>4.540</td>
<td>0.028</td>
<td>4.680</td>
<td>0.063</td>
<td>4.600</td>
</tr>
<tr>
<td>Wave V</td>
<td>90 db 2048 clicks</td>
<td>Mean SD</td>
<td>5.300</td>
<td>0.060</td>
<td>5.400</td>
<td>0.070</td>
<td>5.460</td>
</tr>
</tbody>
</table>

All peaks and SD are in milli seconds  
SD = Standard deviation  
db = decibel
Table 7.34 Means of absolute peaks latency with different stimulus repetition rates, right ear, females.

<table>
<thead>
<tr>
<th>Waves</th>
<th>Age group 50-58 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Click Rates (pulse per second)</td>
</tr>
<tr>
<td></td>
<td>90 db 2048 clicks Mean</td>
</tr>
<tr>
<td>Wave I</td>
<td>1.780 0.021</td>
</tr>
<tr>
<td>Wave II</td>
<td>2.460 0.098</td>
</tr>
<tr>
<td>Wave III</td>
<td>3.530 0.070</td>
</tr>
<tr>
<td>Wave IV</td>
<td>4.500 0.042</td>
</tr>
<tr>
<td>Wave V</td>
<td>5.260 0.049</td>
</tr>
</tbody>
</table>

All peaks and SD are in milli seconds
SD = Standard deviation
db = decibel
Figure 7.11 Peaks latency changes on effect of stimulus rates with different age group, right ear, males, 5 PPS
Figure 7.12 Peaks latency changes on effect of stimulus rates with different age group, right ear, males, 10 PPS
Figure 7.13 Peaks latency changes on effect of stimulus rates with different age group, right ear, males, 20 PPS.
Figure 7.14 Peaks latency changes on effect of stimulus rates with different age group, right ear, males, 50 PPS
Figure 7.15 Peaks latency changes on effect of stimulus rates with different age group, right ear, males, 100 PPS
Figure 7.16  Peaks latency changes on effect of stimulus rates with
different age group, right ear, females, 5 PPS
Figure 7.17  Peaks latency changes on effect of stimulus rates with different age group, right ear, females, 10 PPS
Figure 7.18 Peaks latency changes on effect of stimulus rates with different age group right ear females, 20 PPS

- I
- II
- III
- IV
- V
Figure 7.19 Peaks latency changes on effect of stimulus rates with different age group, right ear, females, 50 PPS
Figure 7.20 Peaks latency changes on effect of stimulus rates with different age group, right ear, females, 100 PPS.
peak latency variation in all age are more or less same in corresponding stimulus rates. As it can be seen from the tables as well as from the figures, effect of higher stimulus rate specially at 50 pps on peak latency of wave V were prominent and that might be the reason that higher stimulus have clinical significant on wave V as in multiple sclerosis diagnosis. Wave V absolute peak latency changes in different stimulus intensity according to changes in age stimulus repetition rates at higher rates had more or less the same effect on the peak latency of all age group in both sexes except in 20-29 age group. From the figures and tables it can be seen that females had shorter peak latency specially in wave V in all age groups than males are shown in Figure 7.21.

The mean of I-III, III-V and I-V interpeak latencies with different stimulus repetition rates according to different age group in males are shown in tables 7.35-7.39 and the corresponding interpeak latencies in females are shown in tables 7.40-7.44. Interpeak latencies in different age groups and both sexes are increased by increasing the stimulus repetition rates and decreased by increasing the age. Females had shorter interpeak latencies in all age groups and stimulus rates compare to corresponding male groups. Interpeak latency difference between the younger and older subjects at lower rates were more than the higher stimulus rates.

The standard deviation calculated for absolute peak latencies, interpeak latencies plus their mean latencies in all age and both sexes shown in normal level according to references mentioned in section 7.3.2.

7.4.3 Discussion

The effect of stimulus repetition rates on BAEP waveform components in different age and sex are reported by various researchers (Fujikaw et al., 1977). Pratt et al (1977) reported an increase of approximately 0.20 ms in wave I latency of normal patients without
Figure 7.21 Variations of waves V in different stimulus rates, males and females, right ear
Table 7.35  Means of Interpeak latency with different stimulus repetition rates, right ear, males

<table>
<thead>
<tr>
<th>Interpeaks</th>
<th>Click Rates (pulse per second)</th>
<th>5</th>
<th>10</th>
<th>20</th>
<th>50</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age Group 13-19 Years</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-III</td>
<td>90 db 2048 clicks Mean SD</td>
<td>2.040</td>
<td>2.070</td>
<td>2.030</td>
<td>2.020</td>
<td>2.210</td>
</tr>
<tr>
<td>III-V</td>
<td>90 db 2048 clicks Mean SD</td>
<td>1.810</td>
<td>1.900</td>
<td>1.870</td>
<td>2.020</td>
<td>1.960</td>
</tr>
<tr>
<td>I-V</td>
<td>90 db 2048 clicks Mean SD</td>
<td>3.920</td>
<td>3.970</td>
<td>3.900</td>
<td>4.040</td>
<td>4.170</td>
</tr>
</tbody>
</table>

All interpeaks and SD are in milli seconds.
SD = Standard Deviation
db = decibel
Table 7.36  Means of Interpeak latency with different stimulus repetition rates, right ear, males

<table>
<thead>
<tr>
<th>Interpeaks</th>
<th>Age Group 20-29 Years</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Click Rates (pulse per second)</td>
</tr>
<tr>
<td></td>
<td>5</td>
</tr>
<tr>
<td>I-III</td>
<td>90 db 2048 clicks</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>III-V</td>
<td>90 db 2048 clicks</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>I-V</td>
<td>90 db 2048 clicks</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

All interpeaks and SD are in milli seconds.
SD = Standard Deviation
db = decibel
<table>
<thead>
<tr>
<th>Interpeaks</th>
<th>Click Rates (pulse per second)</th>
<th>Age Group 30-39 Years</th>
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</thead>
<tbody>
<tr>
<td>90 db</td>
<td>2048 clicks</td>
<td>5</td>
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<tr>
<td>I-III</td>
<td>Mean</td>
<td>1.990</td>
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<td>0.012</td>
</tr>
<tr>
<td>III-V</td>
<td>Mean</td>
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<td>IV</td>
<td>Mean</td>
<td>3.920</td>
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<tr>
<td></td>
<td>SD</td>
<td>0.040</td>
</tr>
</tbody>
</table>

All interpeaks and SD are in milliseconds. SD = Standard Deviation.

db = decibel

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Table 7.38 Means of Interpeak latency with different stimulus repetition rates, right ear, males

<table>
<thead>
<tr>
<th>Interpeaks</th>
<th>Click Rates (pulse per second)</th>
<th>Age Group 40-49 Years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>I-III</td>
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<td></td>
</tr>
<tr>
<td>90 db</td>
<td>Mean</td>
<td>1.950</td>
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<tr>
<td>2048 clicks</td>
<td>SD</td>
<td>0.006</td>
</tr>
<tr>
<td>III-V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>90 db</td>
<td>Mean</td>
<td>1.830</td>
</tr>
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<td>2048 clicks</td>
<td>SD</td>
<td>0.023</td>
</tr>
<tr>
<td>I-V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>90 db</td>
<td>Mean</td>
<td>3.780</td>
</tr>
<tr>
<td>2048 clicks</td>
<td>SD</td>
<td>0.029</td>
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</table>

All interpeaks and SD are in milli seconds.
SD = Standard Deviation
db = decibel
Table 7.39 Means of Interpeak latency with different stimulus repetition rates, right ear, males

<table>
<thead>
<tr>
<th>Interpeaks</th>
<th>Click Rates (pulse per second)</th>
<th>5</th>
<th>10</th>
<th>20</th>
<th>50</th>
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<tbody>
<tr>
<td></td>
<td>Age Group 50 - 58 Years</td>
<td></td>
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<tr>
<td>I-III</td>
<td>90 db</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>2048 clicks</td>
<td>1.970</td>
<td>1.870</td>
<td>0.014</td>
<td>1.830</td>
<td>0.009</td>
<td>1.870</td>
</tr>
<tr>
<td></td>
<td>0.006</td>
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<td>0.009</td>
<td>0.036</td>
<td>0.072</td>
<td>0.035</td>
</tr>
<tr>
<td>III-V</td>
<td>90 db</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>2048 clicks</td>
<td>1.930</td>
<td>1.820</td>
<td>0.007</td>
<td>1.970</td>
<td>0.006</td>
<td>1.930</td>
</tr>
<tr>
<td></td>
<td>0.002</td>
<td>0.002</td>
<td>0.006</td>
<td>0.035</td>
<td>0.072</td>
<td>0.035</td>
</tr>
<tr>
<td>IV</td>
<td>90 db</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>2048 clicks</td>
<td>1.910</td>
<td>1.970</td>
<td>0.014</td>
<td>1.970</td>
<td>0.009</td>
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<tr>
<td></td>
<td>0.002</td>
<td>0.002</td>
<td>0.009</td>
<td>0.035</td>
<td>0.072</td>
<td>0.035</td>
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</table>

All interpeaks and SD are in milli seconds. SD = Standard Deviation db = decibel
Table 7.40 Means of Interpeak latency with different stimulus repetition rates, right ear, females

<table>
<thead>
<tr>
<th>Interpeaks</th>
<th>Age group 13 - 19 years</th>
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<th></th>
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<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Click Rates (pulse per second)</td>
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<td>10</td>
<td>20</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>90 db</td>
<td>2048 clicks</td>
<td>Mean</td>
<td>SD</td>
<td>1.980</td>
</tr>
<tr>
<td>I - III</td>
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<td>90 db</td>
<td>2048 clicks</td>
<td>Mean</td>
<td>SD</td>
<td>1.750</td>
</tr>
<tr>
<td>III - V</td>
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<td>90 db</td>
<td>2048 clicks</td>
<td>Mean</td>
<td>SD</td>
<td>3.730</td>
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</tbody>
</table>

All interpeaks and SD are in milli seconds
SD = Standard deviation
db = decibel
Table 7.41 Means of Interpeak latency with different stimulus repetition rates, right ear, females

<table>
<thead>
<tr>
<th>Interpeaks</th>
<th>Age group 20 - 29 years</th>
<th>Click Rates (pulse per second)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>I - III</td>
<td>90 db 2048 clicks</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
</tr>
<tr>
<td>III - V</td>
<td>90 db 2048 clicks</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
</tr>
<tr>
<td>I - V</td>
<td>90 db 2048 clicks</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
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</table>

All interpeaks and SD are in milli seconds
SD = Standard deviation
db = decibel
Table 7.42 Means of Interpeak latency with different stimulus repetition rates, right ear, females

<table>
<thead>
<tr>
<th>Interpeaks</th>
<th>Age group 30 - 39 years</th>
<th>Click Rates (pulse per second)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>I - III</td>
<td>90 db 2048 clicks</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
</tr>
<tr>
<td>III - V</td>
<td>90 db 2048 clicks</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
</tr>
<tr>
<td>I - V</td>
<td>90 db 2048 clicks</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
</tr>
</tbody>
</table>

All interpeaks and SD are in milli seconds
SD = Standard deviation
db = decibel
Table 7.43 Means of Interpeak latency with different stimulus repetition rates, right ear, females

<table>
<thead>
<tr>
<th>Interpeaks</th>
<th>Age group 40 - 49 years</th>
<th>Click Rates (pulse per second)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>1 - III</td>
<td>90 db</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>2048 clicks</td>
<td>SD</td>
</tr>
<tr>
<td>III - V</td>
<td>90 db</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>2048 clicks</td>
<td>SD</td>
</tr>
<tr>
<td>1 - V</td>
<td>90 db</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>2048 clicks</td>
<td>SD</td>
</tr>
</tbody>
</table>

All interpeaks and SD are in milli seconds
SD = Standard deviation
db = decibel
Table 7.44 Means of Interpeak latency with different stimulus repetition rates, right ear, females

<table>
<thead>
<tr>
<th>Interpeaks</th>
<th>Age group 50 - 58 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Click Rates (pulse per second)</td>
</tr>
<tr>
<td></td>
<td>5</td>
</tr>
<tr>
<td>I - III</td>
<td>90 db</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>III - V</td>
<td>90 db</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>I - V</td>
<td>90 db</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

All interpeaks and SD are in milli seconds
SD = Standard deviation
db = decibel
consideration of their age and sex at the stimulus rate of 10-40 pps. Whereas in this study the mean latency value of wave I at stimulus rates of 10-50 pps in patients with combined age and sex were 0.24 ms. Beagley et al (1978) reported the latencies of wave I-V at stimulus rate of 20 pps in subjects with mixed age group were 0.90 ms, 3.0 ms, 4.0 ms, 5.20 ms and 5.90 ms whereas in this study the same waves had the peak latencies of 1.74 ms, 2.55 ms, 3.69 ms, 4.66 ms and 5.53 ms, respectively. In another study (Chiappa et al., 1979) with mixed gender and sex at stimulus rates of 10, 30 and 70 pps reported that, the absolute peak latency in wave I were, 1.70 ms, 1.90 ms, 1.80 ms in wave II, 2.80 ms, 2.90 ms, 2.90 ms in wave III, 3.90 ms, 4.0 ms, 4.20 ms in wave IV, 5.10 ms, 5.20 ms, 5.40 ms in wave V, 5.70 ms, 5.90 ms, 6.20 ms where in the present study the values at the stimulus rates of 10 and 35 pps in mixed aged and sex were 1.67 ms, 1.83 ms in wave I, 2.48 ms, 2.64 ms in wave II, 3.62 ms, 3.77 ms in wave III, 4.65 ms, 4.77 ms in wave IV, 5.44 ms, 5.71 ms in wave V respectively. Squires et al (1980) reported the prolongation of all BAEP peak latencies as the effect of higher stimulus rates on normal and abnormal patients. In normal patients at the stimulus rate of 20 and 50 pps in mixed subjects the values in wave I were 1.88 ms, 2.0 ms and in wave V, 5.97 ms and 6.20 ms whereas in this work the values for the same stimulus rate in mixed subjects in wave I were 1.74 ms, 1.92 ms and in wave V, 5.53 ms, 5.89 ms. Another study (Harkins, 1980) reported that over the stimulus rates of 20-50 pps the latency of wave I increased by a difference value of 0.07 ms and I-V difference by the value of 0.11 ms whereas in this study over the same stimulus rate in mixed subjects the difference values found to be 0.17 ms for wave I and 0.19 ms for I-V difference. Squires et al (1980) in the same stimulus rate (20-50 pps) reported an increase value of 0.12 ms in wave I and 0.14 ms in I-V difference. Pratt et al (1980) on effect of high and low stimulus rate on BAEP waveform components of normal and abnormal patient suggest that, the wave I and II shown normal latency values at 10 pps in patients suffered from the peripheral type of brainstem lesion but at 50 pps these waves latencies shown prolonged value further beyond the
normal limits. Stockard et al (1977) reported the similar results at stimulus rate of 30 pps. The latencies of BAEP waveform components in mixed normal adult subjects as the stimulus rates of 10 and 50 pps are studied. In this study (Pratt et al., 1981) the values for wave I were 1.65 ms, 1.65 ms in wave II, 2.80 ms, 3.10 ms in wave III, 3.80 ms, 4.0 ms in wave IV, 4.95 ms, 5.15 ms and in wave V 5.60 ms, 5.95 ms but in this study with the mixed subjects at the same stimulus rates (10, 50 pps) the wave I were 1.67 ms, 1.92 ms the wave II, 2.48 ms, 2.76 ms, the wave III, 3.62 ms, 3.86 ms the wave IV, 4.65 ms, 4.88 ms and the wave V, 5.44 ms, 5.89 ms, respectively. In this study the effect of high stimulus rate on BAEP waveform components shown a prolongation in all peak latencies but the prolongation on peak latencies of wave III, IV and V were prominants in BAEP waveform components of all subjects in both sexes. The BAEP recorded at stimulus rate 100 pps shown poor resolution specially in peaks IV and V.

It is reported (Chiappa et al., 1979) that by increasing the stimulus rate, all IPLs are increased. For example at stimulus rate of 10 and 30 pps, the I-III IPL shown the values of 2.10 ms, 2.20 ms, the III-V IPL the values of 1.90 ms, 1.90 ms, and I-V IPL the value of 4.0 ms, 4.0 ms but the values in this work for I-III IPL shown the values of 1.93 ms, 1.95 ms, for III-V IPL, 1.81 ms, 2.11 ms and I-V IPL, 3.76 ms, 3.87 ms respectively. The standard deviation calculated in this study is compared with the previous latencies and interpeak latencies are coincident with their values.

7.5 RELATION BETWEEN LATENCY AND FREQUENCY SPECTRUM WITH MAGNITUDE OF BRAINSTEM AUDITORY EVOKED POTENTIAL SIGNALS

BAEP waveform components that are recorded from the patient is a complex waveform of I-V or I-VII waves. The parameters concerned with BAEP waveform analysis are Peaks latency, amplitude and Frequency. The
BAEP waveform characteristics can be change according to the different factors, some of them discussed in previous sections. Filters will always affect latency and amplitude of evoked potential components to some degree and it is defined on the relationship between the filter and frequency content of the waveforms. The energy in BAEP waveform is concentrated in the area of 15 to 2000 Hz (Kevanishvili et al, 1979). There are three major components (Boston, 1981) of I, III, and V with frequency component around 100 Hz, 500 Hz and 1000 Hz respectively. (Walcoff, 1994) suggested that wave I has a frequency between 1000 to 2500 Hz and wave V a frequency between 500 to 800 Hz.

7.5.1 Results

The procedure adapted while recording the BAEP is same as the technique indicated in the section 7.3.2.

In this study eight normal adult subjects (4 males and 4 females) aged from 10-45 years were used. The patients were asked to lie down on a bed with eyes closed and completely in relaxed position. BAEP signals are recorded for the first 10 ms after the on set of stimulus to right ear with left ear masked. The stimulus intensity is fixed at 90 db and stimulus rate for 20 pulse per second.

The recorded BAEP waveform latencies as shown in tables 7.45-7.47 were ranging from 1.38 to 1.88 ms for wave I, 2.26 to 2.86 ms for wave II, 3.50 to 3.86 ms for wave III, 4.10 to 4.88 ms for wave IV and 5.14 to 5.54 ms for wave V. The filter used for this study was a band pass filter of 100 to 3 KHz with a stimulus reputation of 2048 to get a clear waveform. BAEP components in frequency spectrum had a frequency of 294 to 2413 Hz. Where the frequency of wave I was a wide band ranging from 1054 to 2413 Hz, wave II from 705 to 1513 Hz, wave III from 602 to 989 Hz, wave IV from 487 to 695 Hz and wave V from 294 to 716 Hz. The amplitude related
Table 7.45 Relation between peak latencies, frequencies and amplitudes in different age groups, right ear

<table>
<thead>
<tr>
<th>Waves</th>
<th>19 Years (Male)</th>
<th>29 Years (Male)</th>
<th>38 Years (Male)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Latencies (ms)</td>
<td>Frequencies (Hz)</td>
<td>Amplitudes (nV)</td>
</tr>
<tr>
<td></td>
<td>I 1.74</td>
<td>1360-1940</td>
<td>274</td>
</tr>
<tr>
<td></td>
<td>II 2.86</td>
<td>725-1193</td>
<td>170</td>
</tr>
<tr>
<td></td>
<td>III 3.54</td>
<td>684-767</td>
<td>181</td>
</tr>
<tr>
<td></td>
<td>IV 4.44</td>
<td>512-666</td>
<td>360</td>
</tr>
<tr>
<td></td>
<td>V 5.52</td>
<td>332-517</td>
<td>409</td>
</tr>
<tr>
<td></td>
<td>Latencies (ms)</td>
<td>Frequencies (Hz)</td>
<td>Amplitudes (nV)</td>
</tr>
<tr>
<td></td>
<td>I 1.50</td>
<td>1463-2208</td>
<td>342</td>
</tr>
<tr>
<td></td>
<td>II 2.36</td>
<td>875-1513</td>
<td>201</td>
</tr>
<tr>
<td></td>
<td>III 3.68</td>
<td>747-837</td>
<td>82</td>
</tr>
<tr>
<td></td>
<td>IV 4.54</td>
<td>573-695</td>
<td>377</td>
</tr>
<tr>
<td></td>
<td>V 5.54</td>
<td>333-517</td>
<td>411</td>
</tr>
<tr>
<td></td>
<td>Latencies (ms)</td>
<td>Frequencies (Hz)</td>
<td>Amplitudes (nV)</td>
</tr>
<tr>
<td></td>
<td>I 1.56</td>
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<td>261</td>
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<td></td>
<td>II 2.40</td>
<td>753-1235</td>
<td>148</td>
</tr>
<tr>
<td></td>
<td>III 3.60</td>
<td>648-832</td>
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<tr>
<td></td>
<td>IV 4.70</td>
<td>505-602</td>
<td>396</td>
</tr>
<tr>
<td></td>
<td>V 5.46</td>
<td>339-716</td>
<td>394</td>
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</table>
Table 7.46 Relation between peak latencies, frequencies and amplitudes in different age groups, right ear

<table>
<thead>
<tr>
<th>Waves</th>
<th>45 Years (Male)</th>
<th>10 Years (Female)</th>
<th>24 Years (Female)</th>
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<tbody>
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<td>Latencies (ms)</td>
<td>Frequencies (Hz)</td>
<td>Amplitudes (nV)</td>
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<tr>
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<td>1.86</td>
<td>1154-1892</td>
<td>294</td>
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<td>II</td>
<td>2.26</td>
<td>705-1239</td>
<td>184</td>
</tr>
<tr>
<td>III</td>
<td>3.86</td>
<td>653-719</td>
<td>222</td>
</tr>
<tr>
<td>IV</td>
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<td>368</td>
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<tr>
<td>V</td>
<td>5.54</td>
<td>343-628</td>
<td>389</td>
</tr>
<tr>
<td></td>
<td>Latencies (ms)</td>
<td>Frequencies (Hz)</td>
<td>Amplitudes (nV)</td>
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<tr>
<td>I</td>
<td>1.38</td>
<td>1423-1928</td>
<td>329</td>
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<td>II</td>
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<td>801-1365</td>
<td>228</td>
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<td>602-786</td>
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<td>IV</td>
<td>4.58</td>
<td>524-664</td>
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<td>V</td>
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<td>360-583</td>
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<td>Frequencies (Hz)</td>
<td>Amplitudes (nV)</td>
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<td>III</td>
<td>3.62</td>
<td>804-989</td>
<td>232</td>
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<td>IV</td>
<td>4.62</td>
<td>519-673</td>
<td>365</td>
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<tr>
<td>V</td>
<td>5.22</td>
<td>294-533</td>
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Table 7.47 Relation between peak latencies, frequencies and amplitudes in different age groups, right ear

<table>
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<th>40 Years (Female)</th>
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<td>Latencies (ms)</td>
<td>Frequencies (Hz)</td>
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<tr>
<td>I</td>
<td>1.50</td>
<td>1189-2413</td>
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<tr>
<td>II</td>
<td>2.44</td>
<td>987-1232</td>
</tr>
<tr>
<td>III</td>
<td>3.50</td>
<td>720-883</td>
</tr>
<tr>
<td>IV</td>
<td>4.10</td>
<td>577-657</td>
</tr>
<tr>
<td>V</td>
<td>5.14</td>
<td>389-537</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Waves</th>
<th>Latencies (ms)</th>
<th>Frequencies (Hz)</th>
<th>Amplitudes (nV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1.88</td>
<td>1054-1312</td>
<td>248</td>
</tr>
<tr>
<td>II</td>
<td>2.62</td>
<td>873-1337</td>
<td>163</td>
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<tr>
<td>III</td>
<td>3.56</td>
<td>655-795</td>
<td>226</td>
</tr>
<tr>
<td>IV</td>
<td>4.88</td>
<td>487-599</td>
<td>405</td>
</tr>
<tr>
<td>V</td>
<td>5.44</td>
<td>325-521</td>
<td>383</td>
</tr>
</tbody>
</table>
to each BAEP wave components are also calculated. The amplitudes in different subjects were varying from 242 to 342 nv in wave I, 148 to 228 nv in wave II, 82 to 269 nv in wave III, 312 to 405 nv in wave IV and 378 to 424 nv in wave V.

Overall, the mean peak latency in male and female subjects of different age group are shown in table 7.48. Wave I shown the mean peak latency of 1.62 ms, wave II the value of 2.49 ms, wave III the value of 3.62 ms, wave IV the value of 4.52 ms, and wave V the value of 5.41 ms. The mean of frequency for the lower and higher range in all ages shown the values of 1342 to 1991 Hz for wave I, 812 to 1290 Hz for wave II, 686 to 828 Hz for wave III, 522 to 641 Hz for wave IV and 354 to 564 Hz for wave V. The frequency variations versus BAEP peaks indifferent ages for male subjects are shown in Figure 7.22 and in females in Figure 7.23. The average of frequencies in males and females combined ages are shown in Figures 7.24 and 7.25. Where the average frequency for the waves I, II, III, IV and V shown 1647 Hz, 1065 Hz, 757 Hz, 585 Hz and 453 Hz respectively. The mean amplitude values for all waves in different ages are shown in table 7.48 and the corresponding values for each wave shown in Figures 7.26 & 7.27.

7.5.2 Discussion

The results achieved from this study can be helpful in clinical diagnoses and in better interpretation of brain electrical activities using evoked potentials. In routine BAEP waveform interpretation by most neurologists, absolute peak latencies and interpeak latencies are used to define the defects concerned with different portion of auditory pathway. The difference between the absolute peak latencies and interpeak latencies in normal and abnormal patients are some times so minute which can not easily be identified as abnormal in routine practices. In this situation the frequency spectrum analysis may give a wide variation between the normal
Table 7.48  Means of latencies, frequencies and amplitudes (Males & Females), right ear

<table>
<thead>
<tr>
<th>Waves</th>
<th>Latencies (ms)</th>
<th>Frequencies (Hz)</th>
<th>Amplitudes (nV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1.62</td>
<td>1647</td>
<td>288</td>
</tr>
<tr>
<td>II</td>
<td>2.49</td>
<td>1065</td>
<td>179</td>
</tr>
<tr>
<td>III</td>
<td>3.62</td>
<td>757</td>
<td>206</td>
</tr>
<tr>
<td>IV</td>
<td>4.52</td>
<td>585</td>
<td>370</td>
</tr>
<tr>
<td>V</td>
<td>5.41</td>
<td>453</td>
<td>398</td>
</tr>
</tbody>
</table>
Figure 7.22 Frequency variations vs different peaks, males
Figure 7.23  Frequency variations vs different peaks, females
Figure 7.24 Averaged frequency variations vs different peaks, males & females.
Figure 7.25 Averaged frequency variations vs different peaks
Figure 7.26 Averaged amplitude variations vs different peaks, males & females
Figure 7.27 Averaged amplitude variations vs different peaks
and abnormal waveform. In this regard the frequency of different BAEP waveform components in different ages and sex are studied (Tafti et al., 1996). In this study the frequency in wave V were in the range of 354 and 564 Hz and the frequency in wave I in the range of 1342 to 1991 Hz. Whereas in another study (Walcoff, 1994) the value of wave V were in the range of 500 to 800 Hz, and wave I in the range of 1000 to 2500 Hz. In another study (Boston, 1981) suggested that, in BAEP there are three main components: a low frequency component around 100 Hz, a mid frequency component around 500 Hz and a high frequency component at 1000 Hz and in other study (Kevaniskvili et al 1979) reported at 150, 500 and 900 Hz and Yoganandam et al (1981) suggested that the BAEP reveled the components frequencies at 1000 and 500 Hz.

In this study the resulted amplitude values in waves I, III and V were more or less similar to the values reported by previous study (Parker, 1981) and the frequencies obtained were partly coincident with frequencies suggested by Walcoff (1994).

7.6 VISUAL REPRESENTATION OF BAEP WAVES

Since the BAEP waveform amplitude variation has clinical significance, knowledge about the level of amplitude variation in different parts of the auditory pathway could provide a useful information in the diagnosis of the patients. There are several reports on the distribution of brainstem auditory evoked potentials (BAEPs) on the scalp (Terkildsen et al., 1974, Martin and Moore 1977). Recently, some examples of BAEP maps that agree reasonably with the surface distributions reported by Grandori (1986) and Duffy (1989). In this study a similar technique is used in producing the image of the brain electrical activities with the help of BEAM technique. It produce the visual pattern of the evoked potentials generated at different part of the brainstem auditory pathway. It also could give a much clearer picture of the brain activities than the recorded waveform.
Moreover the variations in voltage that may not be visible in the waveform can clearly be defined by using this technique.

The BAEP datas recorded from the ipsilateral and contralateral ears of two normal adult subjects in same age group of both sex as shown in tables 7.49 & 7.50 are presented in BEAM technique. The related colour coded images are shown in figures 7.28 & 7.29. The electrode locations on the image are selected according to the shortest absolute peak latency and larger amplitude in each peak as determined in chapter 6 by selecting different electrode location over the scalp of various subject as shown in table 6.1 and 6.2. In that work for example the wave I shown shorter absolute peak latency with larger amplitude or the corresponding values for wave V at Cz location. According to the absolute peak latency and amplitude at T4 location determination in each peak, the site of corresponding electrode locations over the scalp is determined and placed on a 64 x 50 grid superimposed on a two dimensional projection of the head. Waves I and II amplitude datas corresponds to each ear is presented in separate location. But the values related to waves III, IV and V presented on the BEAM are the mean amplitude values obtained from the both ears. These values are stored in a separate file and then presented at the same location, as the site of their voltage generation were the same. The colour coded images are driven from the locations over the BEAM were more informative than the recorded waveform. The software used in this study is the modified software which were used to represent the EEG and EP datas in BEAM as discussed in Chapter 5. In this work the software program were needed to read seven datas from the file and calculated the remaining unknown voltage points over the scalp using four nearest neighbour (4 NN) method. Figures 7.28 and 7.29 shown the colour coded images correspond to voltages at each location over the scalp of a male and female subjects.
### Table 7.49 Peaks latency values in ipsilateral and contralateral ears

<table>
<thead>
<tr>
<th>Waves</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1.98</td>
<td>2.00</td>
</tr>
<tr>
<td>II</td>
<td>3.06</td>
<td>3.02</td>
</tr>
<tr>
<td>III</td>
<td>4.00</td>
<td>3.96</td>
</tr>
<tr>
<td>IV</td>
<td>5.18</td>
<td>5.22</td>
</tr>
<tr>
<td>V</td>
<td>5.92</td>
<td>6.04</td>
</tr>
</tbody>
</table>

All values in Milli Seconds.

### Table 7.50 Amplitude values in ipsilateral and contralateral ears.

<table>
<thead>
<tr>
<th>Waves</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>160</td>
<td>153</td>
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<td>II</td>
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<tr>
<td>III</td>
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<td>137</td>
</tr>
<tr>
<td>IV</td>
<td>241</td>
<td>252</td>
</tr>
<tr>
<td>V</td>
<td>283</td>
<td>271</td>
</tr>
</tbody>
</table>

All values in nano volts
Figure 7.28 Colour coded image of BAEP datas in ipsilateral and contralateral ears, male
Figure 7.29 Colour coded image of BAEP data in ipsilateral and contralateral ears, female