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# Comparison of Wearable Video-based Eye Tracking and EOG for Oculomotor Activity Detection in Specific Research Tasks

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***Abstract*—Oculomotor activity measurement is crucial for understanding visual perception and cognitive processes in neuroscience. This study conducts a comparative analysis of wearable video-based eye tracking (Pupil Core) and electrooculography (EOG) in detecting eye movements during a neurophysiological task based on Raven's Advanced Progressive Matrices (APM). Fourteen calibration sessions were performed using five calibration points, and data synchronization was achieved through the Lab Streaming Layer protocol. Both eye tracking methods were calibrated using optimal affine transformation matrices to minimize discrepancies between fixation points and calibration markers. The calibration error averaged 66.4 pixels for the Pupil Core system and 64.73 pixels for EOG data, indicating comparable accuracy between the two methods. Despite EOG's susceptibility to artifacts from muscle contractions and wire movements, its performance suggests it is a viable alternative to video-based systems, particularly in environments with challenging lighting conditions or when long-term monitoring is required.**

***Index Terms*—eye tracking, electrooculography, calibration, visual search**

## I. INTRODUCTION

The study of oculomotor activity is a fundamental aspect of understanding the mechanisms of visual perception and human behavior [1], [2]. In particular, in neuroscience, this research allows us to comprehend the neurophysiological processes underlying attention, cognitive functions, and interaction with the environment [3]–[8]. Precise measurement of eye movements enables the investigation of the neurophysiological basis of human interaction with the surrounding environment, as well as the diagnosis of various neurological disorders [9], [10].

Modern methods for recording oculomotor activity include wearable video-based eye trackers and electrooculography (EOG). Wearable video trackers use cameras and image processing algorithms to determine eye positions and movements in real time. They provide high spatial resolution and allow for the analysis of complex patterns of oculomotor activity. However, their effectiveness can be limited by external factors such as low lighting or head movements.

On the other hand, electrooculography is based on measuring the electrical potentials that arise when the eyeballs move relative to the orbital axis. EOG is less dependent on external conditions and may be more convenient for long-term studies. Nevertheless, this method may be inferior in accuracy and detail compared to video trackers. This method also has several disadvantages, such as wire movement or muscle contractions.

In the context of neurophysiological experiments, it is important to understand which method is most suitable for specific research tasks. For example, when studying rapid saccadic movements or microsaccades, video trackers can provide more detailed information. At the same time, for long-term monitoring of oculomotor activity in natural conditions, EOG may be preferable.

The aim of this work is to conduct a comparative analysis of wearable video-based eye trackers and electrooculography for detecting oculomotor activity in specific research tasks in neuroscience. We will consider the calibration capabilities and accuracy of each method and their applicability in various experimental conditions, as well as the potential impact on the results of neurophysiological studies.

Understanding the efficiency and limitations of these technologies will improve the design of neurophysiological experiments and contribute to a deeper understanding of the mechanisms underlying oculomotor activity and related cognitive processes.

## II. METHODS

This study examined a neurophysiological experiment based on Raven's Advanced Progressive Matrices (APM). APM is widely used to assess abstract thinking and cognitive abilities, requiring participants to identify patterns in visual sequences. Recent research, such as the article [11] demonstrates that the analysis of sequential eye movements can reveal strategies employed by subjects when solving complex cognitive tasks. An eye tracker, Pupil Core, was used to record oculomotor activity, and the actiCHamp amplifier was employed to record the electrooculogram (EOG), capturing both horizontal and

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vertical components. Since eye tracker data and electrooculogram data cannot be directly compared, the EOG data were initially filtered using a band-pass filter in the frequency range of 0.01 to 40 Hz and then normalized to the maximum value along each axis. Figure 1 shows the filtered and normalized oculomotor activity signals for EOG and Pupil Core.

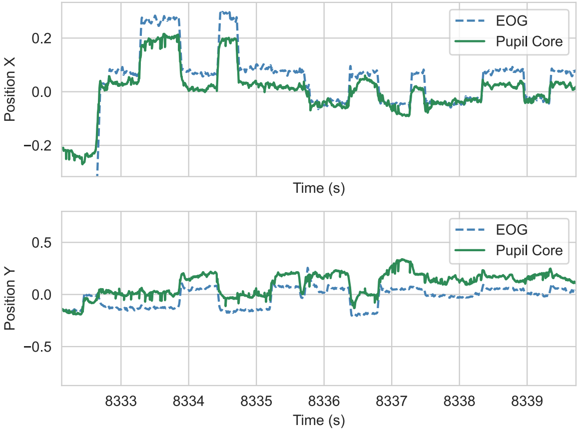

Fig. 1. Time dependence of x and y coordinates position for eye tricking (Pupil Core) and EOG data.

To calibrate the measured data and calculate the coordinates on the monitor screen from the oculographic activity data, 14 calibration sessions were added with a set of 5 points at 4 at the corners and 1 at the center of the screen. The subject had to sequentially move his gaze from one point on the screen to another. The Lab Streaming Layer protocol was used for recording and synchronizing the time series of oculographic data. The Lab Streaming Layer (LSL) is an open-source network protocol designed for the real-time exchange of time series data between applications. It is commonly utilized in neuroscience and psychophysiological experiments to synchronize data streams from multiple sensors and devices, ensuring precise temporal alignment for accurate analysis. For calibration, optimal affine transformation matrices were calculated to minimize the discrepancy between the transformed fixation points and the markers [12], [13]. Figure 2 shows an example of calibrated eye tracker data based on five markers.

The obtained data sets were calibrated for a monitor with a resolution of 2560x1440. Subsequently, the error was calculated as the average distance (in pixels) from the median of the centers of all fixations to the calibration point (marker). Figure 3 shows the error value of each calibration session for the Pupil Core and EOG data.

The obtained results demonstrate that the mean calibration error for the Pupil Core eye-tracking system was 66.4 pixels, while for the electrooculography (EOG) data it was slightly lower at 64.73 pixels. These findings suggest that both methods exhibit comparable levels of accuracy within the experimental setup. The minimal difference in error values indicates that EOG can serve as a viable alternative to video-based eye tracking for certain applications, especially when considering factors such as cost, portability, or environmental conditions that may affect optical systems.

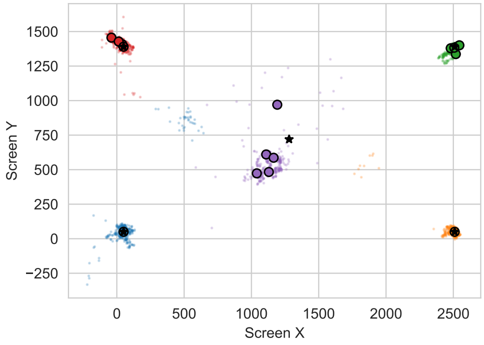

Fig. 2. The eye tracker's point cloud data after calibration, where: '*' indicates calibration markers, circles denote fixations, and colors represent the association of points with specific markers.

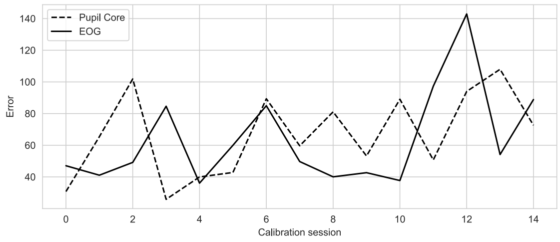

Fig. 3. Error value of each calibration session for the Pupil Core and EOG data

## CONCLUSION

This study compared wearable video-based eye tracking (Pupil Core) and electrooculography (EOG) for detecting oculomotor activity during a neurophysiological task based on Raven's Advanced Progressive Matrices. After calibration using optimal affine transformations, both methods showed similar mean errors: 66.4 pixels for Pupil Core and 64.73 pixels for EOG.

These results indicate that EOG provides accuracy comparable to video-based eye tracking and can serve as a viable alternative, especially when optical methods are hindered by factors like low lighting or head movements. Despite potential artifacts in EOG data, its effectiveness suggests it is valuable for certain research applications.

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