Electroencephalography (EEG)

Aim
The aim of this session is for students to explore the electrical activity of the brain. In this laboratory class you will record electroencephalograms from *two volunteers*, look at interfering signals, and examine the effects of visual activity on alpha waves.

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. Electroencephalography is also used in the diagnosis of epilepsies and the diagnosis of brain death.
EEG recording is technically difficult, mainly because of the small size of the voltage signals (typically 50 µV 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. A specially designed amplifier, such as the Bio Amplifiers in the PowerLab 4/20T, is essential. 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 between a frontal electrode on the forehead, and an occipital electrode on the scalp at the back of the head (Figure 1). A third (ground or earth) electrode is also attached, to reduce electrical interference. In clinical EEG, it is usual to record many channels of activity from electrodes placed in an array over the head.

Setting up the experiment
Although this experiment and its associated settings file have been designed for and tested on a PowerLab 4/20T system, it can easily be adapted for other PowerLab systems (see Appendix B). This general set-up is used for both exercises in this experiment. The PowerLab should already be connected up to your computer and turned on. The equipment required for these exercises is:

- thePowerLab 4/20T [ML860]
- the Bio Amp cable (MLA2540, using three leads)
- three EEG/EMG recording electrodes [MLAWBT9]
- electrode cream or paste [MLA1090]
- an abrasive pad [MLA1092]
- adhesive tape
- a self-adhesive elastic bandage, folded if necessary to be 2–3 cm in width.

Safety
You should read any relevant safety notes in the hardware manuals before proceeding. The Bio Amp input of the PowerLab 4/20T has no direct electrical connection to ground (earth). This isolation protects against a wide range of possible electrical faults. To maintain isolation, don't connect the subject to electrical equipment other than the EEG/EMG recording leads (which in turn should connect only to the Bio Amp input through the supplied Bio Amp cable).

Connecting the equipment

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

1. Plug the Bio Amp cable into the Bio Amp socket on the PowerLab unit.
2. Connect the leads of three EEG/EMG recording electrodes to Earth, CH1 negative, and CH1 positive, on the Bio Amp cable.
3. Attach the frontal EEG/EMG electrode (see Figure 1).

    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 (or a similar position if the volunteer is bald).
    b) Lightly abrade the skin over the cross with an abrasive pad.
    c) If you have electrode cream, squeeze about two drops into the concave (hollow) side of the electrode. Place the electrode over the inked cross and fasten it to the surrounding skin with a 5–8 cm length of adhesive tape.
    d) If you have electrode paste, squeeze some onto your finger and then daub it onto the marked cross. Press the concave (hollow) side of the electrode firmly into the paste.
    e) To prevent the electrode from being pulled off accidentally, use another piece of tape to attach the wire securely to the skin of the forehead.

4. Attach the earth EEG/EMG electrode to the forehead of the volunteer in the same manner as the frontal electrode, but on other side of the midline (see Figure 1).
5. Attach the occipital EEG/EMG electrode (see Figure 1).

    a) Tie a bandage firmly around the head. At the front it should pass between the eyebrows and the previously attached frontal 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 back 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.
    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) If you have electrode cream, squeeze about two drops into the concave (hollow) side of the electrode.
    f) If you have electrode paste, squeeze some onto your finger and then daub it onto the marked cross.

g) Place the electrode over the ink mark, while keeping the hair parted. Push the electrode gently against the scalp to ensure good contact.
h) 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.
i) To prevent the electrode from being pulled off accidentally, attach the wire to the outside of the bandage with adhesive tape.
j) Check again that the electrode is pressed against the marked region of the scalp. If necessary, carefully tighten the bandage.

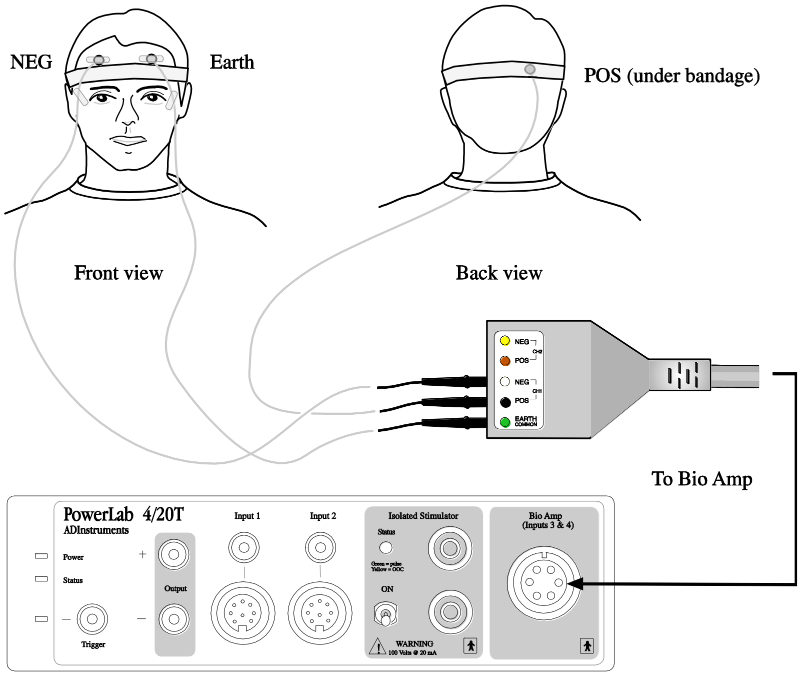

Figure 1.The equipment setup for this experiment, showing the placement of EEG electrodes on the head of the subject.

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. Check that all electrodes are properly connected to the volunteer and the Bio Amp cable before proceeding.

Exercise 1: Recognizing artifacts

Objectives

To examine some of the artifacts that can contaminate an EEG record.

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. Ensure that the settings are as shown in Figure 2, and click the OK button to return to the Chart window.

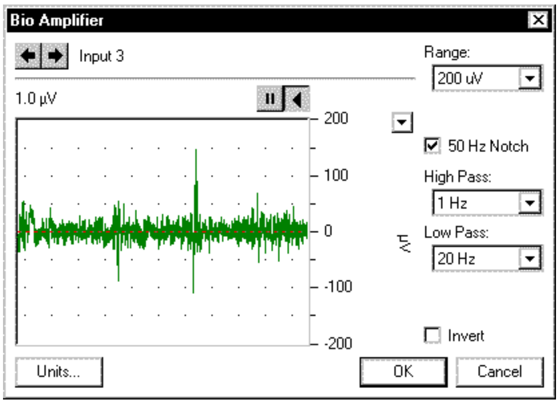

Figure 2.The Bio Amplifier dialog box, showing settings for EEG.

2. Click the Start button to start recording. Type 'blinking' and press the Return key to enter the comment. Ask the volunteer to blink repeatedly. After 5–10 seconds, click the Stop button.
3. Click the Start button to start recording. Type 'eye movements' and press the Return key to enter the comment. Ask the volunteer to direct the gaze alternately up and down, then left and right, in a repeated pattern. The volunteer should keep the head still during these movements. After 5–10 seconds, click the Stop button.
4. Click the Start button. Type 'head movements' and press the Return key to enter the comment. Ask the volunteer to shake his or her head gently, in a repeated pattern. After 5–10 seconds, click the Stop button.

Analysis

1. Examine the vertical scale at the left of the window, and note the positions corresponding to +50 µV and –50 µV. True EEG signals rarely exceed these limits. Use the drag scale to stretch the display vertically.
2. Use the scroll bar at the bottom of the Chart window to review the recordings. You will probably find large signals outside the ±50 µV range. Such large signals are artifacts. 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.

There are three common causes of artifacts such as those you have recorded:
(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.

Exercise 2: Alpha waves in the EEG

Objectives

To examine alpha waves (alpha rhythm) 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. Discard the recorded artifacts from Exercise 1, by choosing the New command from the File menu, and clicking the Don't Save button in the alert box that appears.
3. Click the Start button in the Chart window to start Chart recording.
4. Type 'open' on the keyboard to prepare a comment. After about ten seconds, ask the subject to open both eyes. Immediately press the Return key to enter the comment.
5. Type 'shut' to prepare a comment. After about ten seconds, ask the subject to shut both eyes. Immediately press the Return key to enter the comment.
6. Repeat steps 4 and 5 twice, to give you three sets of results. Your EEG data should resemble Figure 3.

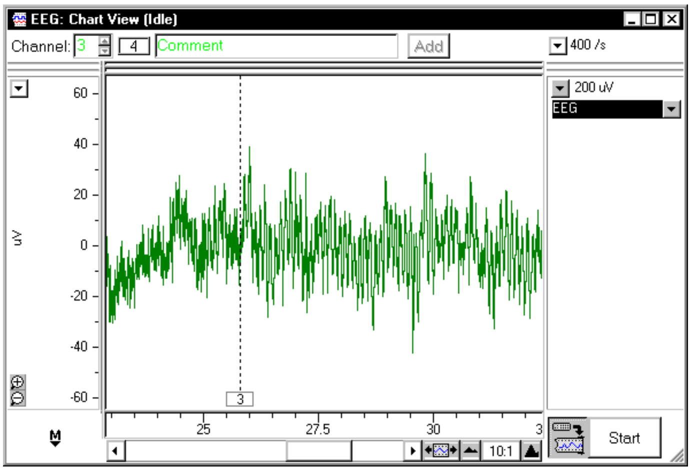

Figure 3. An EEG, viewed with a 10:1 horizontal compression — alpha waves show as fine oscillations after the eyes were shut at the comment.

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 recognise these by their amplitude (usually less than 50 µV, 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 4).
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-attach one or more electrodes, following the instructions given in 'Connecting the equipment' above. 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 Windows menu, choose Spectrum.

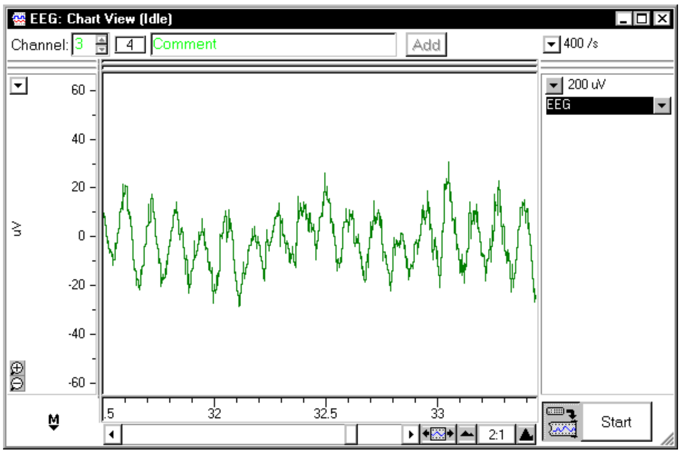

Figure 4. Alpha waves in the EEG, viewed with 2:1 horizontal compression — each alpha wave cycle occupies approximately 0.1 s.

5. The Spectrum window displays the frequency content of the selected data (Figure 5). A mathematical technique known as the Fast Fourier Transform is applied to the raw data. The result of this analysis is a list of amplitudes at different frequencies. The amplitudes (vertical axis) are plotted as a function of the frequency (horizontal axis).

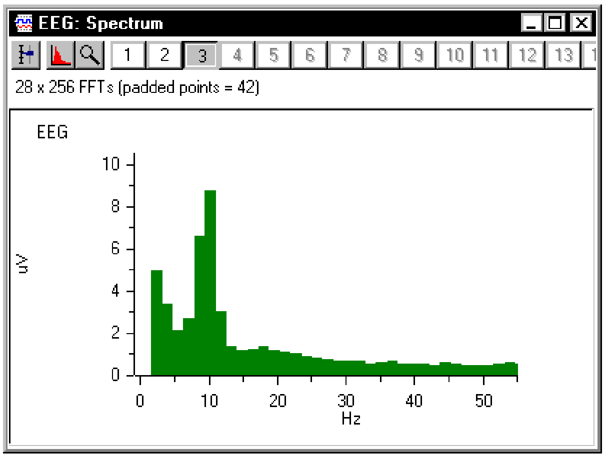

Figure 5. The spectrum of an EEG: the Waveform Cursor is placed over a prominent peak, showing alpha wave activity in the range 8–12 Hz.

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 display.
7. Make a data selection of several seconds from an 'eyes open' part of the recording, and again display the spectrum. Note that there is now no distinct peak in the alpha frequency range (8–12 Hz).

تمرین ضمیمه

تمرین ۳:

برنامه ای در محیط MATLAB بنویسید که انرژی موج α را در سیگنال EEG دریافت شده محاسبه نموده و بدین ترتیب وجود یا عدم وجود موج α را اعلام نماید. توجه نمائید که محدوده فرکانسی آلفا ۸ تا ۱۳ هرتز است.

Study Questions

Explain different components of an electroencephalogram, and how they relate to brain activities. What is the frequency range of each component?
Explain briefly what you expect to learn from this experiment.
Briefly describe the techniques you will use to measure EEG and its components.

1. What are the artifacts that can contaminate an EEG signal? How can we remove them?
2. How do we extract different components of an EEG signal and their spectrums?
3. What will happen to the EEG signal and its components if you do a heavy calculation for 5 minutes with closed eyes?
4. How the rhythm of the EEG signal will change if your subject during experiment 2 falls sleep?
5. Explain 3 applications of EEG signal and its different components (rhythm).