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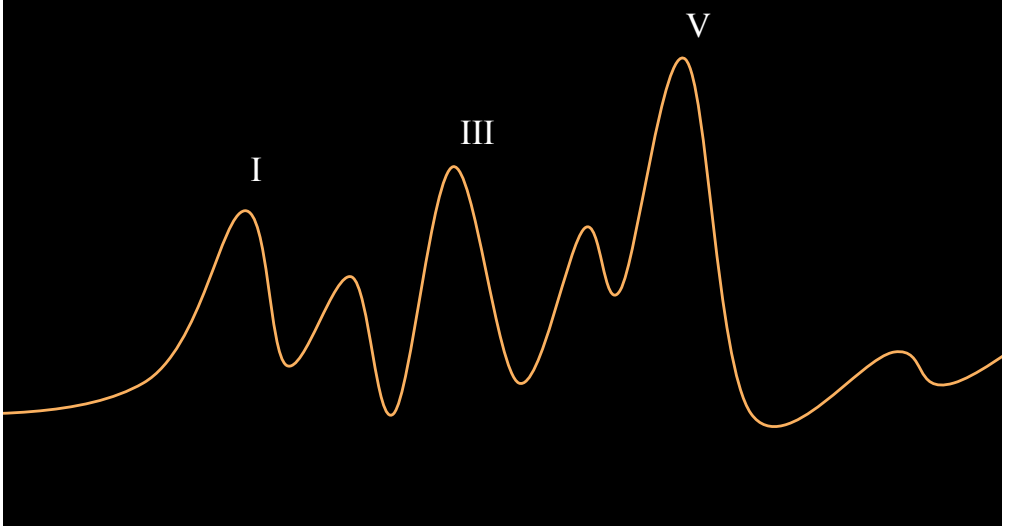
Quick Guide Series Book

The Basics of Auditory Evoked Potentials



There are many types of auditory evoked potentials. This quick guide will provide an overview of common tests and terminology

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This series of brief booklets was created to provide a basic understanding of Evoked Potential (EP) testing including:

- Basic anatomy and physiology for the purpose of understanding EPs
- Basic audiology for the purpose of understanding EPs
- Basic understanding of commonly used tests
- Troubleshooting techniques

It is no way a complete or detailed curriculum in evoked potentials but was developed to provide the reader with a basic understanding of evoked potentials.

The booklets will serve as a reference guide to review the types of tests that are offered in various EP systems, what they may be used for, how the tests may be conducted and what a normal test might look like. Troubleshooting techniques will also be discussed.

You'll find key words throughout the book. When you see a word or phrase that is followed by an asterisk (*), it is an indication that at the bottom of the page there is a definition or a longer description of the word or phrase.

When you see a symbol like this:  it means there is a quick guide, troubleshooting guide, or video available about this topic from Otometrics.

EP Basics

Here, you will learn the very basic premise of Evoked Potential testing, more specifically, Auditory Evoked Potential testing.

What is it?

Evoked Potentials (EP):

- Are electrical signals generated or produced by the nervous system
- Are "event related" meaning they occur because of the presence of something else
- Are useful in diagnosing a variety of neurologic and auditory disorders

Auditory Evoked Potentials (AEP):

- Arise from structures within the ear, nerve and brain
- Occur in response to brief stimulus, usually a click or tone burst/pip (this type of brief stimulus is required to elicit synchronous firing of the nerve fibers)

This means by placing electrodes on the skin, at specific locations, then stimulating the ears with brief sounds, the electrodes pick up the "potential" or neural firing. The EP system generates the stimulus, records and displays the response (waveform).

Why do we do it?

There are a variety of reasons a doctor or audiologist might use an EP system. Auditory Evoked Potential (AEP or EP) testing provides useful diagnostic information.

For example:

- In neurology, EP is used to diagnose and/or evaluate neural integrity, brainstem function in multiple sclerosis, monitor stroke and surgical patients and to differentiate between peripheral and central nervous system disorders.
- In audiology, EP testing is used to evaluate hearing loss, estimate auditory thresholds, diagnose retro-cochlear lesions, auditory processing disorders and differentiate between conductive and sensory-neural hearing loss.
- In pediatrics, EP testing is used to evaluate newborn and infant hearing loss, assess neural integrity, brainstem function as well as auditory processing disorders.

In all populations, EP testing is an important tool for use with difficult-to-assess populations including the severely handicapped, comatose, uncooperative and/or those otherwise unable to respond to more traditional audiometric measures.

How do we do it?

TESTER PREPARATION First and foremost being prepared is the key to obtaining the most information in the shortest amount of time. Preparation is everything from being sure the test environment is ready to being sure there is a sufficient supply of electrodes available. Consider the following:

Environment:

- Is it warm enough?
- Is the chair or bed comfortable?
- Double check that the preamplifier and transducer cables are not touching 
- Good electrical environment? Be prepared to check the mains! 

Necessities and Pretest:

- Extra electrodes and extra electrode leads
- Blanket/Pillow
- Prepare electrodes and insert phones/headphones
- Enter the patient demographics
- Listening Check

PATIENT PREPARATION By placing electrodes at certain locations on the head we record the tiny responses generated by the nervous system. Since these responses are generally very small, patient preparation is extremely important. Electrode sites must be scrubbed properly to get good electrode IMPEDANCE* in order to record these tiny neurologic responses.

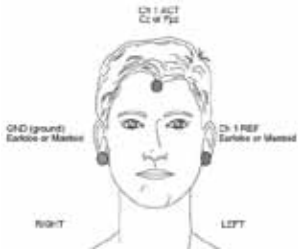
To apply an electrode to the skin:

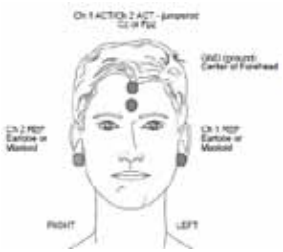
Clean electrode skin sites with an alcohol pad or other cleaning method.
Abrade skin with a mild abrasive solution such as NU-Prep or Prep Pad. Wipe off any excess solution.
Apply electrode paste to reusable electrodes. Disposable electrodes are ready to apply to prepared skin.
Apply the electrodes and secure with tape, if needed.

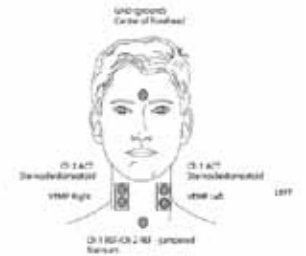
Impedance should be no higher than 5 kOHM and the difference between two electrodes should no greater than 2 kOHM.

HINT: See Otometrics document: Proper Placement of the CHARTR EP 200 Preamp
HINT: It is good practice to check the outlet grounding prior to installation with an inexpensive ground checker!
KEYWORD: Impedance - Contact to the skin at the response generator sites

Examples of common electrode montages







Protocol:	Protocol:	Protocol:
1 Channel 80dB (Switched)	2 Channel 80dB	VEMP 500Hz Tone Burst (with monitoring)
Connect:	**Connect:**	**Connect:**
High Forehead to Ch 1 ACT (+) Left Ear to Ch 1 REF (-) Right Ear to GND	High Forehead to Ch 1 ACT (+) jumpered to CH 2 ACT (+) Left Ear to Ch 1 REF (-) Right Ear to Ch 2 REF (-) Low Forehead to GND	High Forehead to GND Left SCM to Ch 1 ACT (+) Right SCM to Ch 2 ACT (+) Sternum to Ch 1 REF (-) jumpered to Ch 2 REF (-) In the LEFT VEMP and RIGHT VEMP receptacles on preamp are the monitoring electrodes. On the patient these are located below just below the ACTs.

ACT=ACTIVE also known as "+" or "noninverting"
REF=REFERENCE also known as "–"or "inverting"

In EP testing, we record from an active and a reference electrode. Measured potentials that are the same or common at each electrode (line noise) are cancelled out by "common mode rejection" (CMR). What we are left with is the response. This is another reason why good electrode impedance is important. Low and equal impedance is crucial for CMR to work effectively.

EP Tests

Here you will learn the basic information about common AEP tests offered by the Otometrics EP equipment. This section will provide a brief description of ABR, ECochG, ASSR, AMLR, ALR, P300 and VEMP.

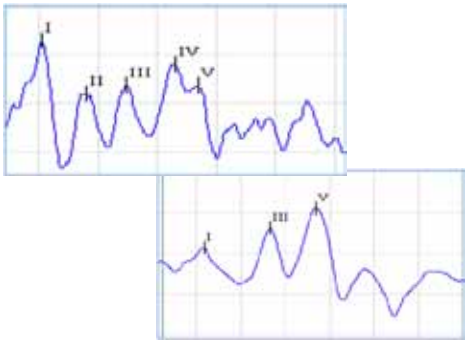
ABR

The Auditory Brainstem Response (ABR) arises from the 8th cranial nerve in response to brief auditory stimulus. The response is quantified by identifying peaks believed to be generated by specific sites along the auditory pathway. These peaks, based on research, should occur within defined time periods to be considered normal. If they fall outside of the normative data range the findings are consistent with abnormal auditory function. In addition to the LATENCY,* measures of amplitude are taken into consideration when evaluating the neural integrity.

ABR is typically used to determine hearing threshold levels for those unable to respond to traditional audiometric test methods. ABR is also used for assisting in retrocochlear pathology diagnosis by using a "rate study" and looking at the Interaural Wave V differences (IT-V).

When combined with Otoacoustic Emissions, ABR is used to identify immature and desynchronized auditory responses (known as Auditory Neuropathy Spectrum Disorder); which is gaining more and more attention in pediatric populations.

Electrodes are placed on the patient either for a 1 channel or a 2 channel recording. Using one of the transducers to present the stimulus (clicks or tonebursts), the ABR response is measured via the electrodes. The ABR response is very small (approximately .6µV) and requires amplification from the EP system to display the waveform on the monitor. The peaks for ABR are commonly known as waves I, II, III, IV and V. Even more common are simply waves I, III and V.



Above is the basic pattern of a typical adult ABR response to an 80dB click presented at a rate of 27.7. If we consider this a basic ABR pattern, later you will learn how it is changed when various parameters are altered.

KEYWORD: Latency - When referring to ABR, timing in milliseconds from the onset of the stimulus to the point of interest. HINT: A Quick Reference Guide for a 1 channel ABR test is available.

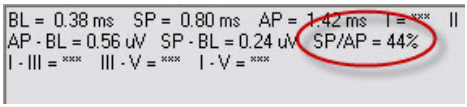
ECochG

The Electrocochleography test (ECochG) is a measure of the electrical activity in the cochlea. It is comprised of three different potentials: the cochlear microphonic (CM), the summating potential (SP) and the compound action potential (CAP). They are typically labeled Baseline (BL), summating potential (SP), and action potential (AP). Keep in mind that Wave I of the ABR is the actual firing of the auditory nerve - this is the AP of the ECochG. Wave I of the ABR and the AP of the ECochG are the same.

The ECochG can be thought of as a "close up" look of ABR Wave I. To measure cochlear potentials, surface electrodes are not sufficient. Gold foil tiptrodes, TM electrodes or transtympanic electrodes must be used.

This test has historically been used in the assessment of endolymphatic hydrops (Meniere's disease). More recent uses include electrically evoked CAPs (for cochlear implants), monitoring of superior canal dehiscence closure surgery and Auditory Neuropathy classifications.

Using one of the types of electrodes mentioned above the electrode sites are prepared. Keep in mind the impedance for these types of electrodes will be higher than skin-surface electrodes. Whether you choose to use a click or tone burst, be sure to select a slower rate. At higher rates the amplitude of AP decreases making it more difficult to identify. Typically, the test is run with alternating polarity to reduce stimulus artifact. Once the three points (BL, SP, AP) are marked, the SP/AP ratio is calculated and found in the waveform information box.



HINT: See booklet on Assessment of the Dizzy Patient with Evoked Potentials for more information on running the ECochG test

ASSR

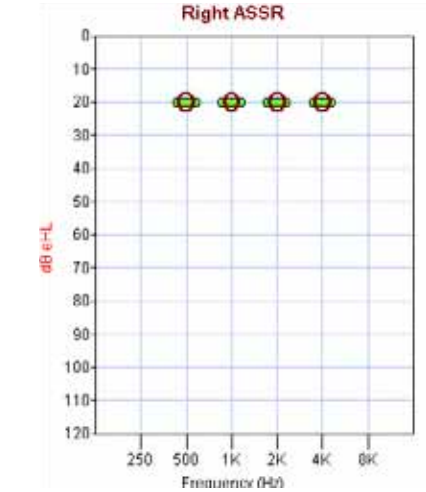
The Auditory Steady State Response (ASSR) is a test that can estimate hearing thresholds using a modulated pure tone as a stimulus. It allows for multiple frequencies to be tested simultaneously because of different modulation rates. Amplitude and frequency modulation is applied to the carrier frequency. The brain recognizes this modulation and a statistical detection method is applied to confirm a response. Each frequency for the left and right ear is given a different modulation rate which allows for this multiple frequency, simultaneous testing.

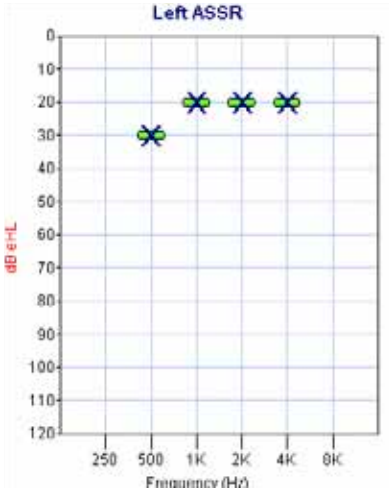
Since not all patients can participate in traditional audiometric testing, the ASSR is a fast, accurate method that can provide ear specific audiometric data in a short time. Some advantages of ASSR include:

- It can test at higher decibel levels than ABR
- It uses an objective statistical method to determine the presence or absence of a response
- It can test multiple frequencies simultaneously

Similar to ABR, the electrodes are applied, transducers are placed and the patient should be relaxed or asleep.

The operator can choose via the software whether to test one or multiple frequencies or one or both ears. Since the ASSR response is smaller than even the ABR response, it is even more important the patient be very quiet if not asleep. It is best to start the stimulus and hit pause to let the patient listen to the stimulus for a short time. Then hit reset to restart the collection. This assures that the patient is in the best state to start the test. The test will run automatically. When a response is found the next level will be tested. When the criterion is met, as set in the protocol, the test will stop. Correction factors may be applied to print an estimated audiogram.



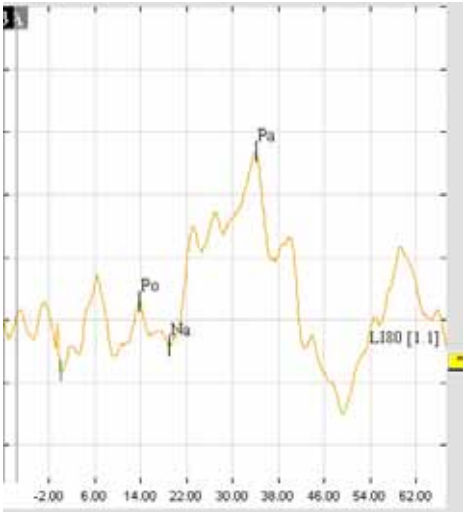


HINT: A Quick Reference Guide for ASSR is available

AMLR/ALR

Auditory Middle Latency Responses (AMLR or MLR) and Auditory Late Responses (ALR or LLR) are typically found between 12ms and 50ms and 50ms and 250ms, respectively, post stimulation. They both reflect responses of the upper brainstem (AMLR) and of the auditory cortex. The AMLR is very sensitive to subject age, arousal state, stimulus rate, filter settings and electrode montage. Each of these tests can provide information regarding the hearing levels of a patient. LLR can also provide information about nervous system abnormalities. Remember to keep the patient awake for these tests!

The AMLR and ALR are used for assessing hearing levels as well as central auditory processing disorders. These are some of the less common tests used and are typically done by more specialized operators.

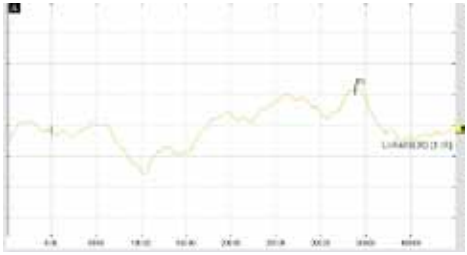


P300

The P300 is a test of cognitive function. This response originates in the auditory cortex and as indicated by its name, occurs approximately 300ms after the onset of the stimulus. This test is slightly different than the more common EP tests in that it is a response obtained using two stimuli; a frequent and an infrequent (sometimes called rare or deviant). The response is generated by the hippocampus which is where short term memory functions are stored.

This test is useful in assessing the language and processing areas of the brain. Like the MLR, it is not a commonly used test and is typically used by the more highly trained or advanced EP users.

For this test, the patient must be awake and alert. As mentioned earlier, two different stimuli are used. The patient is instructed to count the number of random infrequent stimuli. It is the attention to the infrequent stimulus that generates the response. Typically, the tones are of the same intensity but different frequency. Decreases in amplitude and/or increases in latency are indicative of cognitive disorders such as dementia, Alzheimer's etc.



VEMP

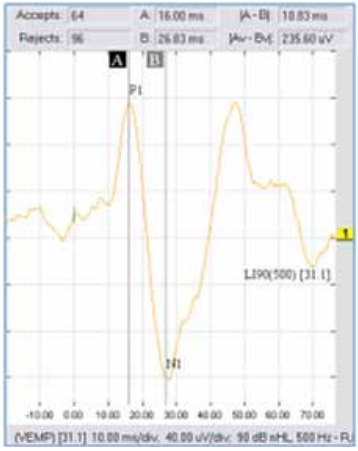
The Vestibular Evoked Myogenic Potentials (VEMP) are short latency electromyographic (EMG) potentials evoked in response to loud stimuli. This means they are recorded from a muscle and are mediated by the vestibular system.

The most common recording sites are the sternocleidomastoid (SCM) for the cervical VEMP (cVEMP) which is an INHIBITORY* response and the extraocular muscles for the ocular VEMP (oVEMP) which is an EXCITATORY* response. The VEMP test is another test in the assessment of the dizzy patient. It is believed possible to determine the status of the saccule and utricle by performing cVEMP and oVEMP.

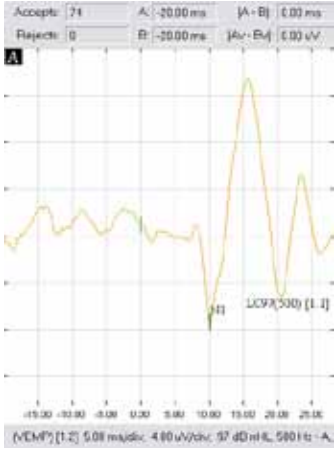
Both the cVEMP and oVEMP require 90dB+ stimulus. For cVEMP, electrodes are placed on the SCM and the patient is instructed to turn their head to the right or left or lift the head from a supine position to contract the SCM for the duration of the test. The cVEMP is an ipsilateral (same side as the stimulus) recording. EMG monitoring electrodes are placed just below the Active (+) electrodes. It is crucial to take into account the amount of EMG activity for accurate analysis. Normalizing the amplitudes of the cVEMP is done by dividing the raw amplitude by the average EMG level. If this is not considered, asymmetry ratios may be inaccurate. We expect to see a peak around 13ms and a trough around 23ms.

For oVEMP, the extraocular muscles are measured/recorded. Placing the ACT and REF electrodes just below the eyes, this contralateral (opposite side of the stimulus) recording is generated by asking the patient to look up or back about 25-30 degrees typically from a supine position. EMG monitoring is not required for this test since it is an excitatory response. We expect to see a negative trough around 10ms.

cVEMP



oVEMP



HINT: A Quick Reference Guide For VEMP is available and more information can be found in the booklet on Assessment of the Dizzy Patient with Evoked Potentials
KEYWORD: Inhibitory - The peak of the response is in reaction to periodic releases of the muscle during the contraction period
KEYWORD Excitatory - The response is in reaction to the actual contraction of the muscle

Notes

Notes

Auditory Evoked Potential testing can be an extremely comprehensive evaluation of the auditory system. From the pre-neural responses within cochlea to the responses of the auditory cortex, EP testing provides objective, quantifiable measures of the auditory pathway. Otometrics provides comprehensive, efficient and user friendly EP solutions in modular packages.

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