# Estimation of Behavioural Threshold Using Click Evoked ALR in Normal and Hearing Impaired Population

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**Abstract**

*Establishing frequency specific threshold has significant importance in reaching appropriate diagnosis and planning individualized rehabilitation program. Auditory evoked potentials are used to predict behavioural threshold in difficult to test population when audiologist fails to obtain frequency specific behavioural threshold. Among auditory evoked potentials ALR require lesser neural synchrony than ABR for recording, so ALR could be a better objective tool to estimate the threshold. The current study investigated the ALR as objective tool to assess behavioural threshold in normal hearing and other clinical population. ALR was recorded from 20 ears with normal hearing, 16 ears with sensorineural hearing and 20 ears with auditory dys-synchrony .ALR recording was initiated at 80 dBnHL and gradually reduced the intensity. The lowest intensity at which $N_1$-$P_2$ complex was observed was considered as ALR threshold. Statistical analysis revealed that a significant positive correlation between ALR threshold and pure tone average in sensorineural hearing loss individuals. However a weak positive correlation was obtained in normal hearing group and auditory dys synchrony group. It can be concluded that ALR can closely estimate the behavioural threshold in sensorineural hearing loss individuals.*

*Key words: ALR, Auditory dys synchrony.*

## Introduction

Auditory long latency response is an auditory evoked potential came in to the field since 1960s. However, it has failed to gain much popularity due to the explosion of interest in the auditory brainstem response (ABR). This could be because of its accuracy and reliability to predict the behavioral threshold. ALR has not gain the popularity to predict behavioural threshold as it is affected by several factors.

Hyde, Alberti, Matsumoto and Liyl (1980) reported that tone burst evoked ALR audiometry can be used specifically at approximating the pure tone audiogram for at-risk infants, difficult-to-test children, and adults with certain mental or physical handicaps. They found that ALR can be used to estimate behavioral threshold within 10 dB in at least 90% of cases and for those subjects, who are both awake and passively cooperative.

Alberti (1970) carried out evoked cortical response audiometry using tone burst in normal hearing and patients with abnormal hearing. All were neurologically normal. He found that nine of the ten normal hearing subject's threshold was within 10 dB at the best conventional threshold tested between 500 Hz and 4000 Hz. The Patients with hearing loss showed a little greater spread from 250 Hz to 2000 Hz and the thresholds were within 15 dB. He also reported that cortical audiometry is valuable in detecting functional hearing loss. However, there are lesser number of studies which used click as stimulus for threshold estimation due to its lack of frequency specificity and short duration. However, use of long duration click could predict behavioral threshold within short period of time.

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The effect of hearing loss on ALR has been studied extensively by several authors. Polen (1984) studied the effect of hearing loss on ALR components and compared the findings with normal hearing group. He found that moderate to severe SN hearing loss resulted in prolongation of latencies of $P_2$, $N_2$ components of ALR. Decreased $N_2$ amplitude in the sensorineural hearing loss group in comparison to normal hearing group was also reported. However, there are inconsistencies among studies of ALR in hearing impaired subjects reported (Oates, Kurtzberg and Stapells, 2002).

Cortical potential like ALR requires different neural synchrony compared to the synchrony required for relatively shorter latency response (Kraus et al., 2000). It is possible that ABR or ALR which requires high synchronization may be disrupted in some subjects; where as low neural synchrony required for ALR may be intact. Auditory dys-synchrony is one such disorder characterized by abnormal or absent ABR and presence of OAE and / CM indicating normal functioning of OHC (Starr et al., 1991). In such condition, ALR recorded from auditory dys-synchrony clients could be an important tool to predict behavioral threshold.

Speech intelligibility is another problem consistent with sensorineural hearing loss and auditory dys-synchrony. Most of the affected adults with auditory dys-synchrony report perceptual difficulties for greater than, would be expected from their behavioral audiogram (Zeng et al., 2001 and Starr et al., 2003). Speech perception ability cannot be reliably estimated from behavioral audiogram in individuals with auditory dys-synchrony, ALR components may offer a means of predicting perceptual skills (Rance et al., 2002). Hence, present study aimed at finding out the relationship between

- Relationship between ALR threshold and pure tone average in individuals with normal hearing, sensorineural hearing loss and auditory dys-synchrony.
- Relationship between ALR threshold and speech identification score (SIS) in individuals with sensorineural hearing loss and auditory dys-synchrony.
- Relationship between click evoked ALR threshold and frequency specific pure tone threshold (250 Hz to 4000 Hz) in individuals with sensorineural hearing loss and auditory dys-synchrony.

## Method

**Participants:** A total of 37 subjects were participated in the study. Participants were grouped in to three groups. Group I: consists of 20 ears with normal hearing from 14 individuals from 18 to 50 years of age with a mean age of 33.9 years. Group II included 16 ears with cochlear hearing loss from 12 individuals. The age range was between 18 to 60 years with a mean age of 36.4 years. Group III: This group consisted of 20 ears of 11 individuals with auditory neuropathy or auditory dys-synchrony with the age range of 18 - 50 years with a mean age of 30.1years. Group II and III were further divided in to three subgroups each depending upon their severity of hearing loss as mild, moderate and moderately severe for comparison.

**Instrumentation:** A calibrated double channel diagnostic Madsen Orbiter 922 (version.2) audiometer with TDH 39 ear phone and B-71 bone conduction vibrator was used to carried out pure tone audiometry. A calibrated immittance meter (Granson Stadler Inc. Tymp Star) was used to assess middle ear status and ILO 292 DP Echo port (Otodynamics, version 5) system was used for recording TEOAEs. Auditory brainstem responses and auditory long latency responses to click stimuli was recorded using Intelligent Hearing System (IHS smart EP, NSB version 2.39) evoked potential system. The click stimuli was delivered using ER-3A insert receiver.

**Procedure**

- Pure tone threshold for air conduction were obtained at octave frequencies between 250 Hz and 8000 Hz and from 250 Hz to 4000 Hz for bone conduction. Modified Hughson –West lake procedure (Carhart and Jerger, 1959) was used to obtain pure tone threshold. Speech identification score was obtained at 40 dB SL with reference to speech recognition threshold in each ear independently using phonetically balanced list developed by Mayadevi (1978)

  Speech in noise test was carried out at 0 dB SNR condition (both signal and noise were presented at 40 dB SL) using the same Phonetically balanced list.

- Tympanometry was carried out using 226 Hz probe tone frequency and acoustic Reflexes were also checked at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz pure tones, for both ipsi and contra laterally to rule out middle ear pathology. TEOAEs were recorded using nonlinear broad band clicks of 256 sweeps presented at around 75 dB peSPL to identify the presence or absence of cochlear pathology.

- After the appropriate placement of the electrodes ABR and ALR were recorded. ABR recording was done using alternate click stimulus at a rate of 30.1/sec at 90 dB nHL. While recording ALR and ABR, Inverting electrode was placed on the left mastoid ($M_1$)/ right mastoid ($M_2$), Ground was on either of the mastoid ($M_2$/$M_1$), Non inverting electrode was on the high forehead (FpZ). ABR was recorded to identify presence or absence of retrocochlear pathology.

- ALR Testing was initiated at 80 dBnHL using alternate click stimulus at a rate of 1.1/sec for normal hearing and sensorineural hearing loss group. Where-as, for auditory dys-synchrony group ALR was initiated at 90 dBnHL. Intensity was then gradually reduced if the observable ALR was noticed. Initially intensity was reduced by 20 dBnHL for normal hearing group and 10 dBnHL for sensorineural hearing loss and auditory neuropathy group till no response was obtained. Then the intensity was increased by 5 dB till the response ($N_1$-$P_2$) was observed. ALR was recorded twice at each presentation level to check for replicability. The presence of $N_1$-$P_2$ complex at the lowest intensities, were considered as threshold.

## Results

The mean, standard deviation (SD) and range were also calculated for each parameter for both sensorineural and normal hearing groups separately. This can be seen in the Table 1. The Krusikal wallis test was carried out for the comparison of latency of the $P_1$, $N_1$, $P_2$ and amplitude of $N_1$-$P_2$ complex across the normal hearing, sensorineural hearing loss and auditory dys-synchrony groups. The latency value of $N_2$ is not considered for this analysis as it was absent in majority of the auditory neuropathy cases. The result indicated that $P_1$, $N_1$and $P_2$ latency and $N_1$-$P_2$ amplitude were significantly different across the groups; Whereas $P_2$ latency did not show any significant difference. In order to know the significant difference between the two groups, Man Whitney test was carried out. This can be seen in Table2

Table 1- Mean, SD, range of the latency for each component of ALR ($P_1$, $N_1$, $P_2$, and $N_2$) and the amplitude of $N_1$-$P_2$ complex at different intensity levels

| | | **Normal** | | | **SNHL** | |
|---|---|---|---|---|---|---|
| | **Intensity** | **80 dBnHL** | **60 dBnHL** | **40 dBnHL** | **80 dBnHL** | **60 dBnHL** |
| $P_1$ Latency | Mean | 58.55 | 78.95 | 94.34 | 50.5 | 76.5 |
| | SD | 9.27 | 9.4 | 11.9 | 6.78 | 18.3 |
| | Range | 40 - 76 | 69 - 96 | 79 - 126 | 44 - 65 | 55 - 99 |
| $N_1$ Latency | Mean | 96.75 | 116.9 | 136.8 | 84.8 | 114.6 |
| | SD | 11.84 | 14.45 | 19.69 | 12.27 | 7.53 |
| | Range | 78 -121 | 92 - 159 | 99 - 180 | 79 - 95 | 98 - 131 |
| $P_2$ Latency | Mean | 148.94 | 168.47 | 187.63 | 146.6 | 175.4 |
| | SD | 15.67 | 14.48 | 22.16 | 14.69 | 21.21 |
| | Range | 103 - 169 | 132 - 200 | 139 - 239 | 121 - 165 | 131 - 163 |
| $N_2$ Latency | Mean | 204.4 | 225.5 | 246.5 | 209 | 235 |
| | SD | 13.85 | 16.95 | 19.12 | 21.21 | 16.14 |
| | Range | 176 - 222 | 195 - 255 | 213 - 285 | 182 - 255 | 219 - 270 |
| $N_1$-$P_2$ Amplitude | Mean | 4.23 | 2.77 | 1.58 | 5.5 | 3.44 |
| | SD | 0.97 | 0.83 | 0.63 | 0.99 | 0.99 |
| | Range | 2.58 - 5.87 | 1.29 - 4.37 | .60 - 3.15 | 3.23 - 6.72 | 1.63 - 5.38 |

It can be seen from the Table 1 that as the intensity of the stimulus was reduced from 80 to 40 dBnHL, there was an increase in the latency of all the ALR components and decrease in the $N_1$-$P_2$ amplitude in both the normal hearing group and sensori neural hearing loss group. The SD and range of latency for different ALR component were more than that of amplitude of $N_1$-$P_2$ complex for both normal hearing and sensorineural hearing loss group. This indicates that the latency of ALR has limited clinical utility.

Table 2 - Depicts the Z-value and the significance level for all the parameters of ALR between the groups at 80 dBnHL

| | $P_1$ Latency | | $N_1$ Latency | | $P_2$ Latency | | $N_1$-$P_2$ Amplitude | |
|---|---|---|---|---|---|---|---|---|
| | Z-value | Sig level | Z-value | Sig level | Z-value | Sig level | Z-value | Sig level |
| Normal Vs SNHL | 2.14 | 0.032 | 3.02 | 0.002 | 1.08 | 0.279 | 2.42 | 0.016 |
| Normal Vs AD | 1.811 | 0.07 | 1.02 | 0.919 | 0.205 | 0.838 | 0.951 | 0.342 |
| AD Vs SNHL | 1.24 | 0.213 | 2.15 | 0.031 | 0.207 | 0.836 | 0.826 | 0.409 |

Table 2 show that between normal hearing and sensorineural hearing loss group, latency of $P_1$, $N_1$ and amplitude of $N_1$-$P_2$ differed significantly, whereas, the latency of $P_2$ did not differ significantly. Between auditory dys-synchrony and sensorineural hearing loss group only the latency of $N_1$ component showed significant difference. Apart from this other latency parameters and $N_1$-$P_2$ amplitude parameter did not show statistical significant difference. Between normal hearing and auditory dys-synchrony group, no significant difference was obtained for all the ALR parameters.

The ALR threshold obtained from different groups were then compared with the behavioral threshold. The mean, SD and range for pure tone threshold and ALR threshold were calculated for all the three groups. Pearson product moment correlation was also done to identify the relationship between the ALR threshold and pure tone average. This can be seen in the Table 3 and 4.

Table 3 - Depicts the mean, SD and range obtained for ALR threshold and PTA for all the three groups

| | ALRT | | | PTA | | |
|---|---|---|---|---|---|---|
| | MEAN | SD | RANGE | MEAN | SD | RANGE |
| SNHL Mild | 49 (n=5) | 5.48 | 40-55 | 32.96 | 3.21 | 30-38 |
| SNHL Mod | 62.5 (n=4) | 5.00 | 55-65 | 50.38 | 6.01 | 60-70 |
| SNHL Ms | 65 (n=7) | 5.00 | 60-70 | 62.34 | 4.29 | 58-68 |
| AD Mild | 85 (n=6) | 8.37 | 70-90 | 34.63 | 4.39 | 26-40 |
| AD Mod | 83.33 (n=3) | 11.54 | 70-90 | 46.07 | 7.74 | 41-60 |
| AD Ms | 75 (n=2) | 21.21 | 60-90 | 58.3 | 0.00 | 58 -58 |
| Normal | 35.25 (n=20) | 6.78 | 20-40 | 7.34 | 2.43 | 3.3-12 |

Table 4 - Depicts the r- value and the significant level obtained between the ALR threshold and PTA for all the three groups

| GROUP | | r value | Sig level |
|---|---|---|---|
| Normal | ALR vs PTA | 0.11 | 0.644 |
| SNHL | ALR vs PTA | 0.833 | 0.000 |
| AN | ALR vs PTA | -0.394 | 0.205 |

It can be seen from the Table 3 that the ALR threshold increased gradually as the degree of sensorineural hearing loss increased. This trend was not observed in the auditory dys-synchrony group. It can also be seen that the difference between the ALR threshold and PTA reduced as the hearing loss is increased. The difference was maximum for normal hearing group. The range of ALR threshold was less in auditory dys-synchrony group even though the degree of hearing loss in this group varied from mild to moderately severe. The behavioral pure tone threshold obtained was lesser than the ALR threshold in all the groups and this was relatively better in auditory dys-synchrony group. Table 4 shows that a highly significant positive correlation obtained between ALR threshold and PTA in sensorineural hearing loss group. A weak positive correlation, but not significant was observed in normal hearing group. Where as in auditory dys-synchrony group weak negative correlation is observed. ALR may not be able to predict behavioral threshold in auditory dys-synchrony individuals rather the presence or absence can give an idea about their processing ability. ALR can be a good tool to predict behavioral threshold in individuals with sensorineural hearing loss.

To understand the relation between ALR threshold and the speech identification scores in individuals with sensorineural hearing loss and auditory dys-synchrony. The mean, SD and range for these two aspects were calculated according to the degree of hearing loss. Pearson product moment correlation was also calculated. This can be seen in the Table 5 and 6.

Table 5 – Depicts the mean, SD and Range of ALR threshold and SIS obtained in sensorineural hearing loss and auditory dys-synchrony group

| | **ALRT** | | | **SIS** | | |
|---|---|---|---|---|---|---|
| | **Mean** | **SD** | **Range** | **SI Mean** | **SI-SD** | **Range** |
| SN HL Mild | 49 | 5.47 | 40-55 | 84 | 9.61 | 70-95 |
| SN HL Mod | 62.5 | 5 | 60-70 | 88.75 | 7.5 | 80-95 |
| SN HL MS | 65 | 5 | 60-70 | 68.57 | 17.25 | 40-85 |
| AD Mild | 85 | 8.36 | 70-90 | 47.5 | 12.14 | 25-60 |
| AD Mod | 83.33 | 11.54 | 70-90 | 55 | 25.98 | 40-85 |
| AD MS | 75 | 21.21 | 60-90 | 77.5 | 17.68 | 65-90 |

Table 6 - Depicts the r- value and the significance level between ALR threshold and SIS for sensorineural hearing loss and auditory dys-synchrony group.

| **Group** | | **r value** | **Sig level** |
|---|---|---|---|
| SNHL | ALRT Vs SIS | -0.242 | 0.366 |
| AN | ALRT Vs SIS | -0.646 | 0.023 |

It can be seen in the Table 5 that SD is more for speech identification scores in individuals with auditory dys-synchrony compared to individuals with sensorineural hearing loss. Table 6 shows that SIS and ALR had significantly negative correlation in auditory dys-synchrony group. SIS reduces as the ALR threshold increased. However, no significant correlation was obtained in individuals with sensorineural hearing loss.

To establish the relationship between ALR threshold and the frequency specific pure tone behavioral threshold, ALR threshold and pure tone threshold was obtained at each frequency from 250 Hz to 4000 Hz. The mean, SD and range were then computed. This can be seen in the Table 7.

Table 7 – depicts the mean, SD and range for ALR threshold and pure tone threshold at each frequencies for different subgroups of sensorineural hearing loss and auditory dys-synchrony group

| | | **Mild SN** | **Mod SN** | **Ms SN** | **Mild AN** | **Mod AN** | **Ms AN** |
|---|---|---|---|---|---|---|---|
| 250 Hz | Mean | 19 | 37.5 | 52.86 | 40.83 | 40 | 55 |
| | SD | 7.42 | 10.41 | 4.88 | 8.01 | 8.66 | 7.07 |
| | Range | 30-40 | 25-50 | 50-60 | 30-50 | 35-50 | 50-60 |
| 500 Hz | mean | 24 | 43.75 | 55.71 | 43.33 | 45 | 55 |
| | SD | 6.51 | 9.46 | 6.07 | 8.16 | 13.23 | 0 |
| | Range | 20-35 | 30-50 | 50-65 | 30-55 | 35-60 | 55-55 |
| 1 kHz | Mean | 32 | 48.75 | 62.1 | 35.83 | 45 | 55 |
| | SD | 2.73 | 2.5 | 5.67 | 3.76 | 8.66 | 0.00 |
| | Range | 30-35 | 45-50 | 55-70 | 30-40 | 40-55 | 55-55 |
| 2 kHz | Mean | 44 | 56.25 | 70 | 25 | 43.33 | 65 |
| | SD | 2.25 | 4.79 | 10.4 | 7.07 | 5.77 | 0.00 |
| | Range | 40-45 | 50-60 | 55-80 | 15-35 | 40-50 | 65 |
| 4 kHz | Mean | 53 | 63.75 | 82.14 | 23.33 | 46.67 | 52.5 |
| | SD | 10.37 | 13.15 | 12.20 | 2.58 | 2.89 | 10.61 |
| | Range | 40-65 | 45-75 | 65-95 | 20-25 | 45-50 | 45-60 |
| ALRT | Mean | 49 | 62.5 | 65 | 85 | 83.3 | 75 |
| | SD | 5.48 | 5.00 | 5.00 | 8.37 | 11.55 | 21.21 |
| | Range | 40-55 | 55-65 | 60-70 | 70-90 | 70-90 | 60-90 |

It is evident from the Table 7 that the ALRT is in close approximity to mid frequency pure tone threshold in sensorineural hearing loss group. Whereas pure tone threshold observed at 4 KHz is seem to be higher than the click evoked ALR threshold. However, in auditory dys-synchrony group, ALR threshold was much higher than any frequency pure tone threshold except for the individuals with moderately severe (Ms) hearing loss. Pearson product moment correlation was done to find out the correlation between ALR threshold and each frequency pure tone threshold. The results of the Pearson product moment correlation coefficient can be seen in the Table 8

Table 8 - Depicts the r value and the significance level between the ALR threshold and pure tone threshold at different frequencies for sensorineural hearing loss group and auditory dys-synchrony group.

| Group | | r value | Sig level |
|---|---|---|---|
| SNHL | ALRT vs 250 Hz | 0.807 | .000 |
| | ALRT vs 500 Hz | 0.757 | .000 |
| | ALRT vs 1 kHz | 0.794 | .001 |
| | ALRT vs 2 kHz | 0.817 | .000 |
| | ALRT vs 4 kHz | 0.711 | .002 |
| AN | ALRT vs 250 Hz | -0.251 | 0.431 |
| | ALRT vs 500 Hz | -0.457 | 0.135 |
| | ALRT vs 1 kHz | -0.326 | 0.302 |
| | ALRT vs 2 kHz | -0.384 | 0.218 |
| | ALRT vs 4 kHz | -0.411 | 0.184 |

Table 8 shows that Pearson product moment correlation for ALR threshold and each frequency pure tone threshold. The ALRT and frequency specific pure tone threshold had shown significant positive correlation in sensorineural hearing loss group. In individuals with auditory dys-synchrony no significant correlation was obtained between ALRT and pure tone threshold at any frequency.

## Discussion

The poor agreement between the ALR threshold and pure tone average obtained in the normal hearing group and good agreement in sensorineural hearing loss group could be due to the active and passive mechanism that takes place at the cochlea. In sensorineural hearing loss group the active mechanism of inner ear is affected, so passive mechanism take part in exciting more number of auditory nerves as it excites larger area of the basilar membrane. This might have resulted in increasing amplitude of the response and passed on to higher centers. This would have given rise to better agreement between behavioral threshold and ALR threshold in sensorineural hearing loss subjects.

Where as in normal hearing group, active mechanism is intact. The presence of active mechanism results in sharp tuning leading to the excitation of a few auditory nerves. This would have resulted in lesser compound action potential. Thus, causing higher ALR threshold resulted in poor agreement between behavioral threshold and ALR threshold.

In individuals with auditory dys-synchrony poor agreement was obtained. This could be due to the reduced transmission of signal to higher centers. This could be due to the leakage of signal conduction or a conduction block due to demyelization. Thus, resulting in reduced but broadening of compound action potential (Starr, Picton and Kim, 2001). Which could have resulted in higher ALR threshold. In auditory dys-synchrony group there is altered temporal synchrony of auditory nerve and afferent discharges (Zeng, Oba, Garde and Starr, 1999). In neuropathy particularly, a demyelinating neuropathy, nerve impulses become slow when a demyelinated segment of the axon is encountered and then regain normal speed when that segment is passed (Mc Donald 1980). This type of conduction change results in a slowing of nerve conduction velocity. Demyelinated axons are impaired in their ability to transmit the information to the higher cortical centers. This might have lead to poor ALR threshold compared to behavioral threshold and thus poor correlation as ALR is a far field recording potential.

In sensorineural hearing loss group, speech perception ability is correlated with the pure tone threshold. The cochlear distortion effects, increases with the increase in the degree of hearing loss results in loss of cochlear amplifier leading to reduction in speech perception (Moore, Poston, Eggermont and Huang, 1996). In cases of sensorineural hearing loss, perceptual problem is related to loss of frequency resolution. The spectral processing that occurs in the normal ears is achieved through “active process” mediated by outer hair cells (Moore, Poston, Eggermont and Huang, 1996). In ears with cochlear hearing loss, outer hair cell damage disrupts the active cochlear mechanism (Sellik and Rubbel, 1982). And frequency resolution is impaired. This would have result in impaired listener’s ability to spectrally separate the features within the speech signal (Moore, Poston, Eggermont and Huang, 1995). Broadening of the basilar membrane movement would resulted in the excitation of more number of neurons resulted in increased compound action potential leading to better ALRT. Thus, this would have resulted in poor agreement between the SIS and ALR threshold in sensorineural hearing loss group.

Kraus et al. (2000) reported that speech evoked ALR is a good predictor of speech processing in individuals with auditory dys-synchrony. Rance et al. (2002) found that speech perception abilities of auditory dys-synchrony children can not be reliably estimated from behavioral audiogram as like sensorineural hearing impaired group. In auditory dys-synchrony group where the difficulty in perception of speech is related to impaired temporal processing. The temporal processing is important for speech perception and to elicit the auditory evoked potentials. Thus, degraded processing would have resulted in better correlation.

## Conclusions

It can be concluded from the present study that click evoked ALR is not a good tool to estimate frequency specific behavioral threshold. However click evoked ALR can closely estimate the behavioral threshold in sensorineural hearing loss group and it can be used as a clinical tool with less time consumption and more effectively in some of the hearing impaired population.

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