RECORDING AND ANALYSIS OF EOG SIGNALS UNDER DIFFERENT EYE MOVEMENTS

Aim:

To record EOG signal while moving pendulum BP measurement with standing, sitting, and supine position.

Objectives:

- To record EOG on the horizontal plane and vertical plane and compare eye movements
- To record EOG and compare eye movements during real-time and simulated tracking of a pendulum
- To record EOG and compare eye movements during real and during simulated tracking of an object in the vertical plane
- To record and compare the "saccadic" eye movements when reading three different ways; silently (easily) and loudly (challenging)

Apparatus required:

- Computer system (running Windows XP)
- Biopac Science Lab system (MP40 and software)
- Electrode lead set (40EL lead set)
- Disposable electrodes, three electrodes per subject
- Pendulum, Sampling frequency=10 KHz
- Pen or another real object for vertical tracking

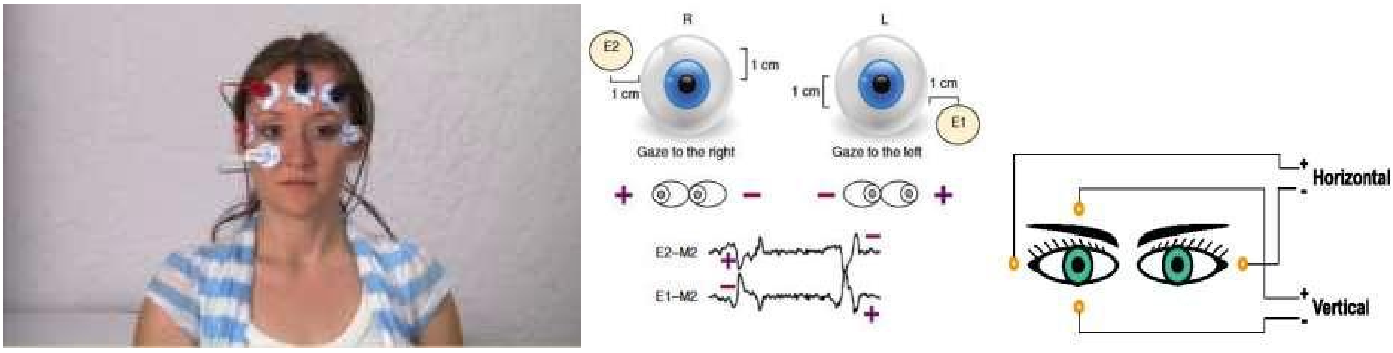
Theory:

EOG signal is a measure of the potential difference between the front and back of the eyeball. Experiments reveal that there exists a linear relationship between eye movement and EOG amplitude up to a certain degree. EOG can thus be used for the detection of eye movements and blinks. Different characteristics of EOG reveal its potential to be implemented for controlling different rehabilitation aids. The main applications of EOG signal include detection and assessment of many ophthalmological diseases such as Retinitis Pigmentosa and Best's disease as well as degenerative muscular disorders and neural diseases like Parkinson's disease. Drowsiness detection and cognitive process modeling are also different applications of EOG analysis.

Horizontal axis electrodes are placed near the outer canthi and vertical axis electrodes 1 cm below (LOC) and 1 cm above (ROC) the eye to measure transient changes in potential during the eye movement.

During any eye movement, the cornea moves toward one electrode, while the retina moves away. When the eye is not moving, the change in relative position is zero, and the eye leads do not record a signal.

The cornea (front) has a positive polarity. The retina (back) has a negative polarity. The electrode toward which the eyes move becomes relatively positive, the other relatively negative.



(a) (b)

Fig 1. (a) Placement of Electrodes for Recording of EOG signals. (b) Polarity of potential produced during eye movements

Method:

- Clean the skin before attaching the electrodes.
- Attach three electrodes to the subject as shown in Fig. 1.
- For the recording of EOG in a vertical plane attached one electrode above the eye and one electrode below the eye. Attach one more electrode on the forehead for grounding, as shown in Fig 2.
- Oscillate the pendulum and record the signal in a vertical plane.
- For horizontal plane recording, attach one electrode to the right temple and one electrode to the left temple, such that it is horizontally aligned with the right electrode. The other electrode is for the ground, and it can be placed anywhere on the forehead as shown in Figure 2.
- Oscillate the pendulum and record the signal in horizontal plane.

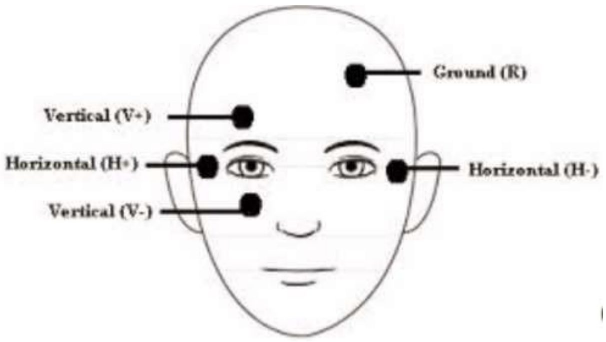


Fig 3. Placement of vertical and horizontal electrodes

Setup:

- Turn On the computer
- Plug the Electrode lead sets as
  - Horizontal lead – CH 1
  - Vertical lead – CH 2
- Attach the electrodes as shown in Figure 1.
- Start the Biopac Lab Program
- Subject should sit with arms relaxed at the side of the body, legs flexed at the knee, and feet support.
- Subject prepares to move eyes horizontally and vertically for the calibration procedure.
- Subject must try to keep head still and avoid blinking.

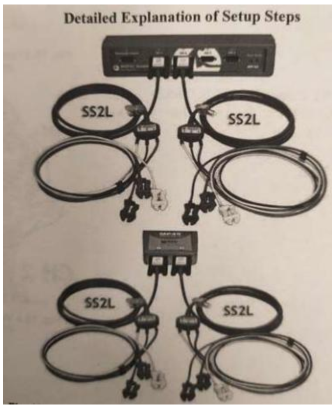


Fig 4. MP3X (top) and MP45 (bottom) equipment connections

Results:

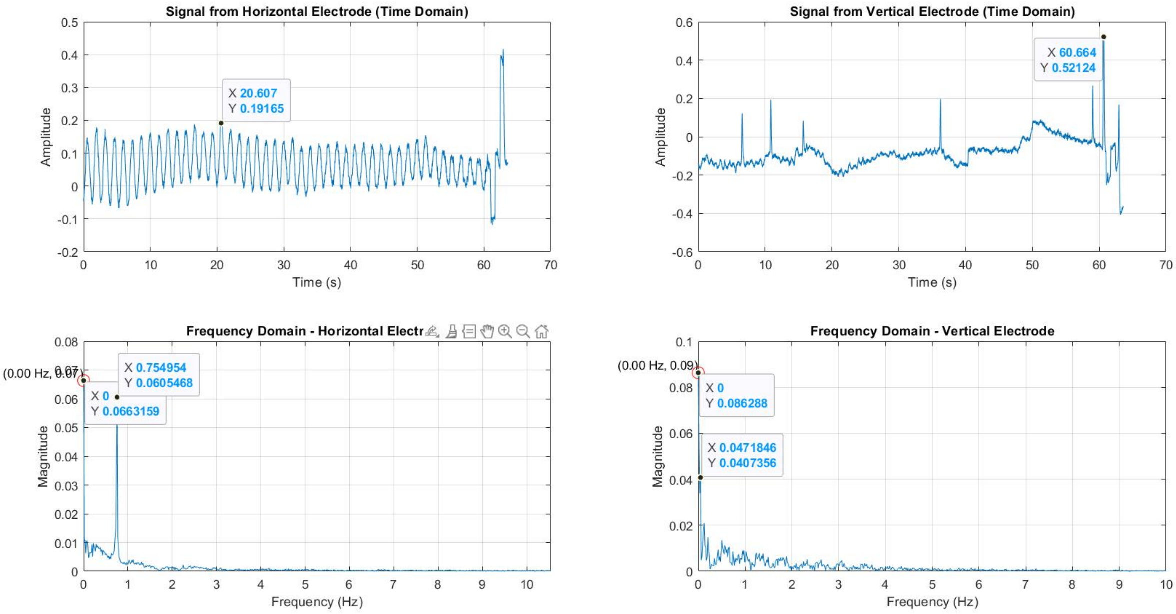


Fig 5. Signal from Horizontal Electrode and Vertical Electrode

Signal from Horizontal Electrode:

The peak amplitude is 0.191 mvolt for electrode placement in the horizontal plane. While two frequency components are found; one is 0.754 Hz, and the second is 0 Hz which contains non-significant components.

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Signal from Vertical Electrode:

From FFT two frequencies are obtained is 0.754 Hz and 1.5 Hz. The maximum peak amplitude is 0.191 mVolt.

Calculation of frequency from pendulum movement

Frequency = Number of oscillations/Time

= 47/ (60.03sec) = **0.7829Hz**

Frequency of the pendulum remains the same. Still, frequency of eye movement is different in horizontal and vertical electrode arrangement.

HORIZONTAL EOG:

Horizontal EOG is having a dominant component of frequency 0.754 Hz which is pendulum frequency. So, the frequency of pendulum is similar as the frequency of the horizontal EOG signal.

VERTICAL EOG:

Vertical EOG signal yields two frequency components and both components are significant which is seen in the plot. One frequency is same as pendulum frequency (0.754 Hz). Another frequency is (0 Hz). So vertical EOG signal contains horizontal as well vertical EOG components. This another frequency component represents the actual vertical EOG. The frequency of the vertical EOG is 0.047 Hz.

Eye movement in a vertical direction appears two times during a single cycle of the pendulum movement. If the pendulum completes one cycle in 1.3 sec, then eye movement in the vertical direction completes 2 cycles in the same direction. So, the frequency of vertical eye movement will be;

Frequency = Number of oscillations/Time
= 2/ 1.3 (sec) = **1.538 Hz**

Calculated frequency can be verified by the FFT of the vertical EOG. Vertical eye movement frequency is double of the horizontal eye movement the frequency as well of horizontal EOG signal. The horizontal and vertical components of the vertical EOG can be plotted using the following code as the pendulum follows the simple harmonic motion, it will produce a sinusoidal signal.

MATLAB CODE:

```
load('E:\AM23M022_SEM2\FINAL_ADVANCED_BM_LAB\dinesh_eog.mat')


% Extract EOG signals from the 'data' variable
horizontal_signal = data(:, 1);
vertical_signal = data(:, 2);


% Constants
Fs = 1000; % Sampling frequency (Hz)


% Calculate time vector
t = (0:length(horizontal_signal)-1) / Fs; % Time vector (seconds)


% Plot signal from horizontal electrode in time domain
figure;
subplot(2,2,1);
plot(t, horizontal_signal);
title('Signal from Horizontal Electrode (Time Domain)');
xlabel('Time (s)');
ylabel('Amplitude');
grid on;
```

```
% Plot signal from vertical electrode in time domain
subplot(2,2,2);plot(t, vertical_signal);
title('Signal from Vertical Electrode (Time Domain)');
xlabel('Time (s)');
ylabel('Amplitude');
grid on;


% Perform Fourier transform to obtain frequency domain representation for horizontal signal
Y_horizontal = fft(horizontal_signal);
L_horizontal = length(horizontal_signal);
P2_horizontal = abs(Y_horizontal/L_horizontal);
P1_horizontal = P2_horizontal(1:L_horizontal/2+1);
P1_horizontal(2:end-1) = 2*P1_horizontal(2:end-1);
f_horizontal = Fs*(0:(L_horizontal/2))/L_horizontal;


% Perform Fourier transform to obtain frequency domain representation for vertical signal
Y_vertical = fft(vertical_signal);
L_vertical = length(vertical_signal);
P2_vertical = abs(Y_vertical/L_vertical);
P1_vertical = P2_vertical(1:L_vertical/2+1);
P1_vertical(2:end-1) = 2*P1_vertical(2:end-1);
f_vertical = Fs*(0:(L_vertical/2))/L_vertical;


% Plot frequency domain representations
subplot(2,2,3);
plot(f_horizontal, P1_horizontal);xlim([0 10]);
title('Frequency Domain - Horizontal Electrode');
xlabel('Frequency (Hz)');
ylabel('Magnitude');
grid on;


% Find peak frequencies for horizontal and vertical eye movements
[max_amp_horizontal, max_index_horizontal] = max(P1_horizontal);
peak_frequency_horizontal = f_horizontal(max_index_horizontal);
peak_magnitude_horizontal = max_amp_horizontal;


[max_amp_vertical, max_index_vertical] = max(P1_vertical);
peak_frequency_vertical = f_vertical(max_index_vertical);
peak_magnitude_vertical = max_amp_vertical;


% Plot marker for peak frequency on horizontal plot
hold on;
plot(peak_frequency_horizontal, peak_magnitude_horizontal, 'ro', 'MarkerSize', 10);
text(peak_frequency_horizontal, peak_magnitude_horizontal, sprintf('(%.2f Hz, %.2f)',
peak_frequency_horizontal, peak_magnitude_horizontal), 'VerticalAlignment', 'bottom',
'HorizontalAlignment', 'right');
hold off;
```

```
subplot(2,2,4);
plot(f_vertical, P1_vertical);xlim([0 10]);
title('Frequency Domain - Vertical Electrode');
xlabel('Frequency (Hz)');
ylabel('Magnitude');
grid on;
% Plot marker for peak frequency on vertical plot
hold on;
plot(peak_frequency_vertical, peak_magnitude_vertical, 'ro', 'MarkerSize', 10);
text(peak_frequency_vertical, peak_magnitude_vertical, sprintf('(%.2f Hz, %.2f)', peak_frequency_vertical,
peak_magnitude_vertical), 'VerticalAlignment', 'bottom', 'HorizontalAlignment', 'right');
hold off;
% Calculate peak amplitudes of horizontal and vertical EOG signals
peak_amplitude_horizontal = max(horizontal_signal);
peak_amplitude_vertical = max(vertical_signal);
% Display results
fprintf('Frequency Analysis:\n');
fprintf('Peak Frequency of Horizontal Eye Movement (Hz): %f\n', peak_frequency_horizontal);
fprintf('Magnitude at Peak Frequency of Horizontal Eye Movement: %f\n', peak_magnitude_horizontal);
fprintf('Peak Frequency of Horizontal EOG (Hz): %f\n', peak_frequency_horizontal); % Assuming same as
horizontal eye movement
fprintf('Magnitude at Peak Frequency of Horizontal EOG: %f\n', peak_magnitude_horizontal);
fprintf('Peak Frequency of Vertical Eye Movement (Hz): %f\n', peak_frequency_vertical);
fprintf('Magnitude at Peak Frequency of Vertical Eye Movement: %f\n', peak_magnitude_vertical);
fprintf('Peak Frequency of Vertical EOG (Hz): %f\n', peak_frequency_vertical); % Assuming same as
vertical eye movement
fprintf('Magnitude at Peak Frequency of Vertical EOG: %f\n', peak_magnitude_vertical);
fprintf('\nAmplitude Analysis:\n');
fprintf('Peak Amplitude of Horizontal EOG (mVolt): %f\n', peak_amplitude_horizontal);
fprintf('Peak Amplitude of Vertical EOG (mVolt): %f\n', peak_amplitude_vertical);
```

Table 1: EOG Analysis in Amplitude and Frequency domain

	Parameters	Values
Frequency Analysis	Frequency of Horizontal Eye Movement (Hz)	0.7829
	Frequency of Horizontal EOG (Hz)	0.754
	Frequency of Vertical Eye Movement (Hz)	0.05
	Frequency of Vertical EOG (Hz)	0.047
Amplitude Analysis	Peak Amplitude of Horizontal EOG (mV)	0.191
	Peak Amplitude of Vertical EOG (mV)	0.521

There is a correlation between eye movement and generated potential. The differential potential in horizontal electrode pair is more. Eye movement in horizontal plane is more compared to vertical plane. In vertical electrode generated potential is less as eye movement is in horizontal plane so its vertical component will be less.

The potential in the eye can thus be estimated by measuring the voltage induced across a system of electrodes placed around the eyes as the eye-gaze changes.

Conclusion:

As the eyes move with pendulum movement, they produce corresponding changes in the electrical potential. This can be verified by noting the corresponding frequency of EOG and pendulum oscillation. Horizontal EOG can trace the pendulum frequency while vertical EOG If Electrodes are placed in the same plane in which eye movement occurs can produce high voltages. Eye movement produces a bipolar voltage that is visible in the plotted graph. The EOG seems like an ideal candidate for a gaze-tracking system. So EOG can be useful to develop a system based on eye movement like EOG controlled wheelchair, Eye writing system and many more.