# Alertness Detection Laboratory

(Electroencephalography Application)

Introduction

The ability to detect the mental state of a subject impacts many clinical areas. The patterns of neurons firing in the brain can provide insight into the mental state of an individual. As described in previous laboratory sessions there are several methods to record the firing of neurons in the brain. One method is to record the potentials of individual neurons by implanting tiny electrode arrays directly into the brain. A benefit to this method is that it can provide good spatial resolution of neural activity in the brain. However, this method is extremely invasive. Therefore, another method to record brain activity is the electroencephalogram (EEG) recording on the surface of the scalp.
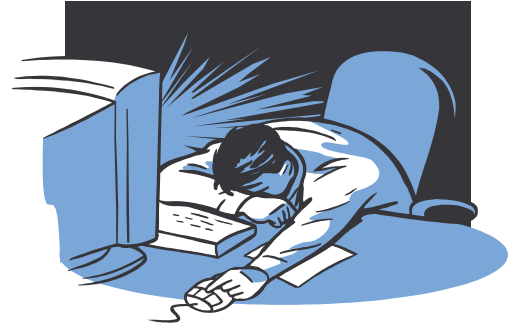
Clinical areas that can benefit from knowing the mental state of an individual include sleep staging during polysomnography studies, the effects of pharmaceutical interventions on psychological function, drowsiness studies which may be an indicator if someone is suited to drive a car or work as an air traffic controller at a particular time, and diagnosing other neurological disorders. The frequencies and amplitudes of the EEG can be used to determine the specific stage of sleep a person is in over the course of the night. Additionally, someone being treated for a neurological disorder, such as schizophrenia, may produce different patterns of EEG in different regions of the scalp during clinical episodes. These patterns can provide insight into the disease and how medication is affecting it. EEG could be used to detect if a person is fit to work in a particular job at a particular time. For example, truck drivers and air traffic controllers are two occupations which require the worker to be alert and attentive. Therefore, before each shift a test could be administered using the EEG signals to determine the particular alertness state before they are allowed to work. These examples illustrate how the EEG signal can be used to detect particular states of an individual.

During this laboratory session you will record four channels of EEG from a subject's scalp. You will then use the EEG signal to detect particular states of the subjects. First, you will use quantitative characteristics of the EEG signal to develop an algorithm that detects whether the subject's eyes are opened or closed. Next, you will apply the same methods to develop an algorithm to determine if the subject is relaxed or performing an intense mental activity.

Equipment required:
- CleveLabs Kit
- CleveLabs Course Software
- Seven (7) Gold cup electrodes
- Conducting gel and gauze pads
- MATLAB® or LabVIEW™

Background

Much of the background information on recording EEG signals you should have previously reviewed in laboratory sessions Electroencephalography I and II. In this laboratory session, you will utilize your previous experience to apply the EEG signal in a practical application.

Several methods have previously been used by researchers to detect the mental state of a subject from an EEG signal. The general process is to quantify specific variables of the EEG signals that are recorded and then correlate them to specific mental activity of the subject. Therefore, one basic method is to quantify the amplitude and frequency of the EEG signal and attempt to correlate them to specific activities. Additionally, specific activity changes in the EEG signal may be more predominant in specific regions of the brain and therefore over specific regions of the scalp. Therefore, it is important not only to know how to process the EEG signal into meaningful quantitative parameters that relate to a particular state, but also over which regions of the brain you should be recording the information.

It can be very difficult to develop algorithms to detect mental state from the EEG signal because there must be a specific gold standard against which you are comparing your EEG signals. For example, you may want to use the EEG signal to detect if a subject is too drowsy to be able to work. Therefore, for your experiment you will record the EEG signal of many subjects at multiple times throughout the day. However, you need to know whether or not they were sleepy during those times that you recorded the EEG. One method for doing this is to simply ask them with a survey. However, this is a very subjective method. Another method would be to have them complete a task in which they must concentrate and respond, such as a driving simulator. You can then correlate the EEG signals to quantitative measures of driving performance with the simulator. This is only one example of how an algorithm may be developed utilizing EEG signals to detect drowsiness. In other cases, such as in the detection of psychological states, such as schizophrenia, it can be much more difficult to develop algorithms based on EEG. Once again, this is because it can be difficult to detect when the person is actually in a schizophrenic state and have a basis on which to correlate the EEG signals.

For the purposes of this laboratory session you will have two specific tasks that will be used to develop algorithms for EEG state detection. Your first outcome measure will simply be whether the subject's eyes are opened or if the subject's eyes are closed and if they are relaxed. This outcome measure will be easy to control since you can ask the subject to open and close their eyes for this particular trial. You will also attempt to utilize the EEG to determine if a subject is performing mental arithmetic or not. This outcome measure will also be easy to control since you will ask the subject to complete this mental activity during multiple recording trials. You will then process the EEG signal into quantitative variables and see how well you can correlate these measures to the outcome measures that you were controlling during the experimental procedures.

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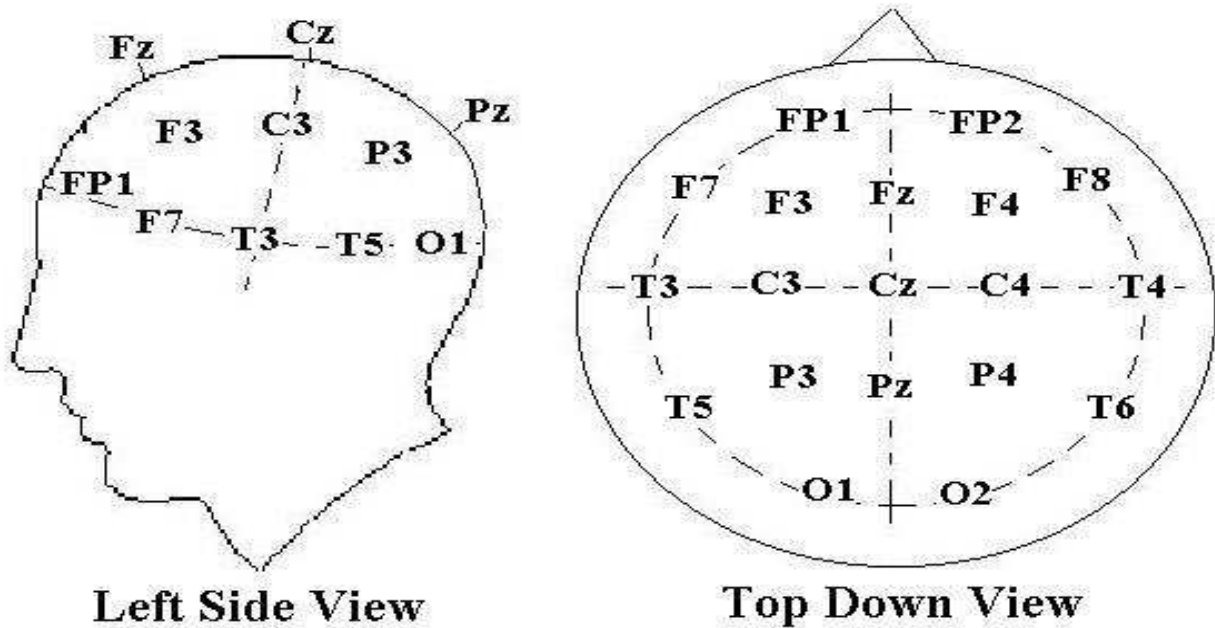
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Experimental Methods

Figure 1: The 10-20 system of electrode placement.

Experimental Setup

During this laboratory session you will record four channels of EEG. Two channels will be recorded from the frontal region and two channels will be recorded from the occipital region. You should view the setup movie included with the CleveLabs software before beginning the experimental setup for this laboratory session.
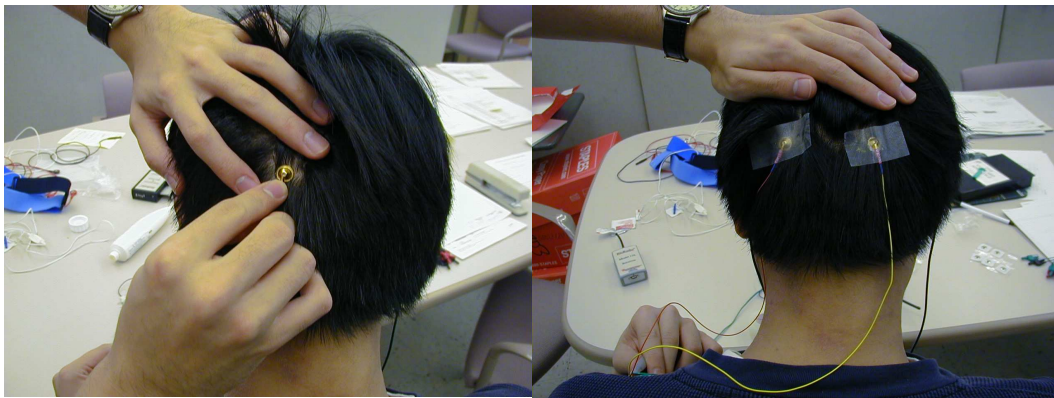

Figure 2: Two of the six gold cup electrodes will be placed at O1 and O2 to monitor EEG.

1. If possible, the subject for this laboratory should be a person with shorter hair. The subject also should have their scalp free of any types of hair gel. You will need seven gold cup electrodes for this laboratory. Gold cup electrodes will be placed at locations O1, O2, Fp1, and Fp2 (Fig 1) to measure EEG, on each mastoid as references, and at FpZ (middle of the forehead) for the ground. The mastoid processes (A1 and A2) are the bony structures that you can feel behind the ears (Fig 3). Before applying electrodes to the subject it is first important to properly prepare and clean the electrode sites. If needed, refer to previous labs for information on cleaning and preparing electrode sites.

2. Now the gold cup electrodes can be attached. Generously fill a gold cup electrode with the provided conductive gel allowing some gel to fill over the top of the cup. Squeeze some of the conductive gel onto a gauze pad as well. Push the electrode into the gel on the gauze pad and then gently push aside the hair and place the electrode on the back of the subject's head at position O1. Repeat for the other gold cup electrode at location O2. The electrode placements for O1 and O2 are illustrated in Fig 2.
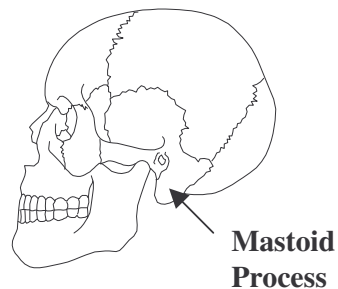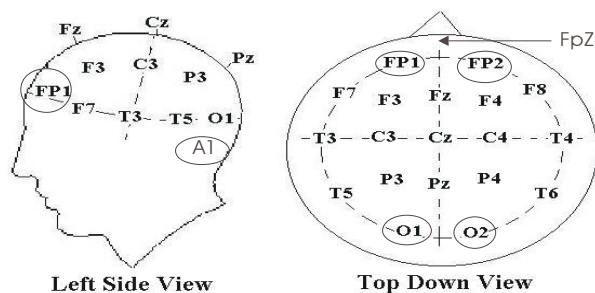
Figure 3: The mastoid processes are the bony structures located behind the ears.

3. Connect gold cup leads and jumpers to channel inputs 1, 2, 3, 4, and the ground using the picture below as a reference (Fig 4). The left side view of the head is symmetrical to the right side view as seen in the top down view.
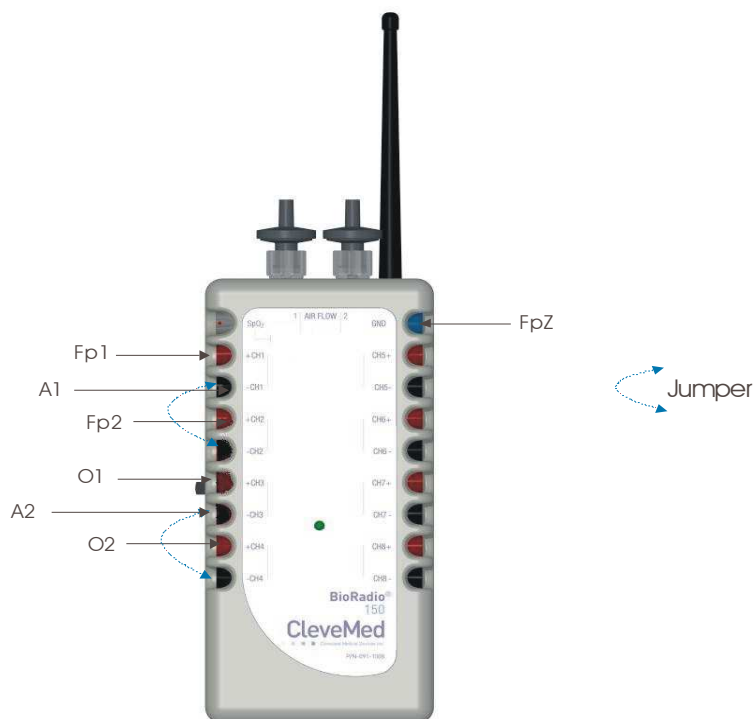
Figure 4: Laboratory Alertness Setup

Procedure and Data Collection

1. Run the CleveLabs Course software. Log in and select the "Alertness Detection" laboratory session under the Clinical Applications subheading and click on the "Begin Lab" button.

2. Turn the BioRadio ON.

3. Your BioRadio should be programmed to the "LabAlertness" configuration.

4. Click on the EEG data Tab and then on the green "Start" button.

5. You should begin to see four channels of EEG scrolling across the screen. Set the time scale to show a 2 second window of data. Click on "Screen Capture" to capture a picture of this for your report. This may not look like EEG yet because you are not filtering out high frequency noise that may be contaminating the signal such as 60Hz noise.

6. Now click on the Spectral Analysis Tab and then the Time Domain subtab. Set the time scale on the time domain plot to be 1 second

7. Instruct the subject to look at the screen. Under filter parameters, set the switch to filtered data, filter type to bandpass, the highpass cutoff to 1Hz and the low pass filter to 20Hz and set the filter order to 4.

8. Set the channel to process to be channel 1. After a few seconds instruct the subject to close their eyes and relax. You are attempting to record alpha waves from the subject (8-13Hz waves). You should see these waves show up as soon as the subject closes their eyes.

9. Repeat step 9 with the channel to process set to 2, 3, and 4. Find the channel that gives the best alpha waves. You should already have some idea what this should be from previous laboratory sessions. Once you find the best channel, report a screen shot of the EEG signal when the subject's eyes are open and when they are closed.

10. Do not change the parameters, but now click on the frequency domain plot tab. Set the data collection interval to 300ms. Note the estimated peak frequency when the subject's eyes are open and when they are closed. When they are open, the estimated peak frequency should be fairly random, however, when they are closed, this frequency should tend to stay within a certain range. Record this range, as you will need it for the next step.

11. Now click on the processing and application tab.

12. Set the time scale in the plot to be one second and set the activity type to "Eyes Opened or Closed".

13. Under EEG Processing parameters, select the channel from which you were able to see the best alpha waves. Then turn the filter on and set the filter type to bandpass, the order to 4, the high pass cutoff to 1Hz, and the low pass filter to 20Hz.

14. You will see the estimated peak frequency of the signal in the "Current Peak Frequency" digital indicator while the software is running.

15. You will now attempt to setup the parameters of an algorithm to automatically detect when the subject's eyes are open or closed. The general algorithm for this state detection is as follows. The peak frequency of the EEG signal is calculated over each data collection interval (300ms in this case). The past ten values of peak frequencies are

stored in memory and can be recalled by the software. A user defined range (see a and b below) is an established range that a peak frequency must fall into for it to be considered eyes closed. If a user defined number (see d below) of past peak frequencies out of a user defined number (see c below) of past peak frequencies fall into that range, then the eyes are assumed closed. These parameters are located in the box labeled "EEG State Tuning".

a. Set "Max Frequency" to be the average maximum frequency that occurred earlier when the subject's eyes were closed. You can set the maximum frequency by clicking on the blue line in the plot and dragging it up and down.

b. Set "Min Frequency" to be the average minimum frequency that occurred when the subject's eyes were closed. You can set the minimum frequency by clicking on the red line in the plot and dragging it up and down.

c. Set the "Samples to Use" number to be the number of past peak frequencies that you wish to examine.

d. Set the "Upper Threshold" and "Lower Threshold". If these numbers are the same, that value corresponds to the number of past frequency samples that must fall within the range you setup in steps a and b in order to qualify the person as having their eyes closed.

Both an upper AND lower threshold value is included to introduce hysteresis into the control algorithm. In this case, the values will be different. The upper threshold will refer to the number of past peak frequencies that must be within the range if the number is increasing. The lower threshold will refer to the number of past peak frequencies that must be within the range if the number is decreasing.

e. The array labeled "EEG Peak Frequencies" shows the past peak EEG frequencies starting with the current one at the top and ending with the earliest at the bottom. The number of frequencies shown depends on the number of samples you wish to use. The past EEG peak frequencies are also plotted on the black line in the lower left plot.

f. The "Past Samples of EEG in Range" array of green LEDs illustrates when a peak frequency was in the correct range. If it was, then the LED next to it will turn green. Ideally, when the subject's eyes are closed you should see all of the LEDs turn green.

g. The box labeled "EEG State Result" should correspond to what the subject's eyes are doing if you have properly setup the tuning parameters. Record approximately the time that the correct State Result occurs for both the eyes opened and the eyes closed.

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16. Finally, save 5 sets of data to file when the subject's eyes are closed and 5 sets of data to file when the subject's eyes are opened. Each data file should be approximately 30 seconds long.

17. You should now repeat steps 9-16. However, this time you will be trying to record beta waves as the subject performs mental activity. This is more difficult than recording alpha waves. In order to illicit beta waves, you should ask your subject to solve math problems in their head at your command. You should as them questions quickly such as "What's 9*2?, What's 9+5?, What's 17-96?, What's 13*14?" Ask them in a quick manner and have the subject just mentally figure out and think the answer, they should not say it out loud. Make sure you ask the questions quickly, so that they are continually solving math problems in their head. You should do this experiment with the subject's eyes closed and attempt to abolish the alpha waves with the mental activity. You may need to change your filtering parameters for this application. You should also flip the activities type switch to "Mental Activities".

18. Finally, you should save five files when the subject is completing mental math activities and five when they are not. Each data file should be approximately 10 seconds long.

Data Analysis

Using the post processing toolbox, MATLAB, or LabVIEW, open the data files that you saved while the subject's eyes were closed. Plot the processed and the raw, unfiltered data from the same channel that you used for the state control. Note the differences in the signals. Determine the mean peak-to-peak voltage and frequencies for the processed data. Repeat for the files when the subject's eyes were opened. Compare these peak-to-peak voltages to typical amplitudes for EEG recordings in Table 1. Repeat for mental activities data.

Try to correlate quantitative variables of the EEG signals with specific states of the subject, i.e. eyes opened or closed, performing mental activity, or relaxed. You may want to start by using the amplitude and frequency of the EEG signals. However, based on the results of your correlations, you may want to use more advanced methods of signal processing in order to obtain better results with other quantitative features. There are several methods that you can use to determine how well your quantitative methods can be used to detect the state. The simplest is just to compute what percent of saved data files your algorithm successfully worked on.

Discussion Questions

Alertness Detection Laboratory

1. Examine the plots made with the eyes open and closed during the first experiment. What differences do you observe in the EEG signal between the eyes closed and eyes opened states? What rhythm is most responsible for quiet, relaxed, eyes closed? What rhythm is most responsible for eyes open? Why do you think this rhythm changes (physiologically)?

2. Does the mean frequency measured for the eyes open and closed exercises fall into expectations?

3. For the mental math experiment, compare the measurements between no mental math and the mental math. How does the EEG signal change as the subject begins to complete mental math? What brain rhythm would you expect to see during these states? Explain any similarities or differences. Explain the relationship between the results for mental math and the eyes open state.

4. Explain sources of noise that you saw in the experiment. Also, suggest some methods for eliminating the sources of noise, and what problems may occur with those methods. Some hospitals have programs for automated EEG analysis to detect seizures or spiking activity that occur during data acquisition. How might a noisy recording affect these automated programs?

5. About what percent of the time did that State Detection Application work properly for Eyes Opened/Closed? For Mental Activities? Why did it work better for one of the four states that any one of the others (i.e. why was it more accurate for eyes open vs. eyes closed or for eyes closed vs. mental activities?) How do you suppose that the algorithm for detecting state from the EEG signal could be improved?

6. Describe the procedures you used to develop your own algorithms using your save data files. How well did they work? What methods did you use to evaluate how well the algorithms worked? What could be done to improve the accuracy of the algorithms?

References

1. Guyton and Hall. <u>Textbook of Medical Physiology</u>, 9th Edition, Saunders, Philadelphia, 1996.

2. Kandel ER, Schwartz JH, Jessel, TM. Essentials of Neuroscience and Behavior.1995.

3. Kooi, Kenneth A. Fundamentals of Electroencephalography, Harper & Row, Hagerstown, MD. 2nd Ed. 1978.