Factors Affecting the Recordability of Auditory Evoked Response Component Pb (P1)

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Abstract

The auditory middle latency response (AMLR) is characterized by two positive peaks (Pa, Pb) and two negative peaks (Na, Nb). The unpredictable nature of the second positive peak, Pb or P1, has made its diagnostic use problematic. Our purpose was to determine an appropriate combination of stimulating and recording variables that evoked a repeatable Pb in adults and children. Three experiments were designed to evaluate systematically the amplitude and latency of the Pb 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 consistently evoked the Pb in all subjects. Results also showed that a longer interstimulus interval (1.1/sec) is more likely to evoke the Pb component. Additionally, results showed that Pb is generally largest when recorded from a noninverting electrode at Fz with a noncephalic reference. Finally, results showed that Pb latency is significantly longer and amplitude larger in children than in adults.

Key Words: Auditory evoked potentials, auditory middle latency response, Pb, P1, recording parameters

Abbreviations: ABR = auditory brainstem response, AER = auditory evoked response, ALR = auditory late response, AMLR = auditory middle latency response, A1/A2 = linked earlobes, CANS = central auditory nervous system, HIV = human immunodeficiency virus, NC = noncephalic, Pb (P1) = the Pb component from the auditory middle latency response is the same as the P1 wave from the auditory late response

The auditory middle latency response (AMLR) is characterized by two prominent positive peaking waves, Pa (μ = 30 msec) and Pb (μ = 58 msec) and two negative peaking waves, Na (18 msec) and Nb (42 msec) (Geisler et al., 1958; Goldstein and Rodman, 1967; Mendel and Goldstein, 1969; Peters and Mendel, 1974; Picton et al., 1974; Musiek and Geurkink, 1981). The most widely studied component of the AMLR, the Pa component, is thought to be generated primarily from the auditory portions of the temporal lobe (Picton et al., 1974; Celesia, 1976; Parving et al., 1980; Ozdamar et al., 1982; Rosati et al., 1982; Musiek and Donnelly, 1983; Lee et al., 1984; Kraus et al., 1985; Kileny et al., 1987; Woods et al., 1987; Deiber et al., 1988; Jacobson et al., 1990). The Pa component is best known for its diagnostic use in the measurement of hearing sensitivity and also shows promise as a measure of auditory cortex integrity (Kraus et al., 1982; Weber, 1987; Jacobson et al., 1990).

Recently, it has been suggested that the Pb component of the AMLR (occurring at 45- to 79-msec post-stimulus onset) may vary independently of its earlier counterpart, the Pa component, and thus may be of clinical value (Buchwald et al., 1981; Hinman and Buchwald, 1983; Erwin and Buchwald, 1986). Results from animal and human studies suggest that the Pa and the Pb are generated from, and are depen-
dent upon, different generator sources (Buchwald et al, 1981; Hinman and Buchwald, 1983; Chen and Buchwald, 1986; Erwin and Buchwald, 1986; Buchwald et al, 1989). Unlike Pa, Pb is thought to be generated from thalamic nuclei that receive input from the mesencephalic reticular activating system (Buchwald et al, 1991; Kraus et al, 1992). Due to the unpredictable nature of the Pb component, only a few research groups have explored the diagnostic value of Pb in human subjects (Erwin and Buchwald, 1986; Buchwald et al, 1989; Hood, 1990; Erwin et al, 1991; Chambers, 1992). Many investigators have acknowledged the existence of Pb and have reported its latency while failing to describe its specific characteristics (Goldstein et al, 1972; Kileny et al, 1983). The few that have observed and described the Pb component have used clicks or low-frequency tone bursts presented at relatively slow rates of 0.5/sec to 4/sec (Peters and Mendel, 1974; McFarland et al, 1977; Thornton et al, 1977; Erwin and Buchwald, 1986; Chambers, 1992). Unfortunately, these waveforms were recorded with restrictive filter settings that have been shown to distort the AMLR components (Scherg, 1982; Kavanagh and Domico, 1986).

Before the diagnostic importance of the Pb component can be studied fully, it is necessary to evaluate systematically the Pb component and report the stimulus and acquisition parameters that best elicit the response. Only when it can be recorded reliably and its characteristics better clarified can the Pb be evaluated as a tool to test central auditory system integrity. For example, some investigators (Buchwald et al, 1989; Chambers, 1992) have demonstrated that a normal Pa and an abnormal Pb may reflect diffuse malfunction such as dementia or Alzheimer's disease, whereas an abnormal Pa concurrent with a normal Pb may provide clinical support for auditory processing dysfunction specific to primary auditory cortex.

The specific goal of this investigation was to define a set of stimulus and acquisition parameters that would ensure a reproducible Pb component of the AMLR. A second goal was to describe the effects of stimulus type, duration and repetition rate, electrode derivation, and subject age on the Pb. This study consisted of three experiments: Experiment 1 evaluated the effects of stimulus type and electrode array on the Pb; Experiment 2 evaluated the effect of stimulus duration and repetition rate on the Pb; and Experiment 3 evaluated the Pb in adults and children.

### METHOD

#### Subjects

A total of 24 female subjects aged 21 to 40 years (mean age = 28 years, SD = 5.4 years), and 9 female children 10 to 14 years old (mean age = 12.6 years, SD = 0.88 years) were subjects for the three experiments. Twelve adults participated in Experiment 1, which evaluated the effects of stimulus type, rate, and electrode array on the Pb. Three adults participated in Experiment 2, which evaluated the effects of stimulus duration on the Pb. Nine adults and nine children participated in Experiment 3, which evaluated age effects on the Pb. All subjects were right-handed as suggested by the Edinburgh Handedness Inventory (Oldfield, 1971). No participant had a history of neurotologic disorders or perceptual, educational, or emotional deficits, as reported by parents of children or by personal interview. All participants had hearing thresholds for pure tones no worse than 15 dB at octave frequencies between 250 and 4000 Hz bilaterally. Each subject demonstrated normal middle ear function in both ears as defined by normal middle ear pressure less than +50mm H$_2$O or greater than -50mm H$_2$O in each ear, normal static admittance, and ipsilateral and contralateral acoustic reflexes elicited between 70 and 100 dB HL for pure-tone signals of 0.5, 1, 2, and 4 kHz (ANSI, 1969). All subjects had normal auditory brainstem responses (ABRs).

#### Instrumentation and Procedures

For all three experiments, AMLRs were recorded with the Nicolet Pathfinder II. Silver-chloride disc electrodes were applied according to the International 10/20 Electrode System (Jasper, 1958). The electrodes were affixed to the head with a commercially available conductant paste (Nicolet EC2 Electrode Cream). Inverting electrodes were located at each earlobe A1 and A2 (linked earlobes) and on the seventh cervical vertebra (noncerephallic [NC]). An electrode placed at Fpz served as the ground. The absolute electrode impedances were less than 5000 ohms. The interelectrode impedances were less than 3000 ohms. For all conditions, auditory evoked responses (AERs) were recorded for 11 msec prior to stimulus onset to establish the amplitude baseline and 99 msec after stimulus onset with an overall analysis time of 110 msec. This recording interval encompassed the ABR as well as the AMLR. The incoming signal was
analog bandpass filtered from 5 to 1500 Hz (12 dB/octave).

Stimuli were presented to the left ear of each subject through Etymotic Research (ER-3A) insert earphones, which introduced a 0.86-msec transmission delay between the onset of the stimulus and the ear canal. All signals were presented at 80 dB nHL (Thornton et al, 1977). For each stimulus condition, the evoked response was averaged over 500 presentations of the stimulus. Recordings were repeated so that reproducibility of the waveform could be assessed. These two independent averages and their grand average were stored on magnetic media for offline analysis. Eye blinks were monitored and eliminated from the AMLR response (rejection limit = 1–50 Hz) by electrodes placed at the outer canthi of each eye. Further, any waveform displaying obvious postauricular muscle artifact was discarded. All testing was conducted in a dimly lit, quiet test room. Subjects were seated in a reclining armchair and asked to relax. Alertness was maintained during the lengthy test sessions to avoid a reduction in the amplitude of the AMLR often associated with sleep. To verify alertness, subjects were required to watch a silent, English-subtitled movie during data collection and to hold short conversations with the tester between experimental trials (Mendel and Goldstein, 1969; Prosser and Arslan, 1985; Erwin and Buchwald, 1986; Kraus et al, 1989).

For each waveform, an amplitude baseline was determined as the mean voltage recorded from the 11-msec prestimulus time period (9% of the total time epoch). Peak latencies and amplitudes of the AMLR components were measured and tabulated. Latency was defined as the time of maximum voltage within the time frame of a characterized deflection (Fig. 1). Amplitude was defined as the maximum voltage from baseline to peak or trough of that wave.

**RESULTS**

The following section details the results of three experiments. Preceding these results is a brief description of the specific stimulus parameters used.
Experiment 1: Effect of Stimulus Type and Noninverting Electrode Location on the Pb

Three stimulus types were presented to each subject; these included a click (0.1-msec rarefaction), a 0.5-kHz tone burst, and a 4-kHz tone burst (rise/fall time = 2 msec; plateau = 1 msec). Stimulus repetition rates were 0.5, 0.7, 1.1, 2.1, and 5.1 per second. For each trial, AMLR waveforms were simultaneously recorded from three noninverting (active) electrode sites at C3, C4, and Fz and two inverting (reference) electrode sites located at A1/A2 and NC. Each listening trial consisted of a six channel recording, that is, C3-A1/A2, C4-A1/A2, Fz-A1/A2, C3-NC, C4-NC, and Fz-NC, which randomly paired each stimulus type with each repetition rate. Fifteen replicated trials were recorded for each subject for a total of 30 listening trials.

A repeatable Pb was recorded in only 6 of the 12 subjects tested during Experiment 1. The 500-Hz tone burst stimulus elicited a “less noisy” Pb with larger Pb amplitudes than did either the clicks or the 4000-Hz tone bursts, as shown in Figure 2. When Pb was recorded at Fz, the mean baseline-to-peak amplitude was largest. The Pb component was often absent at C3 and C4. For all conditions, Pb latencies were approximately 50 msec and ranged from 48.9 to 57.4 msec.

Experiment 2: Effect of Stimulus Duration, Repetition Rate, and Inverting Electrode Location on the Pb

For this experiment, the duration of the 0.5 kHz and 4-kHz tone bursts was lengthened from 5 msec to 60 msec (rise/fall time = 5 msec each; plateau = 50 msec). Experimental repetition rates were reduced to 4 (0.07/sec was eliminated) to shorten test time. Stimulus rates were 0.5, 1.1, 2.1, and 5.1 per second. Noninverting
Figure 4 An example of AMLR waveforms as a function of rate for adult subject JW. As the stimulus rate increased, the amplitude of Pb decreased. The stimulus was a 500-Hz tone burst with a duration of 60 msec. The noninverting electrode was located at Fz and the inverting electrode at NC.

electrode sites C3 and C4 were eliminated for Experiment 2 based on the low detectability of Pb from these sites during Experiment 1. Each two-channel recording (Fz-A1/A2 and Fz-NC) for Experiment 2 paired each stimulus type with each rate for a total of 24 trials.

At the slowest repetition rate of 0.5/sec, a Pb component was evoked in each subject for all three stimulus types from a noninverting electrode at Fz with inverting electrodes at A1/A2 and at NC. At a repetition rate of 1.1/sec, a Pb component was visible in each subject for all three stimulus types only with a noninverting electrode at Fz with inverting electrodes at A1/A2. Using an NC inverting electrode site (at 1.1/sec), a Pb component was visible in each subject for only the 500-Hz stimulus. As shown in the second panel of Figure 3, the largest amplitude Pb component was observed with the 500-Hz stimulus. This was true for each subject. Figure 4 shows AMLR waveforms elicited by the 500-Hz tone bursts at the four experimental repetition rates. As the rate increased from 0.5/sec to 5.1/sec, the detectability of the Pb component decreased. This rate effect was also true for clicks and the 4-kHz tone bursts. Pb responses were inconsistent for rates of 2.1/sec and 5.1/sec under any condition. There was a trend for latencies to be longest for the 5.1/sec stimulus rate. The Pa component of the AMLR was elicited in every subject under every condition even in instances where the Pb component was not detectable.

We evaluated the actual contribution of linked earlobes (A1/A2) to the detectability of the Pb component. AMLRs from five additional subjects were simultaneously recorded using four electrode montages: A1-A2/NC, Fz-NC, Fz-A1/A2, and Cz-A1/A2. The inset in Figure 1 is an example of AMLR waveforms simultaneously recorded from the four channels. The Pb component of the AMLR was detected in every channel except A1-A2/NC (top waveform). Results in four of the five subjects verified that the earlobes were not significantly contributing to the cephalic response.

**Experiment 3: Pb in Adults and Children**

Based on results from Experiment 2, recording parameters were identified that could be used to reliably elicit the Pb component of the AMLR. For Experiment 3, a 60-msec duration, 0.5-kHz tone burst was presented at rates of 1.1/sec and 0.5/sec. AMLR waveforms were recorded simultaneously from noninverting sites Fz (optimal noninverting location), as well as C3, C4, and Cz. These noninverting inputs were referenced to A1/A2 and NC. There were a total of two listening conditions, each replicated, for a total of four listening trials, that is, two listening trials at 1.1/sec and two listening trials at 0.5/sec.

Of 25 subjects, 7 adult subjects did not demonstrate a Pb and they were eliminated from the investigation. Suitable AMLR waveforms were collected from nine adults and nine children for Experiment 3. A series of one-way analyses of variance (ANOVAs) were conducted to test the effects of rate, electrode location, and age on the Pb component of the AMLR. Mean Pb latency recorded from Fz was 53.63 msec (SD = 4.16 msec) for adults and 61.93 msec (SD = 7.16)
for children. The effects of noninverting electrode location on Pb latency (C3, C4, Fz, and Cz in adults and Fz and Cz in children) were determined by conducting two separate one-way ANOVAs for the adult group and the child group. As demonstrated in the first panel of Figure 5, the location of the noninverting electrode had no significant effect on Pb latency when 0.5-kHz tone bursts were presented to adults at 0.5/sec (p = <.50) or at 1.1/sec (p = <.35). In children, however, statistically significant differences in Pb latency were found between Fz (61.93 msec) and Cz (59.47 msec) only at the 0.5/sec repetition rate (p = <.03).

The second panel of Figure 5 shows that the location of the noninverting electrode had a significant effect on Pb amplitude at repetition rates of 0.5/sec and 1.1/sec for both adults (p = <.01 and .0001) and children (p = <.0005 and .0025). A post hoc Scheffe F-test showed the large amplitudes at Fz to account for most of the effect (Fz = largest response). In adults, Pb amplitudes were larger for the 1.1/sec stimulus repetition rate compared with the 0.5/sec rate when recorded at Fz. No significant rate effect was demonstrated for Pb amplitude in children.

### Table 1 Detectability of the Pb Component

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Detectability of the Pb component for each subject during Experiment 3. + = recordable Pb component; = Pb was not recorded. A Pb component was obtained for each subject. The stimulus was a 500-Hz tone burst (duration 5-50-5 msec). DNT = did not test.

Pb amplitude was largest when scalp electrodes were paired with an NC inverting electrode than A1/A2 (p = <.0009). In children, the location of the inverting electrodes did not result in a significant difference (p = <.74) in Pb amplitude. The results from Experiment 3 showed that Pb latency is longer and amplitude significantly larger in children than in adults. Statistical analysis also confirmed that Pb is largest at Fz with an NC inverting electrode. Finally, results showed that a slow stimulus rate of 1.1/sec is ideal to evoke the Pb component of the AMLR.

### DISCUSSION

The detectability of the Pb component of the AMLR is highly dependent upon the stimulus and acquisition parameters used to record the response. Table 1 shows the detectability of Pb at two repetition rates and at four noninverting electrode sites for adults and children (+ indicates a recordable Pb). Note that, for each subject, a Pb component was detected. Results from the present study showed that Pb could be evoked consistently in adults and children by a longer duration, low-frequency tone burst presented at a slow repetition rate.

### Effects of Stimulus Parameters

Figure 6 shows examples of AMLR waveforms recorded with 5-msec stimuli during Experiment 1 (top) and 60-msec stimuli during Experiment 2 (bottom). The longer duration stimuli yielded a less noisy waveform and increased Pb amplitude than the shorter duration stimuli. Stimuli were presented at a rate of 1.1/sec. Noninverting electrodes were located at Fz and inverting electrodes at the earlobes (A1/A2).
Experiment 2 (bottom). For this study, the Pb waveforms generated with longer duration stimuli were larger than those generated with short duration stimuli. This finding is consistent with previous reports of larger Nb/Pb and N1/P2 amplitudes with increases in stimulus duration from 3 to 40 msec (Onishi and Davis, 1968; Lane et al, 1971). Increased volume of activity may provide one explanation for the observed improvement in signal-to-noise ratio and increased Pb amplitude with the longer tone bursts. As afferent activity ascends the central auditory nervous system (CANS) and diverges, neurons are activated that are sensitive to the specific duration of the tone burst. Slower, later responses such as the Pb are comprised of responses from neurons with slower response times in addition to those activated for the earlier on-responders (Davis et al, 1984). For example, Abeles and Goldstein (1972) identified and described four types of neurons that responded to a 100-msec tone burst in the cat cortex. One type remained activated for the duration of the stimulus, a second responded only to the onset of the stimulus, a third responded to the offset of the stimulus, and a fourth responded to both the onset and offset of the stimulus. Humans may have neurons with similar response characteristics that are responsible for the observed duration effects in the present study.

The effects of rise time on AERs may provide a second explanation for the observed duration effects in this study. When the rise time of the stimulus is too long, cortical activity disperses over time, resulting in a reduction in the magnitude of the signal-averaged response (Skinner and Jones, 1968; Lane et al, 1971). When the rise time and plateau of the stimulus are within the minimal temporal integration time of the evoked response, however, the integration of all of the activated cells (those with various response patterns) results in excitation from many axons and increases response amplitude.

With respect to stimulus duration, we may assume that the Pb is a slow cortical response that is similar to the N1 and P2 components of the auditory late response (ALR). The Pa component did not demonstrate larger amplitudes with longer stimulus durations (Lane et al, 1971; Skinner and Antinoro, 1971).

The second panel of Figure 3 shows the mean Pb amplitude during Experiments 1 and 2 for each stimulus type. Results from Experiment 2 revealed that stimulus type affected the recordability of the Pb component. A larger tracing was recorded with the 0.5-kHz tone burst than with the 4-kHz tone burst or click. Larger cortical response amplitudes for low-frequency stimuli have been previously reported (Davis and Zerlin, 1965; Jacobson et al, 1992). The tonotopic organization of the primary auditory cortex in humans may be one reason for this amplitude enhancement. Low-frequency neurons are located nearer to the surface of the cortex than are high-frequency neurons (Lauter et al, 1985). A second explanation could be related to evidence that an intense, low-frequency tone burst causes a spread of excitation into more basal regions of the cochlea, thereby increasing the number of neurons activated (Antinoro et al, 1969; Jacobson et al, 1992). This spread of excitation is less dramatic with a high-frequency stimulus or a click.

Confirming the findings of previous investigations, the present data showed that the Pb component is best evoked by very slow repetition rates (Erwin and Buchwald, 1986; Buchwald et al, 1989; Buchwald et al, 1991; Erwin et al, 1991). Experiment 2 revealed that with increases in stimulus rate above 1.1/sec, the Pb component decreases in amplitude and ultimately disappears (see Fig. 4). This rate effect was absent for the Pa component of the AMLR, which is not significantly affected by stimulus rate. A complete analysis of rate effects on the Pb in children was not possible since children did not participate in Experiment 2, where four different rates were evaluated. Our data suggests that the Pb behaves differently from the Pa component of the AMLR. We postulate that Pb arises from neurons that have a longer refractory time than those generating the Pa or the components of the ABR. The recovery cycle of Pb is more closely related to the slow, later components of the ALR.

Effects of Electrode Configuration

Statistical analysis showed a significant increase in Pb amplitude when recorded over Fz (see Fig. 5). The assumption of significant contributions to the Pb from the frontal lobe is consistent with the findings of Buchwald et al (1989), who suggested that Pb generation was largely related to cholinergic cells that coursed from the intralaminar thalamus to the forebrain. A temporal lobe generator source contributing to the Pb cannot be precluded, however. The appearance of voltage extrema in the frontal central scalp may result from dual temporal lobe dipole sources oriented toward the frontal poles.
In adults, the Pb often could be observed with noninverting electrodes at C3 and C4, although the amplitude was smaller than at Fz. This was not the case for children. Rarely was a well-formed Pb observed from C3 or C4 in this group. This observation may be due to less well-formed neural connections in children between subcortical generator sites of the Pb and the temporal lobes. In contrast, it has been reported (Stein and Kraus, 1988) that Pa can be recorded reliably in children in the 10- to 13-year age range.

The data from Experiment 3 showed that use of an NC inverting electrode input yielded significantly larger Pb amplitudes than use of A1/A2. This was expected based on previous reports on bioelectric contributions to an AER from inverting electrodes placed on the head (Lehtonen and Koivikko, 1971; Wolpaw and Wood, 1982; Erwin and Buchwald, 1986).

Effects of Age

Figure 5 shows that, for the present study, the latency and amplitude of the Pb component of the AMLR were influenced by the subjects' age. Longer Pb latencies and larger Pb amplitudes were observed among the children's waveforms. Age-related differences were further enhanced by electrode location and stimulus rate. There are several possible explanations. The long Pb latencies observed in children may be related to incomplete myelinization of the auditory pathway. Myelinization of the midbrain and cortical areas, as well as the corpus callosum, does not reach maturity until adolescence and can influence the latencies of later evoked potentials (Shah and Salamy, 1980; Salamy, 1984).

Incomplete development of synaptic connections may also contribute to longer Pb latencies and larger Pb amplitudes in children. At birth, cortical dendrites have very few branches and even fewer synaptic connections with other neurons. During the first year of life, however, these dendrites branch and spread exponentially connecting with at least 10,000 other cortical neurons (Musiek et al, 1988). Dendritic arborization continues as a child matures and begins to peak at 2 to 6 years from birth. At this time, there is a marked decrease in the number of connections due to an overpopulation of dendrites and a lack of sensory stimulation needed for the synaptic connection to survive (Kalil, 1989). This increase in dendritic arborization and cortical connections during the first years of life reportedly accounts for the findings from a study on the maturation of the ABR components and may help explain findings (Salamy et al, 1979). Salamy et al (1979) observed a steady increase in ABR wave IV/V amplitude, from birth up to early childhood. They reported a marked increase in IV/V amplitude followed by a sharp IV/V amplitude decrease at about 5 years and into adulthood (down to infant amplitude levels). This pattern was not demonstrated for any of the other components of the ABR. The results of the present study have suggested that Pb amplitude is larger in children. Since it is known that cortical responses reach maturity as late as adolescence, and since it is evident from Salamy et al (1979) that individual components of a waveform can mature independently, it is possible that the larger Pb amplitudes observed in our child population are a result of prolific dendritic arborization and an overabundance of synaptic connections that will decline in number during adulthood. Salamy et al (1979) also offered reduced skull impedance in children as another explanation for larger amplitudes.

Large amplitudes have been reported for both the Pa and the Pb component in elderly subjects when they are compared to waveforms of younger adults (Kelly-Ballweber and Dobie, 1984; Woods and Clayworth, 1986; Chambers and Griffiths, 1991). Chambers and Griffiths (1991) attributed much of the Pb amplitude enhancement demonstrated in their elderly population to an overall positive shift in the baseline. Woods and Clayworth (1986) suggested structural and neurochemical changes, or a reduction of inhibition in the thalamic reticular nucleus, to be responsible for the amplitude enlargement in the elderly. Recall that the Pb is thought to be largely generated from within the ascending reticular activating system, which includes the thalamic reticular nucleus (Buchwald et al, 1991).

Summary and Conclusions

The Pb component was detected in all adult and child subjects (see Table 1). It is important to note, however, that postauricular muscle artifact prevented five potential subjects from participating. Further note that no single set of stimulus or acquisition parameters produced the Pb component in all subjects. For example, in most subjects, a repetition rate of 1.1/sec was most successful in evoking a Pb component. In some cases, however, the Pb was recorded only at a rate of 0.5/sec. This suggests that the absolute refractory time of the generators of Pb
improved the signal-to-noise ratio of the Pb latencies and larger Pb amplitudes and improved the statistical power of the present results. A pre-experimental variable would have reduced the variability of the AMLR. The addition of intensity as an independent variable may have further improved the results. The influence of intensity on the early components of the AMLR (5-1500 Hz) was consistent with results from Thorton et al (1977) on the 90 dB HL presentation level, which is consistent with the results of Thorton et al (1977) on the 90 dB HL presentation level.

Another relevant acquisition factor affecting the detection of the Pb component is filter setting. Narrow filters can alter the AMLR waveform. Pb is large and robust when recorded with narrow filters. Pb component shifts in latency and decreases in amplitude (Scherg, 1982). Pb is large and robust when recorded with narrow filters. Pb component shifts in latency and decreases in amplitude (Scherg, 1982; Kavanagh and Domico, 1986).

In the present study, an all-female subject pool was used to enhance the homogeneity of the group. Gender differences have not been demonstrated for the AMLR and no significant waveform differences would have been expected in a male population.

The clinical usefulness of the Pb component in the field of audiology has received little attention. There are reports suggesting a diagnostic role for the Pb in the detection of disorders related to the arousal system, such as narcolepsy or disorders affecting the cholinergic system such as dementia, HIV infection, and Alzheimer’s disease (Buchwald et al, 1989, 1992; Erwin et al, 1991; Green et al, 1992; Boop et al, 1994; Schroeder et al, 1994). The primary finding of these studies has been a severely reduced Pb amplitude. Although these results seem promising, potential uses of the Pb as a neurodiagnostic tool in audiology requires additional study. The present series of experiments have shown that the Pb component can be absent in normal subjects under certain stimulus and acquisition conditions. In pathologic cases, therefore, it is important to ensure that Pb amplitude is reduced due to the pathology and not measurement conditions.

At the onset of this investigation, very specific questions were asked. Does stimulus type affect the recordability of the Pb? Yes, the Pb was only recorded at Cz and not at Fz.

Does stimulus rate have an effect on the recordability of the Pb? Yes, the Pb is best recorded at a noninverting electrode at Fz and an NC inverting electrode. Is the Pb the same in children and adults? No, children display longer Pb latencies and larger Pb amplitudes than adults. These age-related differences may be related to neural maturation.

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