

# Lab #11: Electroencephalography (EEG)

In this experiment you will observe basic patterns of brain electrical activity. Using electroencephalography, you will record brain wave activity from each member of your group, examine the effects of visual activity on alpha waves, and will attempt to demonstrate recently published observations about brain activity during gaps in unfamiliar and familiar musical songs.

## Background

The cerebral cortex contains huge numbers of neurons. Activity of these neurons is to some extent synchronized in regular firing rhythms ('brain waves'). Electrodes placed in pairs on the scalp can pick up variations in electrical potential that derive from this underlying cortical activity. EEG signals are affected by the state of arousal of the cerebral cortex, and show characteristic changes in different stages of sleep. EEG signals are also affected by stimulation from the external environment, and brainwaves can become entrained to external stimuli. EEG is also used in the diagnosis of epilepsies and the diagnosis of brain death in people that are in persistent vegetative states.

There are various types of brain waves that can be recorded using EEG. Here is a summary of those waves taken from the CrossRoads Institute (<http://www.crossroadsinstitute.org/learningcenter/qeeg/qeeg-brain-wave-info.html>), an organization devoted to understanding neurological disorders. Brain waves vary in terms of frequency (cycles per second, or Hz), and amplitude ( $\mu\text{V}$ ). The raw EEG has usually been described in terms of frequency bands named gamma (greater than 30 Hz), beta (13-30Hz), alpha (8-12 Hz), theta (4-8 Hz), and delta (less than 4 Hz). Our brain uses alpha waves for "active" intelligence. Alpha is a common state for the brain and occurs whenever a person is alert, but not actively processing information. They are strongest over the occipital (back of the head) cortex and also over frontal cortex. You can increase alpha waves by closing your eyes or deep breathing or decrease alpha waves by thinking or calculating. Often we find individuals who exhibit learning disabilities and attention problems having a deficiency of 13Hz activity in certain brain regions that effects the ability to easily perform sequencing tasks and math calculations.

Sometimes, brain activity can be abstract. One example of this is auditory imagery – the processing of auditory information in the absence of auditory stimulation. This is what happens when you have a song stuck in your head; your brain is playing the song to you and although it seems like you are hearing the song, there is no stimulus to the auditory cortex of your brain from your ears. In a recent article in the journal *Nature*, researchers demonstrated that the auditory cortex activity during gaps in music differed if the music was familiar or unfamiliar to the subject (see attached, Kraemer *et al.*, 2005). In class today, we will attempt to reproduce their findings, however, given that our experimental apparatus is much less sophisticated, we must use different analyses of brain activity to attempt this.

EEG recording is technically difficult, mainly because of the small size of the voltage signals (typically 50  $\mu\text{V}$  peak-to-peak). The signals are small because the recording electrodes are separated from the brain's surface by the scalp, the skull and a layer of cerebrospinal fluid. It is also important to use electrodes made of the right material, and to connect them properly. Even with these precautions, recordings may be spoiled by a range of unwanted interfering influences, known as 'artifacts.' In this laboratory you will record EEG activity with two electrodes (one on the side of the head, and one on the forehead) and a third ground (or earth)

electrode on the forehead to reduce electrical interference. In clinical EEG, it is usual to record many channels of activity from multiple recording electrodes placed in an array over the head.

## Setting up the experiment

The equipment required for these exercises is:

- the PowerLab and BioAmp with the Bio Amp cable, push-button switch
- three EEG recording electrodes
- electrode paste, abrasive pads
- adhesive tape, bobby pins
- a self-adhesive elastic bandage, folded if necessary to be 2–3 cm in width.
- source of music, headphones

## Subject preparation

The volunteer will need a place to lie down on his or her back. The supine position reduces interference and results in better measurements.

1. Set up the Bio Amp and a three lead EEG electrode. Attach the negative EEG electrode to the forehead of the volunteer with the following procedure:
  - a) With a ballpoint pen, draw a small cross on the forehead of the volunteer, just below the hairline and about 5 cm to the right of the midline.
  - b) Lightly abrade the skin at the cross with an abrasive pad.
  - c) Dab some electrode paste onto the marked cross with a finger. Press the concave (hollow) side of the electrode firmly into the paste. Secure with adhesive tape. Use a second piece of tape to secure the wire to the skin of the forehead.
4. Attach the ground EEG electrode to the other side of the forehead from the frontal electrode, as above.
5. Attach the positive EEG electrode to the lateral side of the head near where the auditory cortex should be (see attached documents).
  - a) Wrap a bandage firmly around the head to secure the electrodes. At the front it should pass between the eyebrows and the previously attached ground electrode. At the back, it should be at the level of the widest part of the skull.
  - b) Pull the bandage down by 1–2 cm at the side of the head. Part the hair of the exposed scalp, just a few cm from the midline, on the same side as the frontal electrode. It is important to part the hair as completely as possible so that the electrode makes the best possible contact with the skin of the subject. You can use bobby pins to help keep the hair parted.
  - c) With a ballpoint pen, draw a small mark on the scalp skin in the parting.
  - d) Lightly abrade the skin over the mark with an abrasive pad.
  - e) Squeeze some electrode paste onto your finger and then dab it onto the marked cross. Push the electrode gently against the scalp to ensure good contact. It is better to have too much paste than not enough.
  - g) Taking care not to move or dislodge the electrode, pull the bandage up so that it covers the electrode and holds it firmly in place. To prevent the electrode from being pulled off accidentally, attach the wire to the outside of the bandage with adhesive tape.

- i) Check again that the electrode is pressed against the marked region of the scalp. If necessary, carefully tighten the bandage.
6. Get the volunteer to lie in a comfortable position on his or her back, with the head turned so that none of the electrodes are disturbed or compressed.
7. Place the headphones onto the subject.
8. Check that all electrodes are properly connected before proceeding. The BioAmp should be plugged into input #1, and the push-button switch into input #2 on the PowerLab.
9. Turn on the computer and PowerLab, start Chart, and load the “EEG” settings file from the experiments gallery.

## Exercise 1: Recognizing artifacts

### Objectives

Learn to identify some of the artifacts that can contaminate an EEG record. There are three common causes of artifacts and it is important that you recognize them when they occur: (a) electromyographic (EMG) activity in muscles of the face or scalp; (b) mechanical movement of electrodes, especially the occipital one, whose attachment is made insecure by hair; and (c) potentials arising from rotation of the eyes, called electro-oculographic or EOG signals.

### Procedure

Everything should be set up as described in the general notes above. Remember to ensure that the volunteer is relaxed and lies still except when instructed otherwise.

1. Choose the Bio Amplifier... command from the Channel 1 (EEG) Channel Function pop-up menu. Ensure that the settings are as shown in Figure 1, and click OK.

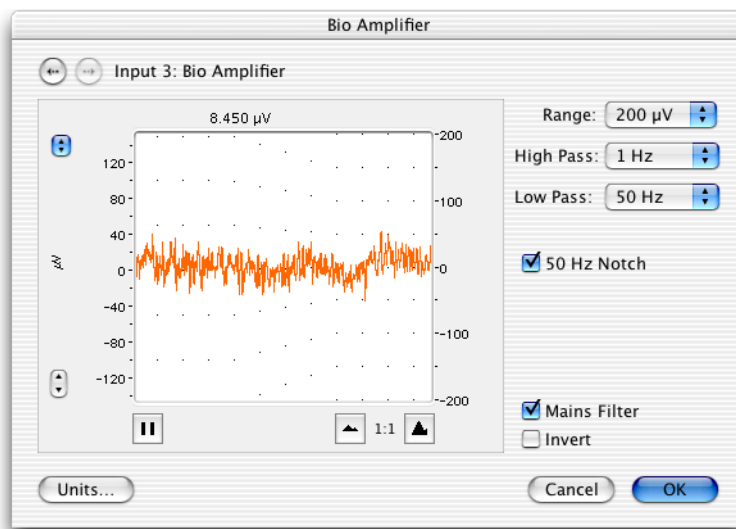


Figure 1. The Bio Amplifier dialog box, showing settings for EEG.

2. For the following treatments, use the push button to mark each blink/movement. Make sure to comment each treatment.
  - Record EEG while the volunteer blinks repeatedly.
  - Record EEG while the volunteer moves only their eyes alternately up and down, then left and right, in a repeated pattern.

- Record EEG while the volunteer moves their head gently, in a repeated pattern.

### Analysis

1. Examine the vertical scale at the left of the Chart window, and note the positions corresponding to  $+50 \mu\text{V}$  and  $-50 \mu\text{V}$ . True EEG signals rarely exceed these limits.
2. Use the scroll bar at the bottom of the Chart window to review the recordings. You will probably find large signals outside the  $\pm 50 \mu\text{V}$  range. Such large signals are the artifacts (eye movements, etc.). If you do not see such signals, check the electrode connections, and if necessary, remove and re-attach any connections that seem of dubious quality.

## Exercise 2: Alpha waves in the EEG

### Objectives

To examine alpha waves in the EEG, and the effect of opening the eyes.

### Procedure

1. Ensure that the subject is relaxed, lying quietly and has both eyes closed.
2. Start recording data. After about ten seconds, ask the subject to open both eyes. Mark eyes open.
3. After about ten seconds, ask the subject to shut both eyes, and mark this.
4. Repeat steps 2-3 several more times. Your EEG data should resemble Figure 2.

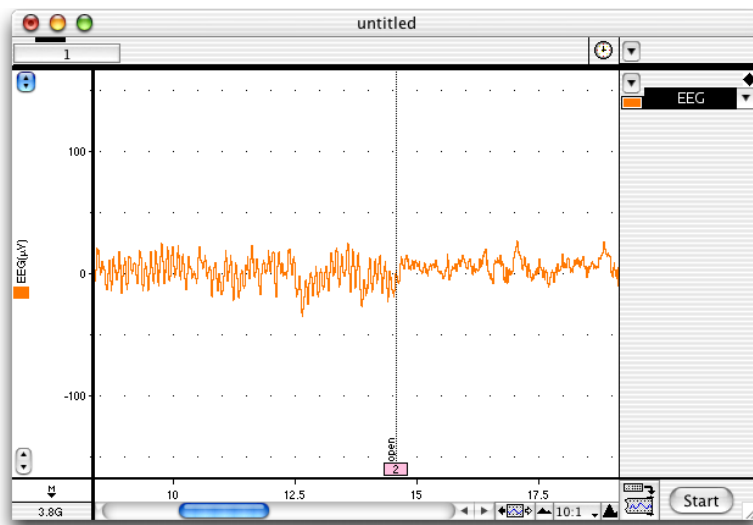


Figure 2. An EEG, viewed with a 10:1 horizontal compression. Alpha waves show as fine oscillations that stop when the eyes are opened (comment 2).

### Analysis

1. Use the View buttons in the Chart window to change the horizontal compression to 2:1. This stretches the data out, and makes it easier to see alpha wave activity.
2. Use the scroll bar to review those parts of your recording that were made with the subject's eyes shut, looking for alpha waves. You can recognize these by their amplitude (usually less than  $50 \mu\text{V}$ , although it can be quite variable from subject to subject) and their timing. Each cycle of an alpha wave should last almost exactly 0.1 s (Figure 3).

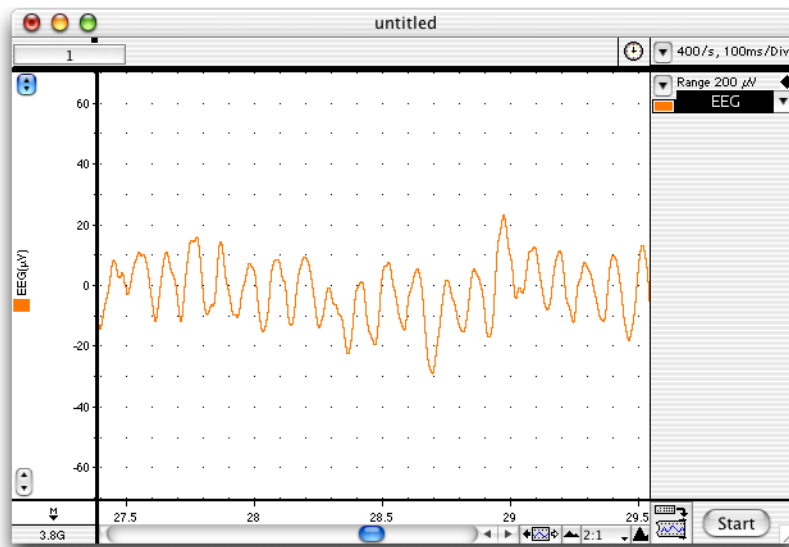


Figure 3. Alpha waves in the EEG, viewed with 2:1 horizontal compression — each alpha wave cycle occupies approximately 0.1 s.

3. If you cannot find any alpha waves, check that you are examining records taken with the subject's eyes shut. If you still cannot find signs of alpha activity, or if your records consist mainly of large-amplitude artifacts, you may need to re-position one or more electrodes. Note however that some otherwise normal subjects may not exhibit alpha wave activity. If this seems to be the case, then try a different subject.
4. Use the View buttons in the Chart window to change the horizontal compression to 10:1. Drag across several seconds' worth of the trace to select it, in an 'eyes shut' part of the recording. Then from the Window menu, choose Spectrum.
5. The Spectrum window displays the frequency content of the selected data (Figure 4). A mathematical technique known as the Fast Fourier Transform transforms the raw data into classes of waves of different frequency. The histogram shows the distribution of amplitudes (vertical axis) at different frequencies (horizontal axis, in Hz or cycles/sec).

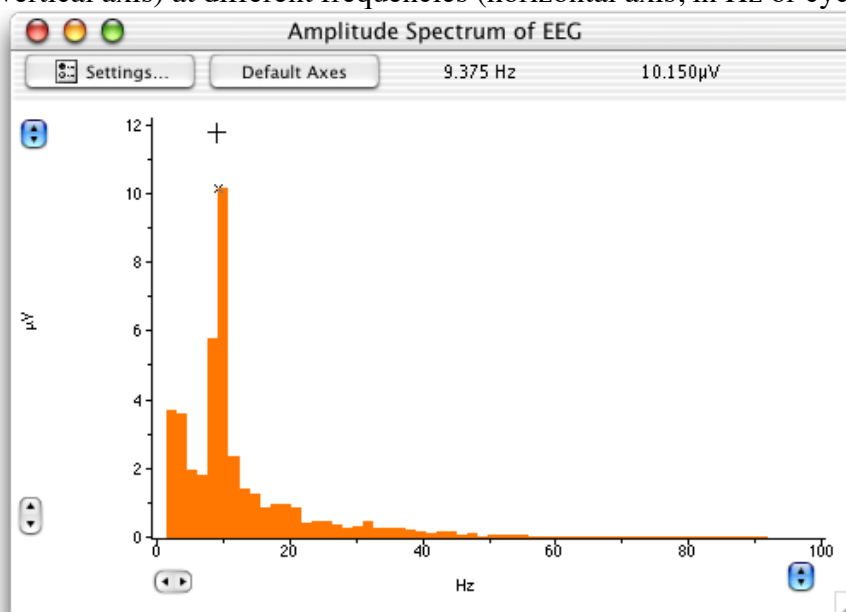


Figure 4. The spectrum of an EEG: the Waveform Cursor is placed over a prominent peak, showing alpha wave activity in the range 8–12 Hz.

6. Alpha activity shows up in the spectrum as a clear peak in the 8–12 Hz range. This is easiest to see if you expand the horizontal axis. Spectral analysis can show frequency components of a signal even if they are too small to be recognized directly in the Chart display.
7. Make a data selection of several seconds from an ‘eyes open’ part of the recording, and again display the spectrum. Note that the peak in the alpha frequency range (8–12 Hz) is small or absent.
8. The easiest way to compare the EEG spectrum is to export the data as a text file (File menu, Save As, Format: Spectrum Text) and then open multiple files in Microsoft Excel, combine the Y-data into one spreadsheet (the x-data should be the same from file-to-file) and plot them on one graph. Your TAs can show you how to do this if you get stuck.

## **Exercise 3: Auditory imagery**

### **Objectives**

Identification of auditory imagery by comparing EEGs in gaps in familiar songs vs. gaps in unfamiliar songs.

### **Procedure**

1. Select a three songs each from the computer’s iTunes library, or from a class member’s phone that the subject lists as familiar (a song that they know well) or unfamiliar (a song that they do not know). Queue up one of these songs.
2. Ensure that the subject is relaxed, lying quietly and has both eyes open.
3. Be sure that the headset is on and that the subject can hear the music playing through the headset at a level that is loud enough to be the dominant sounds heard by the subject.
4. The subject should pick a point on the ceiling and passively stare at it while they relax.
5. Start recording EEG signals while the music plays. At random points, mute the computer using the volume control. In general, you should alternate music and mute randomly, but several times per minute for each song. Do not play music for more than 45 seconds or mute for more than 20 seconds at a time. Indicate with the pushbutton whenever the music is muted.
6. Do step 5 for each of the six songs that you selected.
7. Select a selection of data for each song during the times that the music was on and was muted, and generate a EEG spectrum. Export each spectrum as a text file and use Excel to compare spectral patterns during music and mute periods of each song, and between familiar and unfamiliar songs.
8. Repeat exercises 1-3 for each member of your group.

## **Lab Report**

### **Results**

Include in your results a demonstration of good data versus artifact. For at least one of them, demonstrate what the artifact looks like with a graphic. You can describe in the text what the other artifacts look like. For good data, include an example of good alpha wave activity from one volunteer.

For the main results, present the frequency histograms for brainwave activity while listening to music and for periods of gaps while listening to familiar songs. Do this in the manner that best indicates any differences between the music and gap periods.

Do the same for the unfamiliar song treatment. Describe the important differences between treatments. Look carefully at all of these graphs. What do they show? State it simply and clearly in the text of the results. You can choose to present figures only for the most interesting results (if it's not interesting you can just describe what you saw in words without a figure).

## Questions to consider as you write the discussion

- 1) Did you observe auditory imagery? Describe the evidence that supports your conclusion.
- 2) Did the alpha wave frequency vary greatly between members of your group? What evidence do you have to support your conclusion?
- 3) Based on the information available to you in the experiment protocol, what is one potential explanation of why you are unable to record alpha waves when your eyes are open? What might this explain about how the brain works?
- 4) Did you observe error in your EEG recordings? Briefly explain their potential sources. Would these errors simply add noise or are they serious enough to potentially invalidate the results?
- 5) Can you think of any experimental refinements you could make to better assess auditory imagery using EEG?