

# Recording Electroencephalogram (EEG) and Auditory Related Potentials (ARPs) in Humans

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This application note describes the use of PowerLab with a Bio Amp front-end, together with Scope software, to record EEG and Auditory related potentials (ARPs) to sound stimuli. The software package “Scope” provides a simple, user-friendly, yet powerful interface to the PowerLab recording unit for doing anything from simple demonstrations of EEG averaging (as in this application note) to complex research applications.

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## Introduction

For obvious reasons, we cannot investigate human neural activity using intracellular recording. Another way of investigating neural activity is through the use of external electrodes that measure electrical activity at the level of the scalp. This is known as the Electroencephalogram or EEG. The main advantage of this technique is that it allows non-invasive human studies to be conducted. The method is often referred to as open-field or far-field recording, because the site of the recording electrode on the scalp is receptive to electrical fields from many neurons and is not located at the internal site of any one particular neuron or groups of neurons. The following application note will aim to provide a basic introduction to the use of ERP techniques for teaching and human research.

## Signal Recording

### *The EEG*

When two electrodes are attached to the surface of the human scalp and connected to an amplifier, the output of the amplifier reveals variation in voltage over time. This variation in voltage is known as the EEG. The EEG is characterized by a mixed frequency, low amplitude signal that is considered to reflect the sum of many cortical neurons firing independently. The amplitude of the normal EEG can vary between approximately -100 and +100  $\mu\text{V}$ , and its frequency ranges up to about 40 Hz.

### *The Event Related Potential (ERP)*

If we present a stimulus to a subject while recording EEG, we can define a section (epoch) of the EEG that is time-related to the stimulus. For example, the epoch may begin at stimulus onset and end 1000 ms later. Within this epoch, there may be changes that are specifically related to the brain's response to the stimulus. These voltage changes are what constitute the ERP.

## The ERP Signal

The ERP is a set of voltage changes within a section of EEG that is time-related to a stimulus event. Generally, these changes are tiny in relation to the EEG waveform in which they are immersed. For this reason, it is necessary to employ techniques to extract this ERP waveform from the background EEG. The most commonly used technique for this is signal averaging. This involves recording a number of EEG epochs, time-related to repeated presentations of the same event. The EEG values for the same time points across epochs are then averaged to yield a single waveform. Background EEG unrelated to the stimulus will vary randomly and thus tend to average to zero. The remaining waveform after averaging should therefore mainly represent activity that has a specific temporal relationship to the stimulus event across presentations. This waveform is the average ERP.

## What Does the ERP Represent?

It is accepted that the ERP represents activity originating within the brain. However, we do not completely understand what electrical signals at the scalp are telling us about the brain. However, there is also a lot we have learned:

1. ERPs recorded from the scalp represent net electrical fields associated with the activity of a large populations of neurons.
2. The individual neurons that comprise such a population must be firing in parallel and synchronously if they are to produce fields that can be measured at the scalp.
3. ERP measurement is a valuable in clinical tool in diagnosing conditions of brain dysfunction such as multiple sclerosis, epilepsy, brain death, and sensory deafness.

With these points in mind, we must always be aware that there are numerous functionally important neural processes that cannot be detected using the ERP technique.

## ERP Components & Measurement

For the sake of classification, it has proved useful to distinguish between two classes of components of ERP that follow stimulus events.

### *1) 'Early', 'Endogeneous' or 'Sensory' Components*

Sensory stimuli in all modalities are associated with a series of deflections in the ERP that are related to the transmission of sensory information from the peripheral sensory system to the cortex. For example, after auditory stimuli, one can detect "brainstem responses" that have a latency less than 50 ms and, as their name implies, these deflections have been shown to correspond to the activation of various nuclei in the brainstem that are associated with the transmission of auditory information. These components are 'compulsory' in the sense that they will be observed in every individual unless the sensory systems in question are impaired. This has provided a useful tool in audiometry in distinguishing between biological and psychological deafness and the assessment of hearing thresholds.

### *2) 'Late', 'Slow', 'Endogenous', or 'Cognitive' Components*

These are the components that occur later in the ERP (from about 100 ms) and are thought to represent activity at the level of the cortex. Examples of such components

are the  $N_{100}$ ,  $N_{200}$ , and  $P_{300}$ . The number in subscript roughly denotes the time in milliseconds the component occurs. These components can vary as a function of such factors as attention, task relevance, and the nature of the processing required by the stimulus, and some can even be elicited by the absence of an external event, as, for example, when an expected stimulus does not occur.

Like most rules in science, the endogenous-exogenous distinction is an overgeneralization of the real state of affairs. Many early 'sensory' components have been shown to be modifiable by cognitive manipulations (e.g. attention) and many of the later 'cognitive' components have been shown to be influenced by physical attributes of the eliciting conditions (e.g. modality of the stimulus). Thus, those ERP components that occur roughly within the first 50 ms of stimulus presentation tend to be more exogenous, while those occurring later tend to be more endogenous. The following exercise is designed to investigate such manipulations of early and late components of the auditory related potential or ARP.

## Equipment

- any PowerLab unit with Scope software
- ML132 Bio Amp and MLA1340 Bio Amp cable
- MLA1090 Electrode cream
- 3 MLA WBT-9 EEG/EMG Recording electrodes
- sound amplifier with BNC leads & headphones
- 70% Alcohol preparation & Cotton wool
- surgical tape
- tissues
- water based marker

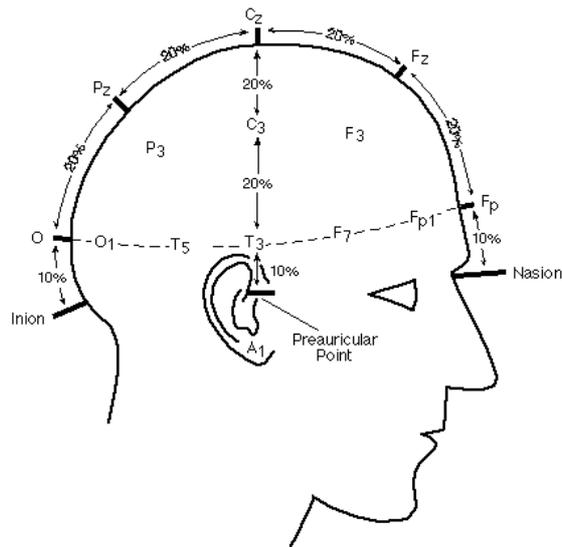
## Setting up the equipment

Ensure all equipment is turned off. Ensure the PowerLab is connected to your computer as outlined in the users manual. If necessary, connect the Bio Amp to the PowerLab unit as outlined in the users manual. Plug the BNC lead from sound amplifier directly into the positive and negative outputs from PowerLab unit. Plug the headphones into the amplifier. The PowerLab will generate the sound stimuli you need through the amplifier to the headphones.

## Method

### *Electrode Placement - The 10-20 System*

Electrode placement positions are mostly described with reference to the 10-20 system (Jasper, 1958). In this system, the location of an electrode is specified in terms of its proximity to particular regions of the cortex (F-frontal, C-central, P-parietal and O-occipital) and of its bilateral location (odd numbers for left side, even numbers for the right side and 'z' for midline). Thus, 'Pz' defines a midline electrode location over the parietal lobe, while 'F<sub>3</sub>' defines a left frontal site. Although these electrode descriptions refer to particular brain areas, it is important to note that activity recorded at any particular scalp site is not necessarily attributable to activity in brain regions in close proximity to that site. This is because the brain acts like a big conductor, meaning that electrical activity generated in one area can be detected at distant locations. See Figure A.



**Figure A.** The 10-20 system of electrode placement.

The electrical measurements taken when measuring EEG are known as *differential*. This is because the electrical signal measured is the difference between electrode sites. The electrode sites commonly used for ARP are A<sub>1 or 2</sub> and Cz. An earth is also connected to offset 50 Hz electrical interference. This electrode is often placed in the middle of the forehead.

1. Measure and mark the positions A<sub>1</sub> and Cz with a marker.
2. Place EEG paste in the electrode cups.
3. Clean each site with 70% alcohol solution, then fix the electrodes with medical tape to A<sub>1</sub>, Cz and the earth to the middle of the forehead.
4. Connect the subject to the patient lead. Ensure the earth electrode is plugged in the green socket marked “earth” on the patient lead.
5. Ask the subject to relax and avoid moving as much as possible.

## Safety

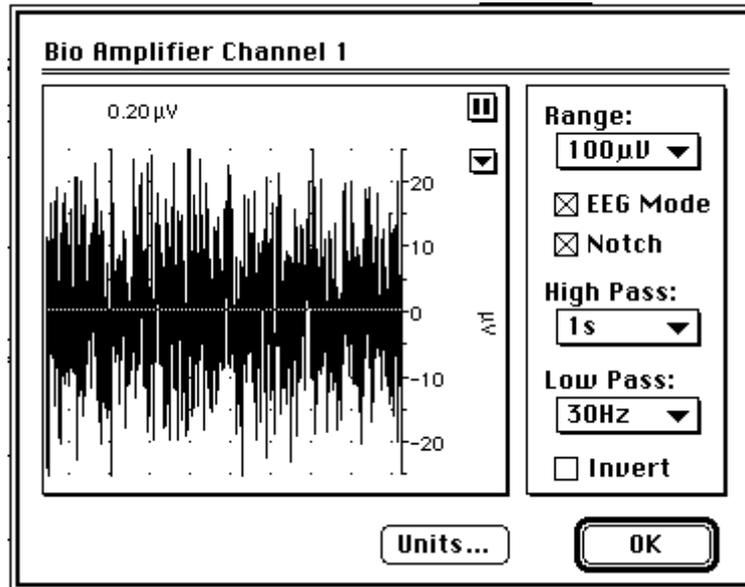
The Bio Amp is specially designed to have no direct electrical connection from the patient to ground. Thus, protecting your subject from any electrical faults. To maintain this patient-isolation, NEVER connect your subject to anything other than the patient lead, which must only be connected to the Bio Amp. The sound amplifier with headphones should not exceed a maximum output of 100 dB, and should not be delivered other than outlined in the following procedures. For guidelines regarding the safe delivery of auditory stimuli, consult appropriate international safety standards.

## Scope Settings

Turn on the sound amplifier, PowerLab unit and computer, in that order.

Open Scope.

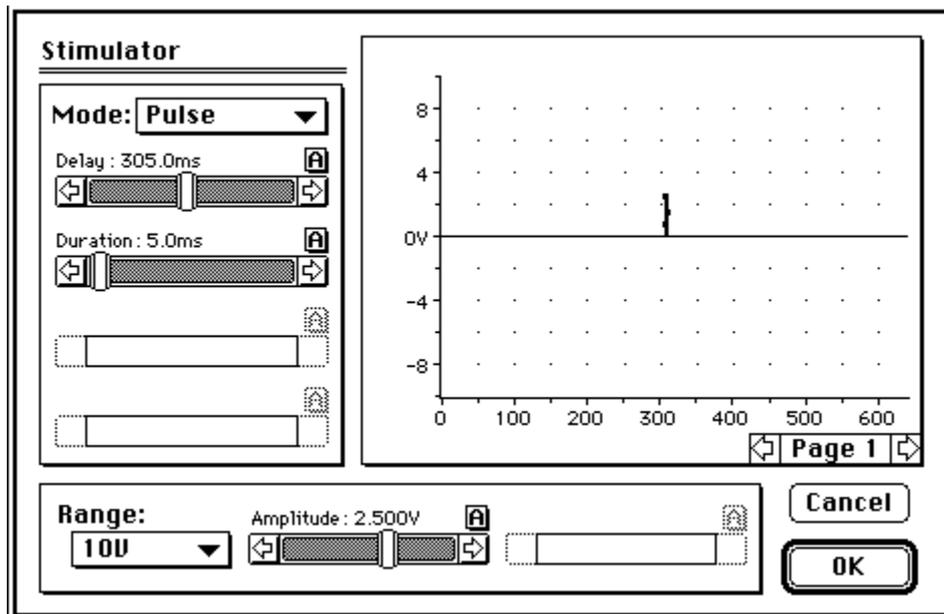
You now need to set up Scope for ARP recording using the Bio Amp. The recommended settings for the Bio Amp are shown in Figure 1a.



**Figure 1a.** The Bio Amplifier dialog box.

The Bio Amp should have a recording range of 100  $\mu\text{V}$ . Click the Bio Amp button. You are now looking at the ongoing EEG of your subject. Ensure the Notch filter and EEG Mode are selected. A recording range with High Pass at 1 sec and Low Pass at 60 Hz is best. However, if your signal is noisy (most likely due to a poor connection of electrodes to the subject), you can set the Low Pass filter to 30 Hz and still achieve a useful recording. The Time window is best set at 500 ms. There should be at least 256 samples within this window. With this setting the Time Base (samples/sec) will be 400 Hz.

We now need to set up Scope so we can deliver a sound stimulus to your subject by clicking the mouse of your computer and viewing this delivery on the Scope display with the resulting ARP waveform. The settings of the Stimulator are shown in Figure 1b.

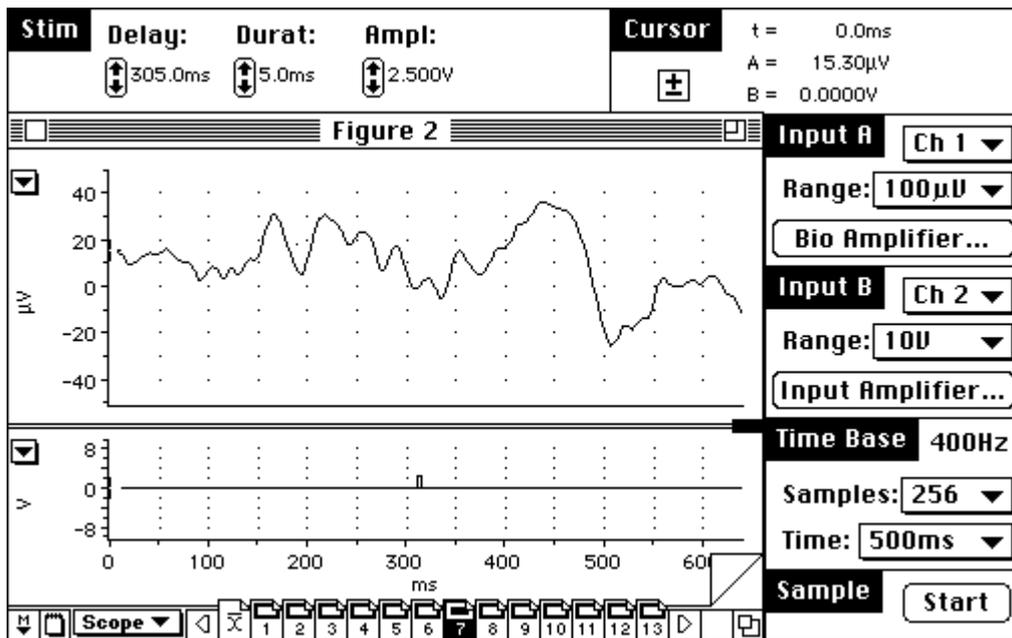


**Figure 1b.** The Stimulator dialog box.

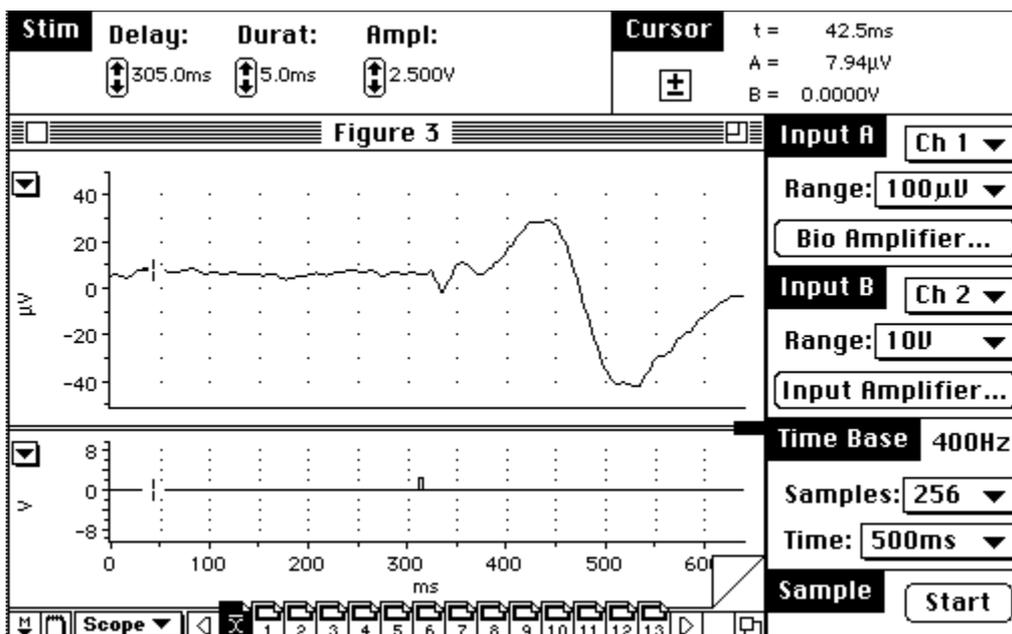
Under the Setup menu, click Stimulator. Set the Mode to Pulse. Set the Delay to 305 ms. Set the Duration to 5 ms. Amplitude and Range settings will depend on the requirements of the sound amplifier you use. Essentially, you want to deliver a loud pulse to your subject of no more than 100 dB. Click OK.

### **ARP to a Loud Random Auditory Stimulus**

1. Explain to the subject that randomly presented tones will be presented via the headphones. Ask the subject to remain as still and relaxed as possible.
2. Ask the subject to put the headphones on and close his/her eyes.
3. Observe the stimulus parameters in the Stim box, ensure these are the correct settings.
4. Click 'Start' on the computer and observe the associated ARP waveform.
5. Continue presenting the stimulus about 30 times, at random intervals (about 1-5 secs). Remember, the more samples, the accurate the averaged waveform will be.
6. Save the file.
7. Along the bottom of the screen in Scope, each stimulus presentation can be observed by clicking the appropriate page. Each individual presentation will not provide ideal data (See Figure 2), but this is the whole point! Only after collecting many samples and observing the averaged waveform, will a recognizable ARP emerge. This is very easily done under Scope by simply pressing the X page in the bottom corner of the screen. A waveform with early and late components, similar to that in Figure 3, should be seen.



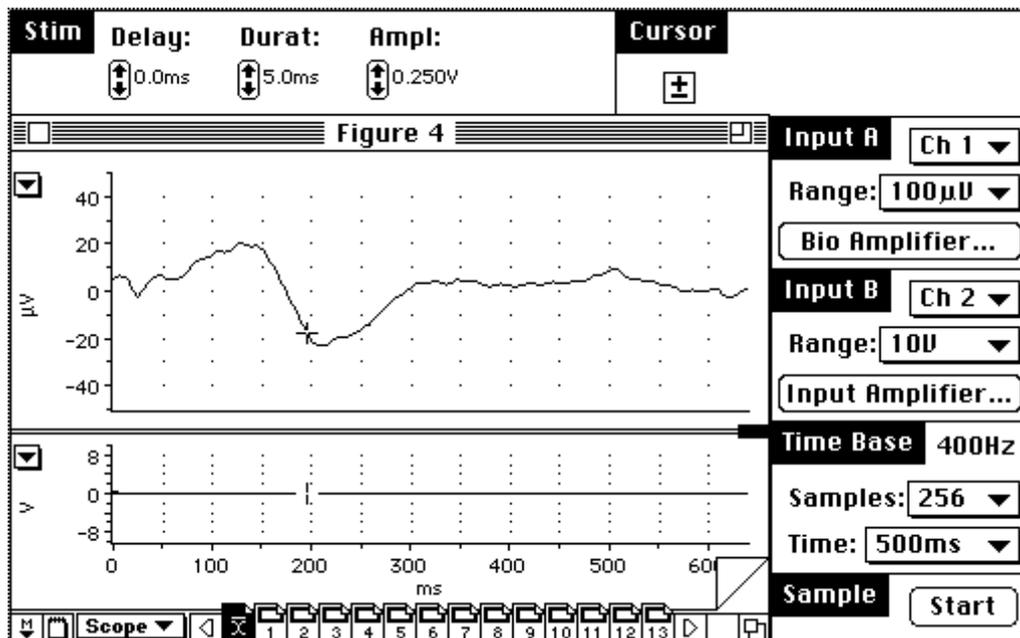
**Figure 2.** An ARP response to an individual stimulus presentation.



**Figure 3.** An average waveform showing a recognizable ARP response.

### ARP to a Soft Random Auditory Stimulus

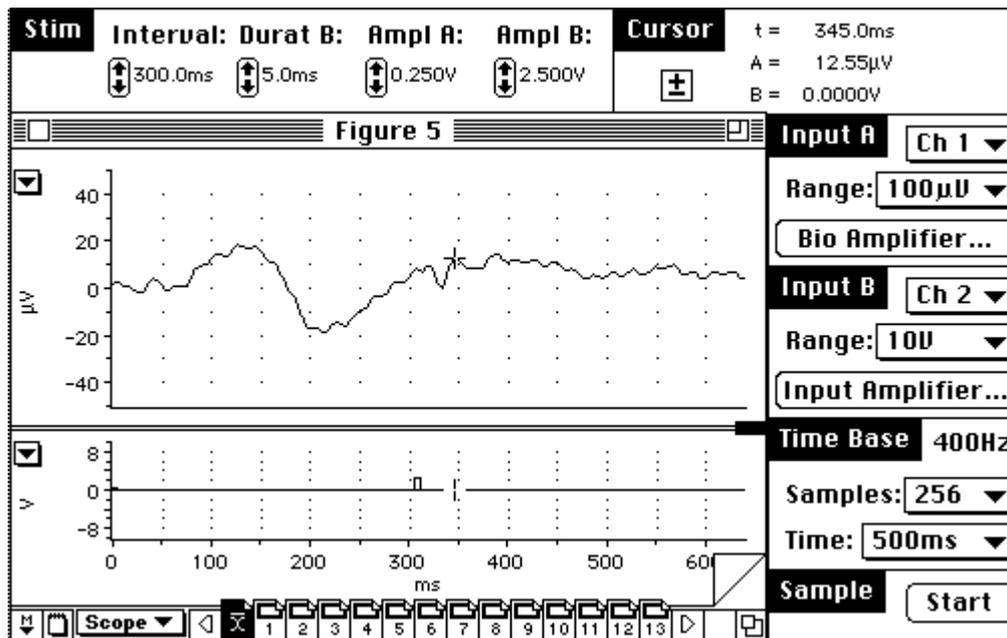
8. Under the Setup menu, open the Stimulator. Change the Delay setting to 0 ms. Amplitude and Range settings will depend on the requirements of the sound amplifier you use. Essentially, you want to deliver a soft pulse to your subject of no more than 50 dB. Click OK.
9. Explain to the subject that the procedure will be repeated using a softer tone.
10. Repeat the procedure outlined in steps 2-7 with the soft tone. A waveform with early and late components, similar to that in Figure 4, should emerge. Generally, the amplitude of the entire waveform should be less than that observed with the loud stimulus. The early components should be less prominent, as they are more stimulus bound.



**Figure 4.** An average ARP responses to a soft random auditory stimulus.

### ARP to a Loud Random Auditory Stimulus with a Soft Prepulse (PowerLab X00 Series Only)

11. Under the Setup menu, open the Stimulator. Change the Mode to Double. Set the Delay to 0 ms. Set Duration A and Duration B to 5 ms. Set the Interval to 300 ms. Set Amplitude of A the same as the soft stimulus in step 8. Set the Amplitude of B the same as the previous loud stimulus. Note that the same loud and soft stimuli, with the same delay and duration are being presented, but this time they are presented together.
12. Explain to the subject that two randomly presented tones will be presented to them, one soft one, followed shortly by a louder one.
13. Repeat the procedure outlined in steps 2-7, presenting both the soft and loud tones together in a random fashion. Two waveforms, one related to each stimulus, similar to that in Figure 5, should emerge. Generally, the first waveform related to the first stimulus should be very similar to that observed elicited in response to the soft stimulus alone (Figure 4). However, the second waveform related to the loud stimulus will look quite different to that elicited in response to the loud stimulus alone. The early components should not be very different, and should be larger than that of the earlier small stimulus, as they are more stimulus bound. The late components will most likely disappear (cf. Figure 5 to Figure 3). This is because late components of the ARP are more related to the cortical interpretation of stimuli. Thus are manipulated by psychological factors such as attention, task relevance and expectancy. The small prepulse tone often acts as a cue to the subject that the loud startling stimulus is coming. Hence, the loud stimulus is no longer unexpected (low amplitude late components), but it is still loud (large early components remain).



**Figure 5.** Average ARP responses to a soft and loud random auditory stimuli.

### Further Investigation

Try manipulating the interval between the loud pulse and soft prepulse. Can manipulating the prepulse-pulse interval affect the amplitude of the late components? What does randomizing the prepulse-pulse interval for each stimulus presentation do to the late components of the second stimulus?

### References

- Jasper, H.H. (1958) The ten-twenty electrode placement system of the International Federation. *Electroencephalography & Clinical Neurophysiology*, 10, 418-24.
- Rugg, M.D. & Coles, M.G.H. (1995) *Electrophysiology of mind: event-related brain potentials and cognition*. Oxford, New York: Oxford University Press.