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Biopac Student Lab® Lesson 10

ELECTROOCULOGRAM (EOG) I

Introduction

Rev. 01152013

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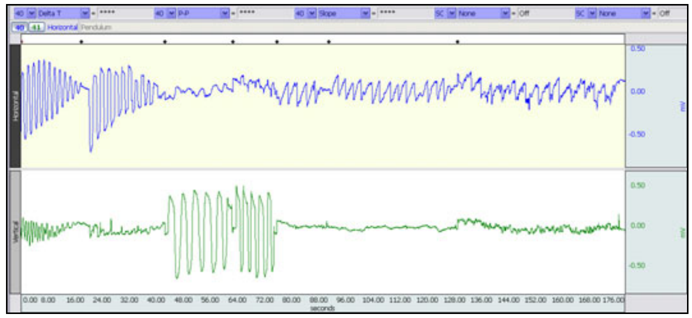


I. INTRODUCTION

A cross-section of the eye is illustrated in Fig. 10.1. Together the *cornea* and the *lens* act like the lens of a camera. They bend the light rays entering the eye and focus them on the retina.

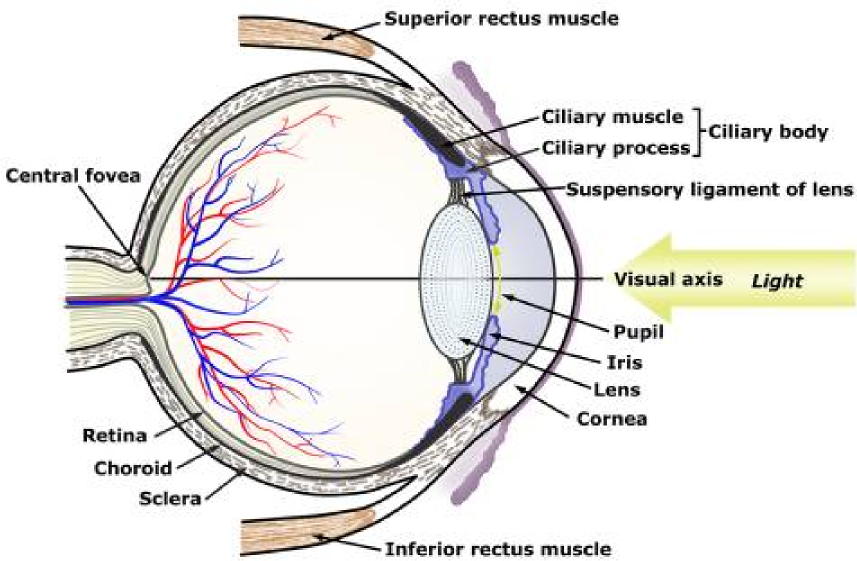


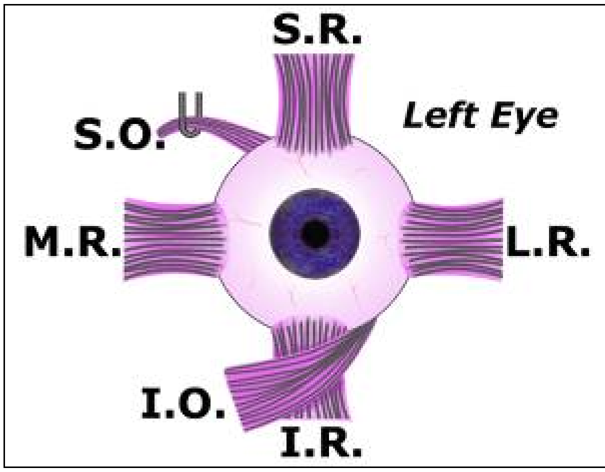
Fig. 10.1 The Eye

Focusing a camera changes the distance between the lens and the film. Our eyes accomplish this feat by changing the shape of the lens. The *ciliary muscle*, a circular muscle attached to the lens by a *suspensory ligament*, contracts, reducing tension on the suspensory ligament thereby allowing the lens to thicken, when focusing on nearby objects. The ciliary muscle relaxes to make the lens thinner and focus on objects that are far away. The *retina* contains a layer of two kinds of light-sensitive *photoreceptors*: cones and rods. *Cones* are used for day vision and color vision. They are most concentrated in the *fovea*, where focused light produces the sharpest image. *Rods* are used for vision in dim light and for the detection of movement in the visual field. Rods are concentrated in the periphery of the retina, hence, the tendency to focus away from the fovea ("look to the side of the eye") in darkness.

Muscular control of the eye works to keep the image on the fovea, regardless of whether the object is stationary or moving. This process is called *visual fixation*. Two primary mechanisms are used to fixate on objects in the visual field, defined as the field of view without moving your head: 1. Voluntary fixation, 2. Involuntary fixation.

Voluntary fixation involves a conscious effort to direct your gaze to a selected object in your visual field and "lock on" to it. This mechanism is used to initially select objects in your visual field. Involuntary fixation involves subconscious mechanisms that operate to keep the selected object in your field of view once you have locked on to it. After you have visually locked on to an object, your eyes continue to move in repetitive, involuntary, imperceptible, minute, jerky movements called *microsaccades* (*micro*-small, *saccade*-jerky movement). These movements counteract perceptual fading, a consequence of rapid adaptation of retinal receptor systems to constant input, by slightly shifting the position of the retinal image within the fovea. Microsaccades also sharpen visual acuity. The recording and measurement of microsaccades is difficult and beyond the scope of this lesson.

The movement of each eyeball in its orbit is caused by the individual contractions of six small voluntary muscles attached to the surface of the eyeball. Four of the six muscles run straight from origin to insertion, and thus are termed recti muscles (*rectus*, straight): the *superior rectus*, the *inferior rectus*, the *medial rectus*, and the *lateral rectus*. The remaining two muscles are obliquely attached to the eyeball surface and are called the *superior oblique* and the *inferior oblique* (Fig. 10.2). Collectively, the four recti muscles and the two oblique muscles are called *extrinsic eye muscles*.



Muscle	Eye Direction
Inferior Rectus (I.R.)	Downward
Superior Rectus (S.R.)	Upward
Lateral Rectus (L.R.)	Laterally
Medial Rectus (M.R.)	Medially
Superior Oblique (S.O.)	Down and Laterally
Inferior Oblique (I.O.)	Up and Laterally

Fig. 10.2 Extrinsic Eye Muscles

Contractions of the extrinsic muscles are controlled by way of motor pathways in the brain and three pairs (one right, one left) of cranial nerves. Cranial Nerve III, the *oculomotor nerve*, supplies all extrinsic eye muscles except the superior oblique and the lateral rectus. Cranial Nerve IV, the *trochlear nerve*, supplies the superior oblique. Cranial Nerve VI, the *abducens nerve*, innervates the lateral rectus.

When a normal person gazes at an adequately illuminated object, the fixation point of the gaze is projected onto corresponding sensory areas in the foveas of the retinas. The occipital lobe cortex integrates the sensory information from each retina, producing normal, single, sharp image of the object. If there is a disruption in the alignment of the eyes, as may occur, for example, in weakness of one or more extraocular muscles, there is a loss of retinal correspondence and the result may be *diplopia* or double vision. Nine cardinal directions of gaze in concerted eye movement and the extraocular muscles moving the eyes to the gaze position are shown in Fig. 10.3.

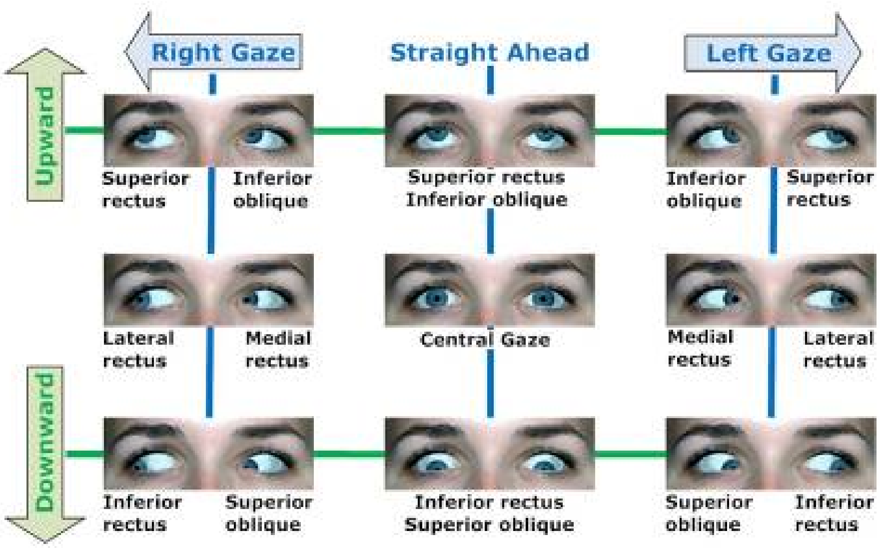


Fig. 10.3 Nine Cardinal Directions of Gaze

As a person voluntarily fixates on a moving object and then involuntarily maintains the visual fix without moving the head, such as in watching the swinging pendulum of a clock, each eye must move precisely and in concert with the other for the brain to receive the sensory information required to produce a clear, single image of the moving object. The eyeball movement involves the extraocular muscles, associated cranial nerves, and motor control centers in the brain. For example, as the clock pendulum swings from left to right, the left eye moves medially (medial rectus / cranial nerve III) and the right eye moves laterally (lateral rectus / cranial nerve VI). When the pendulum swings back, the eye movements are reversed.

The brain subconsciously grades the contractions of extraocular muscles so as to maintain the visual fixation point as the pendulum slows and speeds up during its swing by using visual sensory information regarding change of position of the moving pendulum. The oscillating, or back and forth involuntary movements of the eyes are a form of *tracking movement* in which the eyes maintain a visual fix on an object moving within the visual field.

Coordinated voluntary and involuntary eye movements are controlled by motor centers in the frontal lobe cortex and the motor centers of cranial nerves III, IV, and VI in the brainstem. Cortical activity associated with motor control of the extraocular muscles can be detected and recorded using conventional EEG techniques.

The human eye is an electrical dipole with the positive terminal in front at the cornea, and the negative terminal behind at the retina of the eyeball (Fig. 10.4). The potential between the front and the back of the eyeball, called the *corneal – retinal potential* (CRP,) is about 0.4 – 1.0 mV, and is primarily due to hyperpolarizations and depolarizations of nerve cells in the retina. *Electrooculography* is a technique for recording voltage changes as the eyeballs move in their orbits. The *electrooculogram* (EOG,*)* is an electroencephalographic record of the voltage changes obtained while the subject, without moving the head, moves the eyes from one fixation point to another within the visual field.

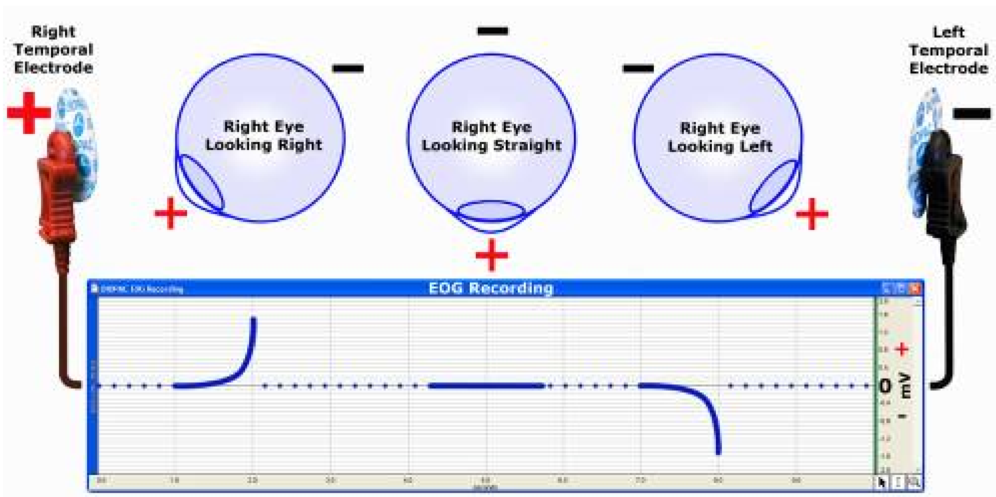


Fig. 10.4 Dipole Model of the Eye and EOG

By placing an electrode on the temporal side of each orbit to detect horizontal eye movement, and another pair above and below the right eye to detect vertical movement, eye movement up to ± 70° can be measured, where 0° is in front and ± 90° is directly lateral or vertical to the eye. The electrodes detect changes in the potential as the cornea moves nearer or further from the recording electrodes (Fig. 10.4). When the eye is looking straight ahead, it is about the same distance from either electrode, so the signal is essentially zero. When the front of the eyeball, the cornea, is closer to the positive electrode, a positive difference in voltage is recorded. The EOG signal is linearly proportional to eye movement, changing approximately 20 microvolts for each degree of eye movement. The EOG signal ranges from 0.05 – 3.5 mV in humans, and is the result of a number of factors, including eyeball rotation and movement, eyelid movement, EEG, head movement, and changing luminescence.

The EOG measurement is susceptible to baseline drift due to minor electrode/skin offset potential changes occurring over several minutes as well as potential baseline shifts due to electrode displacement on the skin surface (typically from electrode leads tugging on the electrodes). To help minimize baseline changes, for this lesson, a 0.05 Hz High Pass filter is used. This filter has minimal effect on the recorded data because the filter's 3.18 second time constant is large compared to the signal variations recorded in this lesson. This filter limitation should be kept in mind when designing additional experiments (optional active learning section); if the eyes fixate on a position for several seconds, the recorded signal will slowly return to baseline (0 mV).

Any movement of the facial muscles or jaw can introduce EMG (muscle) artifact or cause slight baseline shifts due to movement of the EOG electrodes. For this reason it is important to minimize facial and jaw movement when recording EOG data.

An EOG recorded from temporal electrodes placed at the lateral margin of the orbits of a subject visually tracking the movement of a pendulum is shown in Fig. 10.5. The sinusoidal nature of the tracing disappears when the pendulum, and hence the visual tracking, is stopped.

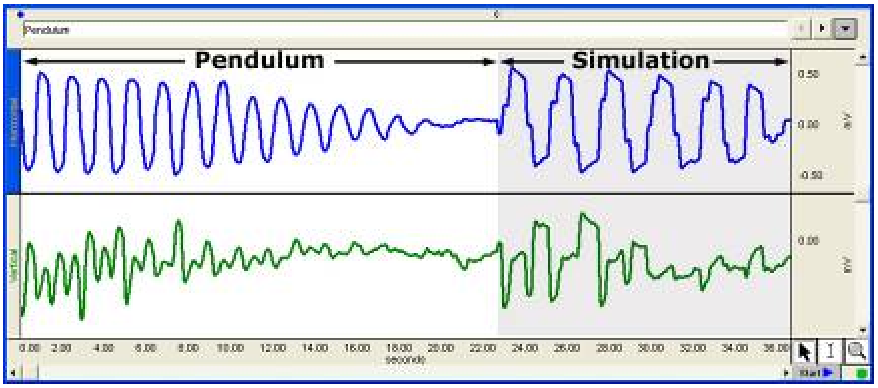


Fig. 10.5 EOG Recording

If the subject, with eyes open, *imagines* a swinging pendulum and attempts to visually track it, the EOG again becomes sinusoidal but jerky, suggesting a reduction in neuromuscular control of the eyes due to the loss of visual sensory input to the brain.

Other changes in the EOG may be recorded when a subject is asked to silently read a brief paragraph, pause, then reread aloud the same paragraph. As the words in each sentence are read, the eyes move quickly and in a jerky manner from one fixation point (a word) to another. Quick, jerky, voluntary movements of the eyes are called **saccades** (*saccade*- jerky). The time interval between saccades is the time spent looking at the word. When the reading is silent, the eyes move quickly from word to word as a line is read, and the interval between saccades is short. When the lines are read aloud, the auditory input slows eye movement to allow time for each seen word to be spoken, and the interval between saccades is longer. Generally, the interval between saccades is longer when reading a difficult passage than when reading an easy passage because more time is required by the brain for information processing.

Electrooculography is commonly used to assess visual defects involving neuromuscular control of the eyes, such as in diagnosis and treatment success of sixth nerve palsy (paralysis of the lateral rectus). Similar eye movement/cranial nerve tests using other cardinal gazes (Fig. 10.3) may be employed in diagnosis and assessment of eye disorders. In addition, recent applications include the use of electrooculography in the design of robotics, such as motorized wheelchairs and other devices that can be guided or otherwise controlled by movement of the subject's eyes.