Vital Signals Lab
Experiment 1 (EOG)

Fall 2024

Mana Mohammadi 810100207
Mohammad Sina Samadbin 810100180
Parsa Darban 810100141

This file contains the report and results of the simulations conducted.

Abstract

In this experiment, we focus on processing EOG signals.

The vertebrate eye is an important sensory organ that converts light energy into nerve impulses. In humans, the position of the eyes in the front of the head creates overlapping visual fields, resulting in stereovision. Eye movements are controlled by a number of small muscles that insert onto the eyeball; these are the extrinsic eye muscles. These muscles allow the eyes to either track moving objects or fixate on stationary ones, even when the head is moving. In this experiment, we aim to collect signals using three electrodes and an EOG Pod, which will be placed as shown below.

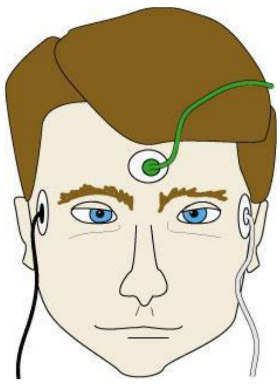

Figure 1(Connecting the EOG lead wires)

EOG and angular displacement

In this section, we need to move our eyes at different angles and record the EOG signals to determine their amplitude.

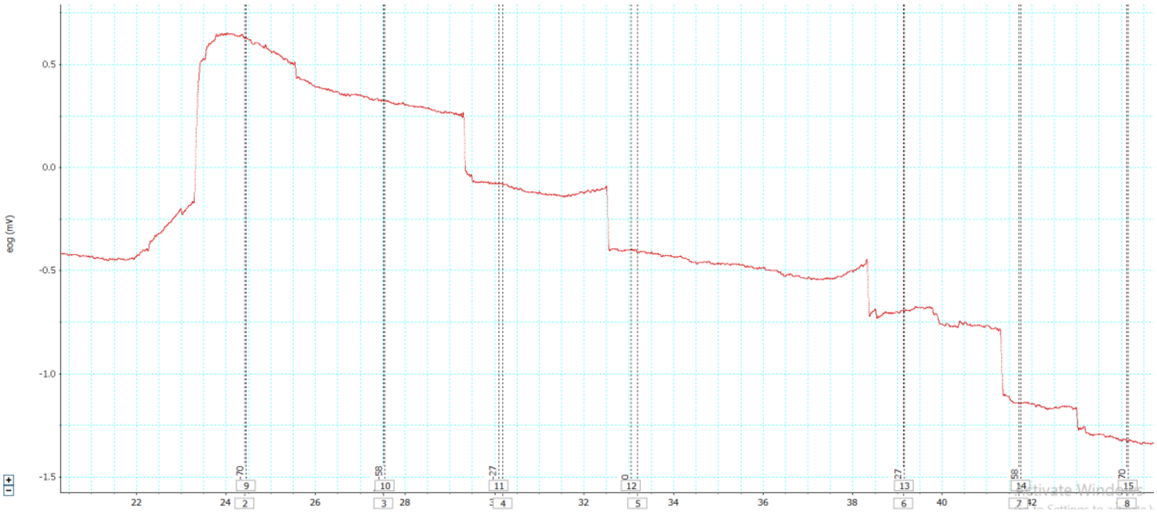

Figure 2 (subject1 angular displacement)

VIEW ANGLE	EOG AMPLITUDE
-70	0.650
-58	0.330
-27	-0.077
0	-0.400
27	-0.697
58	-1.143
70	-1.327

Table 1 (subject1 Amplitude(mv) for Angles(degrees))

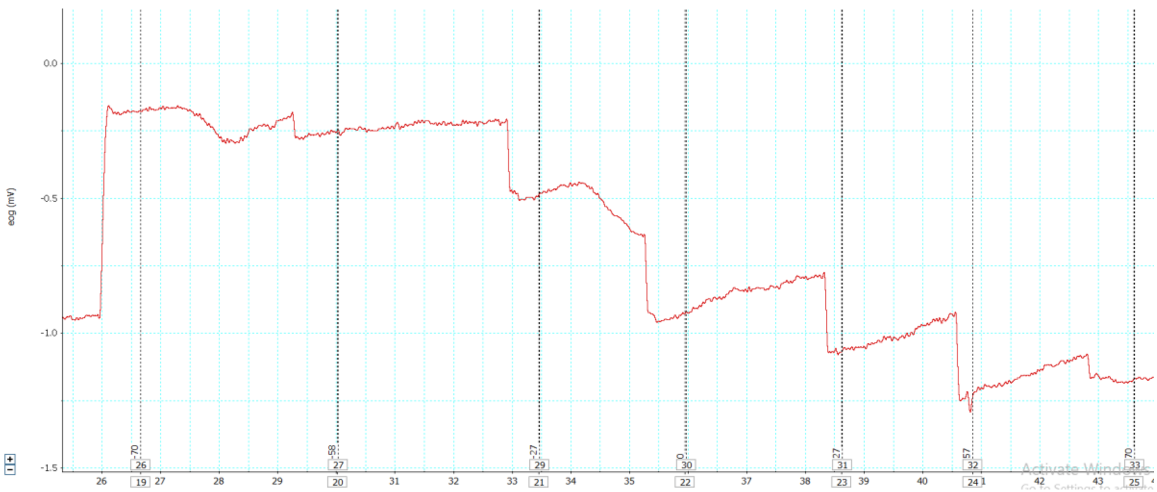

Figure 3 (subject2 angular displacement)

VIEW ANGLE	EOG AMPLITUDE
-70	-0.178
-58	-0.248
-27	-0.450
0	-0.836
27	-1.016
58	-1.158
70	-1.168

Table 2 (subject2 Amplitude(mv) for Angles(degrees))

It is important to note that our reference voltage should be set to zero at the zero angle for accurate calculations. However, in this case, it is not at that level. To linearize the values, we need to add a bias equal to our zero voltage to all measurements.

Saccades

In this section, our subjects were required to read two texts, one in English and one in Persian, in a normal manner without moving their heads. Now, we will analyze the timing of these two subjects.

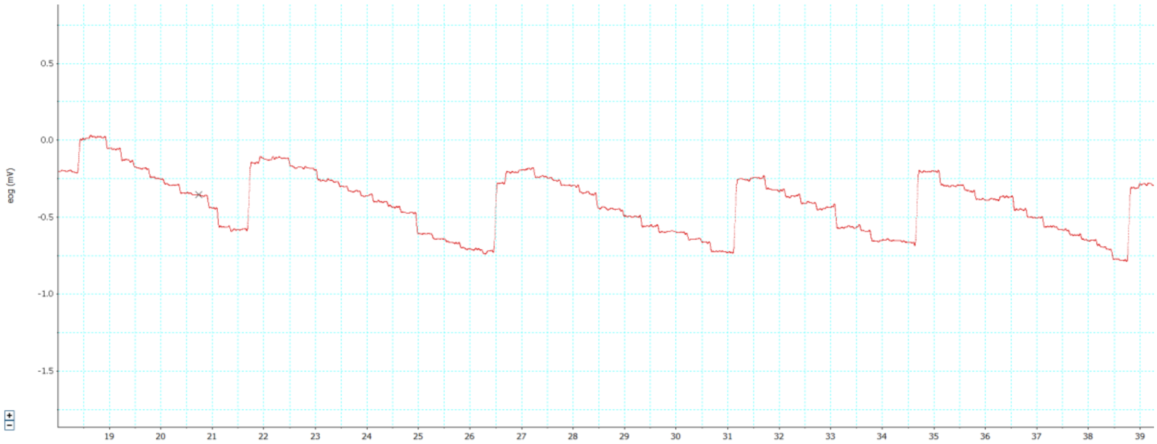

Figure 4 (subject1 Saccade signal)

PARAMETER	DURATION
Saccade 1	3.304
Saccade 2	4.775
Saccade 3	4.654
Saccade 4	3.521
Saccade 5	4.123
Average saccade duration	4.0754

Table 3 (subject1 Saccade's Duration(sec))

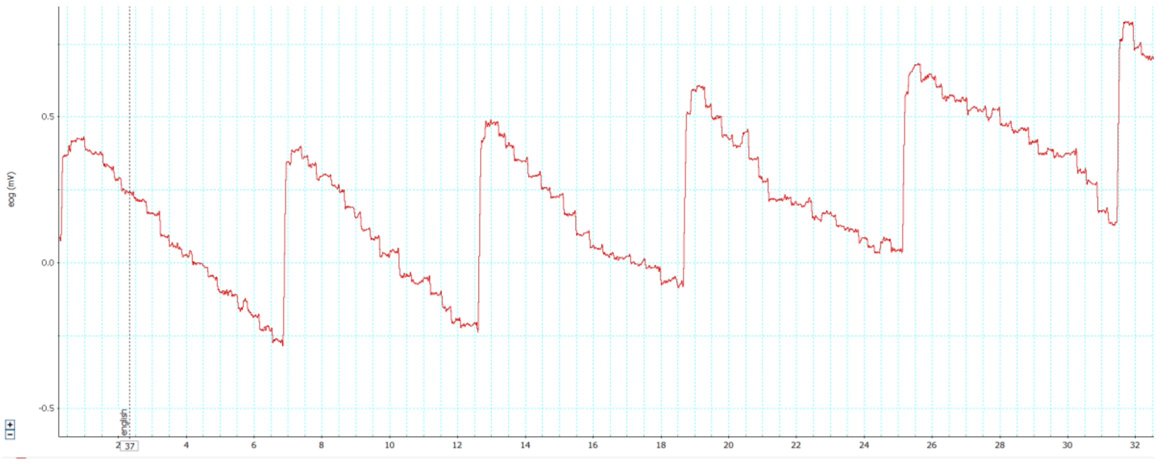

Figure 5 (subject2 Saccade signal)

PARAMETER	DURATION
Saccade 1	6.503
Saccade 2	5.706
Saccade 3	6.068
Saccade 4	6.449
Saccade 5	6.322
Average saccade duration	6.2096

Table 4 (subject2 Saccade's Duration(sec))

As we can see, the first person had a faster reading speed. Additionally, the jumps present in the signal indicate a change in the line being read. The increase in voltage levels in the second person could be due to various reasons, such as head movement, misalignment of the EOG Pod, and similar factors.

Smooth tracking

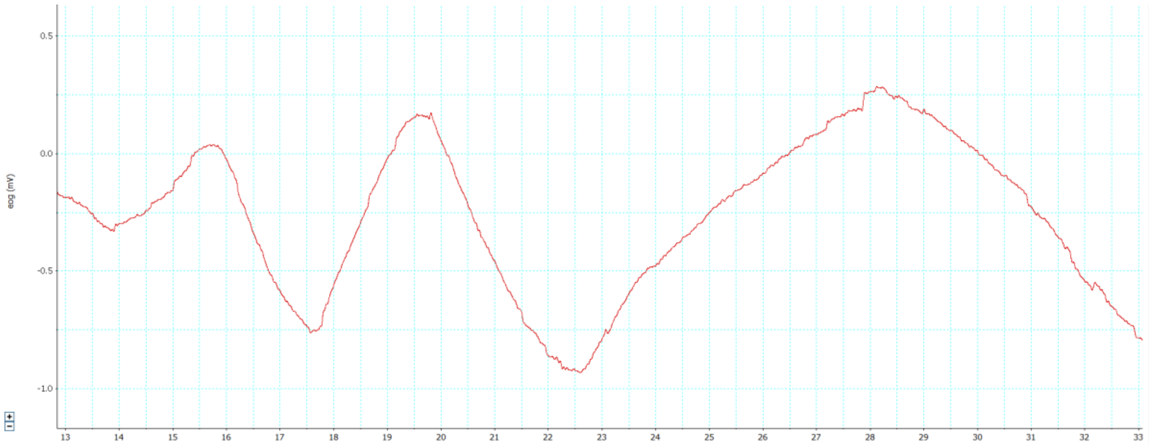

Figure 6 (subject1 smooth tracking)

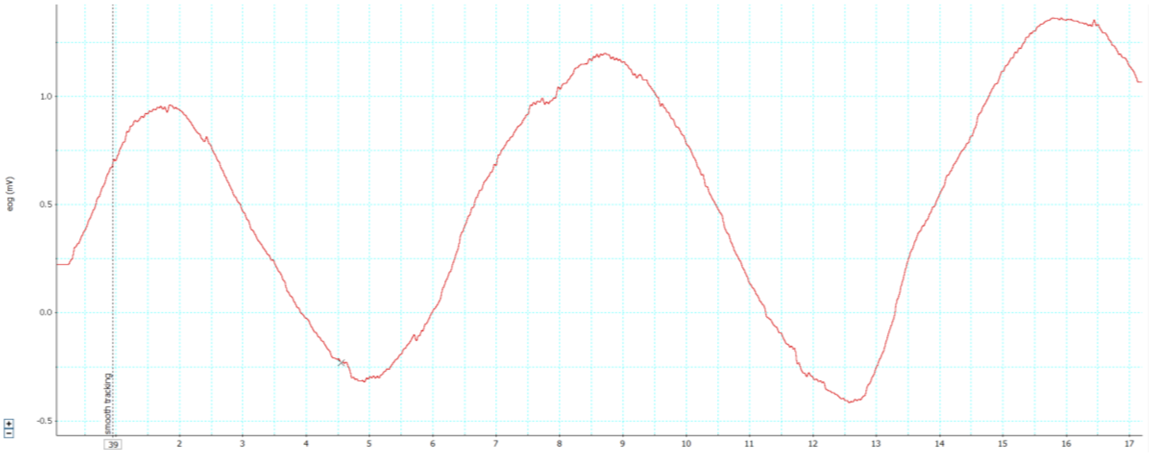

Figure 7 (subject2 smooth tracking)

We understand that there are two important parameters here :

1. The duration of each saccade, which depends on the frequency of the saccadic movement .

2. The angle of the saccadic movement, which affects the peak voltage of the signal .

In this context, the signal and saccading are presented continuously.

Nystagmus

In this section, we aimed to collect the signal by rapidly moving the head while focusing the eyes on a point that served as a reference voltage equal to zero.

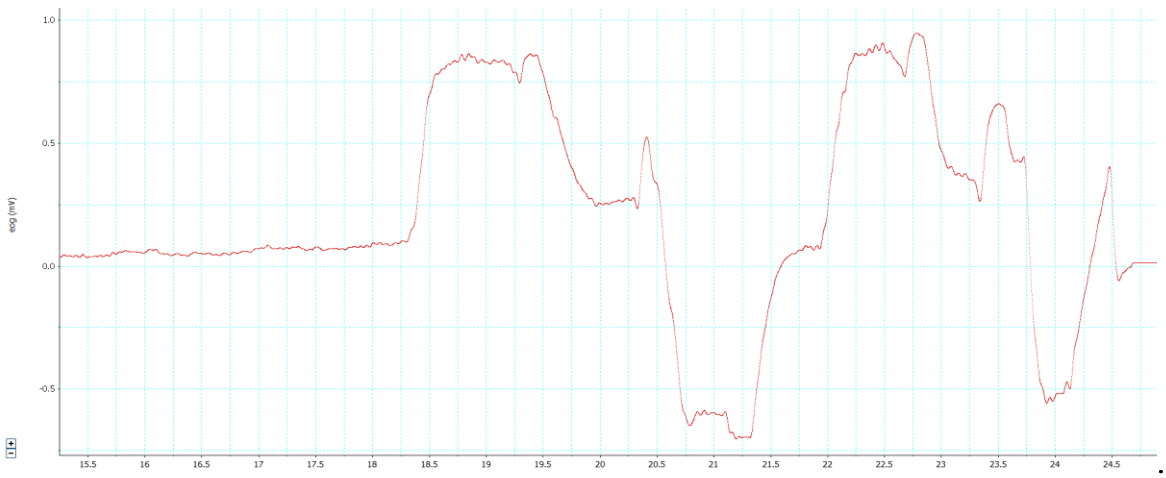

Figure 8 (subject1 Nystagmus)

PARAMETER	VALUE
Maximum EOG amplitude to left	0.95
Maximum EOG amplitude to right	-0.698
Saccade duration	1.885

Table 5 (subject1 Nystagmus(mv))

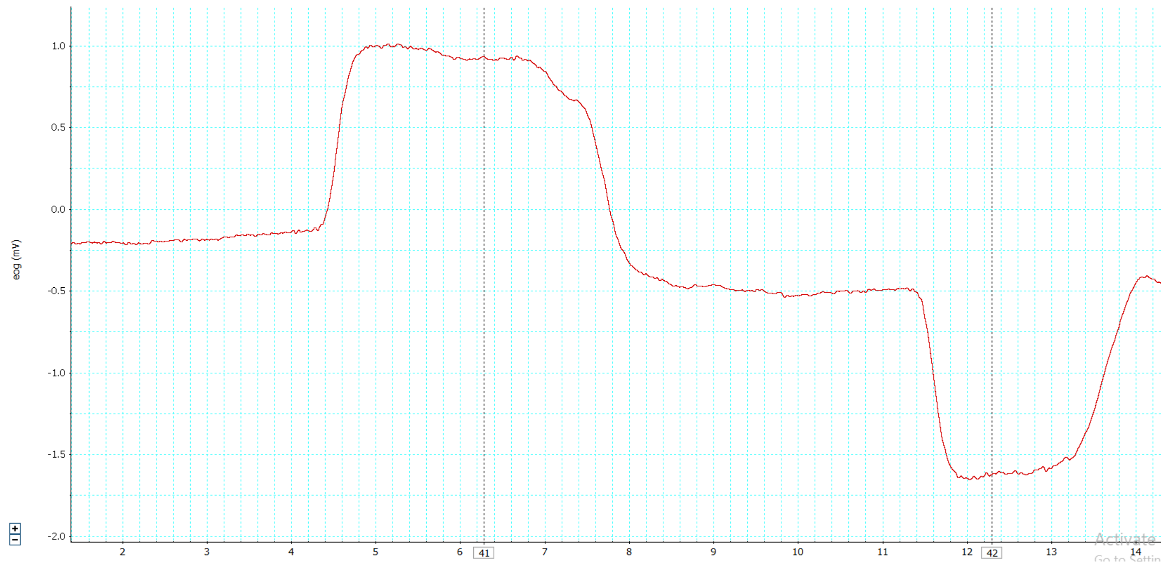

Figure 9 (subject2 Nystagmus)

PARAMETER	VALUE
Maximum EOG amplitude to left	1.011
Maximum EOG amplitude to right	-1.653
Saccade duration	5.065

Table 6 (subject2 Nystagmus)

Result

Figure 10 (subject1 Blinking)

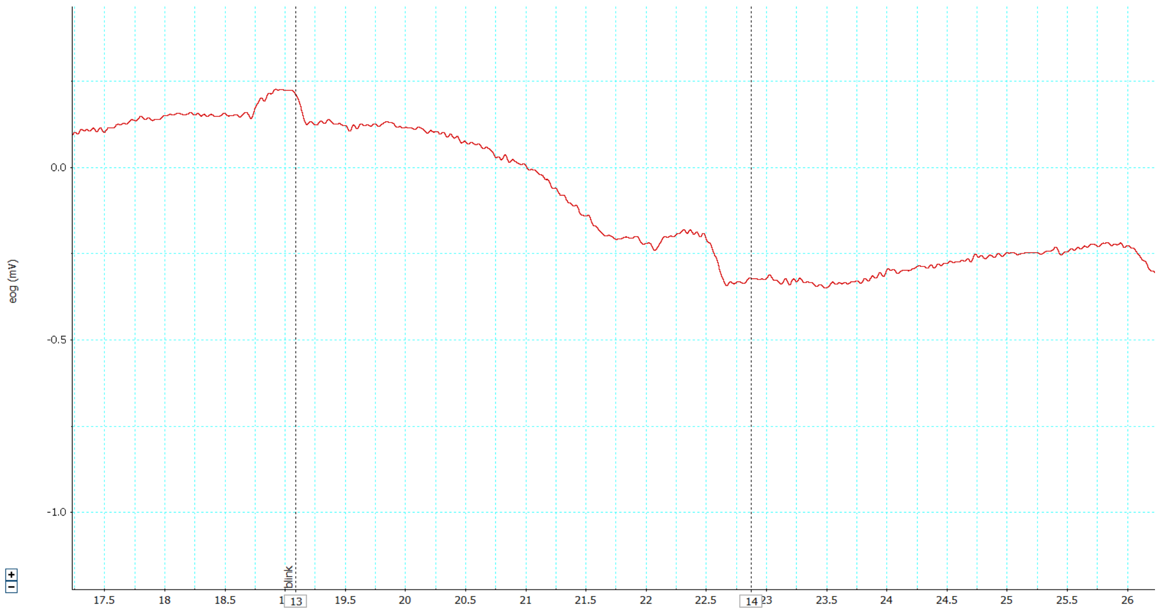

Figure 11 (subject2 Blinking)

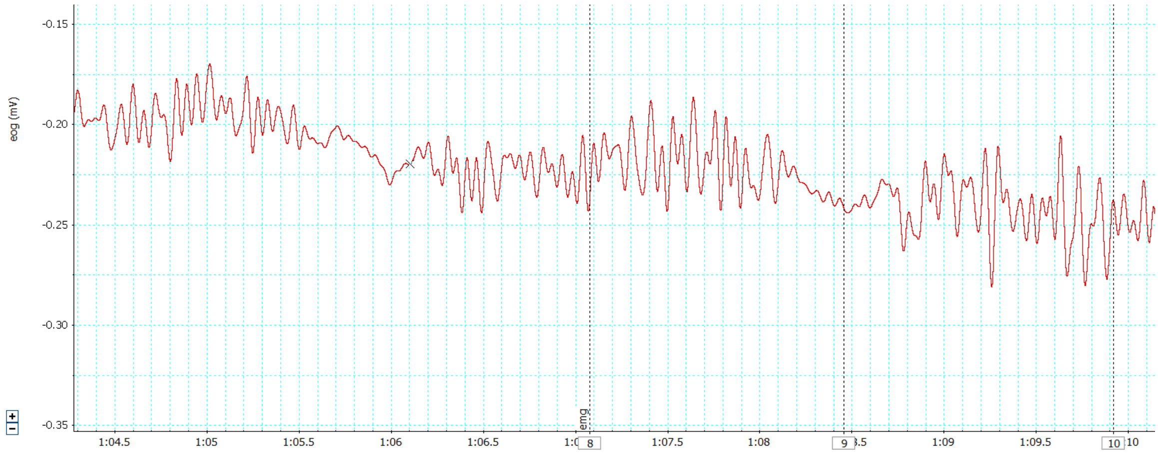

Figure 12 (subject1 EMG signal)

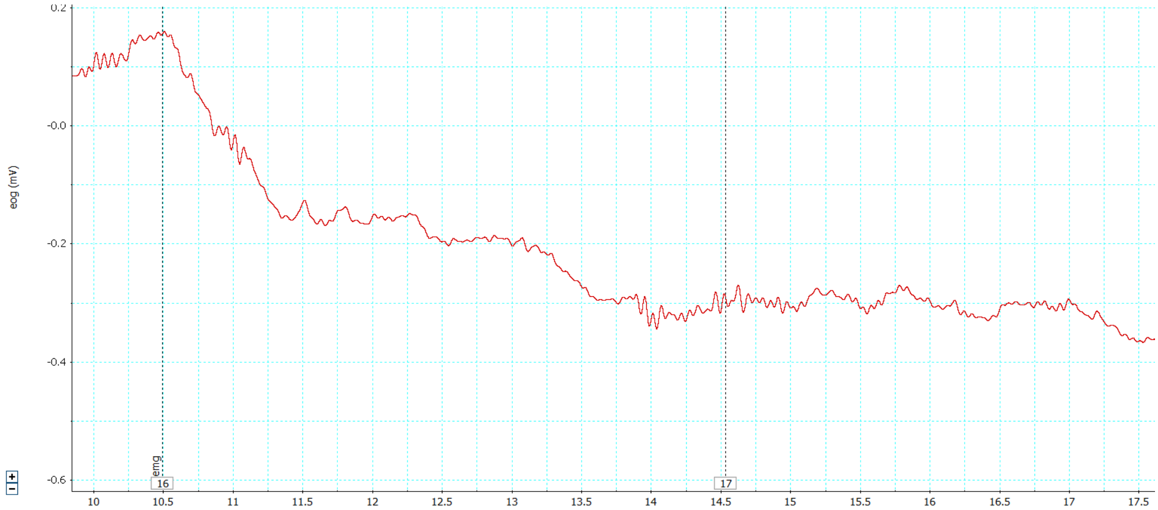

Figure 13 (subject2 EMG signal)

As can be observed, performing movements that are not related to the eye nerve also affects the EOG signal.

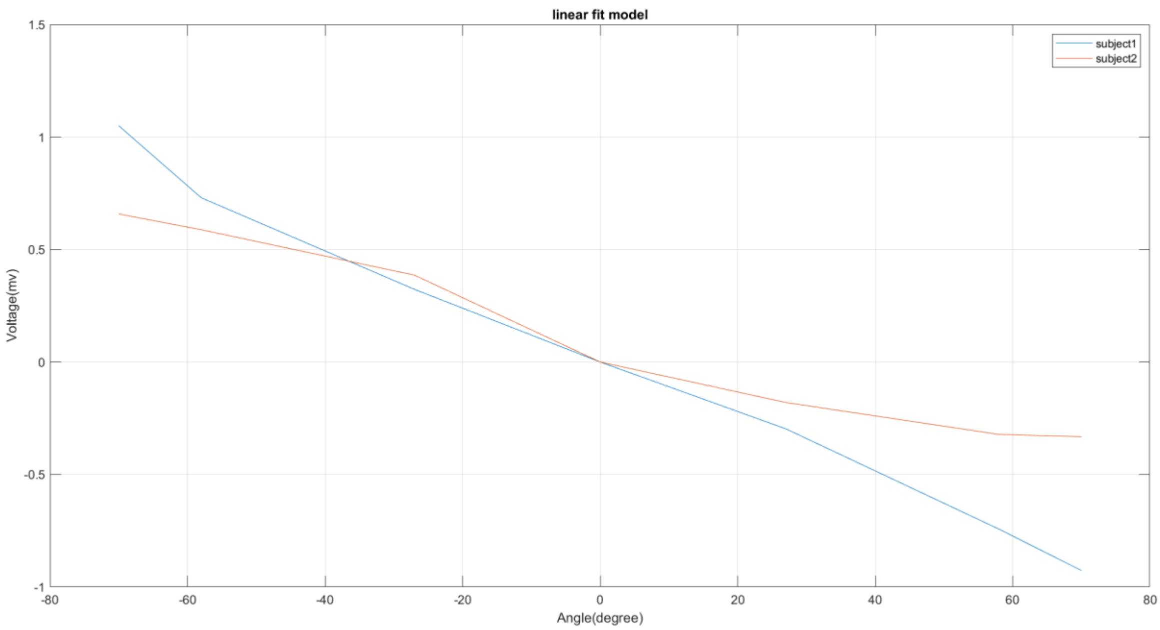

Figure 14 (Linear model of relation between EOG amplitude and Angular displacement)

As we can see, we are dealing with an approximately linear relationship.

Keep in mind that we will subtract all the voltages with the offset, which has arisen due to system factors, from the data in the code.

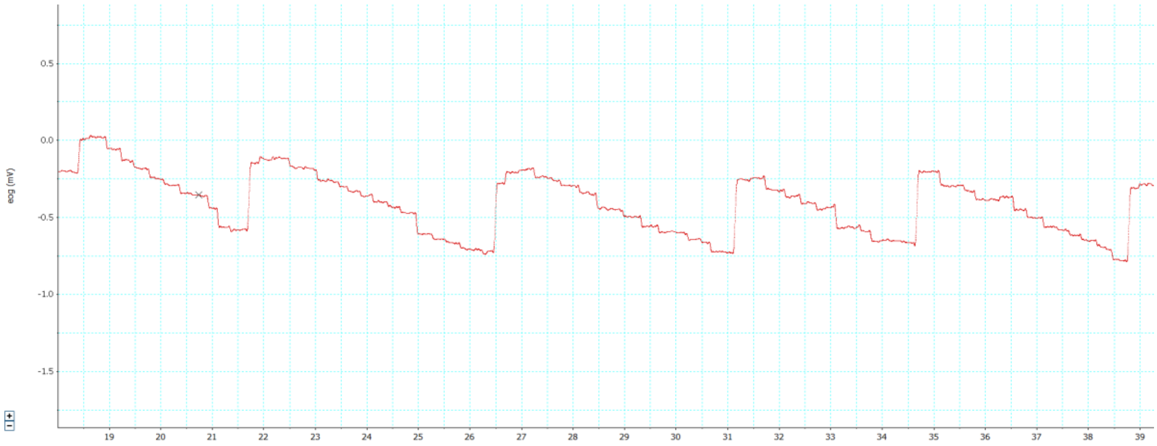

Figure 15 (subject1 Saccade signal)

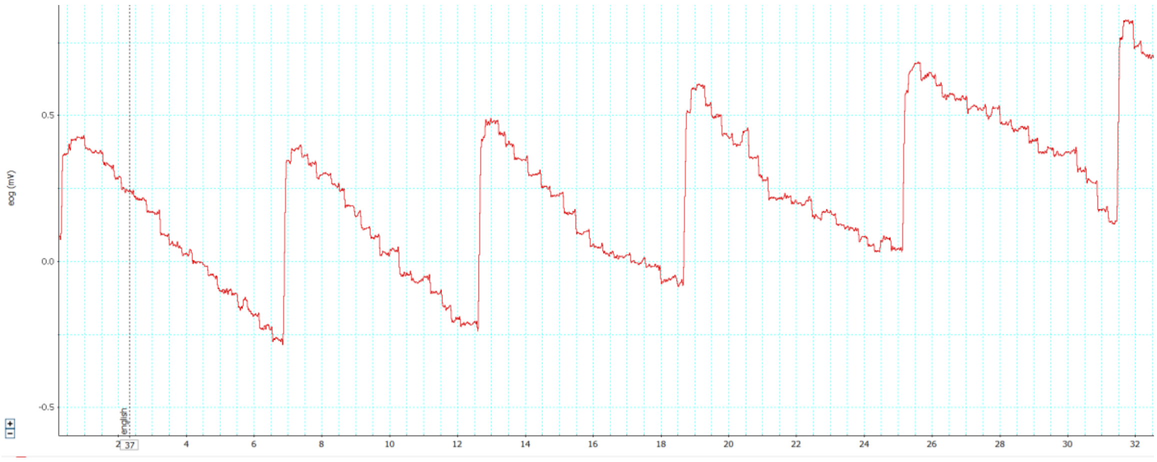

Figure 16 (subject2 Saccade signal)

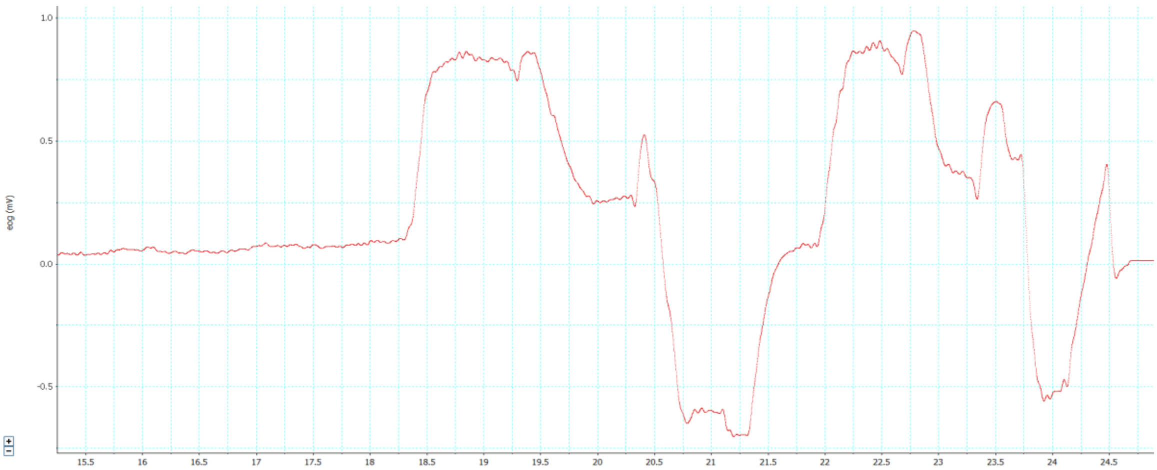

Figure 17 (subject1 Nystagmus)

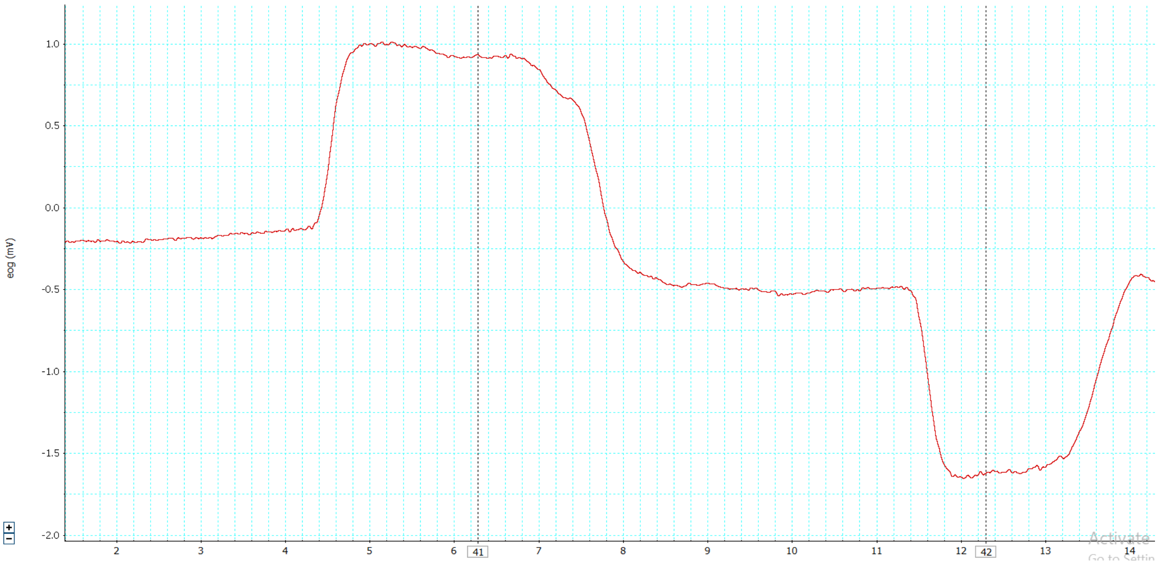

Figure 18 (subject2 Nystagmus(mv))

Conclusion

1) Were you able to detect any EMG or blink artifacts in your experimental EOG recordings? Briefly discuss why blinking would cause an artifact.

Given that blinking is related to the eyes, it acts like an impulse, and this is evident in the figure10 & figure11, appearing like an impulse pulse in our signal. Since the cornea has a more positive charge compared to the retina, blinking disrupts this potential. Also, EMG signals cause artifacts as well. Both are generated by an electrical potential, which combines with the EOG signals. The best approach is to, in addition to taking subject precautions, first capture the blinking signals and then take their effect into account at the end and filter them out.

2) Describe the relationship between EOG amplitude and angular displacement. Was the response linear? Discuss why you think you obtained this result.

Yes, this is evident, and the results of and ‘EOG and angular displacement’ and ‘smooth tracking’ confirm it. If we move our eyes from a point on the left at a constant speed, we can obtain a linear signal with a downward slope. The reason for this is the way the electrodes are connected, where the reference is placed in the middle of the head at 0 degrees. Looking to the left results in higher voltages relative to the potential on the right, and movement in this direction causes voltage changes.

3) Discuss the velocity of saccades in your recording. Why are saccades an important aspect of vision? Do you notice saccades when you are reading?

It depends on two factors:

The speed of the subject's eye movement and the length of the lines being read.

If the eye movement speed is higher, the time decreases, and the longer the line, the time increases.

Saccadic eye movements allow us to scan scenes, gather information, and perceive our surroundings dynamically and efficiently. Otherwise, our vision would be static and limited to the information present at the center of our field of view. Thus, we can scan objects with high speed and accuracy.

We are generally unaware of these saccadic eye movements, but if they were to be absent or disrupted, reading could become slower and more difficult.

4) Did saccades occur during slow tracking? If so, how can you explain their appearance in the data?

Yes, it appears, but if the frequency of the automatic movement increases. In the conducted experiment, since the movement was continuous, our eyes change direction at the same point and, if the frequency remains constant with the previous slope, increases the amplitude, which results in a triangular signal. In the experiment, due to the frequency not remaining constant and the artifacts, the amplitude and slope of the signal are subject to change.

5) How did the EOG amplitude compare between slow tracking and nystagmus? Discuss the relationship between the vestibular system and eye movements.

The EOG amplitude during slow tracking movements is generally lower and more stable. The movements are gradual, resulting in a smoother waveform in the EOG recording. This leads to controlled voltage with consistent changes under the condition of a constant speed of movement. However, in nystagmus, the movements are faster, and the waveform has a greater amplitude.

The vestibular system plays a vital role in coordinating eye movements. This system adjusts eye movements to head movements through the vestibulo-ocular reflex (VOR) to maintain stable vision. Additionally, it integrates information about head position with visual inputs to control both smooth and saccadic movements. The absence of this system can lead to visual disturbances and instability.