

## THE OCULOMOTOR SYSTEM

### Visual Behavior

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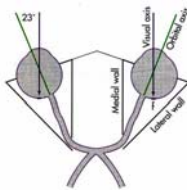
## What do Eye Movements Accomplish?

High *visual acuity* is restricted to the *fovea*. This is due to the local high density of cones and their low convergence onto ganglion cells as well as the reduced optical distortion provided by the displacement of the inner layers (foveal pit).



## What do Eye Movements Accomplish?

Eye movements are therefore used to explore the visual world, as they are necessary to orient the *visual axis* properly so that the images of selected objects or features of interest are brought onto the fovea, where they can be fully analyzed.



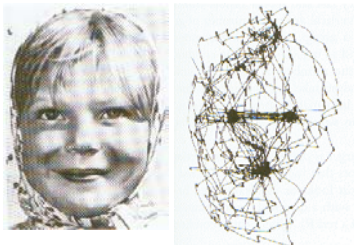
## What do Eye Movements Accomplish?

Vision is an *active process* in which eye movements shift the view several times each second to selected parts of the scene in order to examine *conspicuous features*.



## What do Eye Movements Accomplish?

Eye movements allow us to scan the visual field and intermittently focus our *attention* on the parts of the scene that convey the most *significant information*.



## What do Eye Movements Accomplish?

Eye movements reveal a good deal about the strategies used to inspect a visual scene. Each scan reflects the current task.



Free examination

## What do Eye Movements Accomplish?

Instruction: "Give the ages of the people."



An Unexpected Visitor (I.E. Repin)



## What do Eye Movements Accomplish?

Instruction: "Remember the clothes worn by the people."



An Unexpected Visitor (I.E. Repin)



## What do Eye Movements Accomplish?

Instructions: "Remember the position of the people and the objects in the room."



An Unexpected Visitor (I.E. Repin)



## What do Eye Movements Accomplish?

Instruction: "Estimate how long the unexpected visitor had been away from the family."



An Unexpected Visitor (I.E. Repin)



## What do Eye Movements Accomplish?

The human eyes voluntarily and involuntarily fixate on those elements of a visual scene that carry essential and useful information. The more information is contained in an element, the longer the eyes stay on it.

The distribution of fixations on the elements of a scene changes depends on the *purpose* of the observer, i.e., it is determined by information to be obtained and the thought process accompanying the analysis of this information.

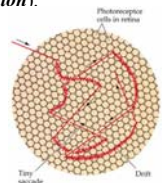
Hence people who think differently also, to some extent, see differently.

A.L. Yarbus (1967)

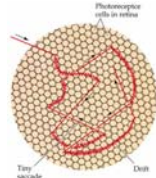
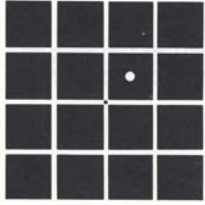
## Eye Movement Functions

Eye movements are made either to direct the fovea to new locations (**foveation**) or to compensate for movements of the target of fixation or movements of one's head that caused the visual axis to be displaced (**gaze stabilization**).

They are also essential for normal **visual perception**. We continue to move our eyes even when we stare intently at a stimulus. Such **miniature** eye movements prevent retinal adaptation that could cause the visual image to disappear.

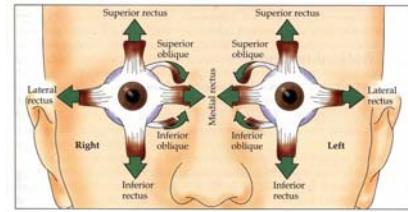


## Miniature Movement Demonstration



## Extraocular Muscles

The eyes are rotated by the action of *six* extraocular muscles, which act as *three agonist/antagonist pairs* allowing rotations in horizontal, vertical and torsional directions.

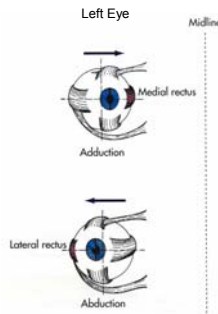


## Action of Extraocular Muscles

The medial and lateral recti are situated in a horizontal plane, so contraction of these muscles rotate the eye around a vertical axis.

Contraction of the medial rectus causes an *adduction* of the eye.

Contraction of the lateral rectus causes an *abduction* of the eye.

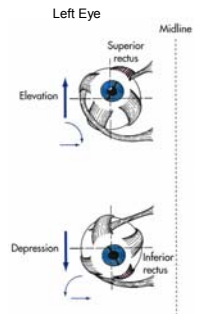


## Action of Extraocular Muscles

The superior and inferior recti are roughly situated in a vertical plane, so contraction of these muscles mainly rotate the eye around a horizontal axis.

Contraction of the superior rectus causes an *elevation* of the eye.

Contraction of the inferior rectus causes a *depression* of the eye.

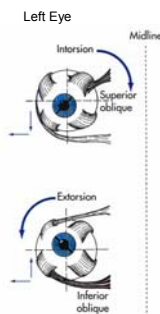


## Action of Extraocular Muscles

The superior and inferior obliques are situated in the plane of the eye, so contraction of these muscles rotate the eye around a torsional axis.

Contraction of the superior oblique causes an *intorsion* of the eye.

Contraction of the inferior oblique causes an *extorsion* of the eye.



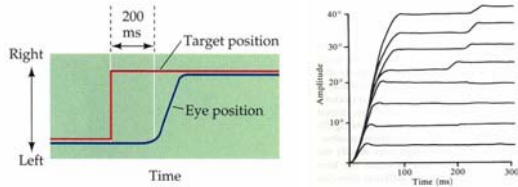
## Types of Eye Movements

There are four basic types of eye movements:

- 1) Saccadic eye movements
- 2) Smooth pursuit eye movements
- 3) Vergence eye movements
- 4) Vestibulo-ocular movements

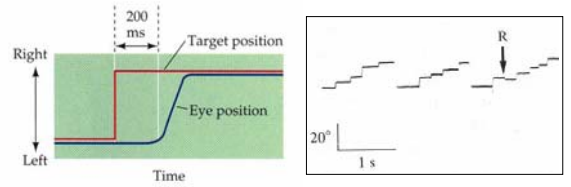
## Saccadic Eye Movements

Saccadic eye movements are *rapid, ballistic* movements of both eyes in the same direction (*conjugate* movements) that abruptly change the gaze fixation position. Their amplitude ranges from miniature eye movements ( $0.1^\circ$ ) to movements  $\sim 45^\circ$  amplitude from the straight ahead position.



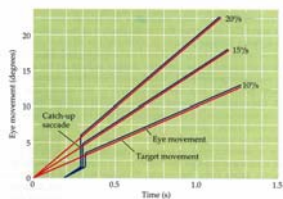
## Saccadic Eye Movements

Saccades are made spontaneously in response to a suddenly appearing (or jumping) object. They are also the eye movements produced while we scan a visual scene or read. Thus saccades can be either *voluntary* or *reflexive*.



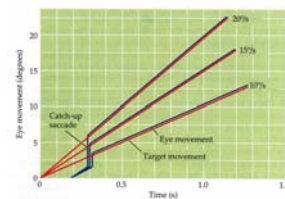
## Smooth Pursuit Eye Movements

Smooth pursuit movements are *slow tracking* movements of the two eyes designed to keep the image of a moving stimulus on the fovea. Fast moving stimuli cannot be tracked with precision, and they usually elicit saccadic eye movements.



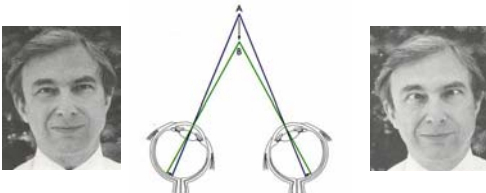
## Smooth Pursuit Eye Movements

The pursuit system needs to compute the speed of the moving stimulus to produce the proper eye velocity. Moving your eyes in this fashion without a moving stimulus is impossible. Pursuit behavior is thus under voluntary control only in the sense that one can choose or not to track a stimulus.



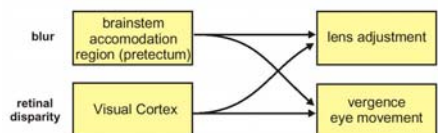
## Vergence Eye Movements

Vergence eye movements align the fovea of each eye with targets located at different *distance* from an observer. They are *disconjugate* movements, i.e., they move the eyes in opposite direction, producing a convergence or divergence of each eye's visual axis to focus an object that is near or far.



## Vergence Eye Movements

*Convergence* is one of the three reflexive responses elicited by a near target. The other component of this *near reflex triad* are *accommodation* of the lens, which brings the object into focus, and *pupillary constriction*, which increases the depth of field and sharpens the retinal image. Thus, either blur or retinal disparity will generate vergence.

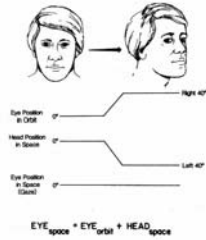


## Vestibulo-Ocular Movements

Vestibulo-ocular movements *stabilize the eyes* relative to the external world, compensating for head movements.

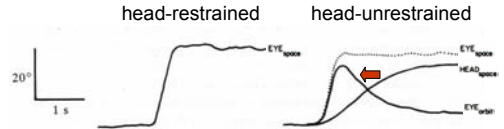
This reflex prevents visual images from “*slipping*” on the surface of the retina as head position varies.

The vestibular system detects brief, transient changes in head position and quickly produces corrective eye movements in a direction opposite to the head movement.



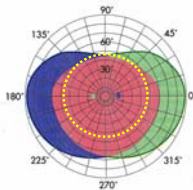
## Vestibulo-Ocular Movements

Vestibulo-ocular movements also act during coordinated eye-head movements, compensating for the portion of the head movement that lags the more rapid displacement of the eye. This permits the visual axis to remain on the newly foveated stimulus.



## Oculomotor Range

Although our visual field covers the space that extend  $\pm 90^\circ$  from straight-ahead fixation, the oculomotor range goes only up to  $\pm 45^\circ$ . Beyond that, visual stimuli can be foveated only if a head movement is combined with an eye movement.



## Oculomotor System: Visual Behavior

### Reference for this Lecture:

- Neuroscience, 2nd edition (2001) by Purves et al., Chapter 20.

### Reference for next Lecture:

- Neuroscience, 2nd edition (2001) by Purves et al., Chapter 20.

### Lectures are posted:

- <http://brain.phgy.queensu.ca/pare>

### Office Time:

- Tuesday & Thursday (15:00-17:00)  
Botterell Hall, Room 438