# Electro-Oculography I Laboratory

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Introduction

Sight is probably the most important of the five senses to many human beings. Our visual system continuously provides feedback on objects and interactions with our environment in almost everything that we do. The eyes help us to focus on objects that are right in front of us such as a book we are reading, they allow us to track a plane shooting across the sky at an air show, and they allow us to focus on an object that is far off in the distance. Several muscles are responsible for moving the eyes around to complete these different types of tasks. Each of these distinct tasks performed by the eyes requires specific types of controlled movements. These movements each have their own name and will be explained in this laboratory. Researchers have performed experiments to understand how the eye functions, and the electro-oculogram (EOG) is one of the observed phenomena that can give us insight.
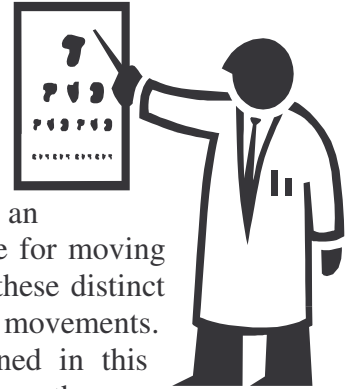
Several theories exist on the exact mechanism responsible for generating the EOG potential. However, regardless of its exact mechanism, the EOG is an important biopotential that can provide us with information about the visual system. One important example where the EOG is used is during overnight sleep studies (you will actually be completing an overnight sleep study in a future lab). Sleep studies often include the EOG as one of many biopotentials that are recorded. During certain portions of a sleep cycle, the eye movements become very erratic and relatively large in magnitude. Monitoring and recording the EOG signal can help to detect these stages of sleep. In addition, completing eye tracking exercises and monitoring the resulting EOG can allow diagnosis of certain eye diseases. For example, an ophthalmologist can use the EOG to diagnose retinal disorders that can lead to blurred vision.

In this lab, students will monitor and record the EOG signal from both the left and right eyes of a subject. Various eye movement experiments, such as target tracking exercises, will be performed. The data will be processed and analyzed to identify characteristics of and problems with interpreting the EOG signal.

Equipment required:

- CleveLabs Kit
- CleveLabs Course Software
- Five snap electrodes and snap leads
- Microsoft Excel
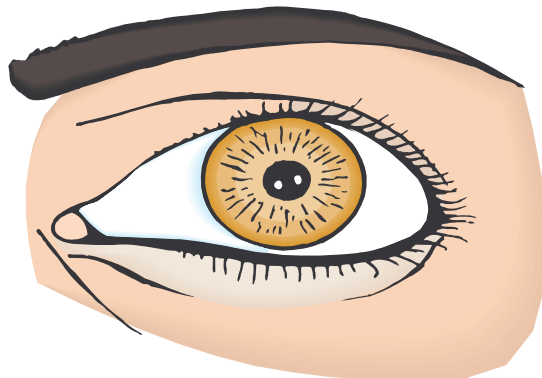- Measuring Tape
- Microsoft Excel®, MATLAB®, or LabVIEW™

Figure 1: The human eye is integral in supplying feedback to the nervous system about the environment.
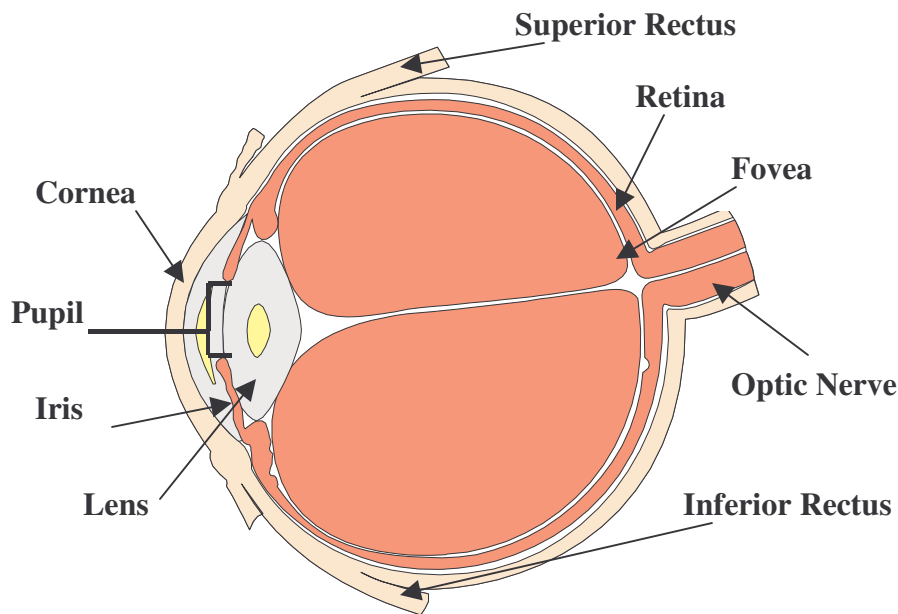
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Figure 2: Several anatomical structures of the eye are responsible for focusing on objects in the visual field.

Background

The human eyes contain several anatomical structures that function much like a camera and allow us to focus on and track objects in the visual field (Fig 2). The cornea and the lens are two important structures that help the eyes to focus on objects. The lens is responsible for focusing the visual image on the back of the eye. The lens changes shape and coordinates with the cornea to change the direction of the rays of light entering the eyes, hence, focusing the light on the retina. The retina contains the photoreceptors (rods and cones) that are responsible for transducing the light into an electrical signal for the brain. The fovea is the part of the retina that is the most sensitive. In the fovea, photoreceptive cells are abundant. The rest of the retina has photoreceptive cells as well, but they are not as densely populated as in the fovea, and thus provide a lower resolution image. The lower resolution region allows for detection of a new object for targeting, such as when you may first recognize an object in your peripheral vision. The extraocular muscles rotate the eyeball to focus the point of interest on the fovea. The pupil opens and closes in response to light intensity. The iris is the colored part of the eye.

There are three pairs of extraocular muscles that control eye movements (Fig 3). The medial and lateral rectus muscles control movement of the eyes in the horizontal plane. The superior and inferior rectus muscles control vertical movement of the eyes. The superior and inferior oblique muscles function to rotate the eye. This torsional movement supplied by the oblique muscles helps to keep the visual fields in the upright position for small lateral rolls of the head.
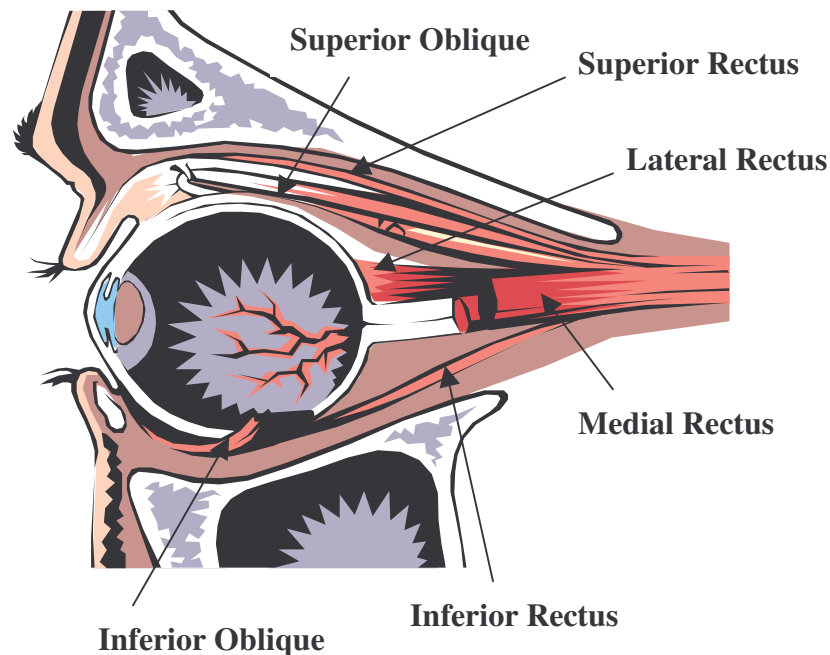
Figure 3: There are three pairs of extraocular muscles that are responsible for moving the eye up, down, left, right, and torsionally.

These muscle pairs are reciprocally innervated. In other words, they are antagonists. When one muscle in the pair contracts, the other relaxes. The reciprocal mechanisms allow the eyes to stay aligned on an object so that the same image appears on both retinas. The extraocular muscles in the eyes allow for depth perception. Double vision occurs when this mechanism does not function properly and the two retinas have different focal points. Cranial nerves III, IV, and VI are responsible for innervating the muscles described above that control eye movements.

The three pairs of muscles that control eye movements are capable of creating many different types of movements. *Fast* saccadic eye movements are used to quickly fixate a target. *Smooth pursuit* eye movements are used for tracking a target. *Vestibular ocular* eye movements keep the eyes focused on a target even while the head is moving. An example of this would be someone running to catch a ball. Their head moves while they run, yet they are able to stay focused on the ball. *Vergence* movements let the eye track near and far targets. The vergence movements are unique from the other types because they are the only ones that allow the eyes to move in opposite directions. *Optokinetic* movements occur when moving through a target filled environment.

Using the extraocular muscles to generate these kinds of movement, we attempt to place the target image on the fovea. The eye can then "jump" to focus on the new target, and this jumping is called a saccade. Saccades can be observed in individuals as they are reading, or looking out the window while riding in a car. When scanning a visual scene, we make about 3 saccades/second, integrating each of these visual "snapshots" into a high-resolution "mind's eye"

view of the scene. Go ahead and watch someone's eyes as they read this lab. You will see several saccades per line of text they read.

So what is the exact physical mechanism responsible for generating the EOG signal we measure? We are not measuring the EMG from the extraocular muscles. Though the exact origin of the EOG has not been conclusively determined, there are several theories that have been proposed as the mechanism behind it. The first is the cornea-retinal dipole theory. It states that an electric dipole is formed through the eye because the cornea is positively charged, while the retina is negatively charged. As you may remember from physics, a dipole creates an electric field that can be measured. This is the potential that is being measured by the EOG. As the eye changes direction, so does the dipole, and thus, the detected signal (Fig 4). The second school of thought is similar to the one described above, but instead of the dipole being created by the cornea and the retina, the dipole is believed to be the potential difference across the retina itself. The third theory states that it is the eyelid movement that creates a sliding potential source, which is responsible for the potential recording. The cornea-retinal theory is most widely accepted, and will be used for illustrative purposes in this lab.
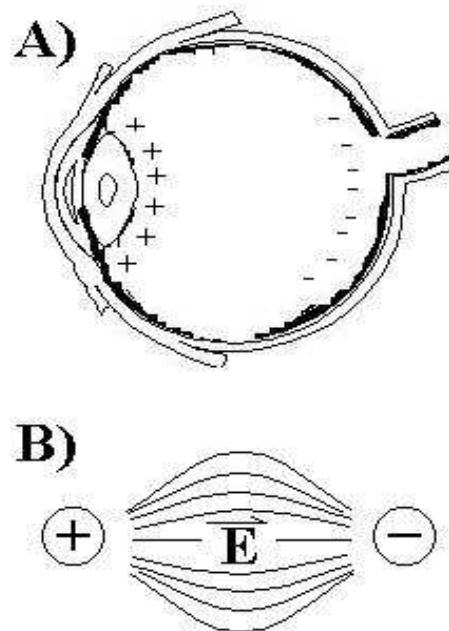
Figure 4: A) The cornea is positively charged while the retina is negatively charged. B) This creates a dipole with an electric field that can be measured.

The EOG is an important signal to be aware of when recording EMG from facial muscles or EEG. Typical EOG signals have amplitudes in the millivolts range with frequencies of DC - 100Hz. We previously learned that EEG signals are on the order of microvolts and that EMG is in the millivolts range. Since the eyes are located close to the brain and facial muscles, the different signals may create artifact in one another. EOG can be severely contaminated by the

EMG signal, and to a lesser degree, by the EEG signal as well. The reciprocal is also true. EOG can contaminate EEG and EMG recorded around the head and face regions. In some cases, such as slow eye movements, the EOG can create a DC offset in the EEG signal. These concepts will be more fully explained in a future laboratory. For the purposes of this laboratory we will be concerned with measuring the DC component of the EOG signal. The DC component of the EOG signal can be used to measure eye movement +/- 30 degrees.

As mentioned in the introduction, the EOG is one of the standard biopotentials measured during a sleep study. This is because a type of sleep of particular interest is called *rapid-eye-movement* (REM) sleep. REM involves, as the name implies, very quick and random eye movements. In a normal night of sleep, REM sleep occurs about every 90 minutes, lasting about 5 to 30 minutes at a time. This is the time that is usually associated with active dreaming, reduced muscle tone, reduced cardiac and respiratory rates, and increases in brain activity. Because the increased brain activity during REM resembles that of a conscious person, REM sleep is also called *paradoxical sleep*.

Experimental Methods

Experimental Setup

During this laboratory session you will record three channels of EOG. You will record the DC coupled component of the horizontal and vertical EOG, plus you will record the AC component of the vertical EOG. You should view the setup movie included with the CleveLabs software before beginning the experimental setup for this laboratory session.

1. You will need five snap electrodes for this laboratory. **NOTE: For this laboratory, you may want to attach all of the snap leads to the snap electrodes before you place the snap electrodes on the subject. It may be uncomfortable for the subject if you apply pressure to these electrode positions afterwards.** Properly prepare and clean the surface of the skin before applying any snap electrodes (Fig 5).

2. As shown in Fig 5, place one snap electrode below the left eye and one above the left eye. These electrodes will be used to measure vertical displacement of the eye. Place one snap electrode to the left of the left eye on the left temple and one to the right of the right eye on the right temple. These electrodes will be used to measure horizontal displacement of the eyes. Finally, place the last electrode between the two eyes, just above the bridge of the nose. This electrode will be used as a ground.

3. If you have not already, attach snap leads to all of the electrodes. Connect those snap leads to the harness input channels 1, 2, 3, and the ground using the picture below as a reference (Fig 5). You will also need to attach jumper wires as shown in Fig. 5. Take all lead wires and run them behind the ear so the subject has an unobstructed field of vision.
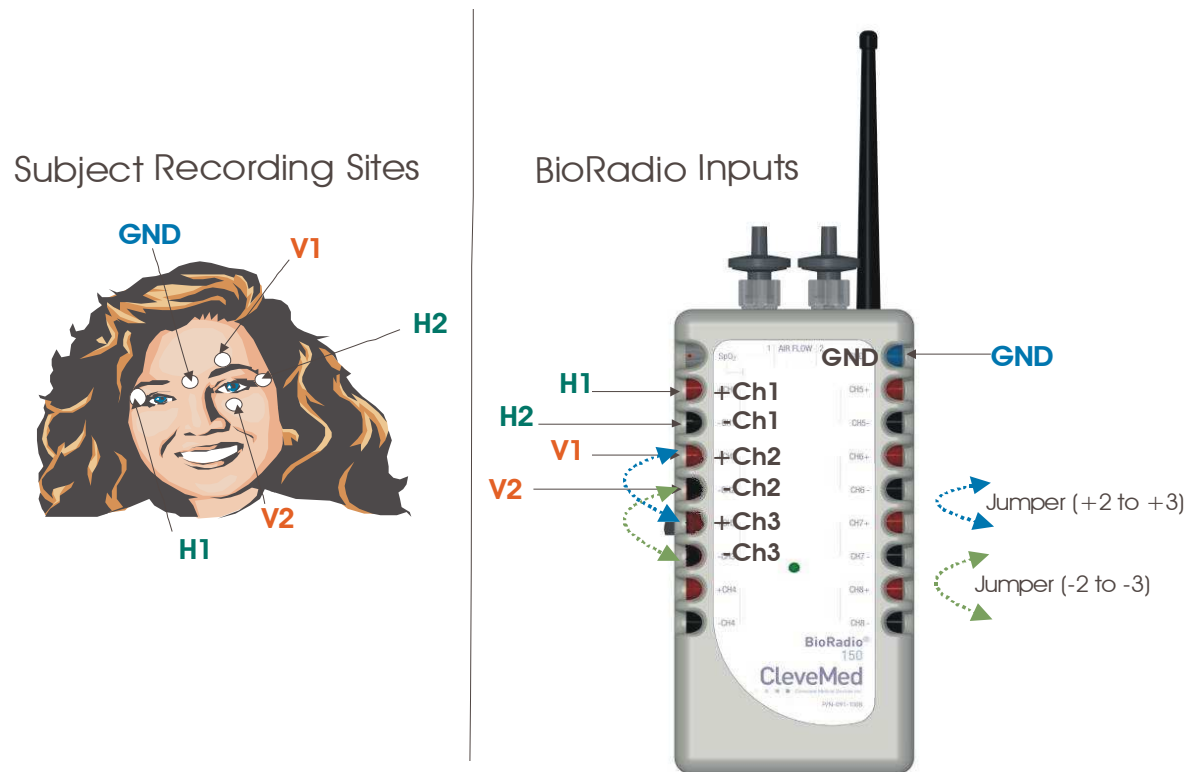
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Figure 5: EOG electrode placements.

Procedure and Data Collection

For each of these experiments, it is very important that the subject keeps their head still while tracking objects. Only the subject's eyes should move to track the object.

1. Run the CleveLabs Course software. Log in and select the "Electro-Oculography I" laboratory session under the Basic Physiology subheading and click on the "Begin Lab" button.

2. Turn the BioRadio ON.

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

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

5. You should see data scrolling across the screen. The first two channels are the horizontal and vertical DC value of the EOG. The third channel is the AC value of the vertical EOG. You many need to use a very small range (approximately 1uV) on the DC plot to

see the changes when the eye moves. You may want to use the autoscale axis feature by right clicking on the scale and turning it on.

6. First we will just examine the signal. Make sure that the time scale is set to about 6 seconds. Then instruct the subject to keep their head still and look all the way up for 2 seconds and then all the way down for 2 seconds. This should give you some idea of the range of the vertical EOG DC signal. Readjust the range of the plot so you can see it well.

7. Now have the subject keep their head still and look all the way up for about a second, then straight ahead for about a second, and then all the way down for a second. Capture a screen shot of this to your report to show the different voltage levels. Save a few seconds of data to a file named "verticalEOG" while they are looking up and down.

8. Repeat steps 6 and 7 for the horizontal. Save a few seconds of data to a file named "horizontalEOG" while they are looking left and right.

9. Instruct the subject to make several blinks and examine what happens to the vertical EOG AC plot. Capture a screen shot during the blinks. Save a few seconds of this data to a file called "eyeblinks".

10. We will now examine how various types of eye movements can impact the EOG signal. First we will examine fast saccadic movements. You should save this data to a file called "fastsaccades". Pick a particular target in the room and instruct the subject to look away from it. Then, when you tell them to, they should focus their eyes on it as quickly as they can. You should complete a few trials of this while you are saving data.

11. Next you should begin saving data to a file named "smoothpursuit". You should save approximately 30 seconds of data to file while the subject attempts to focus on someone's finger tip as they slowly move it around in space.

12. Finally, you should instruct the subject to read a short paragraph in a book or magazine while you record the eye movements. You should record about 30s of data to file while they are reading and name the data file "read".

Data Analysis

1. Using the post-processing toolbox, MATLAB, or LabVIEW, open the saved data file named "verticalEOG". Examine the temporal and spectral features of this file on all channels.

2. Using the post-processing toolbox, MATLAB, or LabVIEW, open the saved data file named "horizontalEOG". Examine the temporal and spectral features of this file on all channels.

3. Using the post-processing toolbox, MATLAB, or LabVIEW, open the saved data file named "eyeblinks". Examine the temporal and spectral features of this file on all channels.

4. Using the post-processing toolbox, MATLAB, or LabVIEW, open the saved data file named "fastsaccades". Examine the temporal and spectral features of this file on all channels.

5. Using the post-processing toolbox, MATLAB, or LabVIEW, open the saved data file named "smoothpursuit". Examine the temporal and spectral features of this file on all channels.

6. Using the post-processing toolbox, MATLAB, or LabVIEW, open the saved data file named "read". Examine the temporal and spectral features of this file on all channels.

Discussion Questions

1. What muscles are responsible for moving the eye quickly in the horizontal direction? In the vertical direction?

2. Which recording channel is most predominantly affected by blinking and why?

3. Describe the temporal and spectral features that you examined in each of your saved data files. Explain how these features could be used to automatically detect which type of eye movement or task is being completed by a subject.

4. How would you calculate the velocity of the eye from the EOG signal?

5. Imagine you are a baseball player standing in the outfield. Suddenly a fly ball is hit to your right and you begin running after it. You run a short distance, plant yourself where the ball is headed, wait a few seconds, and then catch the ball. Explain all of the different eye movements that would have occurred during that sequence of events.

6. Describe several clinical or other applications for which the EOG signal could be successfully used.

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