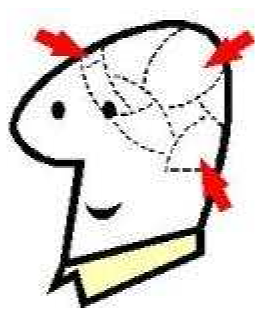
Biofeedback Laboratory



CleveLabs Laboratory Course System Version 6.0

Introduction

Throughout previous laboratory sessions, you have examined various physiological signals. These signals have included brain waves, electrocardiograms, muscle activity, eye movements, and respiration. You have learned how to record and process these signals to capture useful information. Once processed, you saw how these signals could either be used to detect a certain state of the individual or be used to control the state of some external interface. The purpose of this lab will be to integrate several of the biopotentials that we have recorded individually in previous laboratories to monitor sports activities, biofeedback, and lie detection. We will examine how these measured physiological parameters change in response to the state of the individual during each of the three tasks listed above.

Some people are able to focus their attention extremely well and calm their bodies down. For some, calming ones body may be beneficial before a competition while for others this may be done to reduce stress and improve health. Whatever the reason, biofeedback can be used to teach a person to control parameters of the body such as respiratory rate, heart rate, and muscle tone and teach the individual to relax.

Additionally, some individuals are capable of hitting homeruns in the major leagues while others cannot even make contact with the bat on the ball. In addition, some people are able to set new track records with the speeds they can run while others cannot run fast at all. Some nights a pitcher has pinpoint control while on other nights he “doesn’t have it”. All humans are given the same basic set up muscles and nervous system to control them. So what physiological parameters separate professional athletes from the average person?

Finally, a polygraph test is used to monitor several physiological parameters from an individual as they are asked questions. It is theorized that several of these parameters differ when a person is lying and telling the truth. If these variable changes are consistent, then a polygraph test could be used to detect when a person is telling a lie.

Equipment required:

- CleveLabs Kit
- CleveLabs Course Software
- Snap electrodes
- Gold cup electrodes
- Golf balls, a putter, and a cup
- MATLAB® or LabView™
- A watch with a second hand

Background

Biofeedback

There are currently many systems available that provide feedback to individuals who are exercising. One popular example is a treadmill that comes equipped with a heart rate monitor. The treadmill provides a digital display to indicate the heart rate of the person performing a cardiovascular workout. Using this feedback allows an individual to maintain a target heart rate throughout their workout. Other systems are available that measure galvanic skin resistance (GSR) to determine sympathetic tone by measuring the electrodermal response. GSR systems output a small current along the skin, usually between small electrodes on two fingers of the hand. The unit then measures the voltage between the two points. As a person's sympathetic tone increases, they will begin to sweat and the conduction of the skin will increase, i.e. the voltage measured will decrease. Often times these systems supply auditory feedback to individuals for use as a relaxation device. You may have heard of the "fight or flight" response. This occurs in the body when preparing for threatening situations. The responses of the body include increased heart rate, increased blood pressure, increased respiration rate and effort, and sweating. Athletes may experience this before a big game. Therefore, they may use this type of device to calm themselves before an important event.

Sports

Systems that work to improve the performance of an athlete are currently a major market due to the revenues that are generated by professional sports teams. For example, several systems are currently designed to measure the biomechanics of an athlete. Some systems use LEDs (light emitting diodes) located all along a subject's torso and limbs to track the position of their body throughout a motion. For example, a pitcher may be able to use this system to analyze the throwing motion of his arm. They may be able to then determine why on some days he pitches well and on other days he does not pitch well. This system could also be used to effectively analyze a golfer's swing so that it becomes more repeatable. Interestingly, it is currently being shown that recording EMG from muscles can yield similar information about limb orientation as LED markers. Current research has focused on using artificial neural networks (ANN) with several EMGs as inputs to determine the orientation of the arm in space. EEG can also be monitored on athletes. Is there a change in the EEG of a subject between when they are performing well and when they are having a bad day? Does the EEG signal provide insight into when the athlete is sufficiently concentrating or is "in the zone"? Additionally, the ECG and respiration patterns of an athlete can be analyzed and related to their performance.

For example, does an athlete perform better if their respiration and heart rate are slower, illustrating that they are relaxed?

Lie Detection

Finally, polygraph tests are administered to try and detect whether a person is lying or telling the truth. The accuracy of these tests remains a great debate. However, in this laboratory you will attempt to see how the algorithms for lie detection could be developed. You will monitor the heart rate, respiration, and brain waves of a subject when they lie and when they tell the truth. Theoretically, the heart rate, respiration, and muscle tone of the individual should increase when they are lying as compared to when they are telling the truth. Some people are able to "beat" a lie detector test by dampening their physiological responses when they are telling a lie.

Motion Artifact

As you have learned throughout the course of this laboratory course, there are many sources of noise that you may encounter when recording a biopotential. For most of the experiments that we have done up to this point, the site of recording has been kept fairly stationary. Therefore, much motion artifact has been avoided. However, one of the most problematic sources of noise for measurements during activities is motion artifact. An example of motion artifact would be a person wildly moving their arm around when EMG was being recorded from the forearm. Motion artifacts are disruptions in the signal that arise from movement at the electrode-electrolyte interface. The skin stretching during recording is a major reason for motion artifact. Additionally, the motion can cause the wires to move around and cause induction artifact.

Motion artifact may not affect EMG nearly as much as it affects the EOG, EEG, or ECG. This is due to the fact that motion artifact has a low frequency spectrum and EMG has a high frequency spectrum compared to the other signals. Therefore, high pass filtering could be used to remove motion artifact from the EMG signal. Another method for limiting motion artifact is using extra tape to secure the wire leads and electrodes to the skin.

Experimental Methods

A total of three separate experiments will be completed for this laboratory. You will complete a lie detection, sports, and biofeedback activity. While these are all separate experiments, you will not need to change your experimental setup for each of the labs. Each experiment requires you to record two channels of EEG, one channel of ECG, and one channel of respiration using the respiratory effort belt.

NOTE: As described above, in each of these exercises motion artifact can be a problem. In each of these configurations, be sure to run the wires so that they do not impede the movement of the subject. Additionally, you may find the need to use medical tape to ensure that the electrodes stay in place during the experiments. Also, for the experiments below, you may want the same person to be the subject for each of the three tasks. If this is the case be sure to read the setups for each of the tasks before starting. This will prevent you from removing electrodes that would be needed for subsequent tasks and then reapplying them.

Experimental Setup

1. For this laboratory you will need to use two snap electrodes to record the ECG. Remember that the electrode needs to have good contact with the skin in order to get a high quality recording. The surface of the skin should be cleaned with alcohol prior to electrode attachment. For the best recordings, it is best to mildly abrade the surface with pumice or equivalent to minimize contact resistance by removing the outer dry skin layer. Attach one snap electrode over the left clavicle and one snap electrode over the right clavicle on the subject. Connect a snap lead from the electrode over the left clavicle to the input labeled +3 on the BioRadio. Connect a snap lead from the electrode over the right clavicle to the input labeled -3 on the BioRadio.

2. For this laboratory you will need to use five gold cup electrodes from the BioRadio Lab Kit. Two of these will be for recording two single ended channels of EEG, two references, and one ground. You may need to refer to previous lab sessions for the EEG electrode placement. The five gold cup electrodes should be placed at locations A1, A2, FPz, Fp1, and O1.

3. Connect the gold cup electrode lead from Fp1 to the lead labeled +1 on the BioRadio. Connect the gold cup electrode lead from FpZ to the lead labeled GND on the BioRadio. Connect the gold cup electrode lead from O2 to the lead labeled +2 on the BioRadio. Connect the gold cup electrode lead from A1 to the input labeled –1 on the BioRadio. Connect the gold cup electrode lead from A2 to the input labeled –2 on the BioRadio.

4. Finally, the respiratory effort belt should be placed around the subject as described in the Respiration laboratory session.

5. Connect the leads from the Respiratory effort belt to the input channels + and – 4 on the harness as you completed in the respiratory laboratory.

Procedure and Data Collection

Lie Detection

Before starting the lie detection data collection you will need to prepare a total of eighteen questions for the subject. Typical questions for this exercise include "What's your favorite sport?", "What's your mother's first name?", "What kind of car do you drive?", etc. You should then divide these eighteen questions into six groups of three. These questions are not given to you as a part of this exercise so that the subject will not be able to practice them before the data collection sequence. The subject should not see these questions before they are asked to them.

Give the subject a piece of paper numbered 1 – 6. Describe to the subject that they will be asked six sets of three questions. There will be a short break in between each set of questions. They should answer the questions aloud when asked. They should tell the truth for three sets of questions and lie for the other three sets of questions. After each set they should mark on the sheet of paper "lies" or "truth" so that it can be recalled which set of questions were answered with a lie and which sets were answered by the truth.

1. Make sure the computer unit is properly connected to the port on the computer. Run the CleveLabs Course software. Log in and then select the "BioFeedback" session and click on the Enter Lab button.

2. Your BioRadio should be programmed to the Biofeedback configuration file.

3. Turn the BioRadio Unit on ON.

4. Click on the green "Start" button.

5. Click on the tab labeled "Raw Data" if that panel is not already on top. Make sure that all of the appropriate signals can be seen in the plots. Capture a screen shot of the raw data.

6. Begin saving data to a file named "LD1" and immediately begin asking the subject the first set of questions. After they have answered all three questions and written on the piece of paper stop saving the data to file.

7. Begin saving data to a file named "LD2" and repeat step 5. Continue in this fashion until the subject has answered all six sets of questions and you have saved six data files.

Sports

Prior to the data collection sequence of this laboratory, you will need to get the putter, golf ball, and cup that are need for this lab. Setup the cup on its side about ten feet from the subject with the open top of the cup facing the subject. The object for the subject will be to take approximately ten seconds to concentrate and then attempt to putt the golf ball into the cup.

1. Click on the tab labeled "Raw Data" if that panel is not already on top. Make sure that all of the appropriate signals can be seen in the plots.

2. Begin saving data to a file named "SP1". Immediately after you start saving data, instruct the subject to begin. They should concentrate for approximately ten seconds and then attempt to putt the ball into the cup. As soon as they have putted the ball you should stop saving data. It is important that you note whether they got the ball into the cup or not.

3. Begin saving data to a file named "SP2" and repeat step 5 above. You should continue in this fashion until the subject has missed the cup at least five times and also has made the ball into the cup at least five times. Once this has been achieved you can stop saving data files. You should have several data files when you are finished and have a record of which data files correspond to "missed" attempts and "made" attempts.

BioFeedback

The object of this exercise is to illustrate how a subject can use biofeedback to help control the way in which their nervous system is working. You will use a watch to record how long it takes a subject to return several physiological parameters to normal levels with and without feedback. You will also explore how physiological parameters can be translated into observable features to supply feedback. For the purposes of this laboratory, a red circle will be used as biofeedback. The radius of the circle is proportional to the physiological parameter of interest. You will have the option of relating four parameters to the red circle radius, including two sites of EEG frequency, heart rate, and respiration rate.

1. Click on the tab labeled "Raw Data" if that panel is not already on top. Make sure that all of the appropriate signals can be seen in the plots.
2. Now click on the tab labeled "Biofeedback" if that panel is not already on top. Then turn on the switch labeled "Biofeedback".

3. After you select the signal you wish to use for feedback you should setup the filtering parameters accordingly. The filtered signal will be illustrated in the plot labeled "Feedback Signal".

4. If you select to use either of the EEG channels as the feedback signal then you will need to select the "Number of Past EEG Sample Peak Frequencies to Average". This is selectable between 1 and 10. The time length of each EEG sample is based upon the data collection interval setting. For example, if the data collection interval is set to 100ms,

then each sample of EEG is 100ms long. The peak frequency of the EEG signal is calculated over each of the user-defined number of samples. The average peak frequency over the samples is then calculated and used as the feedback parameter. Therefore, adjusting the data collection interval will have an effect on the feedback parameter.

5. If you select to use either the ECG or respiration channel as the feedback signal then you will need to define three parameters. First, you will need to define whether you want to use a peak or a valley in the signal as your threshold indicator. Next, you will need to define the threshold value that the signal must reach (threshold). Finally, you will need to define for how many data points the signal needs to exceed this threshold for it to be considered an event (width).

6. Next you will need to determine a minimum and a maximum for the parameter you are using as your feedback signal. For example, if you are using the ECG and heart rate as your feedback parameter, instruct the subject to relax and record the rate value. Then have the subject jog in place for a minute and record the rate value. Then set these to be the minimum and maximum values of the signal. This will then normalize the maximum and minimum values of the feedback parameter to the maximum and minimum values of the red circle radius.

7. Try using the different physiological parameters as inputs to the feedback circle. Time the differences it takes for the subject to relax (slowed respiration rate, slowed heart rate, and low peak frequency EEG signals) with and without feedback. For example, have the subject jog in place for a minute and begin monitoring respiration or heart rate immediately after. One time just tell them to relax. The next time supply them with the feedback and monitor the time difference. For EEG, you may have them answer several consecutive math questions and then have them try to relax and not think about anything. Capture a few screen shots of this during the biofeedback session.

Data Analysis

Lie Detection

You should have saved six data files as a result of your data collection during the lie detection task. You should also have the list from the subject that reveals to you which sets of questions were answered with a lie and which sets were answered with the truth. It is now your job to analyze the signals and determine if, and if so how, each of the four physiological signals that were recorded change as a function of lying or telling the truth. You can use any of the methods for analyzing signals that have been explored throughout the course of this lab course. You will need to use the post processing toolbox, MATLAB, or LabView to analyze the data. You will need to process the raw data files and then look at specific characteristics to see how they change. For example, you'll need to filter the raw signals and then you will need to examine any amplitude or frequency differences in the signals between lying and telling the truth.

Sports

You should have saved at least ten, but maybe more data files as a result of your data collection during the sports task. You should also have a list that illustrates which trials were made putts and which were missed. It is now your job to analyze the signals and determine if, and if so, how each of the four physiological signals that were recorded change as a function of making or missing the putts. You can use any of the methods for analyzing signals that have been explored throughout the course of this lab course. You will need to use the post processing toolbox, MATLAB, or LabView to analyze the data. You will need to process the raw data files and then look at specific characteristics to see how they change. For example, you'll need to filter the raw signals and then you will need to examine any amplitude or frequency differences in the signals between making and missing putts.

Biofeedback

Analyze the difference in times it took subjects to relax with and without the biofeedback. Also, consider which types of physiological signals were easier for a subject to control with biofeedback.

Discussion Questions

1. During the biofeedback experiment, what determines how quickly the person's heart rate will start to level off? Relate your answer to how the heart develops during physical exercise. Would a physically fit person have a slower or faster heart rate than a non-fit person?

2. Does the EEG change for the concentration exercise before and during the putt? Would you expect it to? Why or why not?

3. How could biofeedback help to increase athletic performance?

4. Consider the lie detection and sports activities. Explain which parameters varied as a function of lying or telling the truth. Explain which parameters varied as a function of making or missing the putt. If these parameters did not vary in a repeatable fashion, explain how you would have expected them to change and why they may not have during this experiment.

5. Describe a type of system that could be put together using biofeedback to increase the performance of an athlete.

6. Suppose that you could electrically stimulate the legs of a paralyzed individual to control the muscles. The level of force produced by the muscle is dependent upon the level of stimulation. There is a positive, linear relationship between the two. Explain how you could use the EMG signals from the walking data to determine how to stimulate the leg muscles to enable a paralyzed individual to walk again.

7. Repeat the regular analysis completed earlier for both the lie detection and the sports data collection. However, this time, do not use all of the data files. For the lie detection data files use two "truth files" and two "lie files". For the sports analysis use three "made putt" files and three "missed" putt files. Using only the subsets of the collected data determine the parameters that can be used to qualify a lie or a "made putt". Then use the remaining data files as inputs to this developed algorithm to test it. Discuss your results.

References

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