QUANTIFICATION OF VARIABLES AFFECTING AUDITORY LATE LATENCY RESPONSES

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Chapter I
Introduction

CHAPTER 1: INTRODUCTION

Brain responses reflect more than just activity evoked by a sensory stimulus, hence the term "event related potentials" emerged (Coles and Rugg, 1995). ERPs are brain responses that are time locked to some specified event. The "event" may occur within a sensory modality or across modalities. The event may be a physical stimulus (such as an auditory tone), a change in a train of stimuli (such as a series of 1000-Hz tones changing to a 2000 Hz tones), a missing stimulus (such as one tone omitted from a sequence of tones), or a stimulus that has been designated as a target stimulus. Indeed, the "event" may be the result of the psychological demands of the situation (Donchin et. al., 1978) and little related to the specific sensory stimuli.

The Auditory Evoked Potentials are a subset of ERPs. It is defined as the brain responses "evoked" by the presentation of auditory stimuli. The development of auditory evoked potentials (AEPs) closely follows advances in electronic technology. The earliest recording of a human AEP was accomplished by Vladimirovich Pravdich Neminsky, a Russian scientist, in 1913 (Brazier, 1984)

AEP classification and nomenclature systems are generally based on several aspects such as

- Time domain within which the response occurs after stimulus onset, known as "latency epoch" (i.e., short/early, middle, long/late) (Ruth and Lambert, 1991)

- Anatomic origin (e.g., brainstem, cortical)
- Stimulus-response relationship (i.e., transient versus sustained, exogenous versus endogenous)
- Electrode placement (i.e., near versus far field) (Jacobson and Hyde, 1985).

The most currently used classification of AEP is based on latency which was adapted from the work of Picton et al. (1974, 1977), and Picton and Fitzgerald (1983). Based on the latency epoch, the responses can be classified into:

- Short latency responses (SLR)
- Middle latency responses (MLR)
- Long latency responses (LLR)

Figure: 1.1

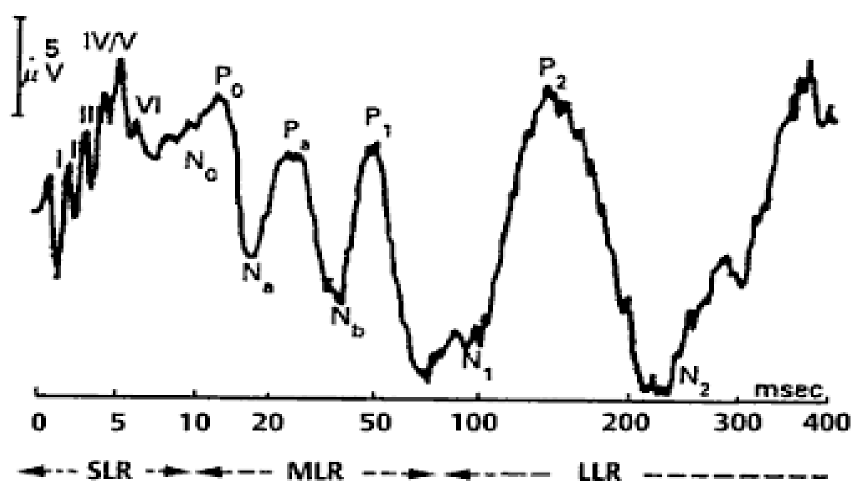

Figure: 1.1 shows general morphological features of the auditory evoked potentials and the event related potentials. The short latency responses (SLR) occur within 10-15ms post-stimulus; the middle latency responses (MLR) occur between 10 and 50 ms post-stimulus; and the long latency responses (LLR) occur beyond 50-80 milliseconds

Short latency responses:

AEP occurring within the first 10-15 milliseconds following stimulus onset are generally referred to as the "early" or "short" latency responses (SLR). The SLR includes the slow-negative$_{10}$ potentials (SN_{10}) (Davis and Hirsh, 1979), Frequency Following Response (FFR) (Moushegian et. al., 1973) and ABR . ABR is the most extensively used diagnostic tool which is the neural representation of the short latency AEPs; they originate from neural structures peripheral to the auditory midbrain. There are seven peaks in ABR represented by Roman numerals I-VII. Among that, waves I, III and V are most reliably recorded and of clinical importance in diagnosing. The different components of the ABR are generated by the auditory nerve and the caudal parts of the main (classical) ascending auditory pathways up to the midbrain structures.

Middle latency responses:

The term "middle latency response" (MLR) is used with reference to those components in the latency epoch of 10-50 milliseconds. The middle latency components are typically indicated by Na, Pa, Nb and Pb. The multiple generators that contribute to the MLR include the thalamo-cortical pathway, the mesencephalic reticular formation, and the inferior colliculus.

Late latency responses:

Hallowell Davis (1896-1992) is often called the father of evoked response audiometry, as he was the first to use long latency auditory evoked potentials to estimate hearing thresholds and obtain so-called objective audiograms. The practical recordings of AEPs in those days were restricted to long latency potentials because they have much greater amplitude than those of short latency response.

The components generated beyond 50-80 milliseconds post stimulus onset are considered to be the "slow" or "long" latency responses (LLR) or "late" potentials. Auditory Late latency responses (ALLR) are recorded from the vertex. It consists of four peaks denoted by P1, N1, P2 and N2. The Auditory late latency response is composed of a positive wave (P1) occurring between 55 to 80 ms, a large negative wave (N1) occurring between 90 to 110 ms, another subsequent positive wave (P2) occurring between 145 to 180 ms and subsequent negative wave (N2) occurring between 180 to 250 ms, which is associated with the perception, discrimination, recognition and classification of an auditory stimulus.

ALLR are typically used to infer the cognitive processing capacities of the brain. These include the N_1-P_2 complex and P_{300} or P_3. These slow cortical responses undergo substantial changes during maturation, and these changes appear to continue into teenage years.

Table: 1.1

Component	Classification	Latency (ms)	Amplitude (µU)	Response features
P1	LAEP Exogenous	55-80	5-7	a. Sensitive to changes in stimulus parameters b. Amplitude changes with sleep state
N1	LAEP Exogenous	80-150	5-10	a. Sensitive to changes in the acoustic features of the stimulus b. Amplitude changes with sleep state and attention
P2	LAEP Exogenous	145-180	3-6	a) Amplitude changes with sleep state and attention
N2	LAEP endogenous	180-250	3-6	a. Sensitive to change in acoustic features of stimulus b. Amplitude significantly affected by attention and sleep state

Table: 1.1 shows the description of ALLR

P1 response is primarily an exogenous potential (i.e., response related strongly to the stimulus parameters). It represents the late thalamic projections into the early auditory cortex and is a part of specific sensory system (Velaseco et. al., 1989). The P1 differs greatly from the N1, P2 and N2 components of LLR and may also be considered as a part of MLR (Pb wave).

N1 is also an exogenous potential occurring ~100msec and is associated with the activity of the nonspecific multisensory system within the contralateral supra temporal auditory cortex (Knight et. al., 1988), which is recorded maximally from the frontocentral electrodes, such as the vertex or high forehead. The scalp recording of the auditory N1 has three contributing components, two of which are generated within the auditory cortex bilaterally. The generation site of the third component is still unclear but appears to be in modality nonspecific areas (Naatanen and Picton, 1987). The first component is a frontocentral negativity generated by bilateral, vertically oriented dipoles in the primary auditory cortices. The second component is the biphasic T-complex with a positive wave at 100ms and a negative wave at 150ms. This complex is best recorded using midtemporal electrodes, originates bilaterally in auditory association cortex in the superior temporal gyrus. This component has a radially oriented generator. The third component is one that corresponds best with early notions of a nonspecific response. It is a vertex-negative wave at about 100msec, whose generator is possibly within frontal motor and/or premotor cortex, under the influence of reticular formation and the ventral lateral nucleus of the thalamus (Naatanen and PIcton, 1987). Interstimulus interval less than 4 seconds reduces the amplitude of this component. The amplitude depends highly on the attention and the level of alertness (Naatanen, 1992).

The generation of P2 components is not well defined. It occurs at the latency of ~160msec and is another exogenous potential of the non specific multisensory system demonstrating activity in the lateral frontal supratemporal auditory cortex (Scherg et. al., 1989).

The major N1 and P2 component receives contributions from primary auditory cortex and supratemporal plane located anterior to this region. Both tonal and speech signal elicits N1 and P2 components generated within the auditory cortex (Tiitinen et. al., 1999). The source of N1 activity elicited by vowels is limited to the left auditory cortex, consistent with the specialization of the left hemisphere for speech processing (Makela and Tiitinen et al., 2004). With selective attention to specific acoustic features of the signals, cerebral regions outside of the temporal lobe play a role in the generation of early and later components within the N1 wave complex, with influence of sub cortical structures, including the thalamus, hippocampus and the reticular activating system (Naatanen and Picton, 1987).

N1-P2 complex is characterized by two primary waves of relatively low fundamental frequency. The comparatively large amplitude of the complex in general allows it to be recorded using lower preamplifier gains and smaller sample sizes than the earlier AEP. When stimulus intensity is lowered, waveform characteristics change in a manner similar to that of other AEP. Component amplitude decrease and absolute latencies increase.

The auditory evoked P1-N1-P2 sequence was considered part of a larger class of "vertex" potentials, which were maximum in amplitude near the vertex for different modalities and thus represent a nonspecific cerebral process.

The N2 is the first of the endogenous potentials (i.e., event related potentials that is produced by the listener's internal processing of the stimulus) occurring at ~200 msec. It is the part of the nonspecific multisensory system in the supratemporal auditory cortex (Velasco et al., 1989), which is dependent on activity within the limbic system and the reticular activating system in the region of the thalamus. This negative wave is highly related to attention. The amplitude decreases when attention wanes.

Table: 1.2

Population	Best: Awake, Alert, eyes open, adults or children age 6 years or older (reading books or watching closed-caption TV)
Stimuli	250 – 4000 Hz tonebursts Rise/fall time: 20 ms Plateau time: 20 ms Rate: 1 per 2 seconds (0.5/sec)
Recording	Electrodes: 1 channel Inverting: vertex Noninverting: ipsilateral or contralateral mastoid 1-30 Hz or 1-15 Hz EEG filters Sensitivity/artifact reject: +/- 100µV (gain = 10,000-20,000) Analysis time: -500 to +1000 ms (i.e., 500 ms prestimulus) No, of trials per average: 25-50 No. of replications: 2 (often 3, especially if <6 years or asleep)

Table: 1.2 shows the parameters for recording ALLR

Electrode*s:*

Electrodes consist of a metal alloy, the most common being tin, gold, silver and silver-silver chloride.

Electrode montage*:*

In referring to electrode montages, the 10 to 20 international system will be used (Jasper, 1958).

The common electrode placement is Cz-Ai.

- Cz (non-inverting)- forehead/vertex
- A1 (inverting)- left mastoid
- A2 (inverting)- right mastoid
- Fpz- ground

The ALLR is maximal when recorded over the vertex at Cz position. Since LLAEP may become contaminated with eye movements, electrodes are placed lateral to the orbit of one eye and superior to the orbit of the opposite eye. This will permit the simultaneous monitoring of the vertical and horizontal eye movement and eye blinks.

NEED FOR THE PRESENT STUDY:

ALLR is presently of importance as it has evolved as an important tool for the neuro-diagnosis of the central site of lesion apart from the peripheral test for hearing sensitivity. Through ALLR the areas in the cortex that responds to the verbal stimulus can be studied intensively and the manner in which the processing of each speech sounds occur can be studied and analyzed, however it has been reported that the processing of the speech sounds gets affected in pathological conditions like persons with hearing impairment, LD, ADHD, CAPD etc., only if we can understand the processes for these pathological cases can we develop strategies to habilitate them.

Before we can study those aspects in detail it is required that for our clinical situation we develop the norms and study variables that affect the ALLR , as it is a very sensitive tool and is affected by various factors.

AIM OF THE STUDY:

- To obtain normative for children and adult using GSI Audera
- To study the effects of stimulus variable and subject variable on ALLR

OBJECTIVE OF THE STUDY:

- To compare the latencies of ALLR waveforms obtained between two ears for adults and children.
- To compare the latencies of ALLR wave forms obtained between males and females for adults and children.
- To compare the latencies of ALLR wave forms obtained between different frequencies for adults and children.
- To compare the latencies of ALLR wave forms at different intensity level for adults and children.
- To compare the latencies of ALLR waveforms obtained between different modes of presentation for adults and children.

- To compare the latencies of ALLR wave forms obtained between the adult and child groups.

Chapter II
Review of Literature

CHAPTER 2: REVIEW OF LITERATURE

Brief historical overview

The ALLR was the first auditory electrical response recorded from the CNS. In 1939 Pauline Davis and colleagues discovered an "on response" to sounds in the EEG and coined the term K complex to describe it (Davis, 1939; Davis, Davis, Loomis, Harvey,& Hobart, 1939). It was by second half of 1960s that instruments for ALLR was reported in the scientific literature (Davis, Mast, Yoshie, & Zerlin, 1966). This devise designed by Hallowell Davis, was referred to as HAVOC which was coupled to GATES (generator of acoustic transients) and a system for amplifying and filtering the incoming EEG signal (Davis, et al., 1966).

ALLR is described as the component recorded between 50-250 ms after acoustic stimulation at a relatively slow rate (1 stimulus ever one or two seconds). Amplitude of ALLR is usually within 3 to 10 μvolt, and occasionally larger.

It consist of four main peaks P1, N1, P2, N2 and are subdivided into exogenous components, which are primarily dependent on the characteristics of the external stimulus (P1, N1 and P2), and endogenous components, which are more dependent on the internal cognitive processes, such as N2. P1, N1, P2 and N2 together are also called as obligatory response because it is primarily determined by the physical properties of the stimuli (Hyde, 1997).

Exogenous LLAEPs are best elicited by tone bursts and have the highest amplitude over the vertex. N1 is the most prominent of the late potentials and is generated from multiple sources including the superior temporal plane, the superior temporal gyrus and frontal motor cortex. The later waves may arise from the auditory association cortex and/or the frontal association cortex.

ALLR is very much influenced by subjects' state of arousal, mode of presentation, analysis time, rate etc Factors affecting ALLR can be reviewed under the following sub headings

1) **Stimulus Characteristics**
2) **Acquisition Characteristics**
3) **Subject Characteristics**

STIMULUS CHARACTERISTICS

Dimitrijevic, A., et al., (2008) examined the auditory cortical potentials in normal-hearing subjects to intensity increments in a continuous pure tone at low, mid, and high frequency. Electrical scalp potentials were recorded in response to randomly occurring 100 ms intensity increments of continuous 250, 1000, and 4000 Hz tones every 1.4 s. The magnitude of intensity change varied between 0, 2, 4, 6, and 8 dB above the 80 dB SPL continuous tone. Potentials included N100, P200, and a slow negative (SN) wave. N100 latencies were delayed whereas amplitudes were not affected for 250 Hz compared to 1000 and 4000 Hz. Functions relating the magnitude of the intensity change and N100 latency/amplitude did not differ in their slope among the three frequencies. No consistent relationship between intensity increment and SN was observed. Cortical dipole sources for N100 did not differ in location or orientation between the three frequencies. The relationship between intensity increments and N100 latency/amplitude did not differ between tonal frequencies. A cortical tonotopic arrangement was not observed for intensity increments.

Tremblay, Billing and Rohila (2007) reported the usefulness of auditory-evoked potentials to examine training-related changes in the human central auditory system, and there is converging evidence that focused listening training, using various training methods and different types of stimuli alters evoked neural activity. They determined that increasing stimulus intensities resulted in decreased latencies and increased amplitudes in both unaided and aided condition. 13 normal hearing young adults were participated in the study. A tone of 1 KHz was presented at seven stimulus intensity levels. P1, N1, P2 and N2 cortical evoked potentials were recorded in sound field for both unaided and aided condition. Results revealed there was no significant effect of amplification on latencies and also demonstrate that 20dB of hearing aid gain effects neural responses differently than 20dB of stimulus intensity change.

Tampas (2006) examined 21 young adults (average age of 24 years) and achieved latencies of 89 ms for N1 and 145 ms for P2. The difference in P2 latency should be related to the evaluated age, thus both N1 and P2 increase according to age. This increase does not mean much for N1, but it is fundamental for P2 which increases 40 ms between 20 and 80 years on the average.

Tremblay, Kalstein, Billings and Souza (2006) studied the neural representation of consonant-vowel transitions in adults who wear hearing aids. Seven adults (50-76 years) with mild to severe sensorineural hearing loss participated in the study. When presented with 2 identifiable consonant-vowel (CV) syllables ("shee" and "see"), the neural detection of CV transitions (as indicated by the presence of a P1-N1-P2 response) was different for each speech sound. More specifically, the latency of the evoked neural response coincided in time with the onset of the vowel, similar to the latency patterns in normal-hearing listeners.

Korczak, Kurtzberg and Stapells (2005) recorded MMN, N1 and P300 for /ba-da/ pair in 14 adults with and without their personal hearing aids and from 20 normal hearing participants. The hearing loss in the hearing impaired groups ranged from moderate to profound hearing loss. Recording was done at two levels 65dBHL and 80dBHL. Behavioral discrimination was also obtained and the reaction time was calculated. Results revealed that the use of personal hearing aids, substantially improve the detectability of all the cortical ERPs and behavioral scores of both stimulus intensities. Even though the majority of subjects with hearing loss showed increased amplitudes, decreased latencies and better waveform morphology in aided condition, the amount of response change (improvements) seen in these measures showed considerable variability across participants . When compared with the response obtained from normal hearing participants, both the groups of hearing impairment had significantly prolonged aided reaction time latencies at both stimulus intensities.

Oates, Kurtzberg and Stapells (2002) studied MMN and P300 potentials in response to /ba-da/ speech stimuli in adults with mild to severe-profound hearing loss who wore hearing instruments. The results showed that sensorineural hearing loss caused amplitude and latency response changes for earlier (N1, MMN) cortical responses. The impact of sensorineural hearing loss was greater for the later evoked potentials (N2/P300) that reflect higher-level stimulus processing. They also reported improvement in cortical response detectability, amplitudes, and latencies in aided condition.

Tremblay (2002) studied about asymmetrical changes induced by auditory training in cortical neural activity. Two synthetic speech variants of the syllable |ba| varied in VOT (-10 to –20 in 10 sec steps) was used in the study. Results reveals P1 amplitude decreases and degree of change was greater frontally (F2). Increase in N1 and P2 amplitudes were recorded from all electrode sites following training. P1 and N1 showed specialized hemispheric changes in amplitude, P2 did not. That is increase in P2 amplitude were seen over both hemisphere, but changes in P1 and N1 amplitude were seen over the right hemisphere only. Asymmetry suggests that 10ms voicing distinctions may be processed as acoustic rather than linguistic cues.

Groenen, Beynon, Snik & Broek (1997) studied ALLRs in individuals implanted with cochlear implant. The subjects were presented with four sound contrasts (500 – 1000 Hz, /ba-da/, /ba-pa/, and /i-a/). N1, P2 responses were present in all participants for all conditions. Prolonged N1, P2 and P300 latencies were found in cochlear implantee group compared to a control group of participants with normal hearing. Cochlear implant users showed smaller amplitudes of P2 for the consonants compared to the controls.

Eddins and Pederson (1999) traced LLR thresholds for stimuli durations of 8, 16, 32, 64, 126 ms with 4 ms rise-fall time. The results demonstrated that LLR threshold decreased as duration increased. With decrease in duration an increase in intensity and significant reduction in N1-P2 amplitude was found.

Sharma, A. et al., (1999) studied cortical auditory evoked potential correlates of categorical perception of voice-onset time. Sixteen subjects participated in identification and discrimination experiments. A sharp category boundary was revealed between /da/ and /ta/ around the same location for all listeners. Subjects' discrimination of a VOT change of equal magnitude was significantly more accurate across the /da/-/ta/ categories than within the /ta/ category. Neurophysiologic correlates of VOT encoding were investigated using the N1, CAEP which reflects sensory encoding of stimulus features and the MMN CAEP which reflects sensory discrimination. The MMN elicited by the across-category pair was larger and more robust than the MMN which occurred in response to the within-category pair. Distinct changes in N1 morphology were related to VOT encoding. For stimuli that were behaviorally identified as /da/, a single negativity (N1) was apparent; however, for stimuli identified as /ta/, two distinct negativities (N1 and N1') were apparent. Thus the enhanced MMN responses and the morphological discontinuity in N1 morphology observed in the region of the /da/-/ta/ phonetic boundary appear to provide neurophysiologic correlates of categorical perception for VOT.

Nelson, M.D. et al., (1997) determined the factors affecting the recordability of auditory evoked response component (P1). Three experiments were designed to evaluate systematically the amplitude and latency of the P1 as a function of duration, stimulus type (500- and 4000-Hz tone bursts and clicks), repetition rate (0.5, 0.7, 1.1, 2.1, and 5.1/sec), and electrode array. Results showed that a longer duration (60 msec), low-frequency (500-Hz) tone burst and longer interstimulus interval (1.1/sec) consistently evoked the P2 in all subjects. Additionally, results that P2 is generally largest when recorded from a noninverting electrode at Fz with a noncephalic reference.

Hall, (1992) indicated that when compared to supra threshold level (about 40 dBnHL or higher) near threshold, the variability of response latency is higher.

Alder and Alder (1989) reported an increase in latency with decrease in intensity (from 60 dBnHL to threshold).

Polich, J. et al., (1988) did two experiments out of which one elicited the P1, N1, P2, and N2 components of the long latency auditory evoked potential (AEP) using a 1000 Hz tone presented at 30, 50, or 70 dB SPL at 1-, 3-, or 5- second inter-stimulus intervals to assess the relative effects of the combination of these variables on component amplitude and latency. Short- term habituations were also studied using 4 blocks of 16 presentations. Experiment 2 employed the same tone stimulus presented at 50 dB SPL and a 3-second inter-stimulus interval. Eight blocks of 64 trials were recorded from each subject on each day for four days to investigate long-term habituation effects. The results stated that intensity and inter-stimulus interval interact to determine AEP amplitude as well as latency values and that the constituent components do not change appreciably with repeated stimulus presentations, even after several days.

Arslan, E., Prosserand, S., Michelini, S., (1984) studied the whole pattern of the fast, middle and long latency auditory evoked potentials (AEP) recorded simultaneously from the scalp surface of 13 normal-hearing adults. Stimulation consisted of 2048 unfiltered clicks, delivered monaurally at 80, 60, 40 dB HL with an ISI of 750 ms. Changes in the mean latency and amplitude of each AEP component were statistically evaluated in relation to intensity and electrode montage (vertex-mastoid ipsi- and contralateral to the stimulated ear). The latencies of the slow P1 increase significantly with declining stimulus intensity. The amplitudes of the slow P1-N1, P2-N2 decrease significantly with intensity. As regards differences due to the electrode montage the contralateral recording causes significant changes in latency of slow P1-N1 and P2-N2. Therefore, as their latency and amplitude seem to be less closely related to the stimulus and electrode placement, the middle components behave differently, compared with the preceding and following components. Based on parametric comparisons of potentials ranging widely in latency, but each one evoked by an equal sensory input, this kind of AEP evaluation may be useful both for neurophysiological and clinical studies of the whole auditory pathway function.

Pfefferbaum, et al., (1980) stated that when latency increase and amplitude decrease with advancing age.

Michalewski, H. J. et al., (1980) stated Peak latency variation and the temporal interrelationships of the auditory event-related potential were investigated in 12 normal adults (ages 28–42). Measures of variation were based on both conventional averages and single trials. Estimates of N1, P2, N2 and P3 latencies were made on a trial-by-trial basis to target stimuli recorded from Fz, Cz and Pz scalp locations. Results showed that single-trial latency variability of the auditory ERP differed both among the various components and between subjects. Larger standard deviations were measured for the later N2 and P3 components than the earlier N1 and P2 components. Regression analyses between various component latencies indicated a strong co varying relationship between N2 and P3, with N2 accounting for up to 61% of the variance of P3 latency at Pz. Earlier N1 and P2 components added little to the overall prediction of either P3 or N2. For the other components, P2 accounted for 9–16% of the variance of N2, while N1 accounted for approximately 1% of the variance of N2; N1 accounted for 8–10% of the latency variation of P2. The correlations between single-trial peak latencies and RTs were positive but of low magnitude. The highest correlations between peak latency and RT were found for N2 (r = 0.33) and P3 (r =

0.24).The low correlations between the single-trial latencies of N1 and P3 suggest that the processes reflected by these components are independent and support a distinction between the earlier and the later components of the ERP. The close temporal coupling between N2 and P3 suggests that N2 may reflect cognitive properties in common to P3 in stimulus evaluation processes

Koendra, Hink, Yamada and Suzuki (1979) studied the effect of rise-time on ABR, MLR and LLR. Stimuli consisted of 1 KHz tone bursts with total duration of 42 ms. Two stimulus rise times of 5 ms (5-32-5) and 20 ms (20-2-20) was used to study the effect of the rise-time. The results showed the increase in rise-time to be associated with smaller peak amplitude (which was not significant for LLR) and longer peak latencies for all evoked potential components measured.

Spink, Johanssen and Pirsig (1979) reported that the largest amplitude increase for LLR occurs within the first 20-30 dB above auditory threshold, and then amplitude increases more gradually with increasing intensity levels, reaching a plateau or "saturation" above approximately 75 dB for some individuals.

Picton, et al., (1973) stated that fifteen distinct components can be identified in the scalp recorded average evoked potential to an abrupt auditory stimulus. The early components (I–VI) occurring in the first 8 msec after a stimulus represent the activation of the cochlea and the auditory nuclei of the brainstem. The middle latency components (N_o, P_o, N_a, P_a, N_b) occurring between 8 and 50 msec after the stimulus probably represent activation of both auditory thalamus and cortex but can be seriously contaminated by concurrent scalp muscle reflex potentials. The longer latency components (P_1, N_1, P_2, N_2) occurring between 50 and 300 msec after the stimulus are maximally recorded over fronto-central scalp regions and seem to represent widespread activation of frontal cortex.

Rothmann (1970) studied on slow cortical responses which were evoked from human subjects by either shocks or clicks. Electrodes were at the vertex and the right mastoid region. Various temporal features of stimulation were explored, such as regularity of stimulus intervals, the duration of these intervals, background stimulation rate and the effect of prolonged exposure to stimulation. The amplitude of response (N_1−P_2) is considerably increased by lengthening the intervals between stimuli. The "recovery process" for shocks appears to be faster than for clicks. Irregularity of stimulation *per se* gives only a slight enhancement. The results obtained suggested that Introduction of irregularity into the intervals between stimuli (with rate of stimulation held constant at 4 per 10 sec) slightly enhanced the responses to shocks and to clicks. Decreasing the rate of stimulation (for shocks), regardless of whether stimuli were regularly or irregularly spaced, caused increase of amplitude. Completely recovery of amplitude occurred when shocks were less frequent than 4 per 10 sec. The length of the last interval before a shock had a strong effect on the response amplitude. With the interval preceding the stimulus of interest held constant at 2.5 sec, a decrease in the over-all rate of clicks from 8 to 4 to 2 per 10 sec increased the amplitude of the responses. . Prolonged exposure to stimulation for many minutes caused a systematic decline in response amplitude for shocks, but no noticeable decline for clicks. Individual exceptions appeared to all of these general statements, sometimes erratically, sometimes associated with particular subjects.

Antinoro, Skinner and Jones (1969) found that there is an interaction among stimulus frequency, intensity and ALR amplitude. Amplitude increases as a function of intensity were steeper for lower frequency stimuli (500 Hz) than for higher frequencies (8000 Hz).

Butler, et al., (1969) pointed out that monaural acoustic stimulation produces a N1 component that is consistently shorter in latency (up to 8 msec) when recorded from the hemisphere contralateral to the stimulus, in comparison to the ipsilaterally recorded response. Also ALR amplitude was greater for binaural than for monaural presentations.

Spoor, timmer, and O'Denthal (1969) found the relationship between the N1 peak latency and N1-P2 peak to peak voltage of the evoked auditory response elicited by amplitude and frequency modulated tone bursts. The result suggested that N1-P2 voltage of the response grown as the intensity of the stimulus is increased, and the latency simultaneously reduced.

Onishi and Davis (1968) conducted extensive study on the effects of duration (rise/fall or the plateau times) on the ALR in normal hearing subjects. The stimuli were 1000Hz tone bursts with linear onset-offset ramps. Varying rise/fall and plateau times produced complex effects on ALR latency and amplitude. At a fixed rise/fall time (30 msec), there was no change in latency (of N1 or P1 components) or of amplitude (N1-P1) as duration was varied from 0 through 300 msec. With a relatively brief rise/fall time of 3 msec, a progressive reduction of plateau time from 30 msec down to 0 msec produced a corresponding reduction in ALR amplitude. With a relatively long fixed plateau time, ALR amplitude remained constant as rise/fall time was decreased from 50 to 3 msec. steeper slopes for the rise/fall time resulted in shorter ALR latencies.

Skinner, P.H., (1968) studied the effects of signal duration and rise time on evoked auditory responses of 40 adult subjects using Summing computer technique. An additional objective was to determine whether signal duration for short signals up to 150 msec would reflect temporal summation through amplitude and latency changes in the wave form of evoked potentials. In the experiment on signal-duration, 1000 Hz tones were presented at near threshold levels (10 or 15 dB SL) to maximize the probability of observing the possible effects of temporal summation. In the second experiment different rise times with 1000 Hz stimuli were presented at four sensation levels: 30, 50, 70, and 90 dB. The results suggested an increase in peak amplitude in the potentials occurred as signal rise-time was decreased.

Rapin, et al., (1966) found the largest amplitude changes with intensity for 1000 Hz, less for 250 Hz, and least for 6000 Hz. ALR latency changes with intensity vary for clicks versus tonal stimuli. There is little change in latency for the N1 or P2 components as click stimulus intensity increases, except at intensity levels very close to auditory threshold. He also pointed out that ALR latency has limited potential for estimation of audiometric threshold.

ACQUISITION CHARACTERISTICS

Tremblay, et al,. (2003) did a study on the test-retest reliability of the P1-N1-P2, Acoustic Change Complex in comparison with mismatch negativity (MMN) and P1-N1-P2 evoked by stimulus onset. Main findings of this study include the following: 1) The ACC shows excellent test-retest reliability for grand mean data and for data from individual subjects. 2) Test-retest reliability of the ACC to speech nearly matches that of the P1-N1-P2 elicited by stimulus onset. 3) The ACC is more reliable than the MMN. 4) The excellent test-retest reliability obtained for the ACC in individual subjects emphasizes that this evoked potential complex may serve as a useful index in the clinical evaluation of speech discrimination capacity.

Vartanyan, I.A. et al., (2001) studied Long-Latency Auditory Evoked Potentials during Radial Motion of the Sound Source. Long-latency auditory evoked potentials were studied during simulation with variable-amplitude pulse sequences from a sound source moving to and from the subject. The study concluded that the N1 peak parameters were shown to depend on an accurate estimate of the direction of the change in the distance to the sound source. Differences in the processing of signals that simulated the approaching and/or distancing of the sound source were found in the N1 and P2 component parameters of on- and off-responses as was a more pronounced long negative potential shift in the evoked response to the approaching source as compared to the distancing source.

Tremblay and Kraus (2001) examined whether the N1-P2 complex reflects training induced changes in neural activity. 10 normal hearing young adults were participated. Two synthetic speech (-10 & -20ms) variants of the syllable |ba| varied in VOT used in the study. In between pre & post - testing sessions, subjects were trained to distinguish the -20 and -10msec. VOT |ba| syllables as being different from each other were presented at fast medium and slow rate during electro physiologic testing. Results reveals the N1-P2 complex proved to be stable response showing no significant changes from pre-test-1 to pretest-2 especially at slow presentation rates. Through training, subjects learned to identify the –20msec VOT stimulus as |ma| and –10msec VOT stimulus |ba| and also increased N1-P2 peak to peak amplitude were observed. Before training there is no significant difference between –20 & -10msec VOT stimulus and also with N1-P2 amplitude.

Coyle, S., (1991) studied the effects of age on event-related potentials (ERPs) elicited during a two-tone discrimination (“oddball”) task in 97 normal subjects aged from 17-80 years. Strong relationships were found between age and the latencies of the later ERP components N200 and P300. For the entire sample, the increase in P300 latency as a function of age was best described at Cz and Pz by linear regression equations. A segmented line model better described the P300/age relationship at Fz — the increase in P300 latency with age in subjects over 61 was five times that of subjects younger than 61 years. In this study the task required button-press identification of the targets — the significance of increased age and a delay in N200 latency is discussed with reference to the possibility of N200 latency indexing the speed of cognitive processing.

Yamamoto, et al., (1979) reported that frequency composition of the ALR is mainly in the frequency region under 30 Hz.

Klass, Cody and Bickford (1967) recognized the influence of sleep on ALR. In sleep, the latency is increased and the intensity at which the ALR is first observed in normal hearers is elevated by approximately 20-30 dB.

SUBJECT CHARACTERISTICS

Lean Ying et al (2010) studied the effects of mental workload on long-latency auditory-evoked-potential (AEP), salivary cortisol, and immunoglobulin A (IgA). 20 Healthy subjects (11 males and 9 females) participated in the experiment voluntarily. The results revealed that the latencies of N1, P2, N2, P3, and mismatch negativity (MMN) all increased significantly after the mental tasks were adopted at all of the three recording sites: Cz, Fz, and Pz ($p < 0.05$). With the introduction of mental tasks, more processing resources are allocated to the primary task (mental task), and decreased processing resources available for the secondary task (auditory task), which is reflected on the increases in the latencies of probe-evoked AEP components.

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Unay, B. et al., (2008) studied visual and brainstem auditory evoked potentials in children with headache. Thirty-seven children fulfilling the International Headache Society Criteria for a diagnosis of migraine, 35 children with tension-type headache and 40 healthy children (control group) were enrolled in the study. The result shows that P100 latency and amplitudes of migraine patients were significantly higher than children with tension-type headache and control subjects. Children with tension-type headache also had higher P100 latency and amplitude values than control subjects but there was no statistical difference. BAEP responses were similar between all groups.

Santos, M.J., (2007) studied Cortical Auditory Evoked Potentials in Elderly with Difficulty in Speech Understanding Complaint. The study group was composed of 19 elderly individuals, with ages between 60 and 80 years old, who had difficulties in understanding to speech complaints unjustifiable on conventional audiological evaluation basis. The latencies values for N1 and P2 cortical auditory evoked potentials were measured. **The study** concluded that N1 and P2 latencies were unaffected by the auditory dysfunction presented in the evaluated individuals.

Brodtkorb, E., (2005) studied the Asymmetry of Long-latency Auditory Evoked Potentials in *LGI1*-related Autosomal Dominant Lateral Temporal Lobe Epilepsy. Eight patients with *LGI1*-related ADTLE belonging to a family with predominantly aphasic seizures were studied. Sixty-five individuals without epilepsy served as controls. AEPs (N1-P2 amplitudes) to binaural tones were recorded over the left and the right hemispheres. The results stated that there is a highly significant reduction in

N1-P2 AEP amplitudes over the left hemisphere was demonstrated in patients with ADTLE.

Stelmack, R.M., (2004) examined Short-term changes in the auditory evoked response to low-frequency tones (0.5 kHz, 80 dB) independent groups of introverts and extraverts under attend and ignore conditions. Introverts displayed greater N1-P2 amplitude than extraverts to the first stimulus in a four-stimulus train. The N1-P2 amplitude differences between introverts and extraverts could not be attributed to differences between the groups in either habituation or attention processes. This effect is indicative of the introverts' enhanced sensitivity to physical stimulation.

Suzanne, C., (2002) recorded late cortical responses using an active listening oddball procedure. Auditory processing disorders were suspected in the LD children after a psychologist found phonologic processing and auditory memory problems. A control group of 10 age- and gender-matched children with no hearing or reported learning difficulties was also tested. Teacher ratings of classroom listening and SCAN Competing Words and Staggered Spondaic Word scores were poorer in the LD children. There were minor ABR latency differences between the two groups. Wave Na of the MLR was later and Nb was smaller in the LD group. The main differences in cortical responses were that P1 was earlier and P3 was later and smaller in the LD group.

Franco (2001), when studying 25 volunteers in normal condition aging from 22 to 58 years (average age 38), reported 90 ms for latencies N1 and 180 ms for P2. Latencies for N1 were lower than the ones from this study and remained the same for P2.

Fitzgerald, R.D. et al., (2000) studied on direct current auditory evoked potentials during wakefulness, anaesthesia and emergence from anesthesia. They had done an explorative study in which DC-AEPs were recorded during propofol and methohexital anesthesia in humans. DC-AEPs were recorded via 22 scalp electrodes in 19 volunteers randomly assigned to receive either propofol or methohexital. DC-AEPs were evoked by binaurally presented 2-s, 60-dB, 800-Hz tones; measurements were taken during awake baseline, anesthesia, and emergence. About 500 ms after stimulus presentation, DC-AEPs could be observed. The results suggested that during sufentanil anesthesia, reduced latencies and amplitudes of P2 and disappearance of P3 were observed compared with the resting state, and it was reported that N1 and P3 could be recorded neither during anesthesia nor during emergence.

Ponton, C. W., (1999) stated that some areas of the brain activated by sound stimulation have a maturational time course that extends into adolescence in the study of maturation of human auditory central auditory system activity: evidence from multi channel evoked potentials. Maturation of certain auditory processing skills such as speech recognition in noise also has a prolonged time course. This raises the possibility that the emergence of adult-like auditory processing skills may be governed by the same maturing neural processes that affect AEP latency and amplitude.

Nelson, M. D. et al., (1997) showed that P1 latency is significantly longer and amplitude larger in children than in adults.

Cranford (1991) reported latencies of 97 ms for N1 and 187 ms for P2 in 40 individuals aging from 20 and 80 years (10 of them were between 60 and 80 years old) with normal hearing regarding their ages. They were volunteers in a study on the effects of contralateral noise presence when researching N1 and P2.

Christie, J. E. et al., 1985, reported that the latency of the P3 was significantly longer and the amplitude significantly smaller in the Dementia Alzheimer Type (ATD) group than in both the Korsakoff Syndrome (KS) and control groups. The KS group did not differ significantly from the control group in either latency or amplitude of P3 but both the KS and ATD groups had reduced N1 and P2 compared to controls. Using a combination of P3 latency and amplitude, 70% of the ATD patients could be separated from the other groups with no false positives.

Rosenberg, C. et al., (1984) studied Auditory Brain-Stem and Middle-and Long-Latency Evoked Potentials in Coma. Twenty-five patients in coma, each with a Glascow Coma Scale measure less than or equal to five, were studied within the first three days of hospitalization with auditory brain-stem and middle- and long-latency evoked potentials. If the group of patients in coma due to head trauma was analyzed separately, survival could be related to the results of the brain-stem evoked potentials. There was no relationship between survival and the results of the initial clinical neurological examination. In patients who survived, there was no pattern of evoked potential preservation that related to the quality of survival.

Shucard and colleagues (1981), in a series of studies of the ALR recorded within a background of complex verbal or nonverbal auditory stimulation in infants, children and adults, found that during verbal and nonverbal conditions, females produced higher amplitude responses from the left hemisphere than male subjects, whereas males show higher amplitude responses than females from the right hemisphere. These data were interpreted as being consistent with expected lateralization of language and spatial functions for males versus females, in children and adults. The results of these studies also serve to emphasize the complexity of interactions among ALR, stimulus conditions, age and gender.

Knight, Hillyard, Woods and Neville (1980) recorded ALRs from patients with confirmed cerebral lesions. Frontal lesions did not produce ALR (N1 and P2) abnormalities, regardless of stimulus rate (ISIs of 0.5-3 sec). The N1 component had poor morphology in patients with temperoparietal lobe lesions; increasing the ISI over this range did not produce the amplitude increase expected for normal subjects. This study also supported that N1 and P2 receive contributions from different neuroanatomic sources.

Chesney, Michie and Donchin (1980) stated that N1 and P2 components are larger when the subject is paying close attention to the stimulus or listening for a change in some aspect of the stimulus. This effect is especially prominent for N1 amplitude, when increasing on the order of up to 50%.

Yellin, A. M., (1980) recorded Auditory-evoked potentials (AEP) to repeat binaural tone pips of several interstimulus intervals (ISIs) ≥1 s from the vertex of young adults with Down's syndrome (DS; trisomy 21) and normal young adults. The following results were obtained: (1) AEP amplitudes, as well as one latency measure, of both experimental groups increased with the lengthening of ISI. (2) AEP peak latencies of the DS group were longer than AEP peak latencies of the normal group for all the ISIs employed. (3) AEP amplitudes of the DS group tended to be larger than AEP amplitudes of the normal group. These findings are discussed in relationship to issues of attention.

Johannsen, et al., (1979) reported significantly shorter P2 latencies for older subjects (average age of 63 years) versus younger subjects (average age of 22 years).

Olhirch, et al., (1978) studied rare longitudinal studies of normal hearing infants and stated that ALR latency decreases and amplitude increases as a function of age during childhood, up until age 10 years, although the most pronounced alterations occur within the first year of life, and to a lesser extend within the 2- to 5-year age range. They reported the latency changes from 15 days to 3 years: P2 from 230 to 150 msec; N2 from 535 to 320 msec; and P3 from 785 to 635 msec.

Goodin, et al., (1978) reported age related decrease in ALR latency up to 15 years with an increase in latency for persons older than 15 years.

Picton and Hillyard (1974) reported that amplitude of N2 component is markedly increased during sleep.

Onishi and Davis (1968) noted that ALR amplitude in general tended to be larger and the amplitude-versus-intensity function steeper for females than for males.

Halliday and Manson (1964) found no significant difference in ALR amplitude during hypnotic anesthesia

Chin, J. H., Killam, E. K., and Killam, K. F., (1964) studied the factors affecting sensory input in the cat: Modification of evoked auditory potentials by reticular formation and **stated that** changes in recording sites and intensity of the auditory stimulus influenced the responsiveness of potentials to the change in level of wakefulness. Reticular-auditory interaction varied with behavioral state, sites of stimulation and recording and intensities of the interacting stimuli. In the drowsy state stimulation of reticular formation consistently reduced the amplitude of response to click. During sleep a threshold stimulus to reticular formation either did not change or enhance auditory potentials while a suprathreshold stimulus reduced them.

Chapter III
Methodology

CHAPTER 3: METHODOLOGY

The present study focused on obtaining normative (children and adults) and studying the variables affecting ALLR using GSI Audera.

SUBJECT SELECTION CRITERIA:

A total of 40 subjects (20 males and 20 females) participated in the study. These subjects were divided into two groups: Group A and Group B having individuals in the age range of 5-15 years (children) and 18-25 years (adults) respectively. Subjects in each group underwent otoscopic examination, tympanometry, reflexometry and puretone audiometry

Inclusion criteria:

- Subjects having otoscopically clean ears,eith right hand preference.
- Bilateral 'A' type tympanogram with ipsilateral acoustic reflexes between 85-95 dB (Gelfand, Schwander and Silmann, 1990)
- Puretone air conduction thresholds not worse than 25 dBHL at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz in either ear were included in the present study.

Exclusion criteria:

- Subjects having middle ear pathology, hearing loss, speech and language problems, neurologic problems, visual problems and metabolic disorders were excluded from the present study.

ADMINISTRATION OF THE TEST:

Testing environment and Instruments: Testing was carried out in a sound treated audiometric room at National Institute of Speech and Hearing, Thiruvananthapuram. The instruments used for the present study were calibrated prior to data collection, and it's as follows:

- Puretone audiometer: GSI 61, a calibrated pseudo dual channel clinical audiometer was used to assess the pure tone threshold for all the subjects
- Middle ear analyser: GSI Tympstar, a calibrated middle ear anlayser was used to check the middle ear status
- Cortical evoked potentials: GSI Audera database version 5.0 and pc version 2.6.740813 was used to present and record the responses. The auditory stimulus was presented through the ER-30 (Etymotic research) Model tip-50 insert ear phone and the visual stimulus was presented using Dell Inspiron n Series.

Consent was taken from the parents and the subjects who were included in the study

Test material for the study:

Auditory presentation - Tone burst was used to evoke the cortical responses for auditory mode of presentation.

Auditory visual presentation –A theatrical animated cartoon was presented along with a tone burst (using Dell Inspiron n Series laptop) placed vertically and horizontally at 0^0 azimuth angle. VCD video files having DAT extension were used to deliver the theatrical animated cartoons.

Table: 3.1

Response stimulus	Recording parameters
Stimulus type	500 Hz and 1K Hz Blackman TB 10-80-10 cycle stimulus
Polarity	alternating polarity
Repetition rate	0.700 cycles/sec
Total number of sweeps	50
High/band pass filter	1-30 Hz BP @ -6 dB+2 dB/ octave bandwidth
Low pass filter	CAEP filter
Noise rejection level	50±µV
Noise rejection level	armed after 100 ms
Sensitivity	150µV

Table: 3.1 shows the response stimulus and recording parameters used in the present study

Instructions:

The subjects were instructed in Malayalam (being their native language) as follows:

"LLR is a simple test with little discomfort. The test will take approximately one and a half hour for completion. It is required that you sit on a chair and relax keeping your eyes open. You have to listen to the sound stimulus presented through auditory and auditory visual mode. Avoid any body movements while the data is being acquired and if any discomfort is felt during the test, please inform.

Before starting the electrophysiological test procedure, forehead, vertex and behind the ears (mastoids) will be cleaned and electrodes will be placed. These electrodes help us to record the responses.

Testing procedures:

1. Puretone audiometry- Modified Hughson and Westlake procedure was used for air conduction and bone conduction hearing threshold estimation.

2. Tympanometry and acoustic reflex thresholds were obtained using a 226 Hz probe tone with a pump rate of 50 daPa.

3. Auditory Late Latency Response (ALLR) - Stimuli were presented through insert ear phone (model tip-50) and Dell Inspiron n Series laptop to all the participants. ALLR was recorded using GSI Audera database version 5.0, pc version 2.6740813.

The electrode skin sites were cleaned with spirit and NU-Prep gel (a mild abrasive). Conduction gel (10-20 conduction paste) was then applied to silver chloride (AgCl) electrodes. The non-inverting electrode (Cz) were placed on the vertex and the inverting electrodes, A1 and A2, were placed over the right and left mastoid. It was held in place by placing a surgical tape (surgipore). The insert earphones were placed in the ear. It was ensured that electrode impedance was less than 5 KΏ.

The ALLR were recorded in the following manner as shown in the table 3.2

Table 3.2

	Group A	Group B
Age	5-15 years	18-25 years
Sex	10 males &10 females	10 males &10 females
Ear	Right/left	Right/left
Intensity	70 and 80 dBnHL	70 and 80 dBnHL
Frequency	500 and 1000 Hz	500 and 1000 Hz
Modes of presentation	Auditory Auditory Visual	Auditory Auditory Visual

Table: 3.2 shows variables used for eliciting the ALLR

ALLR was recorded by presenting a 500 Hz toneburst to both the groups at the intensity of 80 and 70 dBnHL, to right and left ear. After acquired the waveforms, its repeatability was obtained, only the repeatable responses were taken for the study. The same procedure was carried out using 1000 Hz tone burst.

For auditory visual mode, a 500 Hz tone burst was presented along with the theatrical animated cartoon presented through a laptop placed in front of the subject at an angle of 0^0 azimuth angle at an intensity of 80 and 70 dBnHL, to the right and the left ear. After acquired the waveforms, the procedure was repeated at each intensity to assess the wave repeatability. Only those response were noted which had repeatable morphology. The same procedure was carried out using 1000 Hz tone burst .

The latency values of P1, N1, P2 and N2 were marked, taking into account the maximum amplitude points. The latency values obtained for both the auditory and auditory-visual mode for each of the frequency at the respective intensities were then compared.

STATISTICAL ANALYSIS:

The latency of P1, N1, P2 and N2 were obtained. Its Mean and Standard deviations were computed.

- Descriptive analysis was administered to obtain the mean latency response for children and adults.
- Independent'ť'-test was used for comparing the latencies response within Group, across different intensities, frequencies, sex and modes of presentation.
- Paired'ť'-test was used for comparing the latencies between Groups .

Chapter IV
Results & Discussion

CHAPTER 4: RESULTS AND DISCUSSION

The aim of the present study was to obtain normative and study the variables affecting LLR. The variables included in the study were ear specificity, age, gender, frequency, intensity, and auditory and auditory visual mode of presentation.

To facilitate the purpose of the present study the subjects were divided into two groups .Each group consisted of 20 subjects (10 males and 10 females) in the age range of 5-15 years and 18-25 years.

All the subjects underwent pure tone audiometry, tympanometry and reflexometry prior to being subjected to ALLR. Subjects were presented with a 500 Hz and 1 KHz tone bursts at 80 and 70 dBnHL, to right and left ear. After acquired the waveform repeatable peaks were marked and analyzed.

Similarly a 500 Hz and 1 KHz tone burst was presented along with the animated silent moving cartoon presented at 0^0 degree azimuth angle horizontally, through a laptop placed in front of the subject, at an intensity of 80 and 70 dBnHL, to the right and left ear. After acquired the waveforms, the procedure was repeated at each intensity to assess the wave repeatability. Repeatable peaks were marked and analyzed.

The latency values of P1, N1, P2 and N2 were marked, taking into account the maximum amplitude points. The latency values obtained for both the auditory and

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auditory-visual mode for each of the frequency at the respective intensities were then compared.

For ease of understanding, the test results of the current study are discussed in two main subsections:

I. Within group comparison

II. Between group comparisons

Statistical analysis was done by using descriptive analysis, independent and paired‘t’-test.

WITHIN GROUP COMPARISON

GROUP A

Normative for Children

In order to attain the objective of the present study, late latency responses were obtained for 20 children in Group A (5-15 yrs). Latencies responses of P1, N1, P2 and N2 were calculated at 80 dBnHL for right and left ear, using a 500Hz tone burst. Mean and standard deviation for all the peaks were calculated, and the results are shown in the table 4.1.

Table: 4.1

N	Ear	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	Right	70.1	7.4	108.3	12.4	169.3	12.9	221.0	20.8
20	Left	67.7	9.1	103.7	8.8	168.7	14.6	222.2	14.5

The above table 4.1 shows the means and SD for P1, N1, P2 and N2 at 80 dBnHL for right and left ear, using a 500Hz tone burst.

From the table 4.1, it's observed that for right ear the mean latency and SD for P1, N1, P2 and N2 were 70.1 ms, 108.3 ms, 169.3 ms, 221.0 ms, 7.4, 12.4, 12.9 and 20.8 respectively .The mean latency and SD in left ear for P1, N1, P2 and N2 were 67.7 ms, 103.7 ms, 168.7 ms 222.2 ms, 9.1, 8.8, 14.6, and 14.5 respectively.

Hence it's observed that the latencies for ALLR were in the range of 50 – 250ms, for both the ears. This prolongation in the latency response from P1 to N2 could be due to the difference in the site of generation of each peak. P1 represents the late thalamic projections into the early auditory cortex and is a part of specific sensory system (Velaseco et. al., 1989), N1 originated from the contralateral supratemporal auditory cortex (Knight et. al., 1988), whereas P2 is from the lateral frontal supratemporal auditory cortex (Scherg et. al., 1989) and N2 is a part of nonspecific multisensory system in the supratemporal auditory cortex (Velasco et. al., 1989), which is dependent on activity within the limbic system and the reticular activating system in the region of the thalamus.

The latency range in the present study for P1 (46.7 – 83 ms), N1 (86.3 - 140.3 ms), P2 (149 – 197 ms) and N2 (204.7 - 254.7 ms) which is similar to the latency value suggested by Hall (1992) in the range of P1 (50-80 ms), N1 (100-150 ms), P2 (150-200 ms) and N2 (180-250 ms).

Shankar, D. (1997) studied the age related changes in auditory late latency response and the mean latency for all the peaks were obtained in her study for children. The mean latency for P1 peak appeared at 77.61 ms for 7 years, 72.78 ms for 8 years and 61.60 ms for 9 years. The mean latency for N1 falls at 123.99 ms for 7 years, 102.19 ms for 8 years, 114.37 ms for 9 years. the mean peak latency for P2 fall under the range of 138.82 ms for 7 years, 132.92 ms for 8 years and 156.83 ms for 9 years. The mean latency for N2 was 223.64 ms for 7 years, 222.72 ms for 8 years and 230.13 ms for 9 years.

COMPARISON BETWEEN EARS

The present study aimed at studying the effect of ear specificity on the auditory late latency responses. In order to attain the objective of the present study ALLR was obtained at 80 dBnHL for right and left ear using a 500 Hz tone burst.

Table: 4.2

N	Ear	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	Right	70.1	7.4	108.3	12.4	169.3	12.9	221.0	20.8
20	Left	67.7	9.1	103.7	8.8	168.7	14.6	222.2	14.5
t		0.938		1.698		0.176		0.222	
p		0.360		0.106		0.862		0.826	

Table: 4.2 shows the means, SD, t and p values for P1, N1, P2 and N2 at 80 dBnHL for right and left ear, using a 500Hz tone burst

The mean latencies obtained for P1, N1, P2 and N2 , for right and left ear was 70.1, 108.3, 169.3, 221 ms, 67.7, 103.7, 168.7, and 222.2 ms respectively. Standard deviations obtained were 7.4, 12.4, 12.9, 20.8, 9.1, 8.8, 14.6 and 14.5 respectively. Statistical analysis using independent‘t’ test revealed that there was no significant difference between the ears at 0.05 level of significance .

Figure 4.1

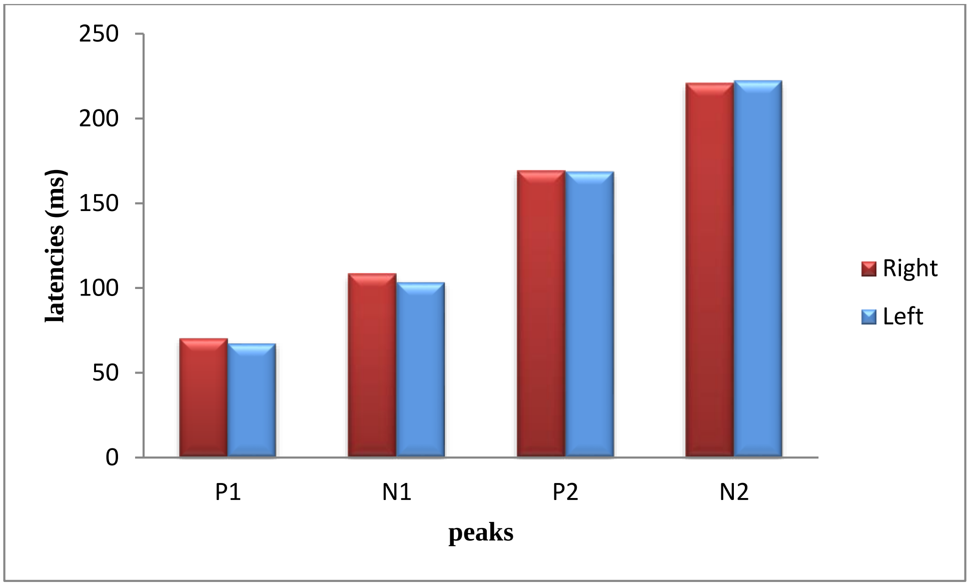


Figure: 4.1 shows a graphical representation of the latency response for P1, N1, P2 and N2 , at 80 dBnHL for right and left ear, using a 500Hz tone burst for children.

From the above figure 4.1 it's observed that the latency response for the left ear is slightly reduced except at N2 when compared to the right ear. This could be due to the fact that the left side dominates in deciphering speech and other rapidly changing signals, while the right side leads in processing tones and music. Because of how the brain's neural network is organized, the left half of the brain controls the right side of the body, and the left ear is more directly connected to the right side of the brain. As tone bursts are tonal signal, more processing takes place in the right hemisphere. As left ear is directly connected to the right hemisphere, it takes only less time to respond to the tone burst than that of the right ear.

Tommasi, 2009 stated that right ear sounds are processed more on the left side of the brain, and left ear sounds are processed more on the right side and the left ear might have an advantage in discriminating non-phonemic aspects of speech (i.e. prosody, emotional cues, etc.). This was the reason of the reduction in latency response of the left ear than that of the right ear when tone burst is used as stimuli.

Similar results were obtained using 1KHz tone burst at 70 and 80 dBnHL and with the auditory-visual stimulus using 500 & 1KHz tone burst at 70 and 80 dBnHL. Results are shown in the Appendix 18, 19, 20, 21, 22 and 23.

COMPARISON BETWEEN GENDER

The present study aimed at studying the effect of gender on ALLR. In order to attain the objective of the present study it was carried out on 10 males and 10 females, using a 500 Hz tone burst at 80 dBnHL.

Table: 4.3

N	Sex	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
10	Male	70.5	5.9	106.3	10.3	166.2	9.3	215.3	19.5
10	Female	69.8	8.9	110.2	14.8	172.4	15.6	226.6	21.4
t		0.221		0.691		1.089		1.236	
p		0.827		0.499		0.291		0.232	

Table: 4.3 shows the means, SD, t and p values for P1, N1, P2 and N2 at 80 dBnHL for males and females, using a 500Hz tone burst.

The mean obtained for P1, N1, P2 and N2, for males and females were 70.5, 106.3, 166.2, 215.3, 69.8, 110.2, 172.4and 226.6 ms respectively, at 80 dBnHL.

Statistical analysis using independent 't' test revealed that there exists no significant differences between male and females.

Figure: 4.2

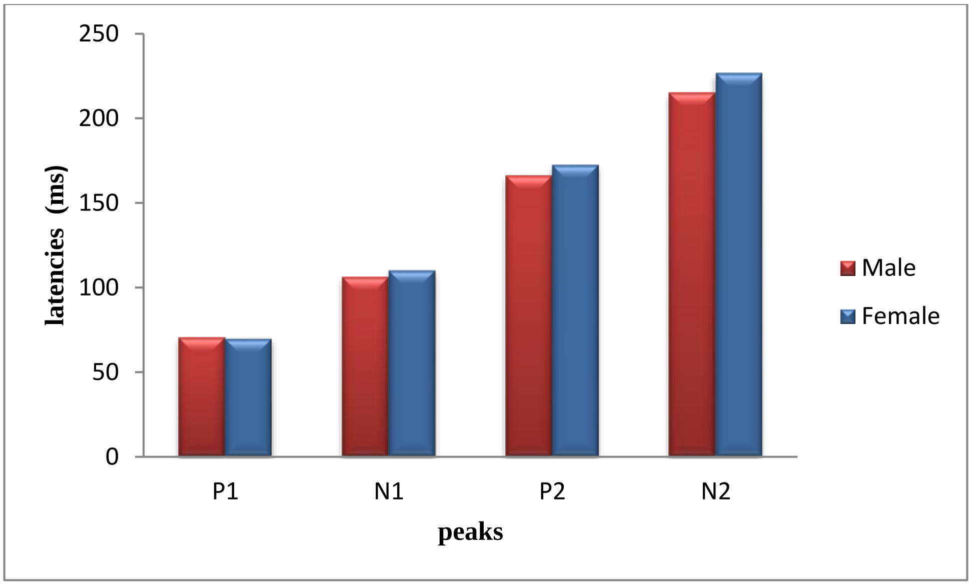


Figure: 4.2 shows the graphical representation showing the comparison between males and females for P1, N1, P2 and N2 at 80 dBnHL, using a 500Hz tone burst.

From the figure above, it's observed that the peak latencies of P1, N1, P2 and N2 were slightly prolonged for females than for male. This could be due to the fact that there is a difference in regional cerebral blood flow in the left and right primary auditory cortex (PAC) when comparing auditory processing of tonal sounds and noise between males and females. The PAC was more activated by music than by tonal sounds in both men and women. But this difference between the two stimuli was significantly higher in men than in women (Frans, W. J. Albers, et al, 2007).

Schlaepfer, T. E. et al., (1995) reported that women had 23% (in Broca's area, in the dorsolateral prefrontal cortex) and 13% (in Wernicke's area, in the superior temporal cortex) more volume than men. Harasty, J. et al., (1997) reported that the volume of the Wernicke's area was 18% larger in females compared with males. Thakur, D. (2011) reported that the latencies and duration were longer in males whereas amplitude was higher in females.

Results similar to our study were obtained by Golgeli, A. (1999), Tucker, D. A. et al., (2002) and Dolu, N. et al., (1999) stated that the latencies of ALLR components were not different between both sexes.

Similar results were also obtained with a 500 Hz tone burst for 70 dBnHL and at 1 KHz at 70 and 80 dBnHL attached in Appendix 24, 25 and 26.

COMPARISON BETWEEN FREQUENCIES

The present study aimed at studying the effect of stimulus frequencies on ALLR for children. In order to facilitate the purpose of the present study it was presented to 20 children using a 500 Hz and 1000 Hz tone burst at 80 dBnHL. Results obtained from subjects were taken for the comparison.

Table: 4.4

N	Frequencies (Hz)	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	500 Hz	70.1	7.4	108.3	12.5	169.3	12.9	221.0	20.8
20	1000 Hz	69.3	11.2	110.2	14.4	169.1	11.3	220.5	17.6
t		0.407		0.534		0.067		0.113	
p		0.688		0.599		0.948		0.911	

Table: 4.4 shows the means, SD, t and p values for P1, N1, P2 and N2 at 80 dBnHL, using a 500Hz and 1000 Hz tone burst

The mean latencies obtained for P1, N1, P2 and N2, at 500 Hz and 1000 Hz were 70.1, 108.3, 169.3, 221.0, 69.3, 110.2, 169.1 and 220.5 ms respectively. Standard deviations obtained were 7.4, 12.5, 12.9, 20.8, 11.2, 14.4, 11.3 and 17.6 respectively.

Statistical analysis using independent 't' test revealed that there is no significant difference across frequencies (500 & 1 KHz) for Group A

This could be due to the fact that anatomical differences for the perception of these two frequency was not widely apart, hence it did not lead to significant difference. However earlier studies have revealed that there exist a significant differences between the frequency that could be due to the fact that the frequency taken for their study was widely apart that is, 250Hz and 4KHz

Figure: 4.3

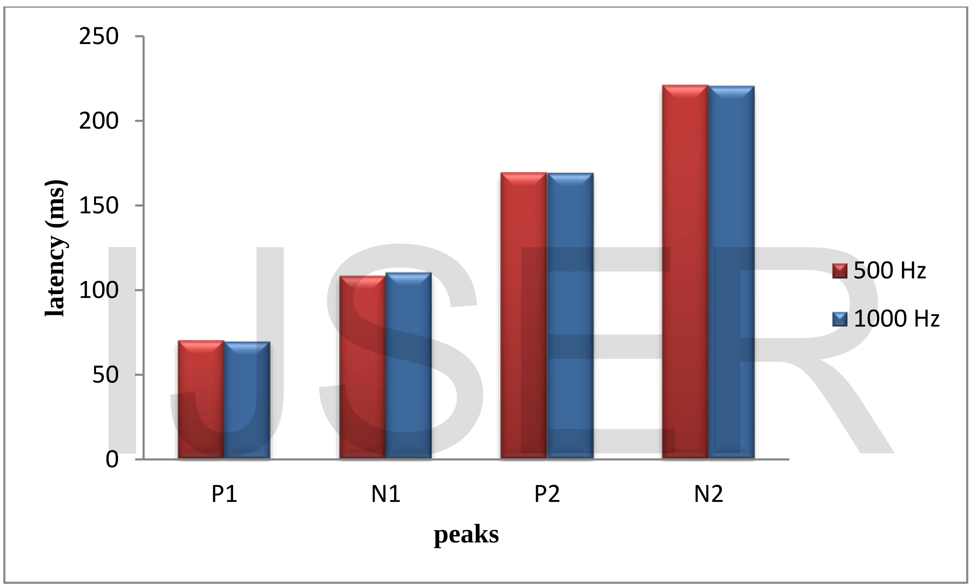


Figure: 4.3 shows the mean latencies of P1, N1, P2 and N2 of 500 and 1000 Hz at 80 dB in right ear using auditory mode alone

It can also be observed from the above figure 4.3 that latencies for 500Hz was slightly more prolonged when compared to 1kz except for N1 peak.

Dimitrijevic, A. et al., (2008) suggested no differences between tonal frequencies when the relationship between intensity increments and N100 latency/amplitude was studied. Loftus, C. W. (2000) stated that at supra-threshold intensities the shortest latencies occurred near characteristic frequency and became progressively longer toward the low- and high-frequency edges of the EFRA (excitatory frequency response areas).

Similar results were obtained using 500 and 1000 Hz tone burst at 70 dBnHL and for 500 Hz and 1000 Hz tone burst at 80 & 70 dBnHL with visual stimulus. Table is shown in Appendix 27, 28 and 29.

COMPARISON BETWEEN INTENSITIES

The objective of the present study was to study the effect of stimulus intensity on the auditory late latency responses. In order to facilitate the objective of the present study it was carried out across 20 children, at 80 and 70 dBnHL, using a 500 Hz tone burst.

Table: 4.5

N	Stimulus intensity	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	80 dB	70.1	7.4	108.3	12.5	169.3	12.9	221.0	20.8
20	70 dB	76.2	6.5	117.9	16.8	178.3	14.6	236.0	18.2
t		3.943		5.789		6.352		7.065	
p		0.001		0.000		0.000		0.000	

Table: 4.5 shows the means, SD, t and p values for P1, N1, P2 and N2 at 80 dBnHL, using a 500Hz tone burst

The mean latencies obtained for P1, N1, P2 and N2, for 80 and 70 dBnHL at 500 Hz were 70.1, 108.3, 169.3, 221.0, 76.2, 117.9, 178.3 and 236.0 ms respectively. Standard Deviations observed were 7.4, 12.5, 12.9, 20.8, 6.5, 16.8, 14.6 and 18.2 respectively.

Statistical Analysis was carried out using independent't' test, the results revealed that there existed a significant difference between the latency response at different stimulus intensities (80 and 70 dBnHL). It was thus concluded from the present study that as the intensity decreases, latency increases and vice versa.

Figure: 4.4

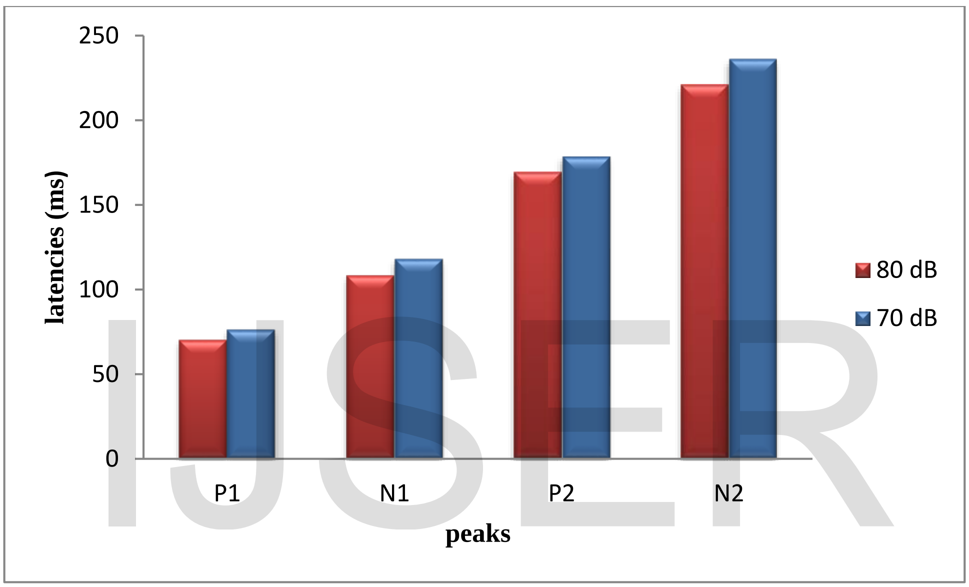


Figure: 4.4 shows the mean latencies of P1, N1, P2 and N2 at 80 and 70 dBnHL at using 500 Hz.

It's observed from the above figure: 4.4 that there was an increase in the latency of all the peaks as the stimulus intensity decreased; more prolongation was noted for N2 peak with respect to other peaks. This could be due to the fact that N2 is an endogenous potential which can be highly affected by the state of the subjects whereas all the other peaks were exogenous, which depends only on the physical parameters of the stimulus.

It was also noted that as the latency was reduced there was a reduction in the peak amplitude. However at lower intensities (50dBnHL) it was noted that the wave morphology was affected, making the identification of the peaks difficult, hence LI function could not be studied at lower levels.

The prolongation of the peaks with the decrease in the stimulus intensity could be due to the fact that at higher levels more number of nerve fiber fires synchronously, leading to reduced latencies.

Xiaofeng Ma, (2008) reported that the response latency of auditory neurons typically shortens with an increase in stimulus intensity

Similar results were obtained by:

Alder and Alder (1989); McCandless and Best (1966); McCandless and Lentz (1968); Onishi and Davis (1968); Ross and Ruhm (1966) reported increase in latency with decrease in intensity from 60 dBnHL to threshold. Jacquy, J. et al., (1993) stated that the latency decreases as an inverse function of the intensity of stimulation in normals. Hall (1992) reported greater variability in the response latency near threshold when compared to suprathreshold level (about 40 dBnHL or higher). Rapin, et. al., (1966) reported that, latency increased as stimulus intensity decreased this relationship is not entirely linear since the latency change is greater for intensity below 45-50 dBSPL. He also stated that there is very little change for the N1 and P2 components as click stimulus intensity increases except at intensity levels very close to auditory thresholds.

Alder and Alder (1989) also supported this finding by stating that an increase in latency resulted due to decrease in intensity (rom 60 dBnHL to threshold..

Similar results were obtained using 1000 Hz tone burst at 80 & 70 dBnHL and for 500 Hz and 1000 Hz tone burst at 80 & 70 dBnHL with visual stimulus . Table is shown in Appendix 30, 31 and 32.

COMPARISON BETWEEN TWO MODES OF PRESENTATION

In order to attain the objective of the present study, a 500 tone burst was presented to 20 children at 80 & 70 dBnHL; the same auditory stimulus was presented along with a slow moving cartoon presented to all the subjects through a laptop placed at 0 degree azimuth angle in the horizontal plane. The auditory latency response under the two modes were recorded and analyzed.

Table: 4.6

N	Mode of presentation	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	A	70.1	7.4	108.3	12.5	169.3	12.9	221.0	20.8
20	AV	72.6	8.9	110.1	14.8	170.9	15.6	219.7	15.9
t		1.445		0.850		0.494		0.358	
p		0.165		0.406		0.627		0.724	

Table: 4.6 shows the means, SD, t and p values for P1, N1, P2 and N2 using a 500Hz tone burst at 80 dBnHL, using two modes of presentation.

The mean obtained for P1, N1, P2 and N2, for 80 and 70 dBnHL using auditory and auditory visual modes were 70.1 ms, 108.3 ms, 169.3ms and 221.0 ms, 72.6 ms, 110.1 ms, 170.9 ms and 219.7 ms respectively.

Statistical Analysis using independent‘t’ test revealed that there existed no significant difference between the latency response for auditory and auditory-visual mode.

Table: 4.7

N	Mode of presentation	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	A	76.2	6.5	117.9	16.8	178.3	14.6	236.0	18.2
20	AV	80.1	12.5	119.9	15.1	183.6	18.0	232.0	20.6
t		1.420		0.869		1.410		1.198	
p		0.172		0.396		0.175		0.246	

Table 4.7 shows the means, SD, t and p values for P1, N1, P2 and N2 values at 70 dBnHL using 500 Hz tone bursts , using auditory and auditory - visual mode of presentation.

The above table 4.7 indicates the values for P1, N1, P2 and N2, for auditory mode and Auditory-Visual mode were 76.2, 117.9, 178.3 and 236.0 ms, 80.1, 119.9, 183.6, 232.0 ms respectively. The standard deviations obtained were 6.5, 16.8, 14.6, 18.2, 12.5, 15.1, 18.0 and 20.6 respectively.

Statistical Analysis using independent‘t’ test revealed that there existed no significant difference between the latency response for auditory and auditory-visual mode at 70 dBnHL, using 500 Hz tone bursts.

Figure: 4.5

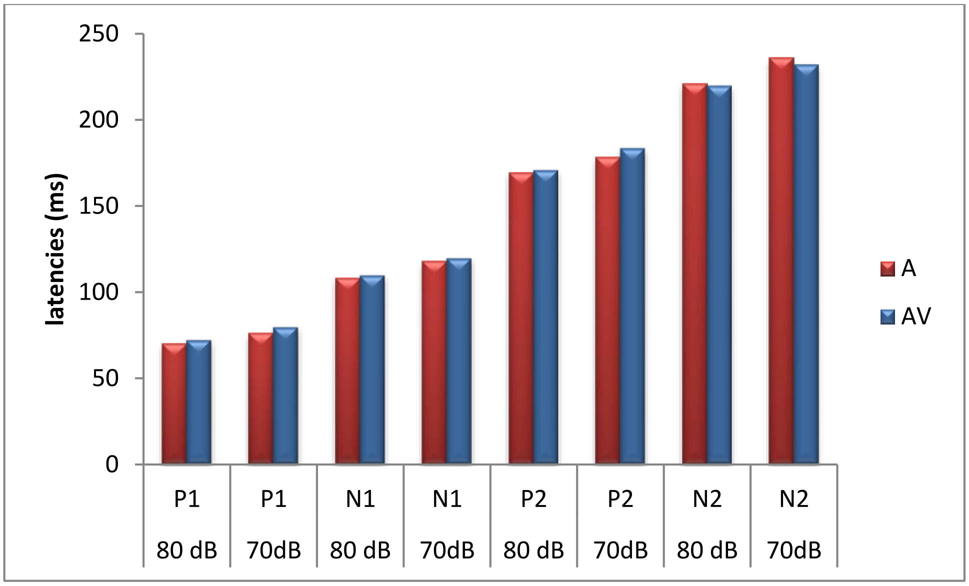


Figure: 4.5 shows the mean latencies for a 500Hz tone burst, at 80 and 70 dBnHL using two modes of presentation, A and AV mode.

From the figure 4.5, it's observed that the latency of occurrence of the peak P1 to N2 were in the mean latency range of 70 - 221ms. It's also observed that as the intensity was reduced, there was an increase in mean latency, using both the modes of presentation.

Xiaofeng Ma (2008) in his study reported that the response latency of auditory neurons typically shortens with an increase in stimulus intensity.

This effect of stimulus intensity on latency was well explained by:

Alder and Alder (1989); McCandless and Best (1966); McCandless and Lentz (1968); Onishi and Davis (1968); Ross and Ruhm (1966) reported an increase in latency with decrease in intensity (from 60 dBnHL to threshold). Hall, (1992) indicate that when compared to suprathreshold level (about 40 dBnHL or higher) near threshold the variability of response latency is higher. Rose, et al., (1971); Heil and Neubauer, (2001) suggested that these findings appeared to be consistent with some of the descriptions of auditory nerve activity accompanying changes in intensity that were generally independent on the frequency of the tones.

Similar results were obtained for 1 K Hz which is attached in the Appendix 33.

GROUP B

Normative for Adults

In order to attain the first objective of the present study, late latency responses were obtained for 20 adults in the age range of 18-25 yrs (Group B). Auditory Late Latency responses for P1, N1, P2 and N2 were calculated at 80 dBnHL for right and left ear, using a 500Hz tone burst. Mean and standard deviation for all the peaks were calculated, and the results are shown in the table 4.8.

Table: 4.8

N	Ear	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	Rt	56.3	11.7	90.7	14.5	157.4	12.9	212.4	19.9
20	Lt	57.0	11.5	94.2	9.2	160.2	13.2	213.4	13.3

Right- Rt, Left- Lt

Table: 4.8 shows the means and SD for P1, N1, P2 and N2 at 80 dBnHL for right and left ear, using a 500Hz tone burst.

From the above table 4.8 it's observed that for right ear the mean latency and SD for P1, N1, P2 and N2 were 56.3, 90.7, 157.4, 212.4, 11.7, 14.5, 12.9 and 19.9 ms respectively. Left ear mean latency and SD for P1, N1, P2 and N2 were 11.7, 14.5, 12.9, 19.9, 11.5, 9.2, 13.2, and 13.3 respectively

The ALLR in adults were also in the range of 50 – 250 ms, for both the ears. This prolongation in the latency response from P1 to N2 could be due to the difference in the site of generation of each peak. P1 represents the late thalamic projections into the early auditory cortex and is a part of specific sensory system (Velaseco et al., 1989), N1 originated from the contralateral supratemporal auditory cortex (Knight et al., 1988), whereas P2 is from the lateral frontal supratemporal auditory cortex (Scherg et. al., 1989) and N2 is a part of nonspecific multisensory system in the supratemporal auditory cortex (Velasco et al., 1989), which is dependent on activity within the limbic system and the reticular activating system in the region of the thalamus.

The latency range for P1 (40.3 - 85.3 ms), N1 (60 - 124 ms), P2 (132.7-189 ms) and N2 (174-259.3 ms) obtained in the present study is similar to the results obtained by: Shankar, D (1997) studied the age related changes in auditory late latency response the mean latency for all the peaks obtained in her study were 61.60 ms, 97.13 ms, 172.54 ms and 225.57 ms for P1, N1, P2 and N2 respectively.

Hall (1992) suggested the latency range of P1 (50-80 ms), N1 (100-150 ms), and P2 (150-200 ms) and N2 (180-250 ms) for adults. Similar results were reported by Cranford (1991) reported latencies of 97 ms for N1 and 187 ms for P2 in 40 individuals aging from 20 and 80 years (10 of them were between 60 and 80 years old) with normal hearing sensitivity regardless of their ages. Barnet et al (1975) supported this result by stating that in normal adult’s values were just fewer than 100 and 200ms for N1 and P2.

COMPARISON BETWEEN EARS

The present study aimed at studying the effect of ear specificity on the Auditory Late Latency responses in adults. In order to attain the objective of the present study ALLR was obtained at 80 dBnHL for right and left ear using a 500 Hz tone burst.

Table: 4.9

N	Side	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	Rt	56.3	11.7	90.7	14.5	157.4	12.9	212.4	19.9
20	Lt	57.0	11.5	94.2	9.2	160.2	13.2	213.4	13.3
t		0.204		1.148		0.794		0.156	
p		0.841		0.265		0.437		0.878	

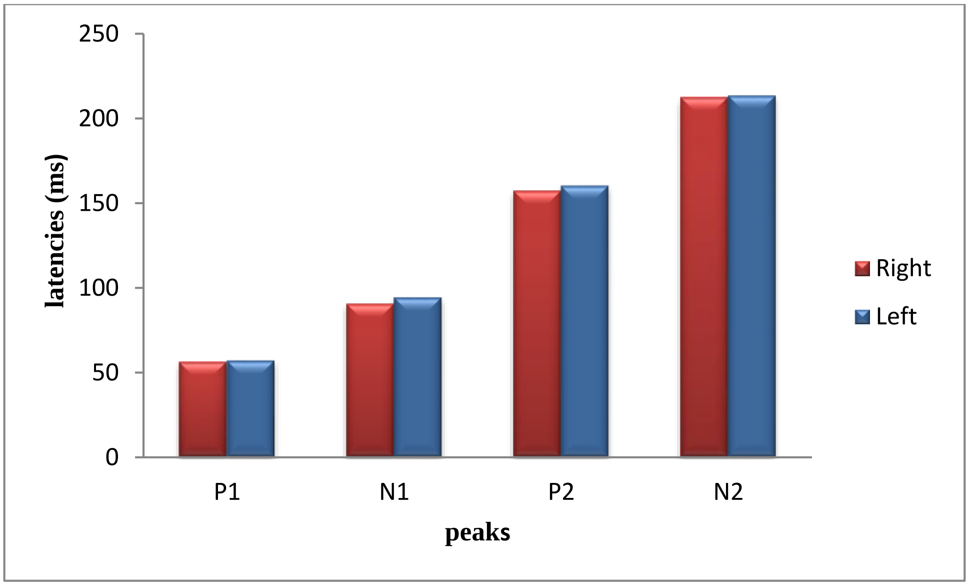
Right- Rt, Left- Lt

Table: 4.9, shows the means, SD, t and p values for P1, N1, P2 and N2 at 80 dBnHL for right and left ear, using a 500Hz tone burst

The mean obtained for P1, N1, P2 and N2, for right and left ear was 56.3, 90.7, 157.4 and 212.4 ms, 57.0, 94.2, 160.2 and 213.4 ms respectively.

Statistical analysis using independent't' test revealed that there was no significant difference between the ears at 0.05 level of significance

Figure: 4.6



The above figure 4.6 shows a mean values of P1, N1, P2 and N2 values at 80 dBnHL for right and left ear, using a 500Hz tone burst

From the above figure, it's observed that the latency of P1, N1 and P2 is slightly reduced in left ear, compared to that of the right ear except for N2, which is an endogenous potential and depends more on the physical characteristics of the subjects This reduction in latencies could be due to the fact that the functions of both the hemispheres are dissimilar. The left side dominates in deciphering speech and other rapidly changing signals, while the right side leads in processing tones and music. Because of how the brain's neural network is organized, the left half of the brain controls the right side of the body, and the left ear is more directly connected to the right side of the brain. As tone bursts are tonal signal, more processing takes place in the right hemisphere. As left ear is directly connected to the right hemisphere, it takes only less time to respond to the tone burst than the right ear.

Tommasi (2009) stated that right ear sounds are processed more on the left side of the brain, and left ear sounds are processed more on the right side of the brain. Left ear might have an advantage in discriminating non-phonemic aspects of speech (i.e. prosody, emotional cues, etc.). This was the reason of the reduction in latency response of the left ear than that of the right ear when tone burst is used as stimuli.

Similar results were obtained using 1 KHz tone burst at 70 and 80 dBnHL and with the auditory-visual stimulus using 500 & 1 KHz tone burst at 70 and 80 dBnHL. Results are shown in the Appendix 34, 35, 36, 37, 38, 39 and 40.

COMPARISON BETWEEN GENDERS

The present study aimed at studying the effect of gender on ALLR. In order to attain the third objective of the present study it was carried out on 10 males and 10 females, using a 500 Hz tone burst at 80 dBnHL.

Table: 4.10

N	Gender	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
10	Male	62.8	10.1	98.0	12.5	163.3	13.1	208.7	10.5
10	Female	49.7	9.5	83.4	13.0	151.5	10.1	216.1	26.4
t		2.988		2.570		2.259		0.821	
p		0.008		0.019		0.037		0.422	

Table: 4.10 shows the means, SD, t and p values for P1, N1, P2 and N2 at 80 dBnHL for males and females, using a 500Hz tone burst

The mean obtained for P1, N1, P2 and N2, for males and females were 62.8, 98.0, 163.3, 208.7, 49.7, 83.4, 151.5 and 216.1 ms respectively, at 80 dBnHL .Standard deviation obtained for males and females were 10.1, 12.5, 13.1, 10.5, 9.5, 13.0, 10.1 and 26.4 respectively.

Statistical analysis using independent't' test was done, results revealed that there exists a significant difference between males and females for P1, N1and P2. No significant difference was obtained for N2, This could be due to the fact that it's an endogenous potential.

Figure: 4.7

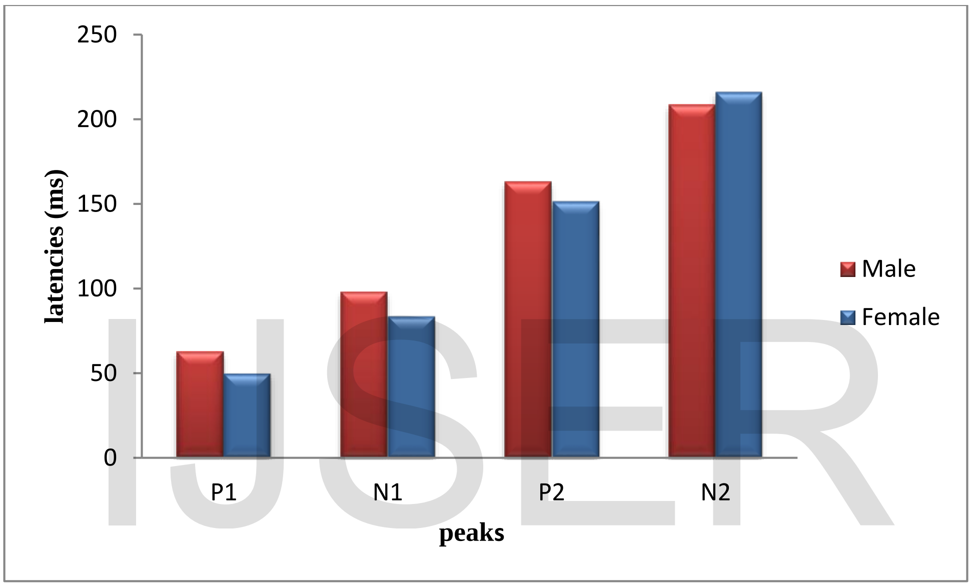


Figure: 4.7 shows the mean values of P1, N1, P2 and N2 between males and females for 500 Hz tone burst, at 80 dBnHL.

From the above figure: 4.7, it's observed that there is a significant prolongation in the mean latency response for P1, N1 and P2 peaks, for males when compared to females at 80 dBnHL for 500 Hz tone burst. This could be due to increased head size of the male subjects than the female subjects (Aoyagi, M. 1990). This could also attribute to the gender difference in the latencies of ALLR. Schlaepfer, T.E. et al., (1995) stated that Women had 23% (in Broca's area, in the dorsolateral prefrontal cortex) and 13% (in Wernicke's area, in the superior temporal cortex) more volume than men.

The results obtained in the present study were similar to the one obtained by:
Thakur, D. (2011) stated that the latencies and duration were longer in males whereas amplitude was higher in females.

Controversial findings were also reported against the result obtained from the present study:
Golgelim, A. (1999) stated that the latencies of N1, P2, N2, P3 components were not different between both sexes.Tucker, D.A. et al., (2002) stated that gender did not have a significant effect on the P1 waveform. Dolu, N. et al., (1999) stated that there was no difference between both sex, for the latencies of N1, P2 and N2 components

Similarly a 500 Hz tone burst at 70 dBnHL and 1 KHz tone burst at 70 and 80 dBnHL,was presented to males and females the results obtained were similar to the above results .Tables are in Appendix 41, 42 and 43.

COMPARISON BETWEEN FREQUENCIES

The present study aimed at studying the effect of stimulus frequencies on ALLR. In order to facilitate the fourth objective of the present study it was presented to 20 adult subjects, using a 500 Hz and 1000 Hz tone burst at 80 dBnHL. Results obtained from subjects were taken for the comparison.

Table: 4.11

N	Frequency	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
	500 Hz	56.3	11.7	90.7	14.5	157.4	12.9	212.4	19.9
20	1000 Hz	54.9	9.8	92.8	8.7	155.8	12.1	211.0	11.3
t		0.510		0.702		0.532		0.308	
p		0.616		0.491		0.601		0.761	

Table: 4.11 shows the means, SD, t and p values for P1, N1, P2 and N2 at 80 dBnHL, using a 500Hz and 1000 Hz tone burst.

The mean latencies obtained for P1, N1, P2 and N2, at 500 Hz and 1000 Hz were 56.3, 90.7, 157.4 and 212.4 ms, 54.9, 92.8, 155.8 and 211.0 ms respectively. The standard deviations were 11.7, 14.5, 12.9, 19.9, 9.8, 8.7, 12.1 and 11.3 respectively.

Statistical analyses using independent't' test was done, results revealed that there exists no significant difference between the frequencies, used in the study.

This could be due to the fact that anatomical differences for the perception of these two frequency was not widely apart from each other hence it did not lead to significant difference . However earlier studies have revealed that there exist a significant differences between the frequency that could be due to the fact that the frequency taken for their study was widely apart that is 250Hz and 4KHz.

Figure: 4.8

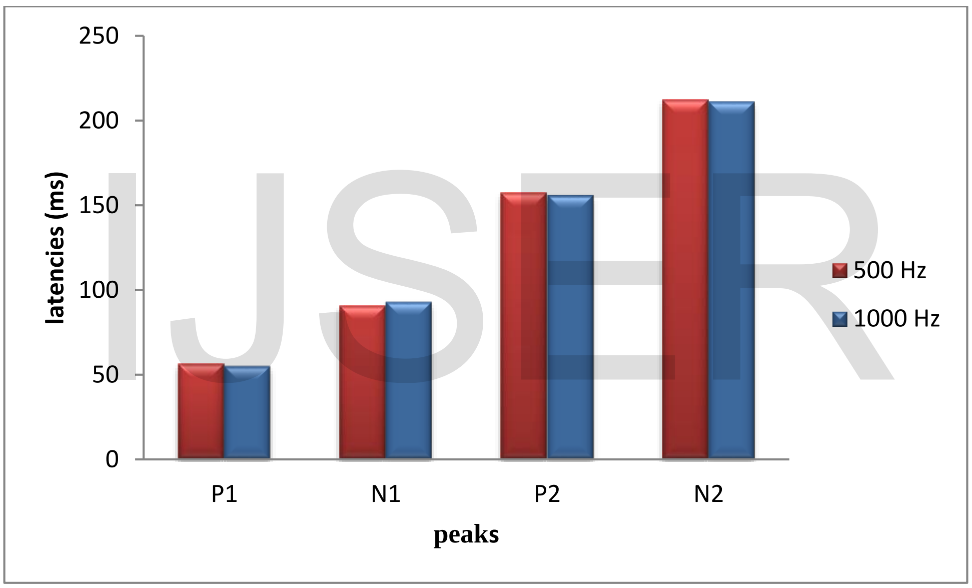


Figure: 4.8 shows the mean latencies of P1, N1, P2 and N2 for 500 and 1000 Hz tone burst at 80 dBnHL.

It's observed from the above figure 4.8 that the latencies for 500Hz was slightly more prolonged for P1 & P2 when compared to 1 KHz, but it's not statistically significant. This could be due to the fact that N1& N2 are exogenous, sensitive to changes in the acoustic features of the stimulus.

Dimitrijevic, A. et al., (2008) suggested no difference between tonal frequencies when the relationship between intensity increments and N100 latency/amplitude was studied.

Similar results were obtained using 500 and 1000 Hz tone burst at 70 dBnHL and for 500 Hz and 1000 Hz tone burst at 80 & 70 dBnHL with visual stimulus. Table is shown in Appendix 44, 45 and 46.

COMPARISON BETWEEN INTENSITIES

Another objective of the present study was to study the effect of stimulus intensity on the auditory late latency responses. In order to facilitate the objective of the present study it was carried out across 20 adults, at 80 and 70 dBnHL, using a 500 Hz tone burst.

Table: 4.12

N	Intensity	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	80 dB	56.3	11.7	90.7	14.5	157.4	12.9	212.4	19.9
20	70 dB	61.2	9.7	97.1	13.0	165.2	11.8	225.4	16.9
t		4.448		3.668		4.344		4.890	
p		0.000		0.002		0.000		0.000	

Table: 4.12 shows the means, SD, t and p values for P1, N1, P2 and N2 at 80 &70 dBnHL, using a 500Hz tone burst.

The mean latencies obtained using a 500Hz tone burst, at 80 and 70 dBnHL for P1, N1, P2 and N2 were 56.3 ms, 90.7 ms, 157.4 ms, 212.4 ms, 61.2 ms, 97.1 ms, 165.2 ms and 225.4 ms respectively. The standard deviations obtained were 11.7, 14.5, 12.9, 19.9, 9.7, 13.0, 11.8 and 16.9 respectively.

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Statistical Analysis was carried out using independent‘t’ test, the results revealed that there existed a significant difference between the latency response at different intensities (80 and 70 dBnHL). It was thus concluded from the present study that as the intensity decreases, latency increases and vice versa.

Figure: 4.9

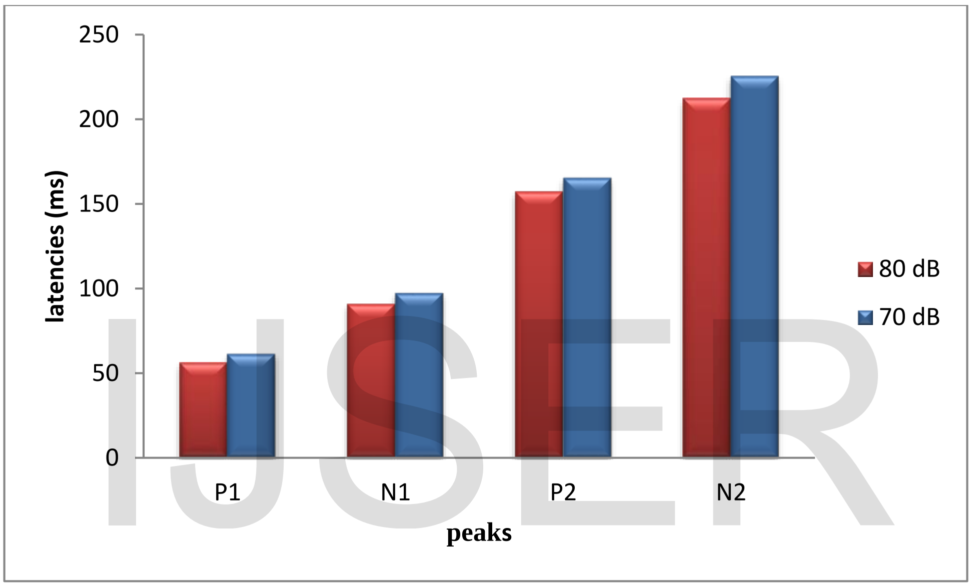

Figure: 4.9 shows the mean latencies of P1, N1, P2 and N2 at 80 and 70 using 500 Hz tone bursts

The figure 4.9 revealed that there is an increase in the mean peak latency responses as the intensity is decreased. It was also noted that as the latency was reduced there was a reduction in the peak amplitude. However at lower intensities (50dBnHL) it was noted that the wave morphology was affected, making the identification of the peaks difficult, hence LI function could not be studied at lower levels.

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The prolongation of the peaks with the decrease in the stimulus intensity could be due to the fact that at higher levels more number of nerve fiber fires synchronously, leading to reduced latencies.

Similar results were reported by

Alder and Alder (1989); McCandless and Best (1966); McCandless and Lentz (1968); Onishi and Davis (1968); Ross and Ruhm (1966) reported an increase in latency with decrease in intensity (from 60 dBnHL to threshold). Hall, (1992) indicated that when compared to suprathreshold level (about 40 dBnHL or higher) near threshold the variability of response latency is higher. Rose, et al., (1971) and Heil and Neubauer, (2001) suggested that these findings appeared to be consistent with some of the descriptions of auditory nerve activity accompanying changes in intensity that were generally independent on the frequency of the tones. Winter and Palmer (1991) suggested that high spontaneous rate nerve fibers generally have lower thresholds and exhibit firing rate saturation at low stimulus intensities. These fibers' discharge rate functions would likely have saturated by 80 dB SPL. The low spontaneous rate fibers show relatively higher thresholds and appear to be of two subtypes: saturating and non-saturating

Similar results were obtained using 1000 Hz tone burst at 80 & 70 dBnHL and for 500 Hz and 1000 Hz tone burst at 80 & 70 dBnHL with visual stimulus. Table is shown in Appendix 47, 48 and 49.

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COMPARISON BETWEEN TWO MODES

In order to attain the objective of the present study, a 500 and 1000 Hz tone burst was presented to 20 adults at 80 & 70 dBnHL, the same auditory stimulus was presented along with a slow moving cartoon presented to all the subjects through a laptop placed at 0 degree azimuth angle in the horizontal plane . The auditory latency response under the two modes were recorded and analyzed.

Table: 4.13

N	Mode of presentation	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	A	56.3	11.7	90.7	14.5	157.4	12.9	212.4	19.9
20	AV	60.0	11.7	93.3	12.2	163.9	9.6	219.8	12.0
t		2.566		0.973		3.306		1.989	
p		0.019		0.343		0.004		0.061	

Table 4.13 shows the means and SD for P1, N1, P2 and N2 values at 80 dBnHL for A and AV mode, using a 500 Hz tone burst.

The mean latency values for P1, N1, P2 and N2, for auditory mode and auditory - visual mode were 56.3, 90.7, 157.4, 212.4, 60.0, 93.3, 163.9, 219.8 ms. Standard

Deviations obtained in the present study were 11.7, 14.5, 12.9, 19.9, 11.7, 12.2, 9.6 and 12.0 respectively.

Statistical analysis using paired‘t’ test revealed that there is a significant difference in the latencies of P1 and P2 only.

Chesney, Michie and Donchin (1980) supported this study by stating that P2 components are larger when the subject is paying close attention to the stimulus or listening for a change in some aspect of the stimulus.

Figure: 4.10

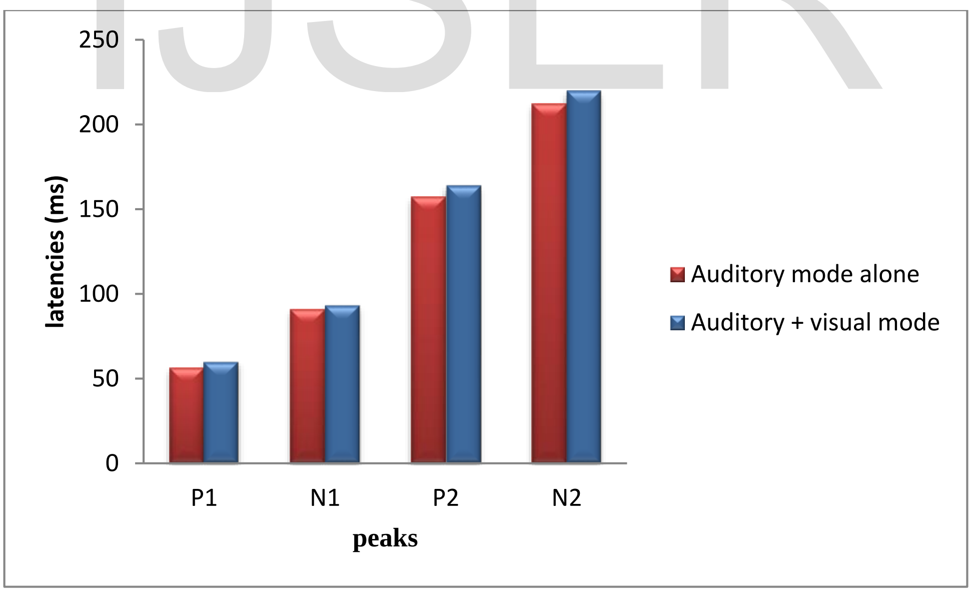

Figure: 4.10 shows the mean latencies of P1, N1, P2 and N2 using auditory and auditory - visual mode, using a 500 Hz tone burst, at 80 dBnHL

From the above figure, it's noted that there is a prolongation of latencies of all peaks when using auditory - visual mode. This is due to the fact that with the introduction of mental tasks, more processing resources are allocated to the primary task (mental task), and decreased processing resources available for the secondary task (auditory task), which is reflected on the increases in the latencies of probe-evoked AEP components **(Lean Ying et al,** 2010).

Table: 4.14

N	Mode of presentation	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	A	61.2	9.7	97.1	13.0	165.2	11.8	225.4	16.9
20	AV	65.1	10.8	103.7	14.1	169.2	11.8	231.8	15.7
t		1.807		2.444		1.786		1.702	
p		0.087		0.024		0.090		0.105	

Table: 4.14 shows the means and SD for P1, N1, P2 and N2 values at 70 dBnHL for A and AV modes of presentation, using a 500 Hz tone burst.

The mean latency values for P1, N1, P2 and N2, for auditory mode and auditory - visual mode were 61.2, 97.1, 165.2, 225.4, 65.1, 103.7, 169.2 and 231.8 ms. Standard

Deviations obtained in the present study were 9.7, 13.0, 11.8, 16.9, 10.8, 14.1, 11.8 and 15.7 respectively.

Chesney, Michie and Donchin (1980) supported this study by stating that N1 components are larger when the subject is paying close attention to the stimulus or listening for a change in some aspect of the stimulus.

Figure: 4.11

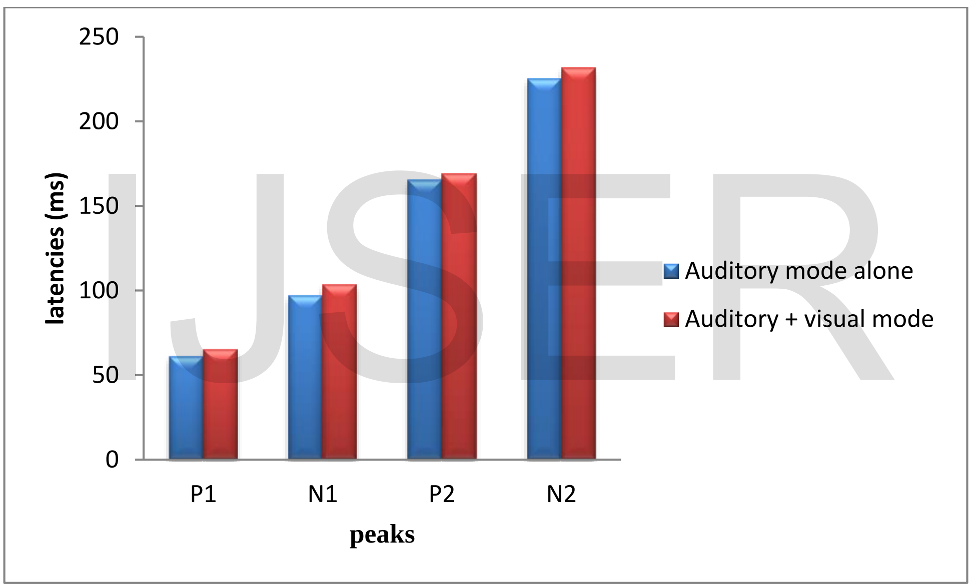

Figure: 4.11 shows the mean latencies of P1, N1, P2 and N2 using auditory and auditory - visual mode, using a 500 Hz tone burst, at 70 dBnHL

From the above figure 4.11, it is noted that there is a prolongation of latencies of all peaks when using AV mode when compared to auditory mode, this is due to the fact that with the introduction of mental tasks, more processing resources are allocated to the primary task (mental task), and decreased processing resources available for the

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secondary task (auditory task), which is reflected on the increases in the latencies of probe-evoked AEP components **(Lean Ying et al,** 2010).

Figure: 4.12

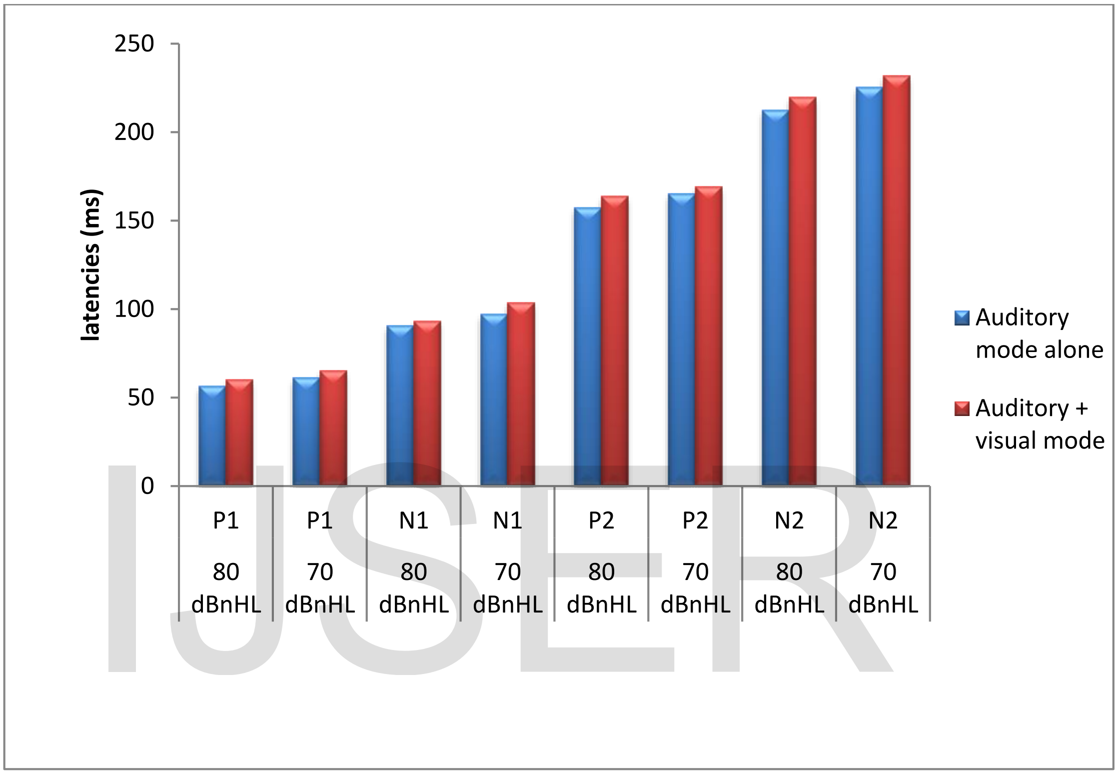

Figure 4.12 shows the mean latencies for a 500Hz tone burst, at 80 and 70 dBnHL using both the modes of presentation

From the above figure 4.12, its observed that the latency of occurrence of the peak P1 to N2 are in the mean latency range of 56.3-231.8 ms . It's also observed that as the intensity decreased, there was an increase in mean latency response, using both the modes of presentation.

Xiaofeng Ma (2008) in his study reported that the response latency of auditory neurons typically shortens with an increase in stimulus intensity.

Table: 4.15

N	Mode of presentation	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	A	54.9	9.8	92.8	8.7	155.8	12.1	211.0	11.3
20	AV	59.7	10.9	97.1	10.2	162.0	15.3	225.0	18.0
t		2.263		2.516		2.771		3.427	
p		0.036		0.021		0.012		0.003	

Table 4.15 shows the means and SD for P1, N1, P2 and N2 values at 80 dBnHL for A and AV modes of presentation, using a 1000 Hz tone burst.

The mean latency values for P1, N1, P2 and N2, for auditory mode and auditory - visual mode were 54.9, 92.8, 155.8, 211.0, 59.7, 97.1, 162.0 and 225.0 ms respectively. Standard Deviations obtained in the present study were 9.8, 8.7, 12.1, 11.3, 10.9, 10.2, 15.3 and 18.0 respectively.

Statistical evaluation using paired 't' test revealed a significant difference in the latencies of P1, N1, P2 and N2 between both the modes of presentation.

Chesney, Michie and Donchin (1980) stating that N1 and P2 components are larger when the subject is paying close attention to the stimulus or listening for a change in some aspect of the stimulus.

Figure: 4.13

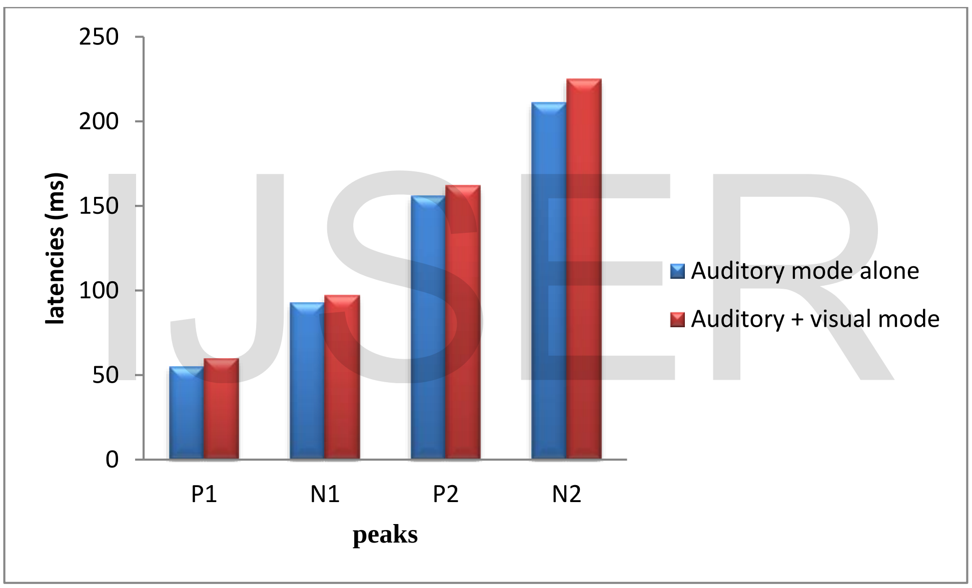

Figure: 4.13 shows the mean latencies of P1, N1, P2 and N2 using auditory and auditory - visual mode, using a 1000 Hz tone burst, at 80 dBnHL

From the above figure 4.13, it's noted that there is a prolongation of latencies of all peaks when using AV mode of presentation. This is due to the fact with the introduction of mental tasks, more processing resources are allocated to the primary task (mental task), and decreased processing resources available for the secondary task (auditory task), which is reflected on the increases in the latencies of probe-evoked AEP components **(Lean Ying et al,** 2010).

Table: 4.16

N	Mode of presentation	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	A	59.6	11.3	99.5	9.6	162.7	10.5	222.8	14.5
20	AV	66.4	14.9	104.7	12.0	169.8	15.4	228.8	20.7
t		2.798		2.165		3.054		1.561	
p		0.011		0.043		0.007		0.135	

Table 4.16 shows the means and SD for P1, N1, P2 and N2 values at 70 dBnHL for A and AV modes of presentation, using a 1000 Hz tone burst.

The mean latency values for P1, N1, P2 and N2, for auditory mode and auditory - visual mode were 59.6, 99.5, 162.7, 222.8, 66.4, 104.7, 169.8 and 228.8 ms respectively. Standard Deviations obtained in the present study were 11.3, 9.6, 10.5, 14.5, 14.9, 12.0, 15.4 and 20.7 respectively.

The result suggested a significant difference in the latencies of P1, N1 and P2.

Chesney, Michie and Donchin (1980) supported this study by stating that N1 components are larger when the subject is paying close attention to the stimulus or listening for a change in some aspect of the stimulus.

Figure: 4.14

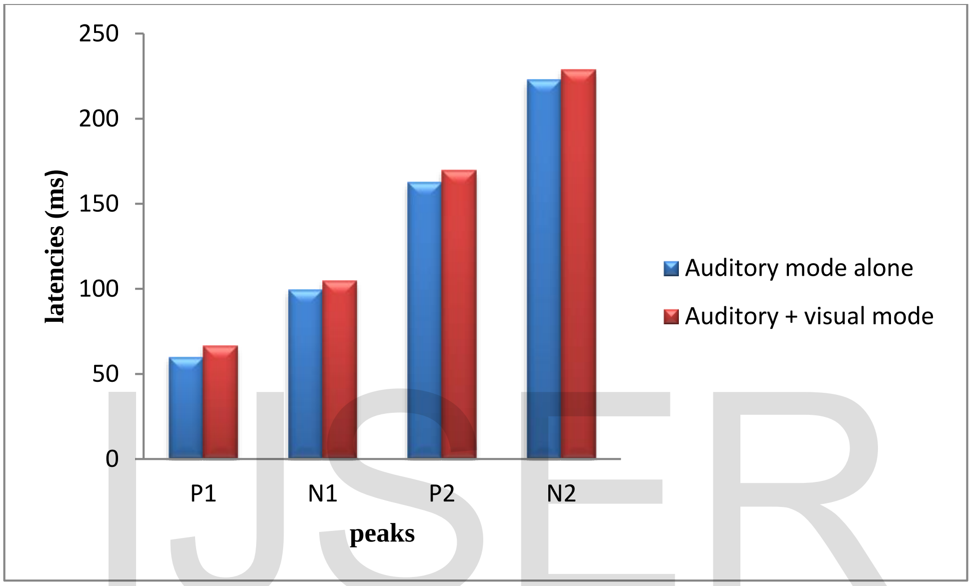

Figure: 4.14 shows the mean latencies of P1, N1, P2 and N2 using auditory and auditory - visual mode, using a 1000 Hz tone burst, at 70 dBnHL

From the above figure 4.14, it is noted that there is a prolongation of latencies of all peaks when using AV mode of presentation. This is due to the fact with the introduction of mental tasks, more processing resources are allocated to the primary task (mental task), and decreased processing resources available for the secondary task (auditory task), which is reflected on the increases in the latencies of probe-evoked AEP components **(Lean Ying et al,** 2010).

COMPARISON BETWEEN GROUPS

The present study aimed at studying the effect of age on the auditory late latency responses. In order to attain the objective of the present study ALLR was obtained using a 500 Hz tone burst for 20 children (5-15 years) and 20 adults (8-25 years), at 80 dBnHL.

Table: 4.17

N	Age	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	Adults	56.3	11.7	90.7	14.5	157.4	12.9	212.4	19.9
20	Children	70.1	11.5	108.3	9.2	169.3	13.2	221.0	13.3
t		4.487		4.093		2.923		*1.324*	
p		0.000		0.000		0.006		0.193	

Table: 4.17 shows the mean, SD, t and p value of adults and children at 80 dBnHL using a 500 Hz tone burst

The mean obtained for P1, N1, P2 and N2, for adults and children were 56.3, 90.7, 157.4, 212.4, 70.1, 108.3, 169.3 and 221.0 ms respectively. Statistical analysis was carried out using paired 't' test; results revealed that there existed significant differences in P1, N1 and P2 between adults and children except at N2.

This could be due to the fact that all the peaks except N2 were exogenous, that is, more related to the physical parameters of the stimuli. N2 was endogenous potentials where the responses are highly related to the state of the subjects.

Figure: 4.15

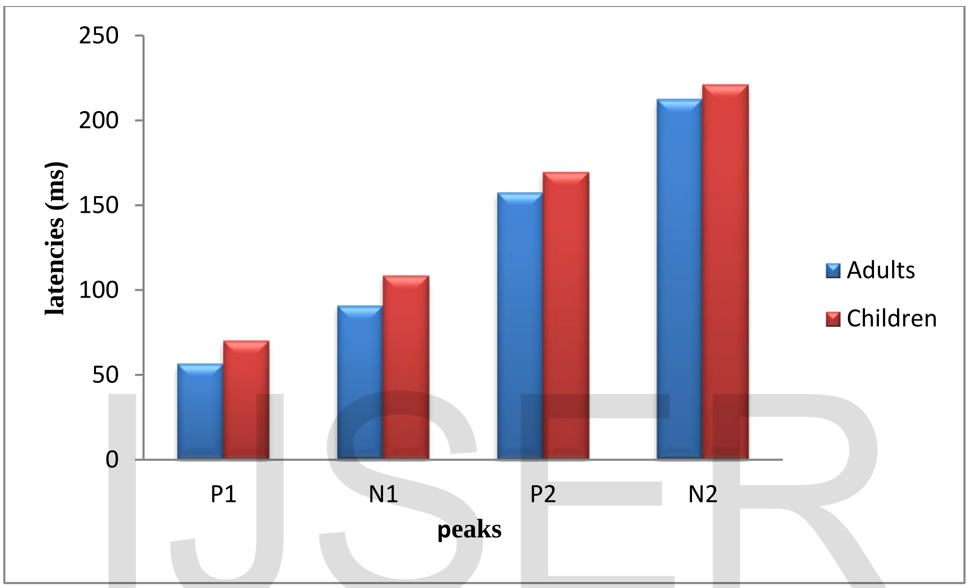

Figure: 4.15 shows the mean latencies of P1, N1, P2 and N2 at 80 dBnHL, using 500 Hz tone bursts for adults and children.

From the figure: 4.15.1 it's observed that there exists a significant difference in latencies between adults and children with the prolongation of P1, N1, P2 and N2 peaks for children. This could be due to the effect of neural maturation of brain structures. Neural maturation will also affect the latency of the late components of AEP.

Similar results were obtained by:

Ponton, et al., (1996) stated that the late components will decrease in latency from birth to about 10 years of age and progressively lengthen with age thereafter. Until about age 7, the EP response presents mostly a large late P1 response. Nelson, M. D. et al., (1997) showed that P1 latency is significantly longer and amplitude larger in children than in adults. Pfefferbaum, et al., (1980) stated that the latency increase and amplitude decrease with advancing age. Johannsen, et al., (1979) reported significantly shorter P2 latencies for older subjects (average age of 63 years) versus younger subjects (average age of 22 years).

Similar results were obtained at 1 K Hz**.** The results for 1 KHz were shown in the Appendix 50.

COMPARISON BETWEEN CHILDREN AND ADULTS USING AUDITORY-VISUAL MODE

The present study aimed at comparing the mean latency response of ALLR for adults and children, using AV mode of presentation. In order to attain the objective of the present study ALLR was obtained for 20 adults & children (8-25 years & 5-15 years), at 80 dBnHL, using a 500 Hz tone burst along with a theatrical animated cartoons which are muted in a laptop kept at a 0^0 azimuth angle in front of the subjects.

Table: 4.18

N	Age	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	Adults	60.0	11.7	93.3	14.5	163.9	12.9	219.8	19.9
20	Children	72.6	11.5	110.1	9.2	170.9	13.2	219.7	13.3
t		3.857		3.911		1.708		*0.037*	
p		0.000		0.000		0.096		0.971	

Table: 4.18 shows the mean, SD, t and p value for adults and children at 80 dBnHL, using 500 Hz tone burst using auditory-visual mode of presentation.

Similar results were obtained at 1 K Hz also.

The mean latency values obtained for adults and children were 60.0, 93.3, 163.9, 219.8 ms, 72.6, 110.1, 170.9 and 219.7 ms respectively. Statistical analysis was carried out using paired't' test, results revealed that there existed a significant differences in P1 and N1 between adults and children. P2 & N2 did not have any statistically significant difference.

Figure :4.16

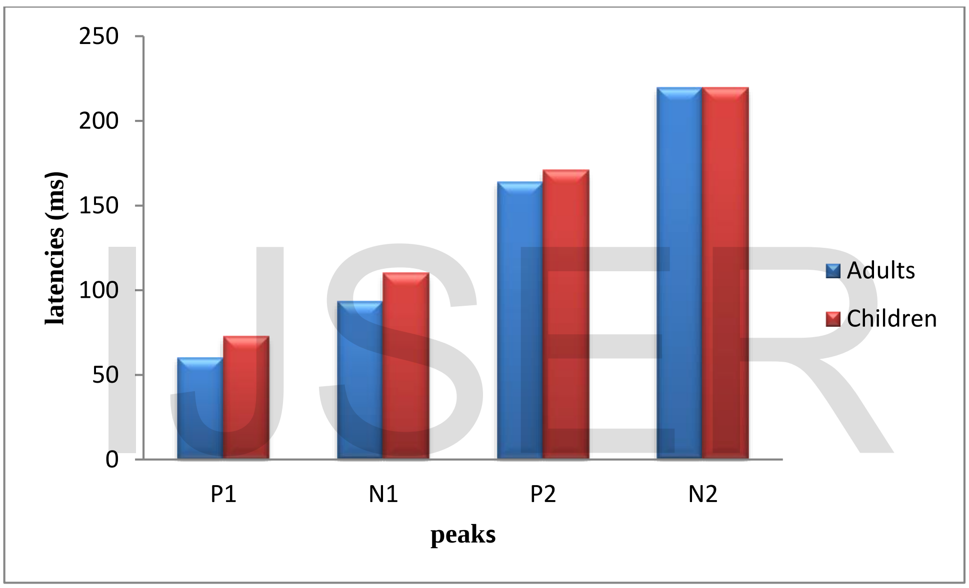

Figure: 4.16 shows mean latency values for adults and children at 80 dBnHL, using 500 Hz tone bursts along with visual mode of presentation.

From the above figure: 4.16, it's observed that there is a prolongation of P1, N1 and P2 peaks of children when compared to adults. This could be due to the effect of neural maturation of brain structures. Neural maturation will also affect the latency of the late components.

Chapter V
Summary & Conclusion

CHAPTER 5: SUMMARY AND CONCLUSION

The aim of the present study:

- To obtain normative for children and adults using GSI Audera.
- To study the effects of variables like age, sex, intensity, frequency and mode of presentation that affect ALLR.

In order to facilitate for the purpose for the presented study, a total of 40 subjects (20 males and 20 females) were selected. These subjects were divided into two groups: Group A and Group B, having individuals in the age range of 5-15 years (children) and 18-25 years (adults) respectively. Subjects in each group underwent otoscopic examination, tympanometry, reflexometry and puretone audiometry

ALLR was recorded using GSI Audera, by presenting a 500 Hz tone burst to both the groups at the intensity of 80 and 70 dBnHL, to right and left ear. The same procedure was carried out at 1000 Hz.

For auditory visual mode, a 500 Hz tone burst was presented along with the theatrical animated cartoon presented through a laptop placed in front of the subject at an angle of 0^0 azimuth angle at an intensity of 80 and 70 dBnHL, to the right and the left ear. Only those response were noted which had repeatable morphology. The same procedure was carried out at 1000 Hz.

The latency values of P1, N1, P2 and N2 were marked, taking into account the maximum amplitude points. The latency values obtained for both the auditory and auditory-visual mode for each of the frequency at the respective intensities were then compared.

Statistical analysis was done using descriptive analysis, independent‘t’ test and paired‘t’ test.

Normative were obtained for children and adults, using a 500 Hz tone burst at 80 dBnHL. Descriptive analysis was carried out to obtain the Mean and SD for both the Groups. The mean latency range obtained for children were 46.7 – 83 ms(P1), 86.3 - 140.3 ms (N1), 149 – 197 ms (P2) and 204.7 - 254.7 ms (N2) and that of adults were 40.3 - 85.3 ms (P1), 60 - 124 ms (N1), 132.7-189 ms (P2) and 174-259.3 ms (N2).

The effect of subject and stimulus variables such as age, gender, ear specificity, intensity, frequency and modes of presentation were studied. The results from the present study revealed that there is a significant difference in the mean latency of response for adults and children in the mean age range of 21.5 years and 10 years respectively, suggesting maturation of the cortical structures even after birth and continues up to 10 yrs of age (Ponton et al., 1996). As age increases, the morphology of the peak improves and the latency reduced.

In order to find the effect of intensity, a 500 and 1 K Hz tone burst were presented at 80 and 70 dBnHL. It’s observed that intensity affects the latency response of ALLR, there is prolongation of the peaks latency when the stimulus intensity was reduced for both the Groups (children and adults) In addition to the latency, the wave morphology became poorer when intensity decreased.

In order to find the effect of different modes of presentation, a 500 and 1 K Hz tone burst were presented at 80 dBnHL for auditory mode and a 500 and 1K Hz tone burst was presented at 80 dBnHL along with a theatrical animated cartoon films set at mute which was presented simultaneously using a laptop computer at an angle of 0^0 to the eye level of the subject for auditory-visual modes of presentation. For children, there existed a prolongation in the latency when modes of presentation changed. Prolongation of latency was increased when auditory - visual mode was used, but it was not statistically significant. The wave morphology of P1 and N1 was poor in children when compared to adults during auditory-visual mode of acquisition.

For adults, statistical significance existed for P1, N1 and P2 latencies when mode of presentation changed. There was a prolongation in the latency when using auditory - visual mode.

From the present study it can be concluded that variables such as gender, ear and frequencies did not have any significant difference for children and adults, where as certain variables like age, intensity and mode of presentation affects the Auditory Late Latency Response, hence normative pertaining to these variables should be used while comparing the results with pathological case.

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FUTURE DIRECTIONS:

- It can be done on a large sample size.
- It can be administered on clinical populations such as CAPD, ADHD and LD etc.
- More detailed study on how the maturation of cortical potentials occurred could be studied by taking children from 2months of age and above, and dividing the pediatric age groups into smaller ranges and studying the maturational changes.
- The affect of advancing age on cortical response could be studied in individuals without hearing loss.
- This study can be implemented in persons with hearing impairment to find out their cortical processing of the sounds in aided and unaided conditions.

Chapter VII
References

CHAPTER 7: REFERENCES

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Appendices

Appendix 1

CONSENT FORM

I, Mr. /Ms…………………………….have been informed about the terms and procedures and the need of the study entitled " QUANTIFICATION OF VARIABLES AFFECTING AUDITORY LONG LATENCY RESPONSES" . I offer my participation without any induced pressure and give consent to evaluate my hearing sensitivity.

I know that the details of this stud will be kept confidential and will not be used for any other purpose.

Signature
Name& Address.

Appendix 2

Raw score for adults aged (8-25 years) at 80 and 70 dBnHL using 500 Hz using auditory mode alone in right ear

Sex	Age (years)	80 dBnHL				70 dBnHL			
		P1	N1	P2	N2	P1	N1	P2	N2
Female	18-25	62.3	101	154.7	245	70.7	93.3	167.3	245
Female	18-25	40.7	86.7	144.3	174	55.3	101.7	154.7	213.3
Female	18-25	42.3	60	156	259.3	48.3	72	164.3	259
Female	18-25	58.7	77.7	142.7	199.3	61.7	85.3	160.7	212.7
Female	18-25	49	97	169.3	195.3	58	109	170.3	229.3
Female	18-25	42.3	73	156.3	189	44	76.3	157	213.3
Female	18-25	41.7	72	142	225.3	49.3	79	147.3	242.7
Female	18-25	54.3	86.7	161.7	230	57	99.7	158.7	231
Female	18-25	41.3	83	136.7	219.7	58	113	157.7	224.7
Female	18-25	64.7	97	151.3	224.3	70.3	101.7	152.3	240.3
Male	18-25	60.3	100.3	158.3	204	65.7	101.7	162.3	211.3
Male	18-25	68	97	160	217.7	66.7	97.3	160.7	229.3
Male	18-25	58	84	165.3	202.7	63.3	95	183.7	234.7
Male	18-25	57	84.7	163	199.3	57.7	86.3	163.3	199.3
Male	18-25	85.3	105	185	226	87.3	110.3	191.3	241.8
Male	18-25	66.3	93.3	182	221.3	64	97	182	237
Male	18-25	50.7	109.7	157	215	56.3	109.7	180.3	230
Male	18-25	59	86.7	142.7	194	66.3	91.7	160	194.7
Male	18-25	70.3	124	169.7	202.7	70.3	124	175.7	208
Male	18-25	53.3	95.7	150	204.7	53.3	98.7	154	211

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Appendix 3

Raw score for adults aged (18-25 years) at 80 and 70 dBnHL using 500 Hz using auditory + visual mode alone in right ear

Sex	Age (years)	80 dBnHL				70 dBnHL			
		P1	N1	P2	N2	P1	N1	P2	N2
Female	18-25	64	93	159.3	212.7	61.7	96.3	168	217.3
Female	18-25	55.3	84.7	159.3	212.7	60	86	160	217.7
Female	18-25	35.7	62.7	148.3	245.7	43	71	179	268
Female	18-25	63.3	78.3	156.3	222.3	62.3	98	154.7	242
Female	18-25	53	107.7	172.1	197.6	60	109.7	172.3	199.7
Female	18-25	53	102.7	157.3	227	80	99.7	157.3	222
Female	18-25	42	82.3	160.7	238.7	46.7	96.3	161.7	230.7
Female	18-25	45.7	78.3	164	238.7	60	92.3	150.7	247.3
Female	18-25	46.7	84.7	156	222.3	58.7	124	159	226.3
Female	18-25	76	103.3	168.7	224.3	71.3	121.7	189	247.3
Male	18-25	66.7	100.3	160	220.7	66.7	104.3	173.3	230.7
Male	18-25	65.7	115.3	160.7	212	66.3	121.7	156.7	233.3
Male	18-25	61.3	94.7	165	216	72.7	105.7	187	255
Male	18-25	58	94	168.7	210.3	61.7	91.7	168.7	218.3
Male	18-25	83	98	186	217.3	86	116	186	231.7
Male	18-25	66.7	102.7	183.7	222	71.3	105.7	182.7	244
Male	18-25	63.3	102	176.7	226.7	57.7	118.3	182	233.3
Male	18-25	59	87	156.3	213.3	62.3	90	159.3	233
Male	18-25	74.3	96.3	160	216	83.7	105	171	216.7
Male	18-25	66.3	98	159	200.3	69	121.3	166.3	221.3

Appendix 4

Raw score for adults aged (18-25 years) at 80 and 70 dBnHL using 500 Hz using auditory mode alone in left ear

Sex	Age (years)	80 dBnHL				70 dBnHL			
		P1	N1	P2	N2	P1	N1	P2	N2
Female	18-25	44.3	98	147.7	221	45.2	98	151	234
Female	18-25	42	82	159.7	227	45	90.7	156.3	227
Female	18-25	65.7	85.3	132.7	221.3	71	103.7	145.3	268
Female	18-25	62.3	84.7	161.7	228.7	62.7	85.3	171	231
Female	18-25	64	98.7	147.3	224.7	57.7	109.7	164	228.3
Female	18-25	79.7	103.3	163	213.7	84.7	105.7	153	219.7
Female	18-25	58.7	97	158.3	210.3	64	75	158.3	238.7
Female	18-25	46	82	153.7	219.7	46.7	98.7	153.7	222
Female	18-25	41.3	94.7	139	186.7	52.3	108	159.3	225.3
Female	18-25	49.3	93.3	158.3	197	67.3	95	158.7	212.7
Male	18-25	61	106	169.7	230.7	65	101	171	233.3
Male	18-25	57.7	101.7	160	191.3	61.7	112	160	196.3
Male	18-25	60.3	79.7	176	216.7	69.7	96.7	176	223.7
Male	18-25	40.3	84	173.3	226.3	51.7	96.3	174	226.3
Male	18-25	62.7	112	161	187.7	63.3	114.3	161.7	193.7
Male	18-25	60	98.3	178	211	66.3	99	178	216.7
Male	18-25	73.7	107.3	161.7	215.3	80	108	162.7	226
Male	18-25	71.3	93.3	151.3	214.3	73.3	94	163	228.7
Male	18-25	56.3	90.7	161.7	208.7	60	114.3	164	227
Male	18-25	43.7	92.3	189	215.3	57.7	113	192	228.7

Appendix 5

Raw score for adults aged (18-25 years) at 80 and 70 dBnHL using 500 Hz using auditory + visual mode in left ear

Sex	Age (years)	80 dBnHL				70 dBnHL			
		P1	N1	P2	N2	P1	N1	P2	N2
Female	18-25	57.7	97	152.7	212.7	63.3	99.3	172.7	212.7
Female	18-25	37.7	86	146	192.3	38	90.3	147.7	210.3
Female	18-25	76.7	109	145.3	237	69	102	143.3	240.7
Female	18-25	37.3	84.7	165.7	227	38	88.3	152	227.7
Female	18-25	73	106	162.3	222	82.3	106.7	164	231.7
Female	18-25	42.3	91.7	152.3	212	40.3	99.3	157	218.3
Female	18-25	46.7	84.3	150.7	219	47.7	81.3	150.7	231.7
Female	18-25	44.3	91	159.3	228.7	47	95	164.7	218.3
Female	18-25	52.3	79	142	207.3	54	92.3	159.3	214
Female	18-25	65.7	97.3	156	215	79.3	103.7	158.3	206.7
Male	18-25	80.7	110.7	184.7	231	72.7	113.7	194.7	247.3
Male	18-25	72.7	103.3	158.7	207.7	74.7	108.3	177.3	207
Male	18-25	69	91	167.3	207.3	59.3	95.7	169.7	223
Male	18-25	58	71.3	150.7	193	58.7	78.3	156	201
Male	18-25	58.7	99.3	158.7	206.7	64	109.7	160	209.7
Male	18-25	53.3	86.3	153	192.3	59.3	86.3	154.7	193
Male	18-25	71.7	88.3	156	209.7	77.3	110.3	162.3	211
Male	18-25	41.3	89.3	142.7	188.3	49.3	96.3	159.3	198.7
Male	18-25	86.7	113.7	144.7	193.7	88.3	114.3	171.7	197
Male	18-25	61.7	109	160.7	201	62.3	110.7	164.7	209

Appendix 6

Raw score for adults aged (18-25 years) at 80 and 70 dBnHL using 1000 Hz using auditory mode alone in right ear

Sex	Age (years)	80 dBnHL				70 dBnHL			
		P1	N1	P2	N2	P1	N1	P2	N2
Female	18-25	77.3	105.7	163	198	90.7	111.7	165.7	219.7
Female	18-25	69	105.7	179	230.7	94.7	138.7	209	243.3
Female	18-25	74.3	127.7	162.3	235.7	84.7	146	197	248.3
Female	18-25	72	95	154.7	197.7	78.3	108	169.3	208.7
Female	18-25	61	102	166.7	209	77.3	112	166.7	209.7
Female	18-25	56.3	106	164.7	210.3	68.7	106	164.7	226.3
Female	18-25	64.7	110.3	176.7	238	76.3	115.7	180.3	256.7
Female	18-25	75	110.7	172.7	240.3	75.3	121.3	197.7	240.7
Female	18-25	105.3	150.3	195.7	234.7	106	154.7	196	234.7
Female	18-25	61	110.3	183.7	222.7	79.7	106	189.3	226
Male	18-25	72	120	175	222	75	135	175.7	222.3
Male	18-25	58.7	130.3	168.7	216.7	80.7	137.3	187	219
Male	18-25	76	119	179.7	238	84.7	119.3	180.3	238
Male	18-25	62.7	99.7	157	183.7	64	112.7	161	193.7
Male	18-25	67.3	107	151.3	211	77.7	115.7	166.7	214.3
Male	18-25	76.3	113.7	163.3	226.3	86.3	113.7	166.3	236
Male	18-25	63.3	86.3	156	196	64	87	164.7	208
Male	18-25	64.7	95	166.3	245	71.3	110.3	176.7	253.3
Male	18-25	52.7	98.3	164	214.3	54	99.3	158.3	236.3
Male	18-25	76.7	111.3	182	239.3	76.3	112	182	241.3

Appendix 7

Raw score for adults aged (18-25 years) at 80 and 70 dBnHL using 1000 Hz using auditory + visual mode in right ear

Sex	Age (years)	80 dBnHL				70 dBnHL			
		P1	N1	P2	N2	P1	N1	P2	N2
Female	18-25	73	107	163.3	240	78.7	112	166	212
Female	18-25	64	99.3	199.3	237	78.3	109	199.7	248.3
Female	18-25	55.7	76.7	196.3	240.7	79	134	225.3	246.7
Female	18-25	63.3	115.3	174	215.3	90.3	125.3	190	224.3
Female	18-25	67.3	97	153	198.7	67.3	113.7	158.7	216
Female	18-25	66.3	97	165	233	68	108	166	245.7
Female	18-25	80	114	158.3	209	90.7	114.7	167.3	222
Female	18-25	68	115.3	184.3	241	82.3	121.7	191.7	241
Female	18-25	92.7	131.3	192.3	221.3	94	135.7	197	230.7
Female	18-25	71.3	101.7	192	225	79.7	123	193.7	226
Male	18-25	95.7	141.3	167.3	208.3	106	130	179.7	219
Male	18-25	71	121.7	199.3	214.3	97	134.3	199.3	215
Male	18-25	87.7	129	183.7	219	91	141	184.3	228.7
Male	18-25	62.7	108.7	179.7	230.7	64.3	110.3	193.7	231
Male	18-25	69.7	115.3	171	208	72	116.7	172.7	217.7
Male	18-25	78.3	128.7	187.7	236.3	83	155.3	212.7	260
Male	18-25	63.3	68.7	149.3	215	64	88.7	160.3	232.3
Male	18-25	72	95.7	167	213.3	76	108.7	178.3	214.3
Male	18-25	64.3	109	160	244	67.3	109	172.7	246
Male	18-25	81.7	110.3	175	228	90.7	112.7	175	239.7

Appendix 8

Raw score for adults aged (18-25 years) at 80 and 70 dBnHL using 1000 Hz using auditory mode alone in left ear

Sex	Age (years)	80 dBnHL				70 dBnHL			
		P1	N1	P2	N2	P1	N1	P2	N2
Female	18-25	57.7	97	152.7	212.7	63.3	99.3	172.7	212.7
Female	18-25	37.7	86	146	192.3	38	90.3	147.7	210.3
Female	18-25	76.7	109	145.3	237	69	102	143.3	240.7
Female	18-25	37.3	84.7	165.7	227	38	88.3	152	227.7
Female	18-25	73	106	162.3	222	82.3	106.7	164	231.7
Female	18-25	42.3	91.7	152.3	212	40.3	99.3	157	218.3
Female	18-25	46.7	84.3	150.7	219	47.7	81.3	150.7	231.7
Female	18-25	44.3	91	159.3	228.7	47	95	164.7	218.3
Female	18-25	52.3	79	142	207.3	54	92.3	159.3	214
Female	18-25	65.7	97.3	156	215	79.3	103.7	158.3	206.7
Male	18-25	80.7	110.7	184.7	231	72.7	113.7	194.7	247.3
Male	18-25	72.7	103.3	158.7	207.7	74.7	108.3	177.3	207
Male	18-25	69	91	167.3	207.3	59.3	95.7	169.7	223
Male	18-25	58	71.3	150.7	193	58.7	78.3	156	201
Male	18-25	58.7	99.3	158.7	206.7	64	109.7	160	209.7
Male	18-25	53.3	86.3	153	192.3	59.3	86.3	154.7	193
Male	18-25	71.7	88.3	156	209.7	77.3	110.3	162.3	211
Male	18-25	41.3	89.3	142.7	188.3	49.3	96.3	159.3	198.7
Male	18-25	86.7	113.7	144.7	193.7	88.3	114.3	171.7	197
Male	18-25	61.7	109	160.7	201	62.3	110.7	164.7	209

Appendix 9

Raw score for adults aged (18-25 years) at 80 and 70 dBnHL using 1000 Hz using auditory + visual mode in left ear

Sex	Age (years)	80 dBnHL				70 dBnHL			
		P1	N1	P2	N2	P1	N1	P2	N2
Female	18-25	61	99	158	177.3	64.3	101	146.7	190
Female	18-25	57	93.3	145.3	211	47	96.7	150.7	231.7
Female	18-25	70.3	123.7	155.3	245	73.7	107.3	160	232.3
Female	18-25	38	85	165.7	227.3	43.7	78.8	152.3	246.7
Female	18-25	76	180.7	172	242.3	65.7	109	170.3	260.7
Female	18-25	45.3	99.3	160.7	230	42.3	103.5	171.7	224.7
Female	18-25	47.7	74.3	153.7	244	46.7	77.7	161	236.3
Female	18-25	45.3	95	160.7	241.7	58	97	160.7	241.7
Female	18-25	59	73.7	156.3	227	44.7	83.7	164	216.7
Female	18-25	58.7	104.7	156	227.7	90	122.3	179	263.7
Male	18-25	83.7	111.3	184.3	250.7	82	113	194.7	256
Male	18-25	73.7	112.7	163.7	221.3	73.7	108.3	172.7	222
Male	18-25	66.7	86	182	228	67.3	95.7	174	223
Male	18-25	58.7	86.3	158.3	211.7	67.3	86.3	162.3	212.7
Male	18-25	67.3	94	185.3	233	76	97.3	196.3	247.7
Male	18-25	78	110.3	158.3	208.7	92.3	118.3	176	212.7
Male	18-25	67.7	102.7	169.7	213.3	72.7	106.7	173.3	226.3
Male	18-25	60	89.3	142	188.3	60	97.3	143.3	189.3
Male	18-25	85.7	113.7	157.7	191.3	94	120.7	176.7	208.7
Male	18-25	62.3	93	168.7	196.3	66.7	93	174.3	199.3

Appendix 10

Raw score for children aged (5-15 years) at 80 and 70 dBnHL using 500 Hz using auditory mode alone in right ear

Sex	Age (years)	80 dBnHL				70 dBnHL			
		P1	N1	P2	N2	P1	N1	P2	N2
Female	5-15	73.7	103.3	153.7	207	76.3	103.7	156	209
Female	5-15	51.7	127	184.7	243.3	77.7	135	204	254.7
Female	5-15	72	90	160	202.7	72.3	96.7	173.3	206.3
Female	5-15	69	119.3	190	249.3	85.3	135	194	255
Female	5-15	73	106.7	180.3	223	73.7	118.3	185.3	226.3
Female	5-15	65	98	153	204	74.7	100.3	153	238
Female	5-15	74.7	105.3	171.7	254.7	78	108.7	176.7	265.3
Female	5-15	75.7	109.7	174.7	234.7	77.7	125.3	187.7	249
Female	5-15	83	140.3	197	245.7	87	165	206.3	263.3
Female	5-15	59.7	102.7	159.3	201.7	74.3	108.7	165	229.7
Male	5-15	75	108.3	177.3	221.3	76	134	184.7	232.7
Male	5-15	65	99.3	157	189	79.7	110.7	163	215.3
Male	5-15	74.3	103.7	171	246	80.7	118.3	184.7	246.7
Male	5-15	65.7	112.7	165.7	188.3	65.7	113	173.3	205
Male	5-15	78	98.7	151.3	204	86	113	166.3	227
Male	5-15	70.3	102	169	220	75.3	114.3	178	239.7
Male	5-15	68	93.3	161.7	202.3	69.7	93.3	165	229.7
Male	5-15	64.7	110.7	181.3	219	66.3	119	182	239.7
Male	5-15	64	104	158.3	222	64.7	108.7	175	233
Male	5-15	80	130.3	169.3	241	83.3	136	192	255

Appendix 11

Raw score for children aged (5-15 years) at 80 and 70 dBnHL using 500 Hz using auditory + visual mode alone in right ear

Sex	Age (years)	80 dBnHL				70 dBnHL			
		P1	N1	P2	N2	P1	N1	P2	N2
Female	5-15	76	91	163.3	228.3	78.7	93	169.7	229.3
Female	5-15	60.3	124.7	179.7	223	60.3	140.3	198	237
Female	5-15	74.3	93	132.7	205.7	77.3	108.7	145	206.3
Female	5-15	72.7	116.3	169.7	220.7	73.7	119.3	169.7	223
Female	5-15	62.7	90.7	172.7	216.3	64	111.3	180.7	217.3
Female	5-15	68.3	103.7	158	207.3	80.3	111.7	158	229.7
Female	5-15	80.3	108.3	158.7	238.7	80.7	134	195.7	268.7
Female	5-15	78	112	174.3	224.3	84	133.3	179.7	236.3
Female	5-15	96.3	150.7	189	254.3	114.3	151.3	206.3	289
Female	5-15	61	107	178.7	209	79.7	113	183.7	230
Male	5-15	71	112	192.3	240.3	76	125.7	195.3	244.3
Male	5-15	78.3	119	170.3	189	84	113	169.7	194
Male	5-15	84.7	110.7	168.7	225.3	87	119	185.3	238.7
Male	5-15	73	113.7	192.3	209.7	90.7	128	207.3	221.3
Male	5-15	76.3	124	159.7	200	88.3	124	171.7	221.7
Male	5-15	73	100.3	159.7	219.3	99.3	126.3	214.3	242
Male	5-15	71	90.7	181.3	228.7	78.7	94.7	190	230.7
Male	5-15	71.3	114	188.7	223.7	72	116.7	196.3	233.3
Male	5-15	65	96	146.3	196.7	68	99.7	162.3	211
Male	5-15	59.3	124	182	233	65	135.7	194	237

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Appendix 12

Raw score for children aged (5-15 years) at 80 and 70 dBnHL using 500 Hz using auditory mode alone in left ear

Sex	Age (years)	80 dBnHL				70 dBnHL			
		P1	N1	P2	N2	P1	N1	P2	N2
Female	5-15	60.3	100.3	149	209.7	63.3	104.3	153.7	217.3
Female	5-15	68.7	97	169.7	235.7	91	119	194.7	252
Female	5-15	66.3	94.7	164.7	213.7	76	104.3	166.3	237.3
Female	5-15	63.3	114.7	186.7	239.3	72.7	123	188.3	245
Female	5-15	66.3	104.3	192.3	242.3	64.7	109.7	184	215
Female	5-15	71.3	106	173.3	204.7	90.7	116.3	187.3	216.7
Female	5-15	66.7	99.7	170.3	222	77.7	108	170.3	241.7
Female	5-15	46.7	104.3	188.3	222.3	73.7	111.3	195.3	233
Female	5-15	82.3	113	184.7	207.3	88.3	124	193.3	245.7
Female	5-15	75	95	157	205.7	83	105.7	174.3	225.3
Male	5-15	75	116.3	151	234	84	119	171	238
Male	5-15	75.3	113.7	164.7	244.3	84.7	125.7	167	252
Male	5-15	74.3	97.3	157	210.3	78.3	125.3	184.7	251
Male	5-15	73	108.3	192.3	223	88.3	120.3	209.7	224.3
Male	5-15	57.7	93.3	172	241.7	60.3	96.3	189	253
Male	5-15	77.3	102.7	178	204.7	86	105	175.7	207.3
Male	5-15	59.3	97.3	152.7	209.7	64.7	99	151	227
Male	5-15	51.3	86.3	153	206.3	69	100	163.3	219
Male	5-15	68.7	113.7	166.3	232.3	77.3	115.3	185.3	239.3
Male	5-15	75	116.3	151	234	84	119	171	238

Appendix 13

Raw score for children aged (5-15 years) at 80 and 70 dBnHL using 500 Hz using auditory + visual mode in left ear

Sex	Age (years)	80 dBnHL				70 dBnHL			
		P1	N1	P2	N2	P1	N1	P2	N2
Female	5-15	73.3	102.7	154.3	218.3	74.3	109.7	157	222.3
Female	5-15	95.7	131	185.3	228.3	108.3	147.7	193.7	237
Female	5-15	69	91.7	148.3	183	78.3	106.7	175	211.3
Female	5-15	69	103.7	163.3	219.7	70.3	109.7	168.7	231.3
Female	5-15	68	99	168.3	228.7	68.3	109	184.3	231.7
Female	5-15	74.3	98	155.3	211.3	75	102.3	176.7	222
Female	5-15	90.7	114.7	179	234	93	117	220	268
Female	5-15	53	101	165.7	224.7	88.3	118.3	167	238.7
Female	5-15	81.7	131	182	233	108.3	142	193	252
Female	5-15	69.7	97.3	163	232.3	78	106	186.7	253.3
Male	5-15	80.7	114.7	178	218.3	106	130	183	224
Male	5-15	74.3	110.3	184.3	212.7	75	113.7	196.3	237.3
Male	5-15	76.7	109.7	161	222.3	83.7	135.7	169.3	228.3
Male	5-15	82.3	132	196	228.7	88.7	139.7	197	229
Male	5-15	68	101	175	211.3	70.3	102.7	198	238
Male	5-15	74.3	103.7	179.7	198.7	77.3	120.7	185.3	222.3
Male	5-15	64.7	114.3	166.7	213.3	67.3	114.3	176.3	219.7
Male	5-15	57.7	97	178.3	238.7	72	106	213.7	243.3
Male	5-15	70.3	108.3	169.3	230.7	73	109.7	175.7	245.7
Male	5-15	79.7	123	176.7	225.3	79.7	129.3	187	246

Appendix 14

Raw score for children aged (5-15 years) at 80 and 70 dBnHL using 1000 Hz using auditory mode alone in right ear

Sex	Age (years)	80 dBnHL				70 dBnHL			
		P1	N1	P2	N2	P1	N1	P2	N2
Female	5-15	77.3	105.7	163	198	90.7	111.7	165.7	219.7
Female	5-15	69	105.7	179	230.7	94.7	138.7	209	243.3
Female	5-15	74.3	127.7	162.3	235.7	84.7	146	197	248.3
Female	5-15	72	95	154.7	197.7	78.3	108	169.3	208.7
Female	5-15	61	102	166.7	209	77.3	112	166.7	209.7
Female	5-15	56.3	106	164.7	210.3	68.7	106	164.7	226.3
Female	5-15	64.7	110.3	176.7	238	76.3	115.7	180.3	256.7
Female	5-15	75	110.7	172.7	240.3	75.3	121.3	197.7	240.7
Female	5-15	105.3	150.3	195.7	234.7	106	154.7	196	234.7
Female	5-15	61	110.3	183.7	222.7	79.7	106	189.3	226
Male	5-15	72	120	175	222	75	135	175.7	222.3
Male	5-15	58.7	130.3	168.7	216.7	80.7	137.3	187	219
Male	5-15	76	119	179.7	238	84.7	119.3	180.3	238
Male	5-15	62.7	99.7	157	183.7	64	112.7	161	193.7
Male	5-15	67.3	107	151.3	211	77.7	115.7	166.7	214.3
Male	5-15	76.3	113.7	163.3	226.3	86.3	113.7	166.3	236
Male	5-15	63.3	86.3	156	196	64	87	164.7	208
Male	5-15	64.7	95	166.3	245	71.3	110.3	176.7	253.3
Male	5-15	52.7	98.3	164	214.3	54	99.3	158.3	236.3
Male	5-15	76.7	111.3	182	239.3	76.3	112	182	241.3

Appendix 15

Raw score for children aged (5-15 years) at 80 and 70 dBnHL using 1000 Hz using auditory + visual mode in left ear

Sex	Age (years)	80 dBnHL				70 dBnHL			
		P1	N1	P2	N2	P1	N1	P2	N2
Female	5-15	73	107	163.3	240	78.7	112	166	212
Female	5-15	64	99.3	199.3	237	78.3	109	199.7	248.3
Female	5-15	55.7	76.7	196.3	240.7	79	134	225.3	246.7
Female	5-15	63.3	115.3	174	215.3	90.3	125.3	190	224.3
Female	5-15	67.3	97	153	198.7	67.3	113.7	158.7	216
Female	5-15	66.3	97	165	233	68	108	166	245.7
Female	5-15	80	114	158.3	209	90.7	114.7	167.3	222
Female	5-15	68	115.3	184.3	241	82.3	121.7	191.7	241
Female	5-15	92.7	131.3	192.3	221.3	94	135.7	197	230.7
Female	5-15	71.3	101.7	192	225	79.7	123	193.7	226
Male	5-15	95.7	141.3	167.3	208.3	106	130	179.7	219
Male	5-15	71	121.7	199.3	214.3	97	134.3	199.3	215
Male	5-15	87.7	129	183.7	219	91	141	184.3	228.7
Male	5-15	62.7	108.7	179.7	230.7	64.3	110.3	193.7	231
Male	5-15	69.7	115.3	171	208	72	116.7	172.7	217.7
Male	5-15	78.3	128.7	187.7	236.3	83	155.3	212.7	260
Male	5-15	63.3	68.7	149.3	215	64	88.7	160.3	232.3
Male	5-15	72	95.7	167	213.3	76	108.7	178.3	214.3
Male	5-15	64.3	109	160	244	67.3	109	172.7	246
Male	5-15	81.7	110.3	175	228	90.7	112.7	175	239.7

Appendix 16

Raw score for children aged (5-15 years) at 80 and 70 dBnHL using 1000 Hz using auditory mode alone in left ear

Sex	Age (years)	80 dBnHL				70 dBnHL			
		P1	N1	P2	N2	P1	N1	P2	N2
Female	5-15	67.3	100	147.3	204	84	118.3	148.3	227
Female	5-15	65.7	132.3	160.7	213.7	71.3	139	176	222.3
Female	5-15	71	92	147	211	78.3	110.3	149.7	220
Female	5-15	71	116.7	164.7	214.3	72.3	123.7	169.7	223.7
Female	5-15	63.3	104.3	164	199.7	64.7	109.7	184	215
Female	5-15	76	97.3	150.7	199.7	95	125.3	175	201
Female	5-15	64.7	97.3	178.7	235.3	68	97.3	187.3	249.7
Female	5-15	76.7	180.3	197.3	260	82.3	136.7	212.7	269.3
Female	5-15	82	105.7	178	212	84.7	122.3	178.7	222.7
Female	5-15	71	109.7	165.7	235.3	78.3	113.7	165.7	253
Male	5-15	71.3	96.3	154.3	237	75.3	108.3	158.7	237
Male	5-15	81.3	105.3	165.7	205	88.7	106	167	211.7
Male	5-15	59.7	114.7	163.3	232.3	81.3	117.7	164	237
Male	5-15	70.3	107.3	162.3	191.3	71.3	120.7	176	220.7
Male	5-15	75	109.7	154.3	203	83.7	121.7	198.7	237.7
Male	5-15	75.3	118.3	187.7	226	77.3	120	200	239.3
Male	5-15	66.3	99	166.7	203	76.7	112.7	169.3	207.3
Male	5-15	76.7	107.7	175	206.3	78.3	110.7	175	212.7
Male	5-15	69.7	109.7	177	225.3	71.3	114.7	178.3	226
Male	5-15	61	102.7	180.3	227	92.3	123.3	192.3	239

Appendix 17

Raw score for children aged (5-15 years) at 80 and 70 dBnHL using 1000 Hz using auditory + visual mode in left ear

Sex	Age (years)	80 dBnHL				70 dBnHL			
		P1	N1	P2	N2	P1	N1	P2	N2
Female	5-15	63	107.7	158	225.3	69	111.3	172	228.3
Female	5-15	57.7	90.7	181.3	228.7	58	105.7	204.7	238
Female	5-15	71.3	93	164.7	219.7	80	104	181.3	222
Female	5-15	81.3	105	146	191.7	93.3	116.7	148.3	192.3
Female	5-15	70.3	101.7	140.3	202.3	86.3	114.3	164.7	218.3
Female	5-15	59.3	83.7	144	206.3	77.7	111.3	176	206.3
Female	5-15	68	97	160.7	241	74.3	112.7	180.7	241
Female	5-15	83	120.7	205.7	259.3	83.7	137.3	207.7	263.7
Female	5-15	90	108.7	172.7	231.3	97	112	172.7	269.3
Female	5-15	67.3	95.7	166.7	215	80	112	175.3	234
Male	5-15	85.3	112.7	169.7	240.2	86.3	119.3	172.7	242.7
Male	5-15	64	126.3	189.3	201	75	139.7	175.7	202
Male	5-15	81.3	112.3	168	238.7	86.3	131.7	184.7	247
Male	5-15	69	117	210.3	243.3	71	119.3	217.7	245
Male	5-15	76.7	121.7	166.7	217.7	90.7	123	202.7	233.3
Male	5-15	75	94	147.7	196	91.7	107.3	160.3	211.3
Male	5-15	64.7	121	168.3	211.7	81.3	109	178.3	232.3
Male	5-15	79	101.7	178	204	83	104	197.7	223
Male	5-15	71.3	110.3	173.3	217.7	76.7	116.7	178.3	250.3
Male	5-15	92.3	112	174	203.3	92	121.7	178	226

Appendix 18

Shows the means and SD for P1, N1, P2 and N2 values at 80 dBnHL for right and left ear , using a 1000Hz tone burst (auditory mode).

N	Side	Mean Latency (ms)	SD	Mean latency (ms)	SD	Mean latency (ms)	SD	Mean latency (ms)	SD
		P1		N1		P2		N2	
20	Right	69.3	11.2	110.2	14.4	169.1	11.3	220.5	17.6
20	Left	70.8	6.3	110.3	18.9	167.0	13.4	217.1	17.1
t		0.544		0.018		0.646		0.982	
p		0.593		0.986		0.526		0.338	

Appendix 19

Shows the means and SD for P1, N1, P2 and N2 values at 70 dBnHL for right and left ear , using a 1000Hz tone burst using auditory mode alone.

N	Side	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	Right	78.3	10.6	118.5	17.7	177.7	15.5	222.8	13.5
20	Left	78.8	9.9	117.6	11.8	176.3	18.4	228.6	18.3
t		0.165		0.125		0.288		0.048	
p		0.871		0.902		0.777		0.962	

Appendix 20

Shows the means and SD for P1, N1, P2 and N2 values at 80 dBnHL for right and left ear , using 500Hz tone burst using AV mode .

N	Side	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	Right	72.6	8.9	110.1	14.8	170.9	15.6	219.7	15.9
20	Left	73.7	10.0	109.3	12.2	171.5	12.0	220.7	13.2
t		0.341		0.314		0.197		0.264	
p		0.737		0.757		0.846		0.795	

Appendix 21

Shows the means and SD for P1, N1, P2 and N2 values at 70 dBnHL for right and left ear , using a 500Hz tone burst using AV mode.

N	Side	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	Right	80.1	12.5	119.9	15.1	183.6	18.0	232.0	20.6
20	Left	81.8	13.1	118.5	14.0	185.2	15.5	235.1	13.7
t		0.470		0.535		0.397		0.718	
p		0.644		0.599		0.696		0.481	

Appendix 22

Shows the means and SD for P1, N1, P2 and N2 values at 80 dBnHL for right and left ear , using a 1000Hz tone burst using AV mode.

N	Side	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	Right	72.4	10.6	109.2	17.7	175.9	15.5	223.9	13.5
20	Left	73.5	9.9	106.6	11.8	169.3	18.4	219.7	18.3
t		0.524		0.601		1.552		0.908	
p		0.606		0.555		0.137		0.375	

Appendix 23

Shows the means and SD for P1, N1, P2 and N2 values at 70 dBnHL for right and left ear , using a 1000Hz tone burst using AV mode.

N	Side	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	Right	81.0	11.8	120.2	15.0	184.2	17.7	230.8	13.8
20	Left	81.7	9.5	116.5	10.2	181.5	17.0	231.3	19.6
t		0.242		1.044		0.516		0.094	
p		0.811		0.310		0.612		0.926	

Appendix 24

Shows the means and SD for P1, N1, P2 and N2 values at 70 dBnHL for males and females, using 500Hz tone burst using auditory mode alone.

N	Sex	Mean (ms) SD	Latency	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
10	Male	74.7	7.8	116.0	12.3	176.4	9.7	232.4	14.5
10	Female	77.7	4.9	119.7	21.0	180.1	18.7	239.7	21.3
t		1.023		0.474		0.561		0.892	
p		0.384		0.641		0.582		0.384	

Appendix 25

Shows the means and SD for P1, N1, P2 and N2 values at 80 dBnHL for males and females, using a 1000 Hz tone burst using auditory mode alone.

N	Sex	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
10	Male	67.0	8.1	108.1	13.4	166.3	10.2	219.2	19.4
10	Female	71.6	13.7	112.4	15.7	171.9	12.1	221.7	16.6
t		0.900		0.660		1.114		0.307	
p		0.380		0.517		0.280		0.762	

Appendix 26

Shows the means and SD for P1, N1, P2 and N2 values at 70 dBnHL for males and females, using a 1000 Hz tone burst using auditory mode alone.

N	Sex	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
10	Male	73.4	10.2	114.2	14.8	171.9	9.7	226.2	17.9
10	Female	83.2	11.1	122.0	17.9	183.6	16.3	231.4	16.1
t		2.054		1.059		1.950		0.680	
p		0.055		0.304		0.067		0.505	

Appendix 27

Shows the means and SD for P1, N1, P2 and N2 values at 70 dBnHL for 500 Hz and 1000 Hz tone bursts, using auditory mode alone.

N	Frequencies	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	500 Hz	76.2	6.5	117.9	16.8	178.3	14.6	236.0	18.2
20	1000 Hz	78.3	11.5	118.1	16.5	177.7	14.4	228.8	16.8
t		1.042		0.075		0.169		1.835	
p		0.311		0.941		0.868		0.082	

Appendix 28

Shows the means and SD for P1, N1, P2 and N2 values at 80 dBnHL for 500 Hz and 1000 Hz tone bursts using AV mode.

N	Frequencies	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	500 Hz	72.6	8.9	110.1	14.8	170.9	15.6	219.7	15.9
20	1000 Hz	72.4	10.6	109.2	17.7	175.9	15.5	223.9	13.5
t		0.102		0.260		1.015		0.835	
p		0.920		0.798		0.323		0.414	

Appendix 29

Shows the means and SD for P1, N1, P2 and N2 values at 70 dBnHL for 500 Hz and 1000 Hz tone bursts using AV mode.

N	Frequencies	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	500 Hz	80.1	12.5	119.9	15.1	183.6	18.0	232.0	20.6
20	1000 Hz	81.0	11.8	120.2	15.0	184.2	17.7	230.8	13.8
t		0.257		0.065		0.103		0.224	
p		0.800		0.948		0.919		0.825	

Appendix 30

Shows the means and SD for P1, N1, P2 and N2 values at 80 and 70 dBnHL for 1000 Hz tone bursts using auditory mode.

N	Stimulus intensity	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	80 dB	69.3	11.2	110.2	14.4	169.1	11.3	220.5	17.6
20	70 dB	78.3	11.5	118.1	16.5	177.7	14.4	228.8	16.8
t		5.255		4.099		3.471		5.032	
P		0.000		0.001		0.003		0.000	

Appendix 31

Shows the means and SD for P1, N1, P2 and N2 values at 80 and 70 dBnHL for 500 Hz tone bursts using AV mode.

N	Stimulus intensity	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	80 dB	72.6	8.9	110.1	14.8	170.9	15.6	219.7	15.9
20	70 dB	80.1	12.5	119.9	15.1	183.6	18.0	232.0	20.6
t		4.440		4.874		4.359		5.397	
p		0.000		0.000		0.000		0.000	

Appendix 32

Shows the means and SD for P1, N1, P2 and N2 values at 80 and 70 dBnHL for 1000 Hz tone bursts using AV mode.

N	Stimulus intensity	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	80 dB	72.4	10.6	109.2	17.7	175.9	15.5	223.9	13.5
20	70 dB	81.0	11.8	120.2	15.0	184.2	17.7	230.8	13.8
t		4.535		3.540		4.489		2.950	
p		0.000		0.002		0.000		0.008	

Appendix 33

Shows the means and SD for P1, N1, P2 and N2 values at 80 dBnHL for 1000 Hz tone bursts using auditory mode alone and using both auditory and visual mode.

N	Mode of presentation	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	Auditory mode alone	69.3	11.2	110.2	14.4	169.1	11.3	220.5	17.6
20	Auditory + visual mode	72.4	10.6	109.2	17.7	175.9	15.5	223.9	13.5
t		1.333		0.293		1.991		0.712	
p		0.198		0.773		0.061		0.485	

Appendix 34

Shows the means and SD for P1, N1, P2 and N2 values at 80 dBnHL for right and left ear , using a 1000 Hz tone burst using auditory mode.

N	Side	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	Right	54.9	9.8	92.8	8.7	155.8	12.1	211.0	11.3
20	Left	59.4	14.9	94.4	11.5	155.5	10.1	210.2	14.2
t		1.722		0.853		0.127		0.274	
p		0.101		0.404		0.901		0.787	

Appendix 35

Shows the means and SD for P1, N1, P2 and N2 values at 80 dBnHL for right and left ear , using a 1000 Hz tone burst using auditory mode.

N	Side	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	Right	54.9	9.8	92.8	8.7	155.8	12.1	211.0	11.3
20	Left	59.4	14.9	94.4	11.5	155.5	10.1	210.2	14.2
t		1.722		0.853		0.127		0.274	
p		0.101		0.404		0.901		0.787	

Appendix 36

Shows the means and SD for P1, N1, P2 and N2 values at 70 dBnHL for right and left ear , using a 1000 Hz tone burst using auditory mode.

N	Side	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	Right	59.6	11.3	99.5	9.6	162.7	10.5	222.8	14.5
20	Left	61.2	15.0	99.1	10.7	162.0	11.5	215.4	14.5
t		2.530		3.221		1.992		1.269	
p		0.020		0.004		0.061		0.220	

Appendix 37

Shows the means and SD for P1, N1, P2 and N2 values at 80 dBnHL for right and left ear , using a 500 Hz tone burst using AV mode.

N	Side	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	Right	60.0	11.7	93.3	12.2	163.9	9.6	219.8	12.0
20	Left	66.0	10.3	97.4	11.1	160.4	8.2	217.9	17.3
t		1.837		1.543		1.434		0.410	
p		0.082		0.139		0.168		0.686	

Appendix 38

Shows the means and SD for P1, N1, P2 and N2 values at 70 dBnHL for right and left ear , using a 500 Hz tone burst using AV mode.

N	Side	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	Right	65.1	10.8	103.7	14.1	169.2	11.8	231.8	15.7
20	Left	67.3	10.7	103.2	13.6	170.8	12.2	229.7	17.7
t		0.823		0.147		0.685		0.362	
p		0.421		0.884		0.502		0.721	

Appendix 39

Shows the means and SD for P1, N1, P2 and N2 values at 80 dBnHL for right and left ear , using a 1000 Hz tone burst using AV mode.

N	Side	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	Right	59.7	10.9	97.1	10.2	162.0	15.3	222.5	18.0
20	Left	63.1	12.9	101.4	22.8	162.7	11.6	220.8	20.7
t		1.345		0.977		0.229		0.332	
p		0.194		0.341		0.821		0.744	

Appendix 40

Shows the means and SD for P1, N1, P2 and N2 values at 70 dBnHL for right and left ear , using a 1000 Hz tone burst using AV mode.

N	Side	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	Right	66.4	14.9	104.7	12.0	169.8	15.4	228.8	20.7
20	Left	66.4	16.1	100.7	12.9	168.0	14.0	227.1	21.7
t		0.012		1.303		0.648		0.300	
p		0.990		0.208		0.525		0.768	

Appendix 41

Shows the means and SD for P1, N1, P2 and N2 values at 70 dBnHL for males and females, using a 500 Hz tone burst using auditory mode.

N	Gender	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
10	Male	65.1	9.4	101.2	10.9	171.3	12.7	219.7	16.8
10	Female	57.3	8.8	93.1	14.2	159.0	6.9	231.1	15.7
t		1.921		1.424		2.687		1.573	
p		0.071		0.172		0.015		0.133	

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Appendix 42

Shows the means and SD for P1, N1, P2 and N2 values at 80 dBnHL for males and females, using a 1000 Hz tone burst using auditory mode.

N	Sex	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
10	Male	65.4	13.5	96.2	13.3	157.7	12.0	203.1	12.5
10	Female	53.4	14.4	92.6	9.7	153.2	7.7	217.3	12.5
t		1.929		0.694		0.995		2.542	
p		0.070		0.497		0.333		0.020	

Appendix 43

Shows the means and SD for P1, N1, P2 and N2 values at 70 dBnHL for males and females, using a 1000 Hz tone burst using auditory mode.

N	Sex	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
10	Male	64.3	8.2	101.8	9.4	166.9	11.6	215.6	12.0
10	Female	54.8	12.4	97.3	9.8	158.5	7.8	230.1	13.5
t		2.025		1.049		1.909		2.543	
p		0.058		0.308		0.072		0.020	

Appendix 44

Shows the means and SD for P1, N1, P2 and N2 values at 70 dBnHL for 500 Hz and 1000 Hz, using auditory mode.

N	Frequencies	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	500 Hz	61.2	9.7	97.1	13.0	165.2	11.8	225.4	16.9
20	1000 Hz	59.6	11.3	99.5	9.6	162.7	10.5	222.8	14.5
t		0.652		0.964		0.896		0.662	
P		0.522		0.347		0.381		0.516	

Appendix 45

Shows the means and SD for P1, N1, P2 and N2 values at 80 dBnHL for 500 Hz and 1000 Hz, using AV mode.

N	Frequencies	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	500 Hz	60.0	11.7	93.3	12.2	163.9	9.6	219.8	12.0
20	1000 Hz	59.7	10.9	97.1	10.2	162.0	15.3	222.5	18.0
t		0.112		1.465		0.862		0.634	
p		0.912		0.159		0.400		0.534	

Appendix 46

Shows the means and SD for P1, N1, P2 and N2 values at 70 dBnHL for 500 Hz and 1000 Hz, using AV mode.

N	Frequencies	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	500 Hz	65.1	10.8	103.7	14.1	169.2	11.8	231.8	15.7
20	1000 Hz	66.4	14.9	104.7	12.0	169.8	15.4	228.8	20.7
t		0.411		0.336		0.187		0.577	
p		0.686		0.741		0.854		0.570	

Appendix 47

Shows the means and SD for P1, N1, P2 and N2 values at 1000 Hz for 80 and 70 dBnHL, using auditory mode alone.

N	Stimulus intensity	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	80 dB	54.9	9.8	92.8	8.7	155.8	12.1	211.0	11.3
20	70 dB	59.6	11.3	99.5	9.6	162.7	10.5	222.8	14.5
t		2.658		3.247		4.436		5.970	
p		0.016		0.004		0.000		0.000	

Appendix 48

Shows the means and SD for P1, N1, P2 and N2 values at 500 Hz for 80 and 70 dBnHL, using AV mode.

N	Stimulus intensity	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	80 dB	60.0	11.7	93.3	12.2	163.9	9.6	219.8	12.0
20	70 dB	65.1	10.8	103.7	14.1	169.2	11.8	231.8	15.7
t		3.081		4.561		2.358		4.667	
p		0.006		0.000		0.000		0.000	

Appendix 49

Shows the means and SD for P1, N1, P2 and N2 values at 1000 Hz for 80 and 70 dBnHL, using AV mode.

N	Stimulus intensity	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD	Mean Latency (ms)	SD
		P1		N1		P2		N2	
20	80 dB	59.7	10.9	97.1	10.2	165.0	15.3	222.5	18.0
20	70 dB	66.4	14.9	104.7	12.0	169.8	15.4	228.8	20.7
t		2.814		4.848		4.547		1.883	
p		0.011		0.000		0.000		0.075	

Appendix 50

Comparison of latencies between adults and children at an intensity of 80 dB in 1000 Hz using auditory mode alone

N	Age	Latency (ms)			
		P1	N1	P2	N2
20	Adults	54.9	92.8	155.8	211
20	Children	69.3	110.2	169.1	220.5
t		4.316	4.637	3.598	2.027
p		0.000	0.000	0.001	0.050