EFFECT OF SENSORINEURAL HEARING LOSS ON SPEECH EVOKED AIDED AUDITORY LATE LATENCY RESPONSE

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Abstract

The aim of present study was to compare the auditory late latency response (ALLR) waveform obtained for naturally produced speech tokens, such as /ba/, /da/, and /ga/ in unaided and aided conditions. It also aimed to evaluate the usefulness of ALLR in selection of amplification device using naturally produced speech tokens. Two groups of participants were taken, including 10 individuals with normal hearing and hearing impairment (9 ears) in the age range of 20 to 50 yrs. Speech evoked ALLR was done both in unaided and aided conditions. Aided ALLR was done with two pre-selected digital hearing aids with first fit. The results revealed that there was significant difference between unaided and aided responses ($x^2 = 197.04$, df = 26, $p < 0.001$). However, only /ba/ and /ga/ for P1 and /ba/ for N1 showed significant difference at 0.05 significance level. The latency was shorter and amplitude was higher for the group with normal hearing than hearing impaired group. There was difference in terms of latency for the speech sounds taken for the study. /ga/ stimulus was found to have shorter latency and /da/ had longer latency out of three stimuli. Similar pattern was also observed for absolute amplitude. Finding from the present study also revealed that there was significant difference between performances of individuals with sloping sensorineural hearing loss with different hearing aids in aided ALLR. Aided ALLR can help in selection of hearing aids as it mimics the hearing aid processing. It can be suggested to use aided ALLR to select hearing aids as it is objective test and can assessed in shorter duration.

Key words: Auditory Late Latency Response, Hearing loss, Hearing aids, Speech stimuli

Cortical potentials reflect the functional integrity of the auditory pathway involved in the processing of complex speech stimuli. It can be used to understand the neurophysiologic basis of speech perception, which would give information of the speech processing abilities of the individuals. It is one of the ideal objective tools for aided hearing instrument evaluation because it is reliably present in young infants and adults, it correlates well with perception, it can be evoked by a range of speech stimuli, and it seems to be sensitive to differences between speech stimuli (Tremblay, Friesen, Martin & Wright, 2003).

The long latency auditory evoked potentials are characterized by components comprising time domain of 50 to 500 msec (McPherson & Starr, 1993) and are labelled according to their latency and polarity at the vertex (Picton, Woods, & Proulx, 1978). The major component of Auditory Late Latency Response (ALLR) are characterized by an initial positive peak between 60-80 msec (P60/P1), having an amplitude of about 7 µv and a width of about 15 msec. The second peak occurs between 90-100 msec (N100/N1) and is a negative peak with amplitude of 10 µv and width of 40-50 msec. The third peak is a positive occurring at about 100-160 msec (P160/P2) and has amplitude of 6 µv and a width of 40-50 msec.

The forth peak occur at 180-200 msec (N200/N2) is a negative peak and has amplitude of 6 µv and width of 70 msec.The major applicability of cortical auditory evoked potentials comes from the fact that it can be recorded from premature and full term newborns, and from older children.Contrary to

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maturation effect seen in early childhood, there is an increase in latency and decrease in amplitude with the advancing age (Cranford & Martin, 1991).

Yetkin, Ronald, Chriestensen and Purdy (2004) suggested the physiological reasons for difference in the ALLR responses for the low and the high frequency stimuli. They reported that the cortical area responding to low frequency auditory stimuli are located more superficially than the deep layer of the cortical regions for high frequency. Hence low frequency stimuli produce smaller latency of ALLR than high frequency speech sounds.

Some of the reports indicate that ALLR may be used to assess the capacity of the auditory cortex to detect changes within the speech stimuli (Martin & Boothroyd, 1999). An investigation by Hinduja, Kusari and Vanaja (2005) revealed that ALLR of individuals with a hearing aid showed larger amplitude and shorter latency when the aided thresholds were within speech spectrum than compared to the hearing aid in which aided thresholds were outside the speech spectrum. These pre-attentive cortical potentials have also been used to reflect on the auditory training induced changes.

Tremblay, Billings, Friesen and Souza (2006) recorded ALLR for amplified speech sounds/ Si/ and / ?i/ in 7 adults with mild to severe sensorineural hearing loss and in 7 normal hearing individuals. The results revealed that the speech evoked ALLR can be used reliably both in aided and unaided conditions. Similar results are reported by Korczak, Kurtzberg and Stapells (2005) in individuals with severe to profound hearing loss.

Most of the subjects with hearing loss showed increase amplitude, decreased latencies and improved waveform morphology in the aided conditions. Furthermore, most subjects with hearing loss tested by Korczak, Kurtzberg and Stapells (2005) showed longer peak latencies and reduced amplitudes than the normal hearing group. The amount of response change is quiet variable across individuals as reported by Tremblay et al. (2006).

ALLR was recorded in both aided and unaided condition using /i/, /m/ and /s/ in 10 hearing impaired children in the age range of 5-7 years (Shruthi, 2007). The response obtained from the three stimuli resulted in distinct responses indicating that the stimuli are coded differently in the auditory system. Stimuli /i/ resulted in better morphology, shorter latency, and higher amplitude than /m/ and /s/ stimuli, indicating that vowels are better coded than the consonants.

ALLR was recorded using three speech stimuli, /ba/, /da/ and /ga/ from cochlear hearing loss subjects (Sumitha, 2008). It was observed that the P1-N1-P2 latency was shorter for /ga/ stimuli, and longer for /da/ stimuli. Amplitude did not show significant difference across the three sounds in both normal hearing individuals as well as individual with hearing loss.

Need for the study

It is important for any listener to listen to all the speech sounds, which encompasses the speech spectrum. It is not sufficient to study only the processing of single frequency stimuli. Hence, there is a need to study the ALLR, which is evoked by speech stimuli which largely encompasses the speech spectrum. Hence, the three different speech stimuli /ba/ which has spectral energy concentration in low frequency, /ga/ syllable dominated by mid frequency spectral energy and /da/ syllable dominated by high frequency spectral energy will be taken up for the study.

Aim of the study

The aim of present study was to compare the ALLR waveform obtained for naturally produced speech tokens, such as /ba/, /da/, and /ga/ in unaided and aided condition with that of normal hearing individual. And also to evaluate the usefulness of ALLR for naturally produced speech tokens, such as /ba/, /da/, and /ga/, in validation of appropriate hearing aid.

Method

Participants:

Two groups of participants were included in the study. Group I included 10 individuals with normal hearing in the age range of 20 to 50 years and Group II included 9 ears with hearing impairment in the age range of 20 to 50 years having moderate to moderately-severe sloping sensorineural hearing loss.

Participant selection Criteria:

Group I included individuals having hearing sensitivity less than 15 dB HL at octave frequencies between 250 Hz to 8000 Hz for air conduction and from 250 Hz to 4000 Hz for bone conduction. They had normal middle ear functioning as indicated by immittance evaluation. Auditory brainstem response (ABR) and transient evoked otoacoustic emission (TEOAE) were done to rule out auditory dys-synchrony. Participants having speech identification scores greater than 90% and having no history of any otologic, neurologic problems were included for this study.

Group II included individuals having pure tone thresholds greater than 41 dB HL and less than 70 dB HL with air bone gap of less than 10 dB. They had normal middle ear functioning as revealed by immittance evaluation. ABR and TEOAE were done to rule out auditory dys-synchrony. Participants having speech identification scores proportionate to their pure tone average and having no history of any otologic and neurologic problems were considered for this study.

Instrumentation:

To carry out the pure tone audiometry and speech audiometry, a calibrated two channels Orbiter-922 diagnostic audiometer with TDH-39 headphone with MX-14/AR ear cushion, Radio ear B-71 bone vibrator, and loudspeaker were used. A calibrated immittance meter, GSI-Tympstar was used to assess middle ear functioning. ILO (version, VI) OAE Analyser was used to check for the hair cell functioning. Bio-logic system (version, 7.0) with matched loudspeaker was used to record and analyse the speech evoked auditory late latency responses (ALLR) and ABR. NOAH HI-PRO software (version, 3.12) was used to program the hearing aids.

Materials:

Stimuli for recording ALLR were /ba/, /da/, and /ga/. Those syllables were spoken by an adult speaker having clear articulation, into a unidirectional microphone connected to the computer. The recording was done using Adobe Audition software (version 2) with a sampling rate 48000Hz and 16 bit resolution. The stimuli duration was kept less than 250 msec across all the speech sounds. The wave file was loaded for ALLR recording.

Test Environment:

All the measurement was carried out in an acoustically treated double room situation. The ambient noise level was within the permissible level according to ANSI (1991). For presentation of stimuli for recording ALLR, the speaker was calibrated with the help of sound level meter. The presentation level of the speaker was adjusted such that the output of the speaker at 1 m distance was 65 dB SPL as measured in sound level meter. The same output level was maintained throughout the study.

Test Procedure for Group I:

Pure tone thresholds were obtained in the sound field for octave frequencies between 250Hz to 8000Hz for air conduction using modified Hughson-Westlake procedure (Carhart & Jerger, 1959). The tympanometry and acoustic reflex were carried to rule out any middle ear pathology. ALLR recording was done for the participants who meet the selection criteria.

ALLR recording: Participants were made to sit comfortably in order to ensure a relaxed posture and minimum rejection rate. Speaker was placed at a distance of one meter and at a 0^0 azimuth to the test ear. Silver chloride electrodes were placed after cleaning the electrode sites with skin preparing gel. Conduction paste was used to improve the conductivity of the signal. The electrodes were secured in place using plasters, conventional electrode montage with non-inverting electrode on Fz, inverting electrode on the mastoid of the test ear and common electrode on the mastoid of the non-test ear. The electrode impedance value was kept less than 5 kΩ and the inter electrode difference was less than 3 kΩ.

Test procedure for Group II:

Similar to the procedure used in group I, pure tone thresholds, Tympanometry and acoustic reflexes were done for participants of group II. Two digital hearing aids having similar features (2 channels, 3 programmable memories, suitable till moderately severe degree of hearing loss) were selected and programmed based on the audiological findings and first fit option was selected. Aided ALLR was used to rate the hearing aids regarding their suitability.

ALLR Recording:

ALLR was recorded separately for the three stimuli / ba/, /da/, /ga/ without the hearing aid as well as with the preselected hearing aids. The procedure selected for the ALLR was same as that used for group I.

Analysis

The waveform was analysed by two audiologists who were unaware of the test conditions identified the P1-N1-P2 peaks. Latency and amplitude of the identified peaks were noted.

ALLR test protocol:

Stimuli	/ba/, /da/, and /ga/,
Stimulus Level	65 dB SPL
Transducer	Loudspeaker at 0^0 azimuth
Rate	1.1/sec
Polarity	Alternating
Filters	1-30 Hz
Notch Filters	On
Number of channels	Single channel
Recording time window	500 msec
Amplification	50,000
Sweeps	200
Number of Repetition	2

Results

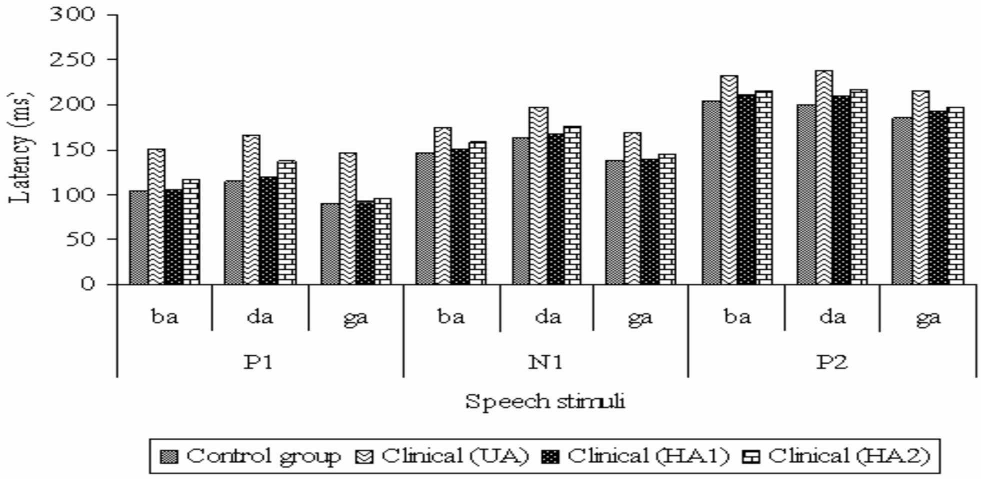
The aim of the present study was to investigate the effects of spectrally different speech syllables on the auditory long latency responses in individuals with normal hearing and sloping sensorineural hearing loss. The latencies and amplitudes of P1, N1, and P2 peaks were measured. The Mean and standard deviation (SD) were calculated for 2 groups for 3 syllables for latencies and amplitudes of P1, N1 and P2.

From table 1 and graph 1, it can be inferred that the unaided mean and SD latencies of clinical group was higher than the control group for /ba/, /da/ and /ga/. Further, it was seen that latencies for aided was shorter than unaided clinical group for P1, N1, and P2.

Similarly from table 2 and graph 2, it can be inferred that the unaided mean and SD amplitudes of clinical group was lesser than the control group for /ba/, /da/ and /ga/. Further, it was seen that amplitudes for aided was higher than unaided clinical group for P1, N1, and P2.

Further, Friedman test was carried out to find out the difference between unaided and aided condition. Results revealed that overall there was significant difference between unaided and aided responses (x^2 = 197.04, df = 26, $p < 0.001$). However, when it was done separately, only /ba/ and /ga/ for P1 and /ba/ for N1 showed significant difference at 0.05 level of significance.

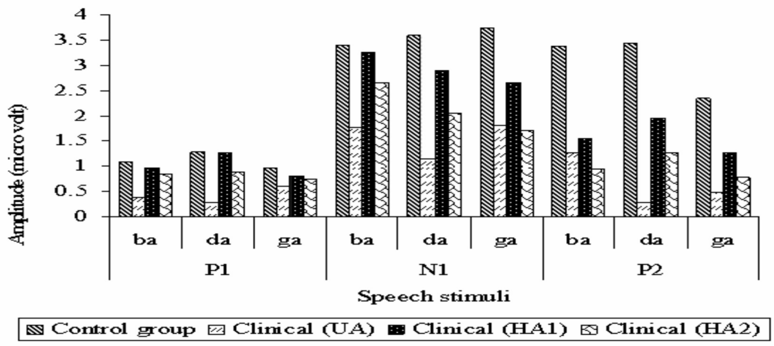
Wilcoxon signed rank test was done to compare the hearing aid 1 and hearing aid 2 findings. Results revealed that there were differences in performance with two different hearing aids for /ba/ stimuli for P1, N1 and P2. Further, for /da/ stimuli only P2 showed significant difference between two hearing aids performance. However, for /ga/ there was no significant difference noticed at all the peaks (Table 3).



Graph 1: Mean for P1, N1, and P2 latencies elicited by /ba/, /da/ and /ga/ syllables in control and clinical group (unaided and aided).

Para meter	Syllables	Control group		Clinical group (Unaided)		Clinical group (HA1)		Clinical group (HA2)	
		Amplitude (µV)		Amplitude (µV)		Amplitude (µV)		Amplitude (µV)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
P1	/ba/	1.10	0.71	0.39	0.16	0.98	0.76	0.85	0.80
	/da/	1.29	0.66	0.28	0.09	1.27	1.03	0.88	0.66
	/ga/	0.96	0.38	0.61	0.53	0.81	0.68	0.74	0.60
N1	/ba/	3.40	1.08	1.77	1.11	3.25	1.41	2.66	1.43
	/da/	3.60	1.57	1.15	0.24	2.89	1.73	2.05	1.89
	/ga/	3.73	1.23	1.82	1.27	2.66	1.76	1.71	1.49
P2	/ba/	3.38	1.44	1.28	1.09	1.54	1.14	0.95	0.71
	/da/	3.44	1.38	0.29	0.22	1.95	0.39	1.27	1.06
	/ga/	2.34	0.80	0.49	1.31	1.28	0.73	0.79	0.55

Table 2: Mean and SD for P1, N1, and P2 amplitudes elicited by /ba/, /da/ and /ga/ syllables in control and clinical group (unaided and aided).



Graph 2: Mean for P1, N1, and P2 amplitudes elicited by /ba/, /da/ and /ga/ syllables in control and clinical group (unaided and aided).

Peaks	Group (HA1 & HA2)	Z-value	Significance level
P1	/ba/2 - /ba/1	-2.07	0.03*
	/da/2 - /da/1	-0.53	0.59
	/ga/2 - /ga/1	-0.23	0.81
N1	/ba/2 - /ba/1	-2.19	0.02*
	/da/2 - /da/1	-1.26	0.20
	/ga/2 - /ga/1	-0.89	0.37
P2	/ba/2 - /ba/1	-2.31	0.02*
	/da/2 - /da/1	-2.31	0.02*
	/ga/2 - /ga/1	-0.17	0.85

Table 3: Wilcoxon signed rank test for comparison of hearing aid 1 and 2 (*$p < 0.05$).

Discussion

The speech stimulus in the present study was selected in such a way that it covered the low frequency, mid frequency and high frequency region. The stimuli varied only in the spectral content. All the stimuli selected for the study was voiced CV syllable, the vowel /a/ was kept constant. Sound /ba/, which has a spectral energy concentration majorly in low frequency, was selected as low frequency stimuli; /ga/ was selected as mid frequency stimuli and /da/ as high frequency stimuli.

It has been noticed in present study that the latency of /da/ stimuli was longer than /ba/ and /ga/ for both clinical group as well as control group. The speech stimuli /ga/ elicited a shorter latency for both control and clinical group (Table1 & graph 1). Further, absolute amplitude of all the stimuli also showed similar patterns (Table 2 & graph 2). Study by Sumitha (2008) also revealed a similar finding in subjects with normal hearing and cochlear hearing loss.

Agung, Purdy, McMohon and Newall (2006) used the speech stimuli /a/, /u/, /i/, /s/, /sh/, /m/ and /ë/ which covered a broad range of frequencies across the speech spectrum. They found that latencies of speech stimuli with high frequency content had significantly prolonged latencies than the other stimuli. In individuals with normal hearing as well as in individual with hearing loss, low frequency speech stimuli represents better responses than mid or high frequency speech stimuli. The present findings are in agreement with the finding of other studies (Agung et al., 2006; Shruthi, 2007; Sumitha, 2008).

The physiological reasons for difference in ALLR responses for low and high frequency stimuli was investigated using fMRI studies by Yetkin, Ronald, Chriestensen and Purdy, (2004). These investigators reported that the cortical areas that respond to the low frequency auditory information are located more superficially (i.e. closer to the surface of the scalp) than the deep layer of the cortical regions for high frequency. Hence, the low frequency stimuli may activate more superficial cortical areas and produce smaller latency of ALLR component than the high frequency speech sounds, when surface scalp electrodes are used.

Finding from the present study also revealed that there was significant difference between performances of individuals with sloping sensorineural hearing loss with different hearing aids in aided ALLR. However, the difference was not noticed for all the individuals in clinical group. It may be because of individual variation. Tremblay et al. (2006) also noticed that even though most of the subjects with hearing loss showed increased amplitude, decreased latency and improved waveform morphology in the aided conditions the amount of responses change was quite variable across individuals. This variability may be related to the fact that the hearing aid alters the acoustics of a signal, which in turn affect the evoked response pattern. It was also noticed that /ga/ stimuli was not showing any changes between two hearing aids performance. Similar finding was also observed by Shruthi (2007).

Conclusion

It can be concluded that the aided ALLR recorded by spectrally different speech sounds were different in individuals with normal hearing and sloping sensorineural hearing loss. This suggests that neurophysiological processes are different for different speech sounds. Longer latency for /da/ suggests that latency of the processing at the cortical center was also different depending on the frequency composition of the signal. Further, it also concludes that aided ALLR can help in selection of hearing aids as it mimics the hearing aid processing. But, it was difficult to say whether it can be sensitive with different configuration of hearing loss. However, one must noticed that there was difference in performance in sloping hearing loss individuals. It can be suggested to use aided ALLR to select hearing aids as it is objective test and can be assessed in shorter duration.

Implication of the study

- It will help us to decide objectively the most appropriate hearing aid for a client.
- To assess the speech perception ability of the cortical structures objectively.
- It helps in selecting hearing aids for difficult to test clients.

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