Electroencephalography (EEG)

The aim of this session is to provide an introduction to the electroencephalogram and to explore the electrical activity of the brain. In this laboratory class you will record electroencephalograms from a volunteer, look at interfering signals, and examine the effects of visual activity on alpha waves.

Background

The cerebral cortex contains large 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 Amplifier front-end, 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 with two electrodes: a frontal electrode on the forehead, and an occipital electrode on the scalp at the back of the head

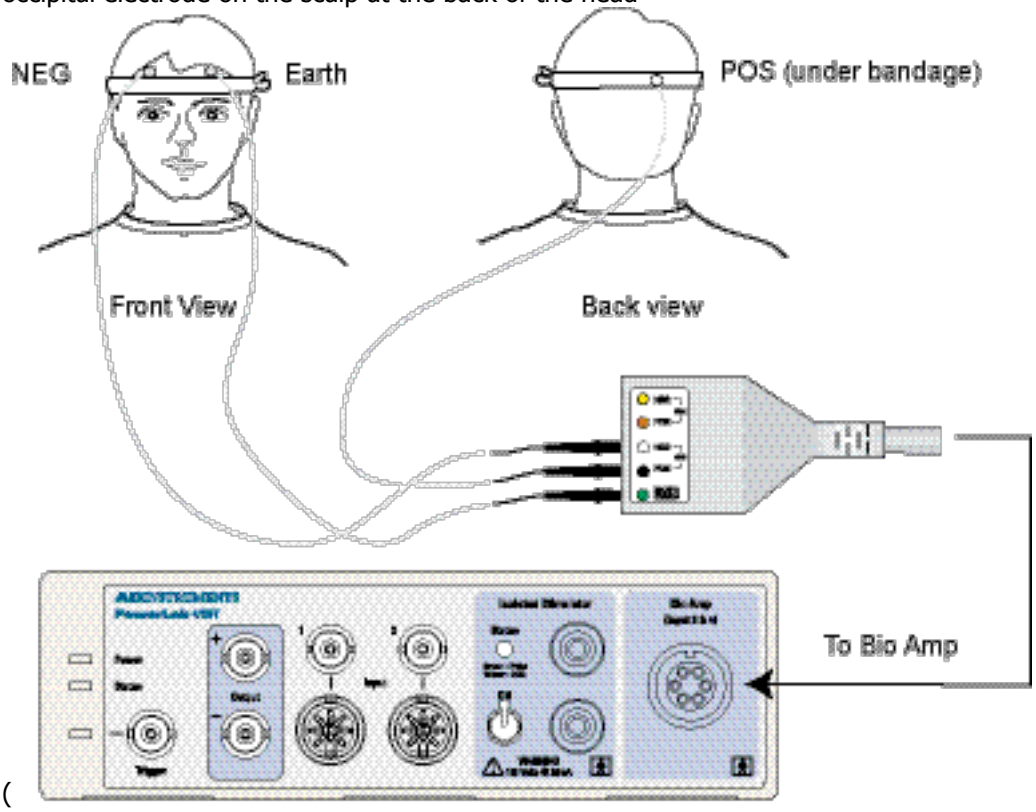

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Figure *1*). A third (ground or earth) electrode is also attached, to reduce electrical interference. In clinical EEG, it is usual to record many channels of activity from multiple recording electrodes placed in an array over the head.

Setup and Required Equipment

The experiment has been designed for and tested on a PowerLab 4/25T system, although it can easily be adapted for other PowerLab systems.

A Computer system
Chart software
PowerLab (with built-in Bio Amp or PowerLab and Bio Amp front-end)
Five-lead Shielded Bio Amp Cable & snap-connect Shielded Lead Wires
EEG Flat Electrodes
Electrode cream or electrode paste
Alcohol swabs (70% ethanol on cotton wool or paper tissue); optional
Ballpoint pen
Abrasive pads/gel
adhesive tape
a self-adhesive elastic bandage, folded if necessary to be 2–3 cm in width.

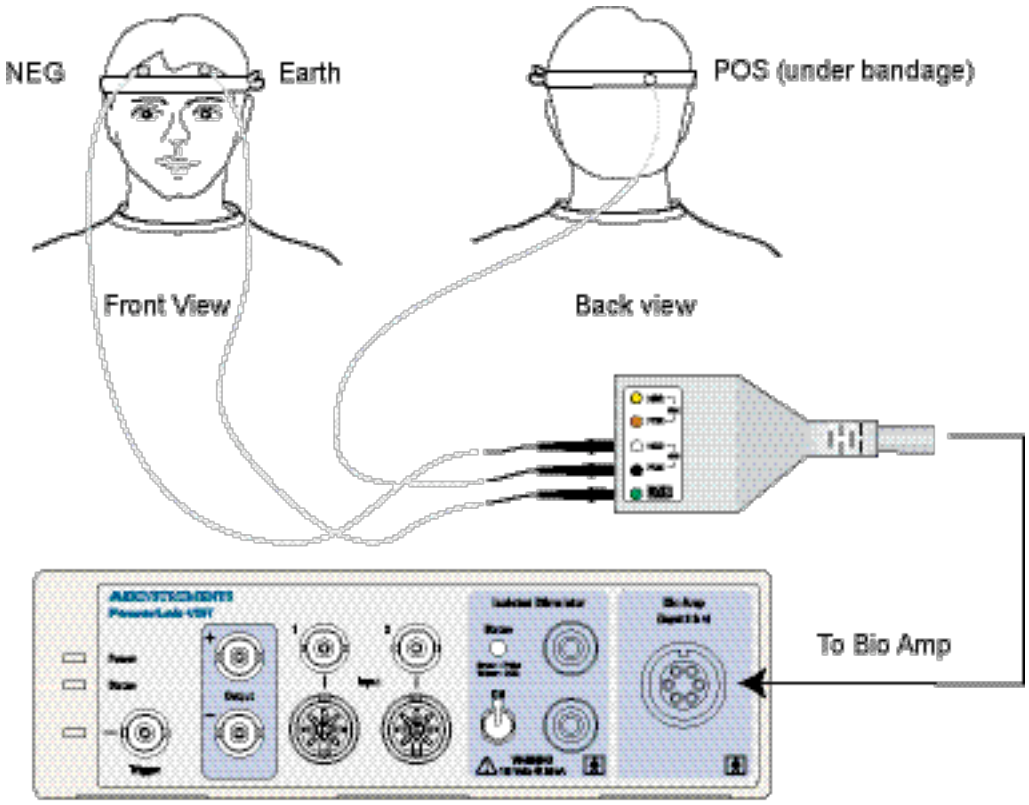


Figure 1. The equipment setup for this experiment, showing the placement of EEG Flat electrodes on the head of the subject.

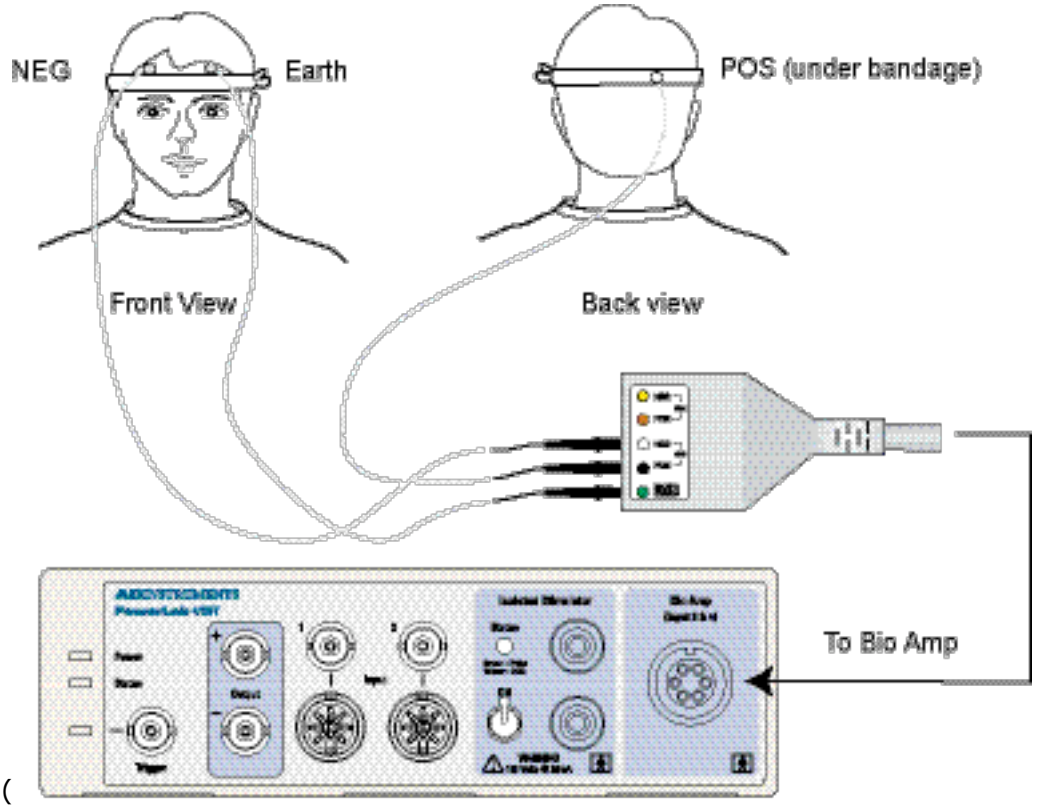
Subject preparation

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

1. Plug the Bio Amp cable into the Bio Amp.

2. Connect the leads of three EEG Flat electrodes to Earth, CH1 negative and CH1 positive, on the Bio Amp cable.

3. Attach the frontal EEG Flat electrode



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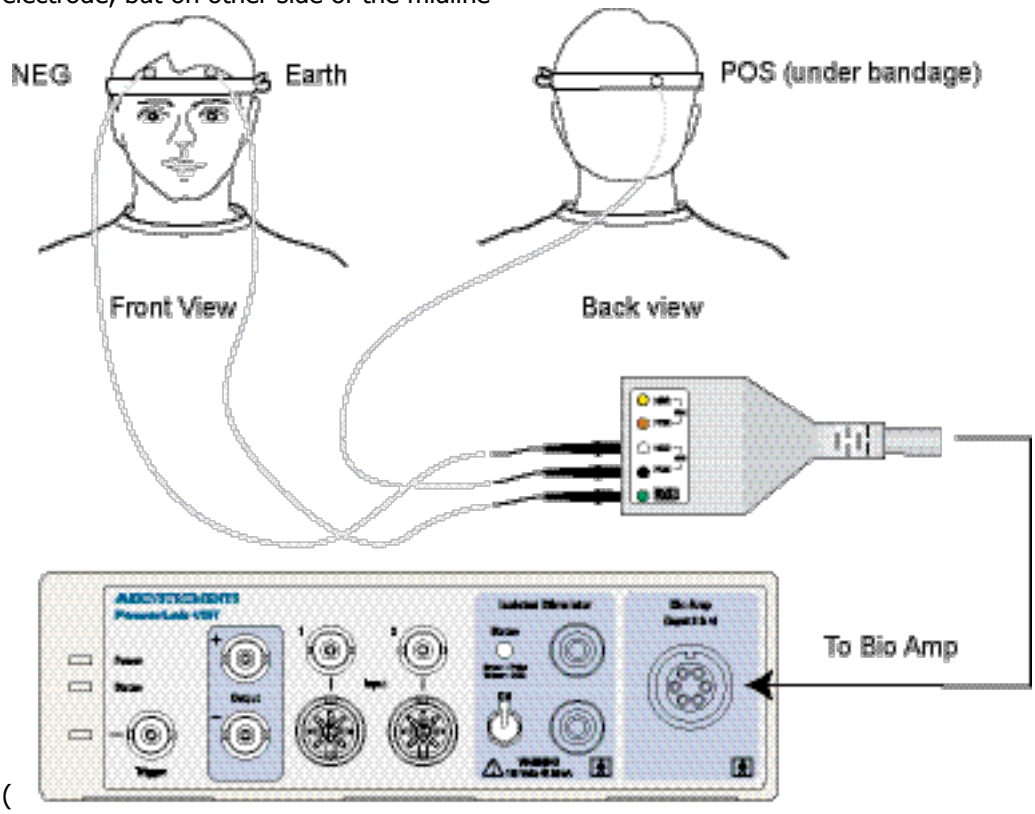
4. Figure *1*).

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/gel.
c) If using electrode cream, squeeze about two drops into the concave (hollow) side of the electrode. If using 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.
d) Place the electrode over the inked cross and fasten it to the surrounding skin with a 5–8 cm length of adhesive tape.
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.

5. Attach the earth EEG Flat electrode to the forehead of the volunteer in the same manner as the frontal electrode, but on other side of the midline



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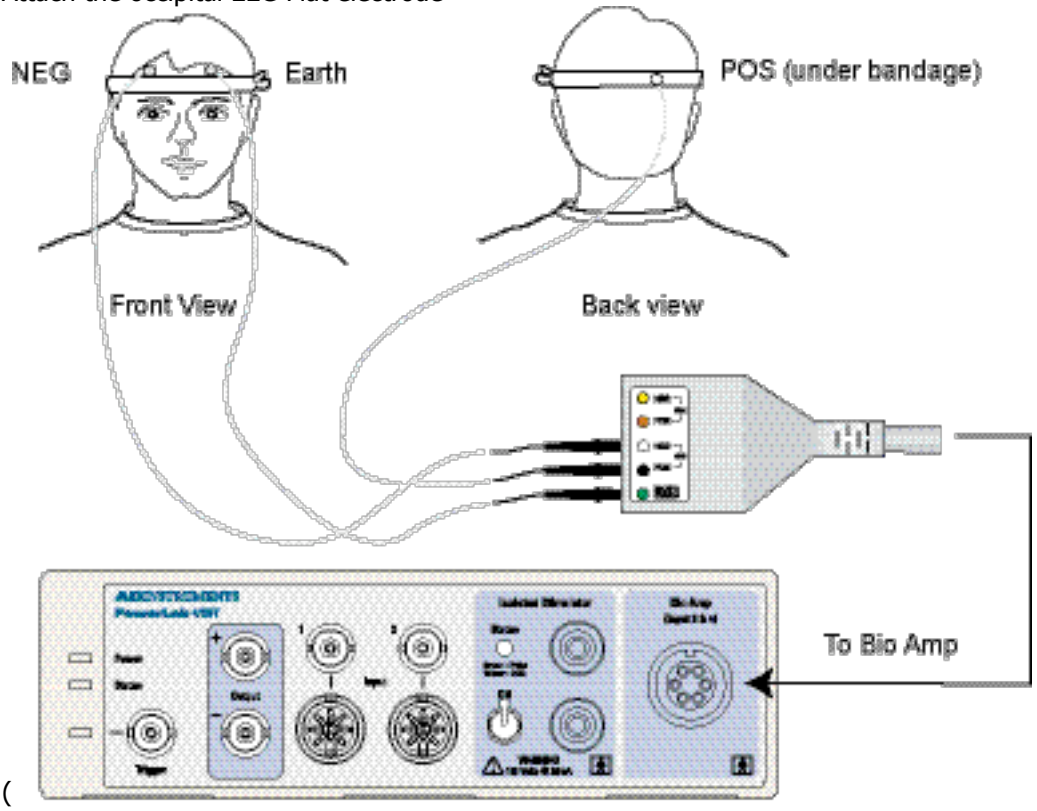
6. Figure *1*).

7. Attach the occipital EEG Flat electrode



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8. 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/gel.

e) If you are using electrode cream, squeeze about two drops into the concave (hollow) side of the electrode.

If using electrode paste, squeeze some onto your finger and then daub it onto the marked cross.

f) Place the electrode over the ink mark, while keeping the hair parted. Push the electrode gently against the scalp to ensure good contact.

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.

h) 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.

9. Get the volunteer to lie in a comfortable position on their back, with the head turned so that none of the electrodes are disturbed or compressed.

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

Starting the software

To set up recording for this experiment, load a settings file from the Experiments Gallery.

1. Locate Chart on the computer and start the software in the usual way. If the Experiments Gallery dialog does not appear in front of the Chart window, choose the Experiments Gallery… command from the File menu.

2. In the Experiments Gallery dialog, select this experiment, Electroencephalography in the left-hand list. Select the "EEG Settings" file in the right-hand list, then click the Open button to apply those settings.

3. After a short time, the Chart window on the computer screen should be set up for the experiment. Channels 1 and 2 are hidden at the top; Channel 3 occupies most of the display and is labeled 'EEG'.

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. Choose the Bio Amplifier… command from the Channel 3 (EEG) Channel Function pop-up menu. Ensure that the settings are as shown in Figure 3, and click the OK button to return to the Chart window.

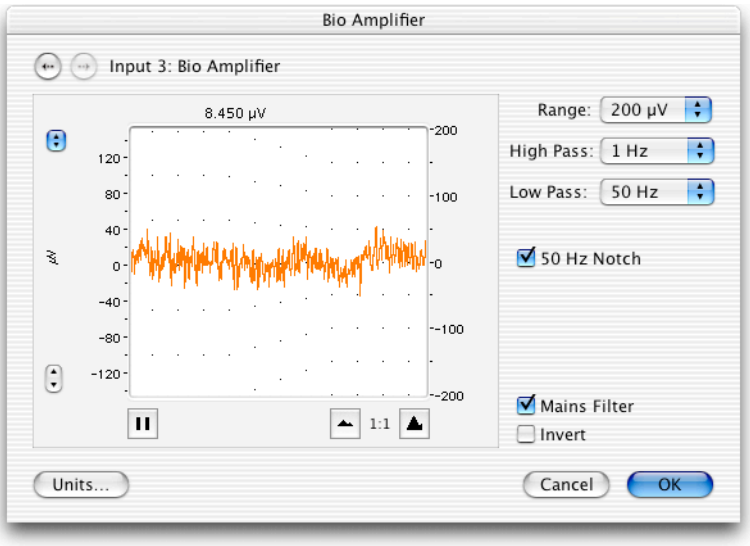

Figure 3. The Bio Amplifier dialog, showing settings for EEG.

2. Click the Start button to start Chart recording. Type 'blinking' and press the Return/Enter 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 Chart recording. Type 'eye movements' and press the Return/Enter 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/Enter key to enter the comment. Ask the volunteer to shake their 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 Chart window, and note the positions corresponding to +50 µV and –50 µV. True EEG signals rarely exceed these limits.

2. Use the scroll bar at the bottom of the Chart window to review the recordings. There may be some large signals outside the ±75 µV range. Such large signals are artifacts. If no such signals are seen, 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/Enter 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/Enter key to enter the comment.

6. Repeat steps 4 and 5 twice, to give you three sets of results. The recorded EEG data should resemble Figure 4. Adjust the vertical scale in the Amplitude axis so that the trace fills a little more of the channel.

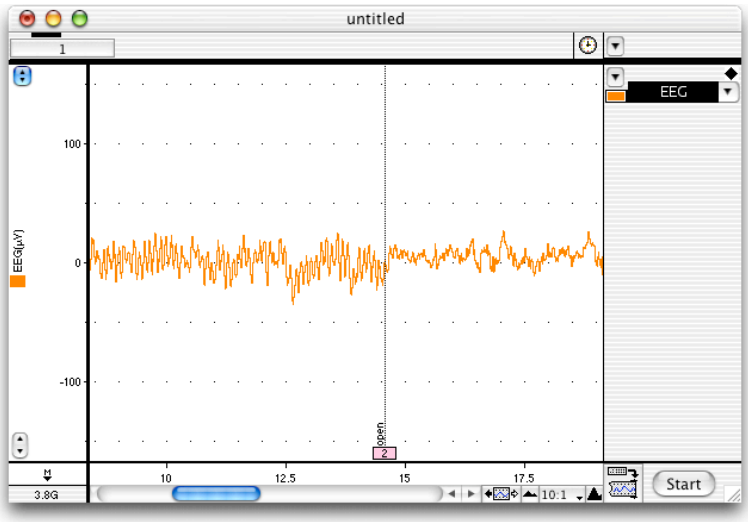

Figure 4. An EEG, viewed with a 10:1 horizontal compression. Alpha waves show as fine oscillations that stop when the eyes are opened (comment 2).

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 the recording that were made with the subject's eyes shut, looking for alpha waves. These can be recognized 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 5).

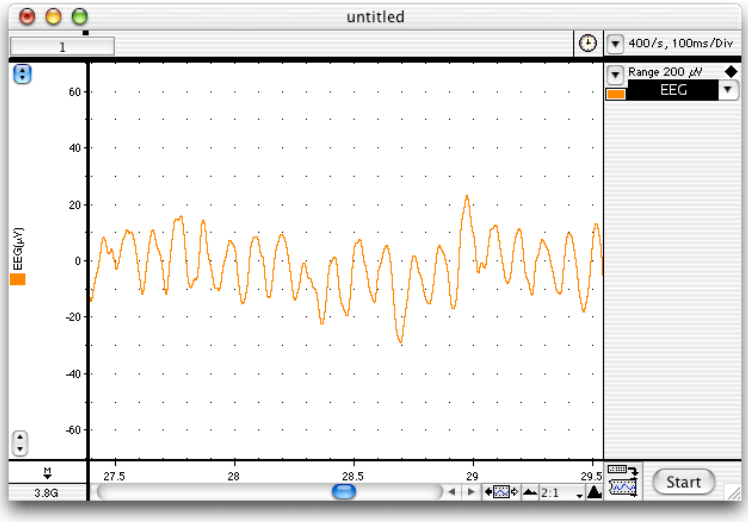

Figure 5. Alpha waves in the EEG, viewed with 2:1 horizontal compression — each alpha wave cycle occupies approximately 0.1 s.

3. If no alpha waves can be found, check that records taken with the subject's eyes shut are being examined. If alpha activity can still not be identified, or if the records consist mainly of large-amplitude artifacts, one or more electrodes may need to re-attached, 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 Window menu, choose Spectrum.

5. The Spectrum window displays the frequency content of the selected data (Figure 6). 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).

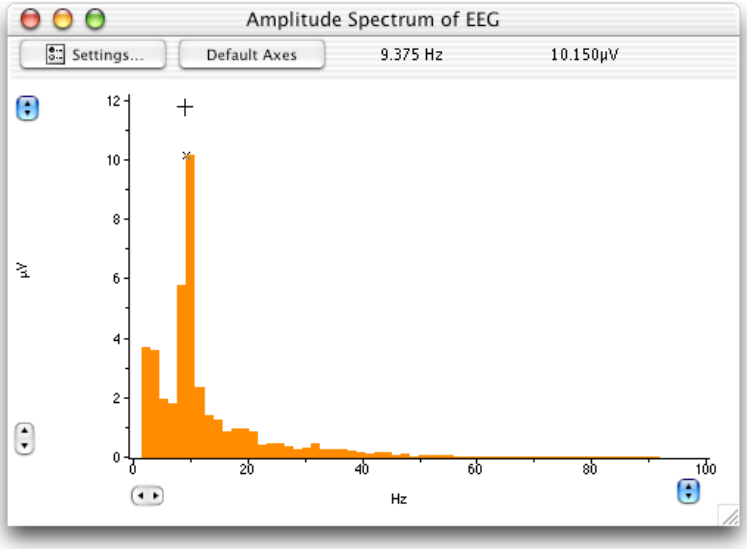

Figure 6. The spectrum of an EEG: the Waveform Cursor is placed over a prominent peak, showing alpha wave activity in the range 8–12 Hz.

6. Alpha activity shows up in the spectrum as a clear peak in the 8–12 Hz range. This is easiest to see if the horizontal axis expanded. 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.