Eye movements: functional overview

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Clinical importance of eye movements

Eye movements are always evaluated in neurological exams: window into the function of brainstem and cerebellar circuitry.

Today: description of different types of eye movements (interface sensory and motor systems).

Context: anatomy and physiology of vestibular system, visual system, anatomy of eye muscles and their innervation.
2 classes of eye movements:

(eye movements work closely with vision, purpose is to facilitate vision)

1. REFLEX (involuntary) eye movements: stabilize the world on the retina.

2. VOLUNTARY eye movements: shift eyes so that images of objects of interest fall on the fovea, central 4 degrees of visual field.
Reflex eye movements: function and types

Stabilize the visual world on the retina when the head moves relative to the visual world.

1. VOR (vestibulo-ocular reflex)

2. nystagmus
Reflex pattern: nystagmus

Visual world moving relative to observer, nystagmus is a NORMAL pattern of alternating slow, smooth eye movements in one direction, quick return of the eyes in the other direction.

Nystagmus may be generated in 2 ways:

1. visual input
2. vestibular input
Visual or optokinetic nystagmus (OKN) ("railway nystagmus")

Maintain fixation on object as you move by it (slow, smooth eye movement), until eyes at extreme position in orbit, then - rapid eye movement in the opposite direction to look at (fixate) a new object.

**Direction** of nystagmus by convention is the direction of the **fast** movement.
Laboratory: OKN

Subject stationary, pattern moved around him/her.

Record eye movements.
Eye movement recording: nystagmus

Several non-invasive methods of recording eye position; plot eye position as a function of time.

Horizontal nystagmus to the left, OKN drum is rotating CW. Typically, both vertical and horizontal eye movements are measured; (nystagmus can be in any direction, not just horizontal).
Vestibular nystagmus: rotation

Rotate subject in a Barany chair-nystagmus, even with eyes closed. It will adapt (disappear) if the eyes are closed.

If the eyes are open, and there is both visual and vestibular input, nystagmus does not adapt.

After rotation stops there is a brief period of nystagmus in the opposite direction, postrotation nystagmus.

https://www.youtube.com/watch?v=YMIMvBa8XGs
Mechanisms of adaptation and post-rotation nystagmus:
Semicircular canals – receptors for rotation.
Rotation: initially endolymph lags, hairs bend, signal of rotation.

Maintained rotation: endolymph catches up after 30-60 sec, hairs not bent, no signal, adaptation.

After the body stops the endolymph keeps moving for a few seconds, generates signal of opposite rotation.
Caloric nystagmus

Vestibular nystagmus: caloric (temperature) stimulation irigate one ear (external auditory canal or meatus) with warm or cool water, currents in the fluid in the canals.

Motion of fluid activates hair cells.

Direction of nystagmus: “COWS” cold opposite, warm same.
(good bedside test although may induce nausea)
Nystagmus: summary

**NORMAL** pattern of eye movements in response to visual or vestibular stimulation.

**ABNORMAL** if it occurs spontaneously, in the absence of stimulation, sign of brain damage or abnormal CNS development.

Spontaneous nystagmus is sometimes seen in Down Syndrome (DS), also in albinism (lack of pigment in skin, hair, eyes; development of visual pathways abnormal).
Voluntary eye movements

Purpose: allow objects of interest to be examined by the **fovea**, specialized area of retina, high density of cones, no rods.
Eye movements and vision

Ability to make voluntary eye movements evolved along with the fovea, correlated with amount of sclera that you see.
Fovea is central 4 deg. of visual field

Distribution of rods and cones across the retina.
Fovea: no rods, high density of cones,
NOTE- X-AXIS= deg. visual angle.
Dimensions of visual field

Entire visual field: all of visual space you see with both eyes open.
Stare at (fixate on) fixation point, defined as center of visual field.
landmarks:
vertical meridian
horizontal meridian
upper visual field: 40°
lower visual field: 70°
out to 90° each side (180° total)
(testing of fields done clinically e.g. glaucoma)
FOVEA is central 4° of visual field.
Binocular and monocular parts of visual field

Our eyes are lateral, 2 eyes see almost but not quite the same part of the visual field.

Part of visual field seen by both eyes is the **binocular** portion (gray).
Each eye sees a sliver out to the side, the **monocular crescent** (white).
Demo: binocular and monocular parts of the visual field

1. Hold up your right hand straight out in front of you at shoulder level, index finger extended
2. Close your left eye, maintain fixation straight ahead and move your hand to the right until it disappears, then move it back to where you can just see it
3. Close your right eye, open your left eye- you will no longer see your hand because its image is in the right monocular crescent, seen only by the right eye and not by the left
4 types of voluntary eye movements

1. saccades
2. tracking or smooth pursuit
3. vergence
4. (fixation- eyes do not move)
Conjugate vs. disconjugate eye movements

Conjugate eye movements: both eyes move in the same direction—saccades and smooth pursuit.

Disconjugate: 2 eyes move in opposite directions: vergence (convergence and divergence).
Saccades

Rapid eye movements.
Allow objects of interest to be seen with fovea, look from point to point at stationary objects.

Pattern of eye movements made by subjects looking at the picture for one minute- saccade-fixation-saccade
Study of saccades

Present lights on a computer monitor S instructed to look at one light, the FP, and then shift gaze to light that is turned on (target) 5° above.

In this example S will make a 5° vertical upward saccade.
Saccade

Vertical eye pos.

Down

Left

Horiz eye pos.

Right

Up 5

time

tgt on
Normal parameters of saccades

Latency: (time to initiate) about 250 msec.
Duration: 10° saccade lasts 45 msec.
Velocity: peak velocity 400°/sec.
Cannot voluntarily control the velocity of saccade; it is determined by amplitude (different from limb movement).
Cannot voluntarily move only one eye.
(In studying eye movements head is kept stationary; normal GAZE SHIFTS are accomplished by a combination of eye and head movements.)
Smooth pursuit or tracking

Saccades are used for stationary objects. Smooth pursuit is used for moving objects. Goal: keep image of moving object on the fovea (30°/sec. or less).

Latency about 130 msec (implication - brainstem circuitry for saccades and smooth pursuit different).

Cannot voluntarily initiate smooth pursuit in the absence of a moving target.
Vergence movements

Adjust the angle of the two eyes to keep images of nearer or farther objects on both foveas.
Clinical importance

Informal testing of eye movements is always part of neurological exams. ("follow my finger")

Eye movements are easy to measure and the normal parameters well-known.

Eye movements are studied in many patient and subject populations, e.g. Parkinson’s disease, schizophrenia, dyslexia, PTSD, etc. Recent interest in autism- study pattern of eye movements as autistic subjects look at faces compared to controls.
EMDR

Brainspotting (BSP) was discovered in 2003 by David Grand, Ph.D. Over 8,000 therapists have been trained in BSP in the US, South America, Europe, the Middle East and Asia.

“Where we look affects how we feel”. BSP makes use of this natural phenomenon through its use of relevant eye positions. This helps the BSP therapist to locate, focus, process and release a wide range of emotionally and bodily-based conditions. BSP is also a brain-based tool to support the therapy relationship. We believe that BSP taps into and harnesses the body’s natural self-scanning, self-healing ability. When a Brainspot is stimulated, the deep brain appears to reflexively signal the therapist that the source of the problem has been found. BSP can also be used to find and strengthen our natural resources and resilience. BSP is designed as a therapeutic tool that can be integrated into many of the healing modalities. BSP can also be used with performance and creativity enhancement. BSP is even more powerful when used with the enhancement of BioLateral Sound CDs.