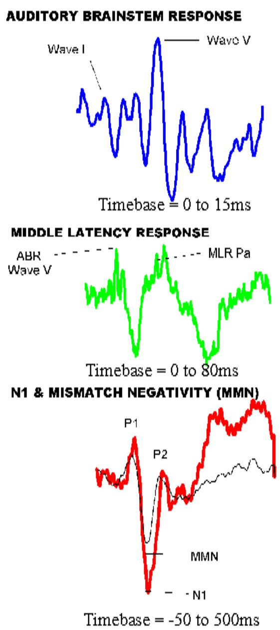
WHAT ARE AUDITORY EVOKED POTENTIALS?

Event-related potentials (ERPs) are brain responses time-locked to some "event". This event may be a sensory stimulus (such as a visual flash or an auditory sound), a mental event (such as recognition of a specified target stimulus), or the omission of a stimulus (such as an increased time gap between stimuli).

Auditory evoked potentials (AEPs) are a subclass of ERPs. For AEPs, the "event" is a sound. AEPs (and ERPs) are very small electrical voltage potentials originating from the brain recorded from the scalp in response to an auditory stimulus (such as different tones, speech sounds, etc.). The AEPs that are recorded from the top of the head originate from structures within the brain (e.g., the auditory cortex, the auditory brainstem structures, the auditory VIIIth cranial nerve). They are very low in voltage: from 2-10 microvolts for cortical AEPs to much less than 1 microvolt from the deeper brainstem structures. Their low voltage combined with relatively high background electrical noise requires the use of highly sensitive amplifiers and computer averaging equipment

The figure to the left shows several auditory ERPs/AEPs (plotted with positivity upwards). *To view/print a larger version, click right button with mouse pointer on figure, and "view image"... it may be a little slow.*



The **Auditory Brainstem Response** ("ABR"; 1.5-15 ms post stimulus), which originates in the VIIIth cranial nerve (waves I and II) and brainstem auditory structures (wave V: region of lateral lemniscus and inferior colliculus).

The **Middle Latency Response** ("MLR", 25-50 ms poststimulus), includes waves Na (negative wave following ABR wave V, originates in upper brainstem and/or auditory cortex) and Pa (positive wave at about 30 ms, originates in the auditory cortex bilaterally).

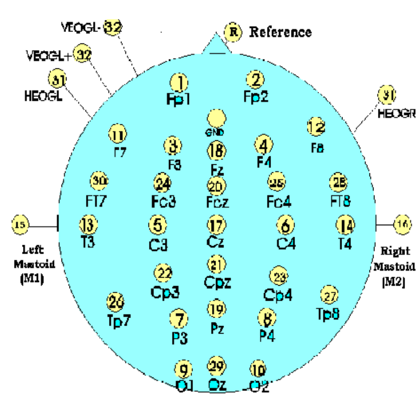
The "**Slow**" cortical auditory ERPs, which include the P1-N1-P2 sequence (50-200 ms poststimulus; originating in auditory cortex). N1 is the large negative wave that occurs about 80-100 ms after the stimulus. It originates primarily in the auditory cortex bilaterally. In the figure to the left, it is the large negative wave seen both in the response to the "standard" (black line) and the "deviant" (or oddball; red line) stimuli.

The "**Late**" cortical auditory ERPs, especially the **Mismatch Negativity** ("MMN"; beginning around the time of N1 *and* later). The MMN is a response reflecting detection by the brain of a *change* in the stimulus. In the figure to the left, the MMN is the increased negativity seen in the response to the deviant or change stimuli (red line), at about the time of N1 and a little later. Other "late" ERPs, not present in these waves, include "N2b" and "P3", which are cortical ERPs which are not specifically from auditory structures (see Cortical ERPs below).

A very different type of auditory evoked potential are the **Auditory Steady-State Responses (ASSR)**, which are responses to stimuli presented at rates such that the brain response to one stimulus is overlapped with responses to other stimuli. Responses to slower modulation rates (<20 Hz) appear to originate largely in *cortical* structures; responses to faster rates (70 Hz and higher) appear to reflect *brainstem* processes. ASSRs to rates >70-Hz show great promise for rapid assessment of hearing infants. The multiple auditory steady-state evoked response (MASTER) technique provides a rapid and objective assessment of hearing. The technique is based on the statistical evaluation of the electrophysiological responses evoked by multiple auditory tones presented simultaneously. These auditory steady-state responses can be recorded from the human scalp intermixed with the other activity in the electroencephalogram (EEG). A combination of averaging and frequency-analysis can distinguish the responses from the background EEG. MASTER typically presents 8 continuous tones (4 to each ear) and each tone is sinusoidally modulated at a unique frequency. The detection of the interwoven responses becomes possible after the electrophysiological data are transformed into the frequency domain. MASTER evaluates the responsiveness of the auditory system to several tonal frequencies in the same time it would take to record one response if each stimulus was presented separately. [Click here to see how this works!] Some of our our current research evaluates the clinical feasibility of MASTER for assessment of hearing in infants and in adults, as well as its possible tool for newborn hearing screening (click here for our recent papers on ASSRs).

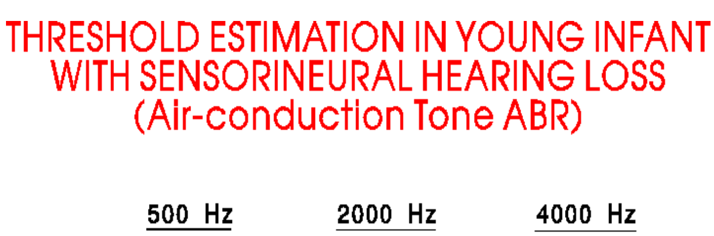
The AEPs in humans are typically recorded using small disk-like *electrodes* which are placed on various places on the head using either tape or water-soluble paste. The electrodes are non-invasive, they do not hurt, and they come off easily after completion of testing. The ABR and MLR and the ASSR are typically recorded using 3 or 4 electrodes; the SLOW and LATE cortical potentials often with many electrodes. In the HAPLAB, we currently record these later responses using 32-channel electrode caps *(see electrode cap figure to the right)*.

HAPLAB 32-CHANNEL ELECTROCAP LAYOUT

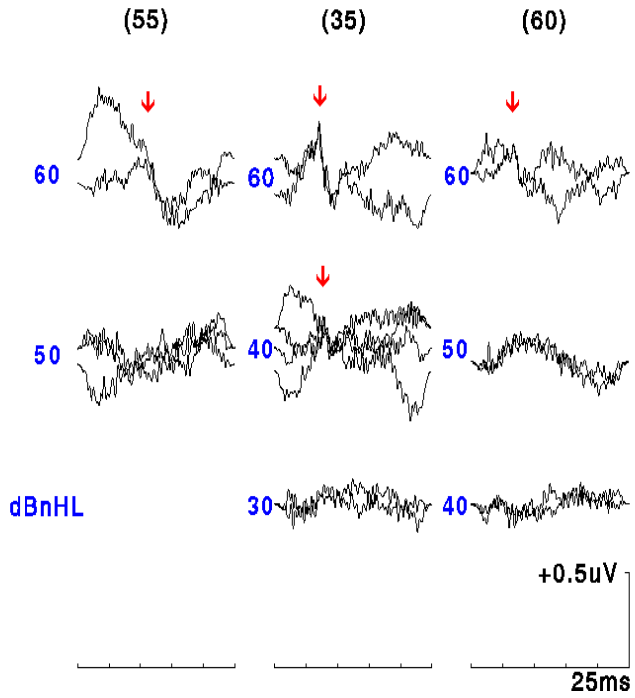


AUDITORY EVOKED POTENTIALS HAVE VERY IMPORTANT CLINICAL USES

- screening hearing in newborns
- assessment of hearing thresholds in infants identified as having a hearing loss
- validation of hearing threshold in some adults
- assessment of 8th nerve and auditory brainstem status in adults and children



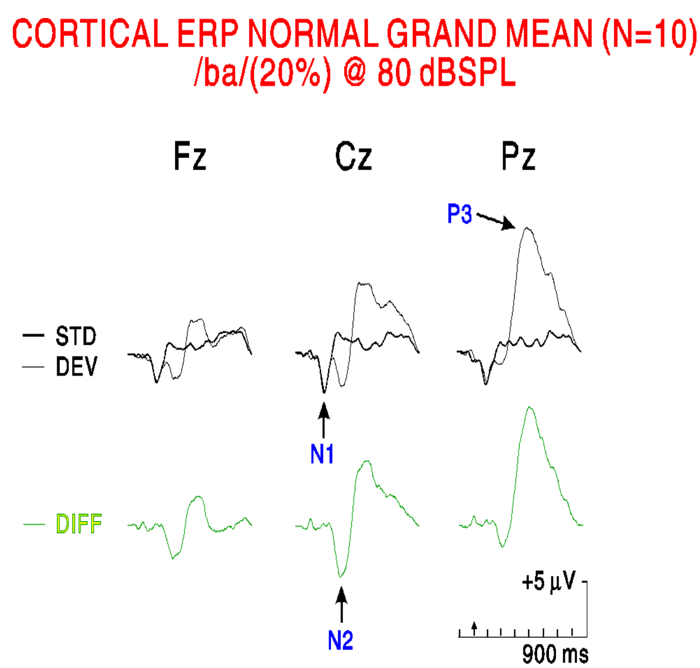
Currently, the brainstem responses are used for the clinical identification ("screening") and assessment of infants and young children with hearing loss *(see figure to the left)*, as well as in the neurophysiological assessment of pediatric and adult patients who may have lesions associated with their VIIIth nerve or



brainstem auditory pathways. Our research over the past 20 years has been instrumental in the application of the tone-evoked auditory brainstem response for estimation of the audiogram [for example, see our list of recent papers], and we continue this research in the HAPLAB. In the HAPLAB, we are also investigating the use of multiple auditory steady-state responses for screening and for diagnostic evaluation. *See the "Clinical ABR Frequently Asked Questions" (FAQ) in the HAPLAB's website.*

The slow cortical AEPs are used by some audiological centres for the objective assessment of hearing threshold in adult compensation cases (for example: The Worker's Compensation Board of British Columbia).

Later-occurring cortical ERPs *(for example, see figure to the right)* are likely to be a useful audiological tool in the near future. The cortical ERPs shown to the right are responses from individuals with normal hearing to the speech sound "/ba/". These responses were recorded in an active condition, where the subjects' task was to press a button whenever the stimulus changed to "/ba/". Responses seen are auditory N1, and the late responses N2b and P3b.



Some of our current research evaluates the use of cortical ERPs to assess a hearing- impaired child's detection and discrimination of speech sounds with and without the use of their prescribed hearing aids.

The cortical ERPs have considerable utility for research. They provide a *window* into the timing, sequence, strength, and anatomic location of brain processes involved with the perception of sounds. Current research underway concerns the use of cortical ERPs to understand the brain processes underlying basic hearing percepts such as loudness, pitch, and localisation, as well as those processes involves with speech perception.

Current research in the HAPLAB involves all of these auditory evoked/event-related potentials.

HAPLAB research concerning frequency selectivity/frequency specificity and auditory evoked potentials

HAPLAB research concerning Auditory Steady-State Responses (ASSRs)