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WAVE III AND V LATENCY DIFFERENCES IN
IPSI LATERAL AND CONTRALATERAL RECORDINGS AS A
FUNCTION OF STIMULUS POLARITY IN NORMAL ADULT FEMALES

By

Nancy Murray, B.A.

University of Montana, 1982


Presented in partial fulfillment of the requirements for the degree of

Master of Communication Sciences & Disorders

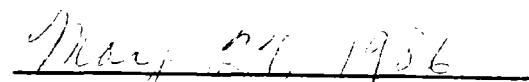
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DEDICATION

To my parents for their never-ending support, encouragement and belief in me throughout the years.

To Lora and Mark for their laughter and understanding during the past few years.

To Rod Peláon, Ph.D. for his guidance and humor throughout my externship and this paper

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CHAPTER I

INTRODUCTION

While behavioral audiological techniques such as visual reinforced audiometry and play audiometry have improved the assessment of auditory function of very young infants or difficult to test patients, these techniques are not successful with all patients. As a result investigators have attempted to develop physiological tests of auditory function, which has focused on parameters such as heart rate, respiration, psychogalvanic skin responses (PGSR), acoustic reflex, and immittance measures (Worthington and Peters, 1984). One relatively recent physiological technique, the auditory brainstem response (ABR), has proven to be an effective clinical tool for testing these difficult to test patients (Jacobson and Hyde, 1985).

Jewett and Williston (1971) described the auditory brainstem response (ABR) as a series of seven waves occurring within 10 milliseconds (ms) following the onset of a click stimulus, and identified many nonpathological factors that influence the response. Over the past fourteen years, numerous investigators have studied the ABR and elaborated on variables which have been found to influence the response. These factors include methodological parameters (recording mode, and electrode placement), stimulus parameters (the intensity, polarity, rate, duration, and type of stimulus), and subject variables (age, sex, body temperature, auditory status, and effects of certain chemicals). According to Stockard, Stockard, Westmoerland and Corfits (1979), most of these studies have assumed that "central" auditory conduction time is independent of these influential factors. One reason for not challenging this assumption much earlier was, in part, due to the "relatively close" interlaboratory agreement of mean interpeak latencies (IPLs) obtained

from normal control groups. Many critical variables (i.e. stimulus intensity and rate) impacting the ABR data have been well documented (Fria, 1980; Hall, 1984; Stockard, Stockard and Sharbrough, 1978). However, other variables as well as the interaction between certain variables has been incompletely studied (i.e. stimulus polarity and recording mode).

Although many differences exist in the reviewed studies, several general trends are apparent. Specifically, rarefaction clicks resulted in earlier latencies for waves I through IV and clearer separation of waves IV and V; however, there were no statistically significant alterations in IPLs. Using the contralateral recording mode, compared to the ipsilateral recording mode, resulted in a strongly reduced or missing wave I, shorter latency for wave III, and a longer latency for wave V; thus causing an increased III-V IPL time. Since both stimulus polarity and recording mode have been found to affect the ABR separately, it is important to evaluate and know their interaction prior to clinically using comparisons between ipsilateral and contralateral data.

The primary purpose of the present study was to investigate the interaction between ipsilateral and contralateral recording mode and stimulus polarity within a group of normal hearing female subjects. Specifically, the study was designed to clarify this interaction on absolute latencies of waves I, III, and V. Further attention was directed toward revealing any effects on the interpeak latency between waves III-V.

CHAPTER II

REVIEW OF THE LITERATURE

AUDITORY BRAINSTEM RESPONSE:

Spontaneous and random bioelectric activity is generated by the central nervous system (CNS) even in the absence of sensory stimulation. Such activity has long been recorded from the surface of the scalp through the placement of electrodes. The subsequently recorded electroencephalogram (EEG) is a standard CNS evaluation for a variety of clinical questions. It is also possible to extract bioelectrical events which are related to sensory stimulation from the ongoing EEG activity.

Auditory evoked potentials (AEPs) have been recorded from many sites in and around the ear or scalp. AEPs arise from many levels of the auditory system. According to Hyde and Jacobson (1985), AEP recordings were first completed by Davis in 1939. Since that time research has focused on the problem of separating the AEPs from ongoing background EEG activity. Currently, the most successful method to extract AEPs from the random EEG pattern involves the principle of algebraic summation (Jacobson and Hyde, 1985). This summation allows for the enhancement of the AEP (the signal) relative to the ongoing EEG (noise). Once researchers could make this separation of the AEPs from the EEG was completed, it became clear that AEPs had wave components which could be accurately described and measured.

Several different sets of waves have been and continue to be investigated. Early researchers concentrated their attention on the so called "slow" or "late" evoked potentials (latency of 50-300 milliseconds). Research has also been directed toward the middle latency responses (15-50 milliseconds). The most recent research and the area receiving the most clinical

attention has focused upon the auditory brainstem response (Worthington and Peters, 1984; Hall, 1984). These "early" AEPs occur within the first 10 milliseconds following stimulus onset. They are believed to originate from the cochlear nerve and ascending auditory pathways through the brainstem.

According to Jacobson and Hyde (1985), the auditory brainstem response (ABR) was first recorded by Sohmer and Feinmesser in 1967, while Jewett and Williston in 1971 were credited as the first investigators to definitively describe the ABR. They described the occurrence of seven waves believed to be an auditory response recorded to click stimuli via far-field techniques. The waves were labeled with Roman numerals, I through VII (Jewett and Williston, 1971).

NEUROANATOMY:

After Jewett and Williston (1971) introduced the labeling of ABR components, investigators often made simple associations between the wave components and successive neural origins within the auditory system. Buchwald and Huang (1975) purposed the following scheme of ABR wave component origins: wave I - the auditory aspect of the VIIIth cranial nerve; wave II - cochlear nuclei; wave III - superior olivary complex, wave IV - lateral lemniscus; and wave V - inferior colliculus. Wave VI and VII are believed to arise from the medial geniculate body and the thalamo-cortical areas, respectively.

Recent evidence indicates that specific generator sites, especially for wave components III, IV, V, VI and VII, are not so clearly defined (Moller and Janetta, 1985). Hall (1984) discussed four factors that contribute to the confusion of wave origin and laterality. First, volume-conducted evoked potentials are not suited for establishing the locus of neural generators. Second, the brainstem wave components III through V probably arise from multiple concurrently active neural sources and not from successive activation of pathways and nuclei, a point well taken

when one considers the increasing complexity of the ascending auditory system. Third, most anatomical studies are completed on animals other than humans. Such data cannot be easily generalized to humans. Finally, within single animal species, there are discrepancies in the determination of ABR generator sites from the pattern of ABR abnormalities in studies analyzing results from defined lesions in the auditory pathways. Research is still needed to adequately clarify the sources of the ABR waves.

NORMAL RESPONSE PARAMETERS FROM HUMANS:

Basic data obtained from the ABR consist of measures of the morphology of the waveform as well as latency and amplitude values from and between various wave components, particularly in relation to waves I, III and V (Glatcke, 1983; Rowe, 1978). These three waves have been found to be the most reliable for both experimental and clinical purposes. Of these, wave V is the most robust and remains rather easily identifiable at stimulus levels at or near threshold. The earlier waves become more difficult to identify at lower stimulus intensity levels and are more susceptible to internal background noise, particularly in the case of wave I.

The latency of an ABR component refers to the time interval between the onset of the acoustic stimulus and positive-voltage peak of the component. Latency measures have typically been accomplished either by determining the interval from stimulus onset to the wave component shoulder immediately before the negative going change. There is no standard or preferred method of calculating wave latency (Hall, 1984). Wave latency is highly reliable, however, with little intrasubject and intersubject variability (Davis, 1976; Thornton, 1975; Hall, 1984). Therefore, even though nonpathologic variables may influence the ABR, the normal ranges for the latencies of the major components can be easily established. These ranges vary with the particular measurement methods employed, but exhibit relative "small" variability in measures

within a given laboratory (approximately ± 0.20 ms) (Hall, 1984).

Response Morphology

The response morphology of the auditory brainstem response is a subjective parameter referring to the visual appearance of the waveform. By conventions positive waves are typically displayed as upward deflections, while negative waves are displayed as downward deflections. As noted, the most prominent and consistently observable wave of the human ABR in response to click stimuli is wave V (Fria, 1980; Picton and Fitzgerald, 1979). The morphology of waves II and III varies between horizontal and vertical electrode montages; waves III, IV and V are to some degree variable between individuals, with wave III sometimes being double-peaked, and waves IV and V "fused" together (Stockard, Stockard and Sharbrough, 1978), forming the IV-V complex (Fria, 1980; Chiappa and Norwood, 1977).

Although the morphology of the response varies between subjects and with manipulation of the stimulus, typically, the normal human ABR to high intensity click stimuli (60-80 dBnHL) reveals clearly defined waves I through V; however, waves II and IV tend to be more poorly defined relative to waves I, III and V.

Response Latency:

The response latency of the auditory brainstem response is the temporal relationship between any component of the response (Fria, 1980). Absolute latency strictly conforms to this definition, while interpeak latency (IPL) is defined as the temporal difference between two component of the waveforms. Both of these measures are specified in milliseconds (ms). The entire ABR occurs within 10 ms following onset of acoustic stimulation of high intensity stimuli. A large number of studies have investigated the latencies of this response. Fria (1980) and

Glatke (1983) have compared these studies and arrived at a similar conclusion: in spite of differences in stimulus rates and recording techniques, the latency values are quite similar across these studies and indicate the relationship that as stimulus intensity increases the response latency decreases.

Interpeak latency values have been reported in various combinations. Clinically, the tendency is to focus on the I-III, III-V and I-V IPLs (Fria, 1980; Glatke, 1983; Hall, 1984). IPL times are believed to represent the time required to travel between various way stations through the peripheral brainstem pathway. The I-V IPL is generally referred to as the brainstem transmission time. Typically the I-III and III-V intervals are approximately 2 ms while the I-V IPL value is around 4 ms.

Response Amplitude

The response amplitude of the auditory brainstem response is defined as the height of a given wave component (Fria, 1980). Absolute amplitude measurements are computed from the peak of the wave to the following trough (assuming that vertex positive waves are displayed in an upward deflection) or from the peak of a wave to the baseline. Relative amplitude refers to the absolute amplitude of an ABR component wave expressed in relation to the absolute amplitude of another wave component within that ABR. Both absolute and relative amplitudes are measured in microvolts. Absolute amplitudes tend to be highly variable within and between subjects; therefore, are not generally recommended for use in clinical interpretations (Stockard, et al., 1979; Stockard et al., 1978; Starr and Achor, 1975). Relative amplitude measures have been found to be more consistent both within and between subjects, and appear to be better indices for comparing amplitude phenomena (Stockard et al., 1978, Starr and Achor, 1975).

NONPATHOLOGICAL FACTORS AFFECTING THE ABR:

1. Subject Characteristics

Subject characteristics such as age, sex, body temperature and the use of certain drugs have been observed to affect the auditory brainstem response. Generally, the mental state of a patient has no effect on the response, but will influence the success in recording the response. Normal latency and amplitude values can be reliably recorded throughout natural sleep, and sleep disorders (i.e. central sleep apnea), while other conditions of mental state may result in abnormal ABRs (Hall, 1984; Stockard, 1980). These apparent effects vary and require further study.

Body temperature and ABR latency are reportedly inversely related in as much as systematic increases in absolute latency and IPL are noted as the body temperature decreases (Stockard et al., 1978). It is suggested that these changes in the body temperature affect the pre- and post-synaptic activity and possibly the receptor activity involved in the ABR.

The effects of gender have also been well documented as affecting the human ABR (Stockard et al., 1978; Hall, 1984). Males typically exhibit longer latencies and smaller amplitudes than females. These phenomena appear to be greatest for wave V and, as a consequence result, in increased IPLs for males relative to females. Although, the reasons for the differences remain unclear, some investigators have suggested that head size differences, hormonal status, and body temperature may account for many of these differences across gender (Hall, 1984).

The age of the subject is yet another factor which influences the ABR. The effects are most prevalent from birth to 18-24 months of age and after fifty years of age (Hecox and Galambos, 1974; Salamy, 1984; Schulman-Galambos and Galambos, 1975; Stockard et al., 1978; Otto and McCandless, 1982). Typically, healthy full-term infants demonstrate a progressive shortening of waves I, III and V latencies with age. This decrease in latency has been attributed to myelination of the auditory pathway which accompanies development (Salamy, 1984).

Between approximately 18 months and fifty years of age, the ABR latency characteristics appear to be relatively stable. Then beginning somewhere during the fifth decade of life, there is a gradual increase in latency and concurrent decreases in amplitude of the ABR. Furthermore, these changes appear to be independent of any sensorineural hearing loss associated with age (Hall, 1984). The exact nature of these "older" age related ABR changes is unclear at this time.

Finally anesthetic agents and CNS depressants appear to have little, if any, influence on the ABR (Fria, 1980). Conversely, the consumption of alcohol in chronic users seems to alter latency; albeit, there is no current conclusive associations between alcohol consumption and ABR measurements. In addition, toluene sniffers also demonstrate "severe" ABR abnormalities (Hall, 1984).

2. Stimulus Parameters

Various stimulus parameters such as frequency composition, repetition rate, intensity, presentation mode, envelope (duration and rise-fall time), polarity, and recording sites may influence the ABR. The most effective and widely used stimulus is an acoustic transient or click stimulus (Jacobson and Hyde, 1985; Eggermont, 1982), which is generated by a square wave pulse or the haversine transformation of a high frequency sinusoid delivered to an earphone transducer. The click essentially has an instantaneous onset and brief (1 ms) duration. Because of these qualities, it is well-suited for generating the synchronous neuronal firing or onset response, which underlies the generation of the ABR (Hall, 1984). As stimulus onset time is increased, the ABR latency values increase and amplitude values decrease, which result in a deterioration of the waveform morphology. Stimulus fall time has little if any influence on the response since the ABR is primarily an onset response.

A click transduced by standard earphones yields a wide range of spectral energy. The 1 - 4

kHz region is the most important region for generating a response in the wide range of frequencies (Hall, 1984). As lower frequency stimuli require more travel time along the basilar membrane, they are typically less effective in stimulating a large numbers of auditory neurons synchronously. Consequently, they contribute little, if at all, to the generation of the ABR.

Tone pips have also been used in ABR testing. Tone pips are filtered clicks produced by delivering a rectangular electric pulse (or single sine wave) to a narrow-band pass filter adjusted to pass the desired frequency range (Fria, 1980). Although they offer more frequency specific information than do the clicks, they yield less distinct waveforms, especially the lower frequency tone pips, making the interpretation of the ABR difficult.

When Jewett and Williston (1971) described the ABR, they also noted changes in the response as a function of stimulus repetition rate. In general, an increase in repetition rate resulted in reduced wave definition and caused an increase in the absolute latencies of all ABR components (Jewett and Williston, 1971; Stockard et al., 1978; Chiappa, Gladstone and Young, 1979). Although wave V persists with a prolonged latency for rates above 30 clicks/sec., there are some questions as to whether the other ABR components persist when rates greater than 30 clicks/sec. are utilized. It has been suggested that the effect of stimulus rate may be due to a central nervous system (CNS) synaptic adaptation mechanism (Hall, 1984). The basis for this effect is unclear, however. Clearly, examiners need to individually determine the stimulus presentation rate which would be most effective and efficient for each particular case. When one is contemplating routine measurements, a stimulus presentation rate of 21.1 clicks/sec. should produce, in normal subjects, well defined responses in a minimum of test time (Glatcke, 1983)

ABR measurements are also affected by the mode of presentation (binaural verses monaural). There is general agreement that the amplitude of response to binaural stimulation exceeds that of the algebraic sum of two monaural responses (Ainslie and Boston, 1980). Some

researchers contend that by subtracting the sum of the two monaural conditions from the binaural response yields a "difference wave" that consists of a main component (vertex-negative) and at a latency of approximately 6 ms (Ansile and Boston, 1980). The nature of the difference wave is unknown. It has been suggested that such factors as binaural interaction at the level of the superior olivary complex or higher centers may be the basis (Hall, 1984; Ansile and Boston, 1980).

In addition, different earphones will vary resonance characteristics of the spectrum of the stimulus resulting in acoustic signals with significantly different spectral compositions. By paying closer attention to the transducers used in various clinical and experimental applications the audiologist may obtain additional information with regard to differences in the measurement values reported in the literature.

The polarity or phase of stimulus onset is another stimulus parameter that may influence the ABR. This variable will be discussed in considerably more detail in a later section.

3. Recording Parameters

In addition to stimulus parameters, variations in recording techniques such as electrode location, filtering, response reference points and recording mode (ipsilateral versus contralateral) can also influence the auditory brainstem response. Typically, three electrodes are used in the following montage: 1) an active electrode placed on the vertex or the forehead mid-line at the hairline; 2) a reference electrode placed on the mastoid or earlobe of the test ear; 3) a ground or common electrode placed on the mastoid or earlobe of the nontest ear (Hall, 1984; Glatkke, 1983; Fria, 1980). Optimal recording sites vary with the ABR wave components under study. Stockard et al. (1978) reported an increase in the amplitude of wave I when the responses were referenced to the ear lobe rather than the mastoid. They also reported decreased amplitudes

for waves I and III, a more prominent wave II, a clearer separation between waves IV and V, and an increased latency for wave V, when using contralateral reference recordings. The implications of these findings will be discussed in a subsequent section.

Various high-pass and low-pass filters are used in ABR testing to eliminate low and high frequency noise prior to computer averaging. A standard amplifier bandpass of 150–3000 Hz is usually recommended for completing clinical measurements (Hall, 1984; Glatke, 1983; Jacobson and Hyde, 1985). Wider bandpass settings allow unwanted neuromuscular activity to be included in the ABR recordings. In addition, generally lowering the high frequency limit yields rounded averaged response peaks and shorter ABR latencies (Glatke, 1983), while lowering the low frequency limit to 10–40 Hz allows for an enhancement of wave V.

In summary, there are several non-pathological factors involving subjects, equipment, stimulus characteristics and recording methodology which can influence the measurement of the auditory brainstem response. These differences reveal the importance for each facility to generate a protocol suited to its needs and to obtain its own normative data prior to making clinical judgements about "abnormal" ABRs. Two parameters, stimulus polarity and recording mode, are of central concern to this investigator in obtaining normative data. The literature in both areas is controversial and warrants further investigation.

STIMULUS POLARITY:

Stimulus polarity can be discussed in terms of the electrical drive to the headphone as well as the acoustical pressure profile at the tympanic membrane (phase onset). For all practical purposes, if the initial stimulus segment yields positive pressure, causing inward movement of the tympanic membrane, it is referred to as a condensation stimulus or positive polarity. If, on the other hand, the initial stimulus segment yields negative pressure, thus causing outward

movement of the tympanic membrane, it is referred to as a rarefaction stimulus or negative polarity. When conducting ABR testing, successive stimuli may be presented with constant (either positive or negative) or alternating initial polarity.

According to Jacobson and Hyde (1985), Stockard et al., (1978), and Coats and Martin (1977), a stimulus series that is alternating in polarity between successive stimuli tends to reduce stimulus artifact arising from electric field coupling between the transducer and recording electrodes. However, condensation and rarefaction stimuli may cause slightly different patterns of excitation on the organ of Corti. This alternating polarity may result in observable effects on the transient ABRs (Jacobson and Hyde, 1985; Stockard et al., 1978). Another issue relative to using alternating click stimuli is that only one direction of movement of the basilar membrane is believed to excite the primary auditory neurons (Jacobson and Hyde, 1985). This movement will occur at different times for condensation and rarefaction stimuli, causing the components of the ABR to have slightly different latencies. Subsequently there may be problems encountered which are not well understood when the responses to alternating polarity are averaged together. Finally, polarity alternation may reduce the ABR components that exhibit waveform polarity which is determined by the stimulus cochlear microphonic and frequency following response. Although the alternation of stimulus polarity allows for reduction of stimulus artifact, it may exhibit undesirable side effects such as less defined wave components in the recorded ABR.

Several investigators (Borg and Lofqvist, 1982; Rosenhamer et al., 1978; Emerson, Brooks, Parker and Chippa, 1982; Hughes, Fino and Gagnoon, 1981; and Stockard et al., 1979) have compared ABRs evoked by either condensation or rarefaction clicks. While Rosenhamer et al. (1978) and Coats and Martin (1977) reported no significant ($p > 0.05$) latency or amplitude differences in ABRs from normals when polarity was reversed, others Stockard et al. (1979); Emerson et al., (1982); and Hughes et al., (1981) have reported significant individual variation

within groups as well as between groups. Stockard et al. (1979) reported that significant condensation-rarefaction differences were obtained in relation to peak latencies on a group of 64 subjects (30 males and 34 females) between the ages of 18-75 years who were described as neurologically and audiometrically normal. The study was completed using broadband click stimuli at intensity levels ranging from 35-75 dBnHL with rate varied between 10-80 clicks/sec. The study indicated that wave I demonstrated the most sensitivity to the phase of the click stimulus, while wave V was the least sensitive to phase characteristics. Rarefaction clicks elicited an earlier wave I in 61% of the subjects. In 17% of the subjects, condensation clicks produced the earlier wave I, and in 22% of the subjects there was no observable condensation-rarefaction difference in the latencies of wave I. They reported no statistically significant latency changes for wave V.

Stockard et al. (1979) also reported finding within subject variability for amplitude, waveform morphology and IPLs. Specifically, when the absolute changes in IPLs within individuals were investigated the reversal of stimulus phase resulted in statistically significant alterations of the I-III IPLs for approximately one-third of these normal adults. In addition, they reported that rarefaction clicks often produced a broad double-peaked or unrecordable wave I when using a 50 dB SL clicks. In addition, each subject who demonstrated this response also revealed a similar response in wave III; however, wave V appeared to be unaffected. Finally, these authors investigated the rate-phase interactions. The results revealed significant ($p < 0.001$) IPL shifts due to rate changes and these effects were highly dependent on the stimulus phase with greater shifts observed in response to rarefaction clicks rather than to condensation clicks (Stockard et al., 1979).

Hughes et al. (1981) examined a single ear from 17 subjects (10 female, 7 male) between the ages of 20-50 years. The subjects reportedly had normal hearing and presented no

neurological complaints. All ABR testing was completed using click stimuli at a rate of 10 clicks/sec. Their findings indicated that three components (In, III_n and IV_n, where "n" indicates that the respective wave component was measured as a negative deflection) had significantly longer latencies (0.1, 0.12, and 0.16 ms, respectively) at the $p < 0.05$ confidence level when rarefaction clicks were used.

Emerson et al. (1982) and Borg and Loqvist (1982) concentrated their research on the effects of click polarity on the wave V component in the ABR. Emerson and his colleagues examined forty-five normal adults (17-54 years of age, 25 females, 20 males) using a presentation rate of 10 clicks/sec. and an intensity level of 70-80 dB SL. The contralateral ear was masked using white noise at 20-30 dB below the intensity of the click stimuli. These investigators reported small but statistically significant latency changes in waves I through V. Rarefaction clicks produced shorter wave I, III and V latencies compared to condensation clicks. However, these earlier latencies did not result in significant I-III and I-V IPL differences. Finally, the condensation clicks tended to fuse waves IV and V, while the rarefaction clicks resulted in two distinct peaks.

Borg and Loqvist (1982) focused their study on the variability of absolute latency differences for wave V in response to click polarity. Utilizing a 75 dBnHL stimulus, seven otologically and neurologically normal adults (sex unreported) were tested. The results revealed that the variability of the condensation-rarefaction difference covers a 0.5 ms range. The latency difference of wave V ranged from -0.35 to +0.41 (positive values indicate longer condensation latencies) across a 95% confidence level. Roughly 70% the subjects demonstrated shorter latencies for rarefaction click stimulus when compared to the condensation click stimulus (Borg and Loqvist, 1982).

In summary the majority of the research indicates a general trend for rarefaction clicks to

elicit earlier wave I-IV components; however, the phase of the stimulus does not appear to influence wave V. Still, rarefaction clicks separate waves IV and V into two distinct peaks. There does not appear to be any statistically significant alterations on IPL intervals. Although no statistically significant IPL alterations appear evident, investigators have noted differences, which may be attributed to experimental design. All the reviewed studies combined data from both genders, which may affect the ABR outcome since differences between the sexes has been documented. Additional confounding factors related to methodology exist in that no two studies appeared to use the same electrode montage. Furthermore stimulus intensity differed, and stimulus rate was varied with the majority of the studies utilizing 10 clicks/sec. Finally, Borg and Loqvist (1982) and Hughes et al. (1981) were the only investigators to report stimulus polarity from the earphones.

Although the reviewed studies differed in methodology, sample size, and combined data from both genders, each one of these studies reported distinct differences in the parameters of the normal adult human ABR as a function of stimulus polarity. Stockard et al. (1979) and Hughes et al. (1981) reported a high degree of intersubject variability and concluded that although mean values for various wave components and IPLs tend to be similar among various laboratories, the ranges and limits of normality are the most important considerations in diagnostic applications.

Clearly these studies provide an argument stressing the importance of signal polarity of the click stimulus during the determination of ABR normative data, and its subsequent application to the assessment of clinical populations. Unfortunately, considerable differences exist across these published studies. Additional research into the effects of stimulus polarity on the auditory brainstem response is warranted.

IPILATERAL-CONTRALATERAL RECORDING MODE:

Data collection during auditory brainstem response testing is generally completed utilizing an ipsilateral recording mode. A small number of investigators have examined the clinical utility of contralateral recordings. In one study, Rosenhamer and Holmkvist (1982) obtained ABRs from both ears of 16 normal hearing females using unfiltered alternating clicks (20/sec) at 90 dBnHL, while another study, Hughes et al. (1981) examined a single ear of 17 subjects (7 males, 10 females) using filtered (280-2800 Hz) clicks at a rate of 10/sec., at 80dB SPL. Both studies observed the following events during contralateral recording:

1. wave I appeared in no more than one-third of the subjects;
2. wave III latency was shortened ($p < 0.001$); and
3. longer III-V IPL intervals ($p < 0.001$).

Prasher and Gibson (1980b) evaluated the results from ipsilateral and contralateral recordings in 23 normal hearing adults (15 females; 8 males) using 100 microseconds unfiltered alternating click stimuli (10/sec) at 90 dB SL. Their results were in agreement with #1 and 3 above. In addition, they reported statistically significant ($p < 0.01$) increased wave V latencies using a contralateral recording mode. This was quite different from the Rosenhamer and Holmkvist (1982) study which observed only a "tendency for wave V to lag and be smaller in amplitude" for contralateral ABRs. A possible explanation of this difference may be found in that only Prasher and Gibson reported using an electromagnetically controlled environment.

In summary, while all three studies varied in methodology, each of these investigations demonstrated differences between ipsilateral and contralateral recordings. The general trend for contralateral recording appeared to be a missing or diminished wave I; an earlier wave III, and a prolonged wave V. Clearly, some of the specific differences may be explained by methodologic factors. Rosenhamer and Holmkvist (1982) and Prasher and Gibson (1980b) used alternating

polarity, which has been hypothesized to alter patterns of excitation and, thus, possibly cause latency shifts of the ABR (Jacobson and Hyde, 1985). In addition, electrode montages as well as stimulus intensity and stimulus rate were varied across these studies. Finally, the recorded data from both males and females were combined in these studies and, as a result, they may not account for any gender differences in the response.

CLINICAL APPLICATION

The auditory brainstem response lends itself to a variety of clinical applications for both audiological and neurological questions. Until recently, the clinical investigation of any ABR abnormality has focused on the correlation between that abnormality and site-of-lesion detection. The present focus of research is to determine how the response may be differentially altered by specific pathophysiologic processes rather than a site-of-lesion identification. The use of the ABR for these new clinical approaches requires two phases: 1) a distinction must be made between normal and abnormal results while considering technical and subject parameters and 2) the results must be interpreted in conjunction with other related information (i.e. behavioral audiometric findings, case history, physical abnormalities, etc.) in order to support a diagnosis of a specific lesion, hearing impairment or disease process.

The literature does suggest very different ABR results for various hearing impairments and disease processes. Still several nonpathological factors have not been held constant nor controlled within or between studies, and therefore, specific criteria as to what factors influence abnormal responses are not consistent or complete. It is not the purpose of this paper to discuss the varying results of pathological factors and the interested reader is referred to Hall (1984), Fria (1980), Glattke (1983) and Katz (1985) for more detailed discussions as to specific ABR characteristics or changes as related to auditory and neurologic impairments. Table 2.10 provides a brief

Table 2.10: Possible outcomes of ipsilateral ABR measurements.*

Results	Conclusions/Additonal Questions
Normal Threshold and latency characteristics	Normal high-frequency hearing Sensitivity
Elevated threshold, normal I-V interval, prolonged absolute wave V latency	Probable high-frequency loss with no retrocochlear component
Elevated threshold, prolonged I-V IPL time Abnormal waveform	Probable retrocochlear component Need to determine if ABR is near threshold
No wave I, poor definition of wave V	Conductive loss, severe sensori-neural loss or a retrocochlear disorder Need to rule out a dead ear

*Glattko, 1983.

summary of some possible outcomes of ipsilateral ABR measurements (Glatcke, 1983). One of the main purposes of the ABR testing has been to differentiate cochlear from retrocochlear auditory dysfunction. However, a review of Table 2.10 indicates that the sensitivity of the response for this differentiation is inconsistent and incomplete. Hall (1984) as well as Keith and Jacobson (1985) have suggested that condensation and rarefaction stimuli should be utilized in both ipsilateral and contralateral recordings during clinical applications..

A number of preliminary studies have revealed that polarity may in fact affect the ipsilaterally recorded ABR in clinical populations. Borg and Loqvist (1982) discussed two distinctive features in the ipsilateral ABR relative to retrocochlear pathology: 1) the wave V latency range was above 10 ms, which is not seen in subjects with normal auditory sensitivity or cochlear losses; and 2) wave V latency is not dependent upon polarity. Hall (1984) reported that one of the most powerful ipsilateral ABR characteristics for retrocochlear hearing loss is the absence of later wave components (III to V). Emerson et al. (1979) reported that a wave V response while using rarefaction stimulation could not be delineated in 17 of 20 subjects with confirmed retrocochlear pathology. In these patients demonstrating a wave V response, the IPLs were prolonged in the ear contralateral to the side of the lesion (Hall, 1984; Emerson et al., 1979). In Hall's review of various ABR studies (Hall, 1984), he estimated that the ABR sensitivity in tumor identification to be approximately 90–95%. This is consistent with Turner's (1984) estimate as he obtained a 95% hit rate for ABR test results identifying retrocochlear pathology. They also reported a false-positive error rate at 7 and 9%, respectively. In contrast, Olsen, Noffisigner and Kurdziel (1975) demonstrated that acoustic reflex decay testing resulted in a 47% hit rate and a 17.2 % false-positive rate. This is also supported by Turner (1984) who reviewed acoustic reflex decay testing and obtained a 53% hit rate and a 8% false positive rate for retrocochlear pathology.

Investigators have also used ABR procedures with patients demonstrating specific neurological disorders such as Down's Syndrome, autism and multiple sclerosis (MS). The studies have indicated that these disorders yield abnormal ABR recordings, as compared to normals (Rosenblum, Arick, Krug, Stubbs, Young and Pelson, 1980; Stein and Kraus, 1985; Tanguag and Edwards, 1982). Audiological tests, including physiological measures, have not yet proved to be helpful in differentiating MS from many other disease processes. This lack of differentiation has been attributed to the observation that various abnormalities are found within both the CNS and vestibular systems as a result of plaques in the nerve root (Keith and Jacobson, 1985). Ipsilateral ABR testing has presented a wide variety of results from the MS patient. These reported abnormalities have consisted of asymmetries, delays in latency, fragmented responses, decreased amplitudes or absence of peaks, poor reliability, and abnormal responses to rate changes. In one study, Prasher and Gibson (1980a) evaluated MS patients using ipsilateral and contralateral recording modes. They concluded that the detection of MS using latency criteria improved considerably by using both the ipsilateral and contralateral recordings. However, these results as well as those reported from Barajas (1982, cited by Keith and Jacobson, 1985) are relatively vague regarding specific abnormalities. Further investigation of recording mode may also contribute to detecting the reported subclinical lesions.

Although ABR testing has provided a means of assessing the integrity of the auditory mechanism, the patients are often only adequately served due to limitations of existing test procedures. Once the complex interactions between recording, stimulus and patient variables are understood population-specific normative data may be established (Stockard et al., 1978). With this normative data established and with properly interpreted ABR results, critical information to differential diagnostic decisions can be obtained. Although the recent literature has demonstrated that stimulus polarity and contralateral measurements may contribute more and better

information in relation to audiological and neurological disorders, most of the current testing is in the ipsilateral recording mode with little regard to stimulus polarity.

STATEMENT OF THE PROBLEM

The review of literature on ipsilateral versus contralateral recording modes (Prasher and Gibson, 1980; Hughes et al., 1981; Rosenhamer and Holmkvist, 1982) has revealed a significant discrepancy in to ABR latency measures. In addition, a review of the literature on stimulus polarity (Stockard et al., 1977; Coats and Martin, 1977; Emerson et al., 1982; Hughes et al., 1981; Rosenhamer et al., 1978) has also unveiled discrepancies in ABR latency measures. If either variable affects the ABR latency values and/or an interactional affect exists, then the clinical interpretation of the obtained results may be influenced. Therefore, the purpose of this study was to investigate the effects of recording mode and stimulus polarity on the latencies of the ABR wave components III and V in normal hearing women. Specifically, the following questions were addressed:

1. Do differences exist in absolute latency values of ABR wave components III and V as a function of stimulus polarity?
2. Do differences exist in absolute latency values of ABR wave components III and V as a function recording mode?
3. Does significant interaction exist between stimulus polarity and recording mode relative to latency values of ABR wave components III and V?

CHAPTER III

METHODS

SUBJECTS:

Seventeen female subjects participated in this study. Mean age was 24.5 years with a range of 17 and 30 years. All subjects were required to have no history of known hearing loss, chronic otological difficulties, head trauma, or problems with the CNS or other neurological difficulty. In addition all subjects were in good health and free from any form of medication (see Appendix A).

Each subject exhibited normal peripheral auditory status based upon the criterion levels described below. The criterion test battery was completed prior to subject inclusion in the research project.

1. Each subject demonstrated pure tone air conduction thresholds of 15dB HL or better re: ANSI (1969) from 500-6000 Hz, bilaterally.
2. Pneumatic otoscopy revealed normal appearing and mobil tympanic membranes, bilaterally.
3. Complex oto-admittance testing required that each ear must demonstrate normal appearing tympanograms both in terms of overall shape and amplitude, with middle ear pressure between +50 and -100mm H₂O.
4. Acoustic reflexes were required to be present for each ear during both ipsilateral and contralateral stimulation from a 1000 Hz pure tone signal. The contralateral reflex threshold was required to be between 70-105 dB HL while the ipsilateral threshold was required to be between 70-100 dB HL.

5. ABR criterion testing was completed under ipsilateral test conditions for both ears utilizing broad-band negative polarity click stimuli presented at a rate of 21.1/sec. Step one utilized a 70 dBnHL presentation level. Under this condition each ear was required to demonstrate repeatable ABRs (± 200 microseconds) with well defined waves I, III, and V. Step two utilized a 30 dBnHL stimulus and required each ear to demonstrate a well defined and repeatable wave V.

EQUIPMENT:

All testing was completed at the Child Development and Rehabilitation Center (CDRC), Crippled Children's Division (CCD) of the Oregon Health Sciences University (OHSU). A Grason-Stadler 1704 audiometer with Telephonic TDH-50 earphones in Telephonic MX-41/AR cushions were used for the pure tone air conduction testing. Grason-Stadler 1720 B or 1723 otoadmittance meters and a Macromatics MD-1 microprocessor impedance analyzer were used to complete all admittance testing. All pure-tone testing was completed within sound treated rooms designed by Industrial Acoustic Corporation (IAC).

The ABR testing was completed with a Nicolet CA-1000 evoked potential system coupled to Telex 1470-A earphones with MX-41/AR cushions. Grass Instruments E55-H silver cup electrodes with hole were applied at the forehead mid-line position at the hairline and at the promintory of each mastoid with EEG glue (collodian). EEG jelly was introduced to the skin through the hole of each electrode via syringe and blunted #18 gauge needle. The skin was abraded until an inter-electrode impedance of 1000 ohms or less was realized as monitored through a Nicolet HGA 200-A physiological amplifier. Electrode integrity was checked preliminary to testing and each time following electrode manipulation between right and left ear test conditions.

Throughout all experimental test conditions, the equipment was set-up to deliver broadband

clicks, 100 microseconds in duration, at an intensity of 70 dB nHL, and at a rate of 21.1 clicks per sec until 2000 click repetitions had been averaged. Each response to the click stimulus was filtered between 150 and 3000 Hz. A sensitivity level of ± 10 microvolts or less, and a common mode rejection level of 20% was maintained throughout all analyzed runs.

Calibration procedures were completed on all equipment and were conducted to conform with existing standards (ANSI, 1973a; 1973b). Interrogative checks were completed using a Micronta multimeter, a CA-100 calibrator and the HGA 200 A physiological amplifier.

The polarity of the signal was checked from the earphone via a sound level meter (SLM) (Brüel & Kjaer type 2203) in conjunction with an oscilloscope (Tektronic) as described by Gorga, Abbas and Worthington (1985). The sound level meter was fitted with a 6 cc coupler and microphone. The test earphone was then placed on top of the coupler. Once the test earphone was positioned, a condensation signal was created by gently tapping against the back of the earphone and the direction of shift was noted on the oscilloscope. The direction of voltage change corresponded to the manually induced condensation phase, and indicated that the sound level meter did not reverse the phase of signal delivered to its microphone.

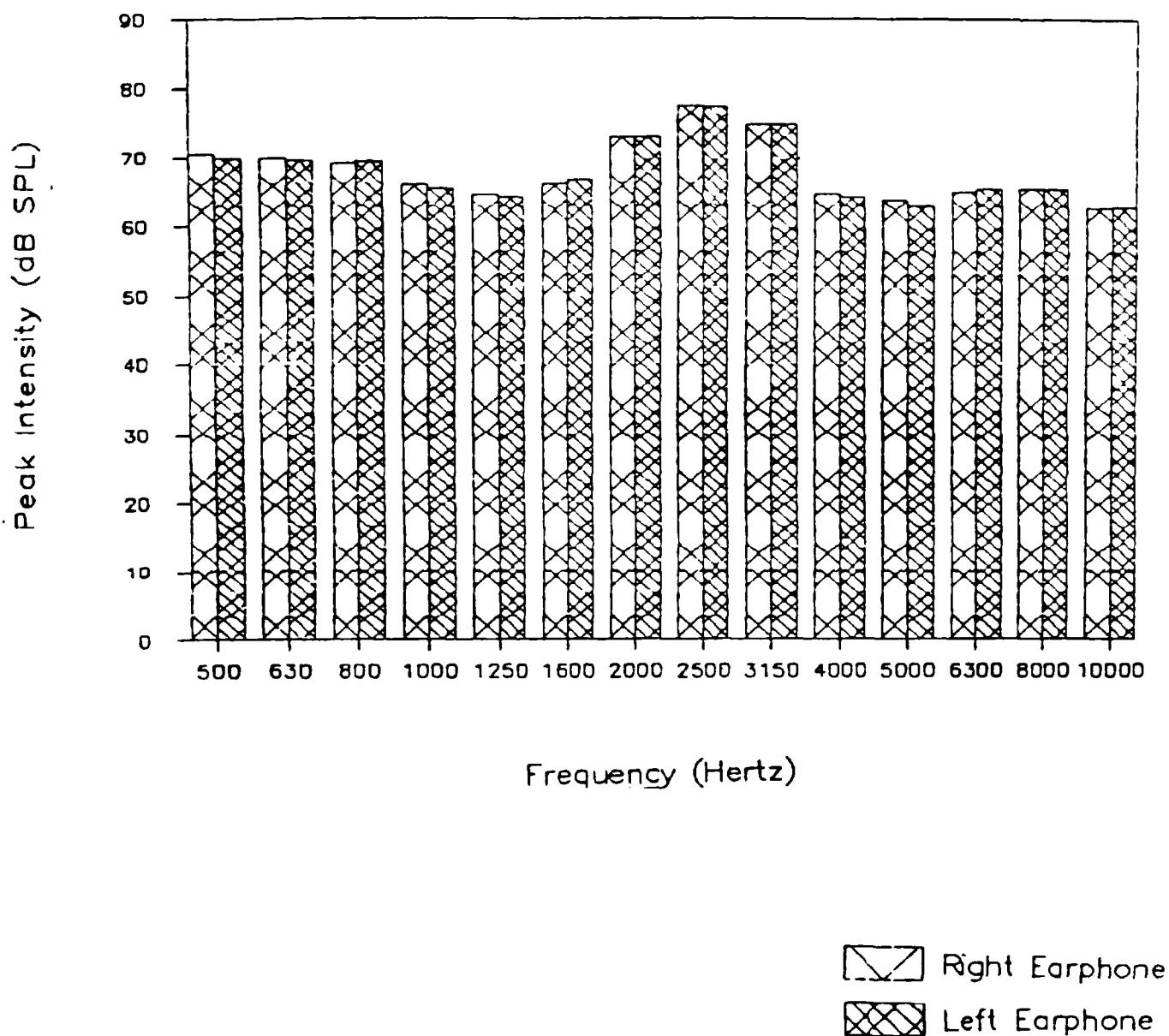
A third octave spectral analysis (500–10,000 Hz, inclusive) of the Telex earphones was obtained by recording the sound pressure levels of 100 microsecond duration clicks, presented at a rate of 81.1/sec at an intensity of 70 dBnHL. Equipment used included a Brüel and Kjaer (B &K) type 2203 SLM, a one-third octave filter set (B&K type 1616), a type 4152 artificial ear and associated 6 cc coupler, and a type 4132 condenser microphone. The earphones were compared against one another as well as against a new unused identical head set. The spectral characteristics of the click stimulus are presented in Figure 3.1.

FIGURE 3.1

AMPLITUDE SPECTRA OF CLICK STIMULUS

PRESENTED THROUGH TDH-50 EARPHONES

(ONE-THIRD OCTAVE ANALYSIS)



PROCEDURES:

Testing took place in one to three sessions depending upon the time constraints for each subject. All subjects were given detailed instructions in each task. Prior to participation in the project, each subject or legal guardian read and signed an informed consent form (see Appendix C).

After each subject passed the behavioral hearing screening criterion, they were asked to submit to ABR criterion testing. Participants were instructed that they would be subjected to a rapid series of click stimuli. Every effort was made to provide reasonable comfort. The test room was darkened. Adequate warmth provided. Subjects were asked to establish and maintain a calm, relaxed state and to sleep if possible.

In all cases the ABR instrumentation was adjusted, as described above, and to ± 10 microvolts or less as determined by subject artifact level. The ABR preliminary testing consisted of three runs utilizing the ipsilateral recording mode. The first run was completed using a stimulus intensity level of 70 dBnHL; the second was an exact replication; and the third was a replication of one and two with the exception of the utilization of a 30 dBnHL stimulus intensity level. Upon successful completion of the preliminary screening the experimental testing commenced utilizing the conventional ipsilateral recording mode. Experimental testing was completed in the following order for each ear:

1. Ipsilateral condition: negative, alternating, positive.
2. Contralateral condition: positive, alternating, negative.

Thus, each subject received a total of 3 preliminary runs and 6 experimental trials per ear. Both ears were tested.

All subject data was stored on floppy disk via a Nicolet DC-2000 Disk Controller for later analysis. Following the data collection for each subject, the absolute latencies for waves I, III, V

and IPL values for III-V were computed and recorded for each condition in preparation for computer entry.

The latency data was entered on a Harris 8686 system and the means, standard deviations and variances were obtained for all conditions: stimulus polarity, and recording mode. A 2 x 3 analysis of variance (ANOVA) was completed using the Statistical Package for the Social Sciences (SPSS) (Nie, Hull, Jenkins, Steinbrenner and Bent, 1975) in order to determine all significant ($\alpha=0.01$) variables and any interactions between the variables.

CHAPTER IV

RESULTS

The statistical analysis of wave III and V absolute latency measures and the III-V interpeak latency (IPL) interval from the 36 ears of the 18 normal hearing adult females revealed significant ($p < 0.01$) statistical differences between recording modes. However, there were no statistically significant ($p > 0.01$) differences between stimulus polarities (positive, alternating and negative) used in this study, nor was there an interaction between recording mode and stimulus polarity. The mean (\bar{x}) and standard deviations (sd) for the absolute and interpeak latency measures of wave components III and V, as a function of recording mode and stimulus polarity, are presented in Tables 3.10, 3.20, and 3.30. The 2 x 3 ANOVA summary of the measures are presented in Tables 3.11, 3.21 and 3.31, respectively. A review of the data revealed the following about contralateral recordings relative to ipsilateral:

1. Wave III occurred earlier (decreased in latency) by approximately 0.09 ms;
2. Wave V occurred later (increased latency) by approximately 0.11 ms; and
3. The III-V IPL interval increased by approximately 0.2 ms.

Table 3.40 presents the percentage of ears demonstrating longer latency values in response to negative versus positive click polarity. The data from wave I was based solely on ipsilateral recordings due to the low incidence of occurrence during contralateral recordings. Only four (11%) of the 36 ears tested in the contralateral condition demonstrated a wave I ABR component. In two of these four ears with an observable wave I under the contralateral condition, the morphology of this component was severely diminished making latency determination extremely difficult.

Although considerable variability existed across all conditions, definite general trends emerged from all of the latency measures relative to stimulus polarity. Reviewing tables 3.10, 3.20 and 3.30, it becomes apparent that negative click polarity as compared to positive click polarity yielded shorter wave III latency values and longer wave V values. As a result longer III-V IPL values were observed when the negative click polarity was utilized. These trends were observed in both ipsilateral and contralateral conditions. The observed tendency for shorter wave III latency values in response to negative click polarity was slightly greater in the contralateral condition as compared to the ipsilateral condition (0.01 and 0.04 ms, respectively). In contrast, the tendency for longer wave V latency values in response to the negative click polarity was relatively the same for both contralateral and ipsilateral conditions (0.02 and 0.01 ms, respectively). The III-V IPL interval demonstrated a 0.06 ms increase in latency while using negative polarity in the contralateral recording mode relative to the ipsilateral recording mode, which revealed a 0.01 ms increase in latency time for the negative click polarity.

Table 3.10: Wave III latency means (\bar{x}) and standard deviations (sd) in milliseconds for recording mode and polarity.

Stimulus Polarity		Recording Mode		
		Ipsilateral	Contralateral	Total
Negative	\bar{x} :	3.68	3.57	3.63
	sd:	.155	.144	.158
Alternating	\bar{x} :	3.67	3.59	3.63
	sd:	.141	.136	.145
Positive	\bar{x} :	3.69	3.61	3.67
	sd:	.142	.150	.148
Total	\bar{x} :	3.68	3.59	
	sd:	.145	.143	

Table 3.11: Summary ANOVA for wave III latency measures relative to recording mode (RM) and polarity (P).

Source	SS	df	MS	F	P
RM	.3918519	1	.3918519	33.915	0.01
P	.0050815	2	.0025407	.419	N.S.
RM x P	.0226815	2	.0113407	2.039	N.S.
error	.1890519	34			
Total	.6086668	39			

F at df = 1,34; α at 0.01 = 7.44

F at df = 2,34; α at 0.01 = 5.29

Table 3.20: Wave Y latency means (\bar{x}) and standard deviations (sd) in milliseconds for recording mode and polarity

Stimulus Polarity	Recording Mode			
		Ipsilateral	Contralateral	Total
Negative	\bar{x} :	5.51	5.63	5.57
	sd:	.140	.173	.166
Alternating	\bar{x} :	5.49	5.60	5.55
	sd:	.147	.164	.164
Positive	\bar{x} :	5.50	5.61	5.55
	sd:	.173	.160	.165
Total	\bar{x} :	5.50	5.61	
	sd:	.153	.165	

Table 3.21: Summary ANOVA table for wave V latency measures relative to recording mode (RM) and polarity (P).

Source	SS	df	MS	F	p
RM	.7396741	1	.7396741	95.411	0.01
P	.0273926	2	.0136963	4.915	N.S.
RM x P	.0022370	2	.0011185	.366	N.S.
error	.1038963	34	.0030558		
Total	.873200	39			

F at df = 1, 23; α at 0.01 = 7.44

F at df = 2, 34; α at 0.01 = 5.29

Table 3.30: Wave III-V interpeak latency (IPL) means (\bar{x}) and standard deviations (sd) in milliseconds for recording mode and polarity.

Stimulus Polarity		Recording Mode		
		Ipsilateral	Contralateral	Total
Negative	\bar{x} :	1.83	2.06	1.94
	sd:	.130	.130	.171
Alternating	\bar{x} :	1.82	2.02	1.92
	sd:	.093	.140	.155
Positive	\bar{x} :	1.82	2.00	1.91
	sd:	.114	.128	.152
Total	\bar{x} :	1.82	2.02	
	sd:	.113	.134	

Table 3.31: Summary ANOVA table for the III-V IPL measures relative to recording mode (RM) and polarity (P).

Source	SS	df	MS	F	P
RM	2.2082667	1	2.2082667	154.870	0.01
P	.0503111	2	.0251556	3.546	N.S.
RM x P	.0149333	2	.0074667	1.179	N.S.
error	.2152000	34	.0063294		
Total	2.4887111	39			

F at df = 1, 34; α at 0.01 = 7.44

F at df = 2, 34; α at 0.01 = 5.29

Table 3.40: Percentages of ears demonstrating longer latency values as a function of stimulus polarity.

POLARITY	WAVE I %	WAVE III %	WAVE V %
Negative	61	36	44
Positive	19	46	35
No Change	20	18	21
TOTAL	36	72	72

CHAPTER V

DISCUSSION

The purpose of this investigation was to collect ipsilateral and contralateral auditory brainstem response (ABR) data relative to stimulus polarity, on a homogeneous group of normal adult females. Specifically the study was designed to determine: 1) wave III or V absolute latency differences between ipsilateral and contralateral recordings; 2) absolute latency differences of wave III or V relative to the initial phase of stimulus onset; and 3) any interactional effects between the recording mode and the phase of stimulus onset.

The results of this study showed statistically significant ($p < 0.01$) wave III and V absolute latency differences when utilizing ipsilateral versus contralateral recording modes for normal adult females. There were no statistically significant latency differences in response to the polarity of the click stimulus, nor was there any statistically significant interaction between recording mode and stimulus polarity. However, trends in latency differences do exist in both ipsilateral and contralateral recording modes relative to stimulus polarity.

The findings that statistical differences did not exist in relation to phase of stimulus onset agree with those reported by Coats and Martin (1977) and Roehamer et al. (1978). However, these data are in disagreement with the data reported by Emerson et al. (1982), Hughes et al. (1981), Borg and Loqvist (1982) and Stockard et al. (1979). The results from these latter studies have ranged from the observations of shorter, or earlier, wave V latency measures in response to condensation clicks (Borg and Loqvist, 1982), to shorter wave V latency measures in response to rarefaction click stimuli (Emerson et al., 1979).

Some of these factors which can contribute to these discrepancies in latency changes relative

to phase of stimulus onset may lie in the experimental design. First, the present study used only female subjects whereas the other studies combined data from both females and males. It has been well documented (Stockard et al., 1978; Jewett and Williston, 1971) that the adult male exhibits longer absolute latency values, relative to the adult female, even though the IPL times remain comparable. Therefore, when attempting to determine the affects of one or two other variables, gender should be controlled for in order to more clearly interpret the findings relative to the test variables.

Secondly, although a click is determined to be of a positive or negative polarity at the earphone, there are no standards for click generation (Glattke, 1983), and conceivably one can generate different degrees of condensation and rarefaction clicks (Lilly, 1986). Without standards for click generation comparisons of normative data across laboratories is compromised. Compromises also occur relative to pulse duration, earphone selected, earphone placement on the subject, and other factors. These compromises, in turn, may cause differences in the response parameters of the recorded ABR and, as a result, interpretation of the results is more difficult. In this study, all equipment, including that needed for controlling stimulus polarity at the earphones, was checked both at the beginning and end of the study. Many of the reviewed studies, Emerson et al., (1979), for example, did not report the calibration protocols of their instrumentation. Therefore, when comparing these studies which investigated differences in ABR due to click polarity, several questions arise in relation to the click generation and the polarity of the click itself.

In addition, the studies varied in relation to the rate, intensity, and filtering of the auditory stimuli. Filter differences ranged from using unfiltered click stimuli (Rosenhamer and Holmkvist, 1982; Emerson, et al., 1979) to filtered click stimuli from 20 Hz - 3 kHz (Coats and Martin, 1977) to 100 Hz - 3.2 kHz (Stockard et al., 1979). In an unfiltered click, as compared

to filtered clicks, more of the basilar membrane is stimulated, and in turn, generates increased electrical activity. This spread of excitation along the basilar membrane results in longer ABR latency values due to traveling wave mechanics. Thus, filtered clicks depending upon the bandpass of the filter generally result in shorter latency values. Stockard et al. (1979) reported statistically significant ($p < 0.001$) rate-phase interactions. Specifically, greater shifts of IPLs were noted in response to rarefaction clicks as compared to condensation clicks. In contrast, wave I was often unaltered, in response to rarefaction clicks at rates of 80 clicks/sec., while with condensation clicks wave I was prolonged. In addition, Stockard et al. (1979) reported "dramatic" morphological changes while using a stimulus level of 50 dB SL. Rarefaction clicks produced a broad double-peaked or unrecordable wave I. Many responses characterized by poorly defined wave I's also demonstrated a similar response pattern for the wave III component. However, the wave V component showed little morphological differences. Responses at 30 dB SL demonstrated similar patterns of effects on the absolute latency values for waves I, III, and V (Stockard et al., 1979). The interaction of stimulus polarity and rate or intensity have not been extensively studied and warrants further investigation.

Finally, all studies differed relative to inter-electrode impedance levels. For example, Rosenhamer et al. (1978) required inter-electrode impedance levels to be equal to or less than 5000 ohms. Emerson et al. (1979) required these impedance values to be equal to or less than 3000 ohms. The present study required inter-electrode impedance values of less than or equal to 1000 ohms. The higher the impedance value the more internal and external "noise", relative to the subject, is allowed to be averaged within the ABR. With this added "noise", the recorded ABR wave components are not as well defined, making the interpretation of the absolute latency values difficult, and in some cases impossible.

Although the phase of stimulus onset was not found to be statistically or clinically

significant in the present investigation it should not be ignored. First, the literature supports both points of view that stimulus phase may or may not be clinically significant. In addition, although this study as well as those reviewed revealed high intersubject variability (see table 3.40), definite trends were observed for all the components measured relative to stimulus polarity. Some of this variability as well as those discrepancies noted in the phase literature may be due to differences in stimulus intensities as well as subject age, sample size and click generation. However, further investigation using carefully controlled experimental design, including documentation of stimulus polarity and consistency of click generation techniques with normal subjects is needed.

The results of this study revealed statistically significant ($p < 0.01$) differences between ipsilateral and contralateral recordings. This data obtained in relation to recording mode, relative to wave III, agrees with that reported by Rosenhamer and Holmkvist (1982), Prasher and Gibson (1980b) and Hughes et al. (1982). However, relative to wave V component, the present data agrees with Prasher and Gibson's (1980b) finding that wave V increases in latency (lags) under contralateral recording conditions. Rosenhamer and Holmkvist (1982) reported a tendency for this occurrence, but indicated that it was not a statistically significant ($p > 0.05$) finding. In contrast Hughes et al. (1982) reported no significant changes of trends in relation to the lagging ABR wave component V.

Some of the factors which can contribute to these discrepancies in latency changes relative to recording mode may again lie in the experimental design. The variables affecting the response, relative to stimulus polarity, as described above, may also affect the response relative to recording mode. For example, as discussed above, differences exist between genders. Females demonstrate shorter wave V's relative to males. Thus, careful description of stimulus, subject, and methodological variables is important to understand the nature of their effects on the recorded

ABR.

Statistical analyses varied considerably between the reviewed studies and the present investigation. This investigation used a 2 x 3 ANOVA with a 0.01 level of confidence. The only statistically significant differences evidenced were the differences between the ipsilateral and contralateral recording modes. However, when reviewing tables 3.10 through 3.31, questions about the actual clinical significance (0.20 ms) of the reported differences are raised. Ipsilateral and contralateral mean latency times differed by 0.9 ms, 0.11 ms, and 0.20 ms for wave III, wave V and the III-V IPL interval, respectively. Therefore, if 0.2 ms is used as the level of clinical significance, the only qualifying level is that of the III-V IPL interval. However, the differences between the other measures are consistent among subjects as well as with the general trend of the literature, and may offer valuable information.

In summary, ipsilateral-contralateral ABR latency measures differ in normal adult females. The effects of stimulus polarity remain unknown. Since the developmental course of the contralateral response is not known (Edwards, Duriex-Smith and Picton, 1985) and the complete effects of stimulus phase are undefined, an interaction between these two parameters in normal subjects cannot be ruled out. Further investigation is required to answer questions relative to stimulus phase effects and the interaction between recording mode and stimulus phase. Once these parameters and interactions are more clearly understood in normals, research should turn to the investigation of the effects of these parameters in disordered populations. The current literature suggests that people with disorders such as multiple sclerosis (Prasher and Gibson, 1980a), Down's Syndrome (Worthington and Peters, 1984), and autism (Rosenblum et al., 1980) exhibit distinct differences in the ABR. If this is the case, data needs to be obtained documenting the effects on the response by the variables studied in this investigation. These data, when

interpreted with other test results, may then be useful in answering differential diagnostic questions.

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APPENDIX A
INTAKE INFORMATION

Name: _____

Identification number: _____

DOB: _____

Evaluation Date: _____

Present Health: _____

<u>Medical History</u>	<u>YES</u>	<u>NO</u>	<u>COMMENTS</u>
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head injury

neurological problems

seizures

ear problems

ear surgeries

accidents

present medications

<u>Family History</u>

hearing loss

seizures

neurological
problems or disease

APPENDIX B

OHSU

Crippled Children's Division

INFORMED CONSENT

Brainstem Evoked Response Audiometry:
Ipsilateral vs. Contralateral Stimulation of the
Auditory System of Females

I, _____, consent to my/my child's participation in a study under the supervision of Rodney O. Pelson, Ph.D. and Nancy Murray, Audiology Intern, at the Crippled Children's Division, The Oregon Health Sciences University. The purpose of this study is to obtain normative data on a relatively new and unexplored area of brainstem evoked response audiometry (BSERA). Electrical brain activity resulting from stimulating the auditory system with a broad band "click" stimulus will be recorded using electrodes glued to the forehead and behind each ear, upon the mastoid processess.

This procedure will require the participant to lie on a padded table while wearing earphones for approximately one hour. Prior to this testing the participant will be required to pass a preliminary audiometric test battery to insure normal peripheral hearing sensitivity. The preliminary test battery will take approximately one hour.

All testing will take place at Crippled Children's Division (CCD), The Oregon Health Sciences University (OHSU), in one or two separate appointments. Participation is on a volunteer basis with no payments made or charges assessed to the participant. All participants attending school will be tested during non-school hours. There is no physical, psychological or social risk inherent in participation in the research study described. The only possible slight discomfort is having the electrodes glued to the scalp. No medications will be used.

This study will provide me with a professional evaluation of my/my child's hearing status, and will be made available to me and to medical records upon request. The information obtained from the study will be useful to medical science in understanding a relatively new and unexplored area of BSERA. I understand that all identifying information, including the participant's name, will be held confidential. Dr. Pelson and Ms. Murray have offered to answer any questions I might have regarding the study, specifically the test procedures and the participant's involvement. I may contact them at CCD, The OHSU (phone 225-8356). I also understand that the participant is under no obligation to complete the study, and that withdrawal from the study will not affect the participant's relationship with, or treatment at The Oregon Health Sciences University.

The Oregon Health Sciences University, as an agency of the State, is covered by State

