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<th>System</th>
<th>Head-Fixed</th>
<th>Eye-Fixed</th>
<th>Used With</th>
<th>Geometry Based Upon</th>
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<td>Table-Mounted Projectors (Major</td>
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<td>Listing</td>
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<td>Used with perimetry</td>
<td>Polar</td>
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1. Matching on all 5 Coordinate Systems and Stuff on the 2 Relevant Laws (Fig 3.3-3.7)

Information on Listing Coordinate System

i. Approximates physiological coordinate system used by oculomotor system.
   - ii. Reduces # of degrees of freedom from 3 to 2.
   - iii. Rotation of eye to any direction of gaze could be described as though it resulted from a rotation about a single axis within the equatorial plane.
   - iv. Does not require a 3rd degree of freedom—eye torsion about the line of sight
   - v. The torsion of the eye is independent of the path the eye followed to reach any given direction of gaze.
   - vi. Clinically used to describe location of blind areas in visual field.

Hess Screen

Hess Screen is rectilinear.

Most common way of measuring eye position is by prism neutralization during alternate cover test in primary and tertiary directions of gaze. Each coordinate system needs 3 degrees of freedom to describe eye position, where 3rd degree is eye torsion about line of sight. (The first two degrees are vertical and horizontal rotation)

Laws

Donders Law: For any determinate position of the line of fixation with respect to the head, there corresponds a definite and invariable angle of torsion, independent of the voition of the observer & independent of the manner in which the line of fixation
has been brought to the position in question. (AKA The law of constant orientation)

ii. Listing's Law: When the line of fixation is brought from its primary position to any other position, the torsional rotation of the eyeball in the second position will be the same as if the eye had been turned around a fixed axis perpendicular to the initial and final directions of the line of fixation.

g. Listing's Plane: A plane passing through the center of rotation perpendicular to the primary position of the line of sight. According to Listing, all fixational movements of the eye can be analyzed in terms of rotation of the line of sight about axis in this plane. (AKA Primary Axis Plane)

2. False Torsion and Centroid. Know how things translate on rotation.

a. False Torsion:
   i. The apparent cyclorotation associated with a change in direction of regard from primary position to tertiary position which occurs when movement of the eye is analyzed in terms of one of two ways.
      1. azimuth and elevation (Helmholtz system)
      2. longitude and latitude (Fick System)
   ii. When movement is analyzed in terms of rotation of eye around Listing's axis, no cyclorotation or torsion is found; hence, the cyclorotation found by other means of analysis is called false torsion.
   iii. The vertical axis projected by the laser up and to the left remains vertical in Fick system, but is levorotated in Helmholtz system. So, Helmholtz has a vertical problem and Fick has a horizontal problem.

b. Centricle: The eye doesn't rotate about a fixed point but rather a fixed arc called the centriole. So, because the center of rotation is not the center of the eye's entrance pupil or nodal point, whenever the eye rotates, it causes a small translation of the retinal image.

c. Translation on Rotation
   i. As you adduct, eyes move forward. As you abduct, eyes move backward.
   ii. As you adduct, eyes move up. When you move back to primary position, eyes move back down. When you abduct, eyes move back up.
   iii. As you elevate, there's a nasalward shift. A temporal shift occurs as you move back to primary position, and then another nasal shift as you depress.

2. Cerebellum

a. Input and Output
   i. Input: From afferent sources via...
      1. Climbing Fibers (Visual Stimulus; from Inferior Olive)
      2. mossy Fibers (Anything else)
   ii. Output:
      1. Purkinje Cells (exclusively inhibitory output)
         a. Project to various supranuclear relay stations.
         b. Serve to dampen or shorten.
iii. Interconnection Bwn Input and Output
   1. By Granular Cells (T-Junction)

iv. Other Components Between Input and Output
   1. Parallel fibers in the molecular layer allow the parallel processing and computing.
      a. Climbing Fibers go directly to Purkinje cells because they are wrapped around the Purkinje fibers.
      b. Mossy fibers go to granular cells to the parallel fibers to the Purkinje cells.

2. Golgi Cells
3. Granular Cells

b. Gross Anatomy
   i. Floculus and Nodulus (Vestibulocerebellum)
      1. Responsible for maintaining equilibrium
   2. Lesion here can cause
      a. Nystagmus
      b. Pursuit problems
      c. Cogwheel nystagmus (saccades invade pursuits)
      d. Slow phase of OKN
      e. Lose ability to suppress VOR

   ii. Vermis
      1. Fast movements
      2. Shapes saccades

c. Infantile Squint Syndrome (ISS): Eyes drift to side of occluded eye and jerk back. Only present when an eye is occluded
   i. Latent Nystagmus (monocular only)
      1. Ipsil NOT not stimulated
      2. Jerk form due to disruption of normal development of binocular vision as a result of esotropia.
      3. 1st 6 months
      4. Normally, NOT receives input from retina of contra eye and cortex of ipsil eye. So when one eye is occluded the open eye sends balanced input to contra NOT and ipsil NOT.
      5. When strabismus is present, the cortical input doesn't develop. In monocular viewing, only contra input to NOT from open eye is stimulated. Causes eye to drift to side of stimulated NOT, causing nystagmus. With both eyes open, there's a balance and eyes are stationary.
      6. Disappears in adolesence as pt. learns to suppress with pursuits.

   ii. Assymetric OKN (monocular only)
      1. Occur normally with temporal to nasal when target is with single eye viewing.
2. Abduct not good; Adduct ok
3. OKN can only be stimulated by nasally upward motion of VF. Temporal is ineffective because its normally sent via the cortex to the opsi NOT.

iii. Dissociated Vertical Deviation (DVD)
   1. Double hyper
   2. When one eye is occluded, it deviates upward under the paddle.
   3. When the other eye is occluded, it also deviates upward.

4. There are NUMEROUS QUESTIONS on all types of acquired nystagmus
   a. Direction of problems affected canals
      i. Sick canal: Drift toward the "not comfortable" side with jerk away from that side.
      ii. COWS (refers to saccade): Cold Opposite; Warm Same. So Cold is similar to sick state.
   b. Gaze holding: when in non primary position, eyes drift to primary because there isn't adequate tonic signals to hold in the tertiary position
      i. Endpoint
         1. If you try to fixate near the limit of gaze, the eye fatigues and drifts back to primary position and saccades back to tertiary.
         2. Used to detect DUI
      ii. Rebound
         1. An extension of endpoint nystagmus
         2. Jerk in opposite direction when return to primary position.
         3. So, eyes drift to tertiary and saccade back to primary.
         4. Most evident in the dark.
   iii. Periodic Alternating Nystagmus (PAN)
      1. Jerk reverses every 1-2 minutes.
      2. Problem with the nodulus.
      3. Probably reverses because the cerebellum is attempting to repair the unstable jerk nystagmus.
   iv. Vertical Nystagmus (name describes last phase)
      1. Frequency: 3 Hz
      2. Amplitude: 2 degrees
      3. Types
         a. Upbeat Nystagmus
            i. Could be a benign disorder
         b. Downbeat Nystagmus
            i. More serious
   v. Seesaw Nystagmus
      1. Pendular wave
      2. Frequency: 1 Hz
3. Eye move up on one side and down on the other, and then reverses.
4. During the up movement, the eye Intorts.
5. During down movement, eye extorts.
6. Problem with oblihths and followus/modulus.

5. Basics of Fixation
   a. 3 Main Components
      i. High frequency twitch/tremor: 50-60 Hz; must have high sample rate; \( \frac{1}{2} \) min of arc
      ii. Drift: Slow control mechanism; 6 min of arc; binocular; velocity 1 arc min/sec
      iii. Small saccades: 6 min of arc; 2-5 times/sec; monocular; back toward target; two eyes are conjugate, but can have different amplitudes
   b. Overall diameter: 10 min of arc. Patch: 1/6 deg - 1/4 deg

6. Details on how Ophthalmostatic (Goggle) and Ophthalmokinetic (VOR) systems work
   a. VOR Details
      i. Latency: 10-15 msec
      ii. Velocity: 200-300 msec
      iii. 4 Hz frequency
   b. Endolymph
      i. Endolymph is a fluid that serves to place pressure on the receptors within the labyrinth to signal motion of the head.
      ii. Due to organization of hair cells, Horizontal canal is stimulated with endolymph is moved toward ampulla
      iii. Hair cells in Vertical canal depressed when endolymph moves away from the ampulla.
   c. Hyperpolarization, Depolarization related to kinocilium (large cilium)
      i. When small cilia move toward kinocilium \( \rightarrow \) depolarization \( \rightarrow \) excitation
      ii. When small cilia move away from kinocilium \( \rightarrow \) hyperpolarization \( \rightarrow \) inhibition
   d. Gravity and Linear acceleration (both utricle and saccula deal with linear, not circular acceleration)
      i. Utricle: rocking or side to side motions; horizontal meridian
      ii. Saccula: deals with velocity and vertical up/down acceleration and gravity

7. Pursuit
   a. Stimuli
      i. Velocity (Step Ramp Experiments: Is position or velocity more important?)
      ii. Position
      iii. Proprioception (Turn off lights and track finger)
      iv. Inferential Motion
   b. Characteristics of Response
      i. Open Loop response
         1. Start phase is always the same
         2. The 1st 20-40 msec is independent of the stimulus
3. The next 60-80 msec is related to initial target velocity
4. Response velocity continues to increase to reduce error:
   Negative feedback.

c. High Brain Centers
   i. MT: For Retinotopic (not foveated)
   ii. MST: For Egocentric/Head (foveated)
   iii. Pathway
      1. MT and MST → (FEF) → DLGN → flocculus → VN → Motor Neurons

<table>
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<tr>
<th>Latency</th>
<th>Pursuit</th>
<th>Saccade</th>
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<tbody>
<tr>
<td></td>
<td>100-125 msec</td>
<td>200 msec (1st 110 can be adjusted; last 90 cant)</td>
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<tr>
<td>Prediction</td>
<td>20-40 msec</td>
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<tr>
<td>Velocity</td>
<td>&lt; 100 deg/sec</td>
<td>&lt; 1000 deg/sec</td>
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<tr>
<td>Center</td>
<td>MT for Retinotopic</td>
<td>MT for Retinotopic</td>
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<tr>
<td></td>
<td>MST for Egocentric</td>
<td>FEF</td>
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</tbody>
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8. Saccadic Suppression Details
   a. Begin about 50 msec before beginning movement
   b. End about 30 msec after
   c. Components
      i. Backward Masking
         1. Strongest
         2. Perception of prior target suppressed by later one
         3. Stronger stimulus at end of saccade overtakes the prior
            weaker stimulus during saccade and suppresses within the
            visual pathways.
      ii. Optical Smearing of retinal image during saccade
      iii. Reduce Visual Sensitivity by 20%

9. Lesions of Superior Colliculus and Frontal Eye Fields
   a. FEF Function
      i. Specifies to SC the amplitude and direction of upcoming saccade
      ii. Involved in process of maintaining and releasing fixation.
      iii. Codes movement.
      iv. Not a retinotopic map.
      v. Innervate contra: move away.
   b. Lesion of FEF
      i. Prevents patient from making voluntary saccades to a remembered
         target location without strong visual stimulus to guide them.
         (Pseudo-ophthalmoplegia)
   c. SC Function
      i. Represents retinal error the saccade is to correct.
      ii. Also a visual grasping center—sensory-motor coordination in
          reorienting eye.
      iii. Holds image on fovea once its grasped.
      iv. A retinotopic motor map.
   d. Lesion In SC
i. Causes prolonged latencies for saccades
ii. Inaccuracies in saccade amplitude.
iii. It's also difficult to break from one target and foveally grasp a new stimulus.

10. Pulse and Step Mismatches
   a. Pulse
      i. Velocity
      ii. Burst
   b. Step
      i. Final Position
      ii. Tonic
   iii. Leaky Integrator cause it to drift back

11. Main sequence and other response characteristics of saccades
    a. Main sequence issues are incredibly predictable.
    b. If you know the amplitude, you can predict velocity and duration.
    c. Main sequence does not talk about latency thought
    d. Tight distribution
    e. Duration and velocity are the same no matter what the saccade
    f. Latency not a part of changes

12. Alexander's Law: Amplitude of jerk nystagmus increases as eyes fixate in gaze away from the null point in the direction of the fast saccadic phase
Saccadic Suppression

1) Backward masking
2) Smearing
3) Tonne Sensitivity

All these Microtremors (3-5, 10/100 sec)

Is it a phase step probe?

Pursuit

Lottery

100-125 ms

100-200 ms
8. Saccadic suppression details.

9. Lesions of the vermis and frontalis eye fields.

10. pals and step reflexes and fine as in item 8 as well as in the end of the saccadic chapter.

11. Main sequence and other response characteristics of saccadic.


13. a) Amplitude, b) epoch, c) amplitude and frequency of brain holding.


15. a) Hypothalamus, b) hypothalamic systems work.