VS III: Ocular Motility and Binocular Vision
Spring 2007
Pursuits

Reading Chapter 4, Eye Movement Basics for the Clinician

I. Introduction

- Pursuits are the major eye movement involved in tracking objects smoothly in space. →What types of activities in your life would involve pursuit movement ?

- The main goal of this system is to match your eye velocity to target velocity.

Pursuits are also a form of, Slow Eye Movements…SEM Pursuit system can over ride the vestibular system a pursuit movement can happen while the head is being turned…..think of basketball

II. Facts about Pursuits

A. General facts

- Conjugate eye mvts.
  - Motion/movement, not the target's overall position on the retina is the stimulus for a pursuit. (E.g. target velocity and acceleration mostly, although target position may also drive the system to some extent).
    - The motion of the target causes "retinal slip,"
      - Happens when the images start to slide off of the fovea through movement.
      - This stimulates a pursuit (and, if it is fast and big enough, a saccade, too). But, it is not just the position of the target relative to the fovea (this is more a static thing) that stimulates the pursuit→ it is the movement of it, by causing retinal slippage.
- Work best with slow target mvts with a velocity of 20-50 degrees per second.
  - If the target too fast, creates a large retinal error (e.g. it's too far off of the fovea), which reduces your resolution of the target (how well you see it) and may stimulate a saccade to get things back on track. In your clinical testing, why would this be important?
- No suppression/omission of information occurs during a pursuit (unlike in saccades)→ the goal is to keep the object ON the fovea for clear vision. It is called a continuous control system, and samples the target constantly, responding to any small change in position as it goes along.
- Sustained periods of foveal pursuit allow maximal resolution of the target, as well as better information gathering and processing of fine details of the moving object. Evolutionarily, think how important this was for hunting the Woolly mammoth, Saber tooth tiger, etc.…..
  - Latency of the pursuit system is 100 msec; this is how long it takes to process the neural signal. Latency is slightly longer for slow targets. Know for NBEO.

- With retinal peripheral targets, a pursuit can be triggered before a saccade when the target starts moving over that portion of the retina. Why would this be good for the visual system?

B. Facts concerning pursuits and predictable targets:

- If the target is predictable, then the eye will anticipate and start to move even before the target starts to move. (We saw this in the section on saccades and anticipation).
- If the target is still, then anticipatory drifts will not be made unless the person imagines an apparent motion of the target or if the lights are turned off.
- The brain is using some kind of memory in relation to perceived target motion and stopping.
- With training, a person can match pursuit mvts almost perfectly with the motion of the target. This may be due to:
    - Memory of the patterned mvt
    - The brain's extrapolation of the target's behavior
      What advantage would there be to be able to match these so well?

- Pursuit system can continue tracking a stimulus for about 190 msec at 60% of original velocity after the stimulus is gone.
- Smooth pursuit of predictable target motion is superior to that of nonpredictable motion
  Can you think of ways that this might manifest in a clinical testing situation?

***Efficiency of pursuits to predictable target motion varies with subject, testing protocols, and how the data is analyzed. How might this impact your results when testing a 6 yo child?

III. Models of the Pursuit system

A. Open and closed loops

- Open loop systems for control of neuro pathways do not continuously sample the environment; their reactions, instead, rely only on the initial information given to the system. Closed loops use feedback from within the system and sample data constantly to adjust the outcome. This makes it more precise. Can you think of a closed loop system we've already studied?
- The pursuit system is traditionally considered to be a continuous control system. In other words, it continuously samples the environment to make the movements more precise. So is the pursuit system more open or closed loop?
- The earliest models of the pursuit system considered it to be only a basic velocity mechanism, e.g. all it did was to match eye velocity to target velocity, which reduces retinal slippage and keeps things clear as you track them.

B. These models generally had the following components (see diagram):

- A differentiator (s) that converts position information into velocity information.
- A limitor, which prevents motor response to a velocity input greater than the patient's preset system level (e.g., if the target goes too fast while you track it, then the limitor stops the pursuit from firing so that the saccadic system can take over and track it).
- An open-loop gain (K) to combine with other things to form a "leaky" neural integrator.
- A processing delay
- A saturation element which prevents the response from being too large
- An integrator (1/s) which converts a velocity signal into an eye position signal; this makes the eye muscles move.

- But, there are a few problems associated with this model, so a more complex model was Formulated which included an input for target velocity relative to the environment and positive feedback information about retinal velocity and acceleration as the eyes track.

IV. Neuroanatomic Control of and Signal Processing for Pursuit Eye Mvts

A. 100 msec latency time for pursuits: this is how long it takes to process the neural signal and get the eyes moving.

- The initial 20-40 msec presaccadic portion is independent of target stimulus and just works to get the eyes moving somewhere. This is considered more open loop, because it doesn't really sample any environmental data, it just tries to get the eyes moving.
- The last 60 msec of that 100msec time is considered closed loop, for it is loosely related to target velocity and is under visual feedback (e.g. the pursuit generated is related to either a real or perceived target velocity).
- After that initial 100msec, the pursuit system continues to be closed loop. How will that affect the accuracy of response?
- Details about the flow of information along the pursuit system are less well understood than in the saccadic system.

B. The neurological pathway for pursuits:

- **Magnocellular** pathway is likely the one used (makes sense as it detects motion→ which is what stimulates the pursuit system).
- The M path is also called the "Where" pathway,
  - →different from the "what" path of the parvocellular. It is likely that the two systems talk to one another via crosslinks; so keep that in mind as you think about which system does what. Here is the basic pathway in diagram form:

Insert fig p. 92

- The magnocellular pathway has heavy inputs into Brodman's area V1, the primary striate visual cortex. V1 has cells that respond to motion-→ projects into the middle temporal area of the extrastriate visual cortex.

- The **Middle Temporal (MT)** area then encodes and processes the direction and velocity of the motion detected→ projects into the **Medial superiotemporal (MST)** visual area.
- The **Medial superiotemporal (MST)**area encodes visual related to pursuit and efference copy of the eye mvt command (remember efference copy from the section on saccades?) This means that an eye velocity signal is added to the retinal motion signal carried by the MT.
- Both the Medial temporal **(MT)** and the medial superiotemporal **(MST)** area project into the **posterior parietal cortex.** This area plays a part in attentional aspects of motion (e.g. you paying attention to the target)
    - These two areas plus the posterior parietal area project into the frontal cortex, specifically into the **frontal eye fields** (remember them from saccades?), Brodman's area 8. The frontal eye fields have cells that fire during pursuits, esp. predicable pursuits (e.g. they program predictive pursuit mvts).
- The **MT** and **MST** areas and frontal eye fields project into the **dorsolateral pontine nucleus (DLPN),** and they discharge in response to pursuit mvt. This area of the pons also receives an efference copy from the MST area. The DLPN contains a mixture of eye movement signals and visual information.
- The **DLPN** then goes into the **cerebellum** (flocculus, paraflocculus and vermis areas). The flocculus and paraflocculus have cells called Purkinje cells that live there and discharge with respect to gaze velocity during pursuits. The neurons in the vermis encode target velocity in space (e.g. eye velocity plus retinal slip velocity).

The cerebellum plays a really important part in synthesizing the pursuit signal. The flocculus maintains pursuit during steady state tracking, while the vermis does this during target velocity changes.

- The cerebellar **flocculus** then projects into the brainstem, esp. into the (1) **ipsi medial vestibular nucleus** (remember from saccades?) , which discharges according to gaze velocity and the (2) **nucleus prepositus hypoglossi.** Both brainstem structures are involved in neural integration (just like in saccades and fixation)→ convert eye velocity signals to eye position signals→ oculomotor neurons→ move the eyeballs.
- The **cerebellar vermis** projects into the **inferior** and **lateral vestibular nuclei** and the reticular formation, which is located close the Abducens nucleus and the DLPN. Less is known about this pathway, however.

If there are lesions along the pathway, then certain defects in pursuit mvt will occur:

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V. Abnormal pursuits

Errors in pursuit may be in the following areas:

1. Initiation
    - Latency
    - Initial 100msec open-loop phase

- Maximal eye acceleration

2. Pursuit ability can be reduced in the following ways:
   - By adding a stationary or moving background, (esp if put near the target plane). Such background clues may cause retinal slip of the background information towards the opposite direction of the pursuit mvt; this could be a stimulus for OKN. The reduction in gain could be the visual systems effort to cancel out the OKN response triggered in this case.
     - By increasing the amplitude of the target over a 5-20 degree range…WHY?
   - Accuracy is partially determined by either predictable or unpredictable target mvts. Do predictable targets have higher or lower gain?
   - Accuracy can also be **reduced** by:
     - increased target velocity and acceleration
     - increased target eccentricity
     - increased target nonpredictability
     - increased age of viewer
     - Smaller targets
     - Vertical target mvt (vs horizontal)
     - Moving background distractions
     - Inattention
     - Fatigue
     - Lack of other proprioceptive or auditory cues
     - Alcohol
     - Barbiturates
     - Meds (esp. diazepam)
     - Neurological disease (esp. those involving the cerebral cortex and cerebellum)
     - Jerk nystagmus
     - Amblyopia (due to decr. Foveal sensitivity)

- Note: Pursuit ability is related more to maximal target acceleration than to its velocity; velocities up to 30-40 degrees per second offer the best gain.
- Patients with pursuit deficiencies do not complain of visual symptoms…they substitute multiple saccades for the pursuit movement. They do no realize that their movements are jerky and not smooth.
- Impaired tracking can be an indication of a lesion of the vestibulo-cerebellum region
- Parietal lobe lesions may lead to slow pursuit in one direction with normal pursuit into the opposite. Remember this for OKN Remember the lesion will be on the same side as the poor pursuit. A lesion in the parietal lobe will often have a contralateral homonymous hemianopsia…..to differentiate from an occipital lobe lesion, parietal will have loss of OKN when the stripes move to the side of the lesion. No pursuit to follow and produce OKN.

VI. Can Pursuits be improved (and why would you want to anyway??)

- YES! In an experiment, Shalen found that moderate improvements could be made in velocity matching and correction of positional errors.
  - Other research by Boman and Hotson showed that horizontal and vertical pursuits can become more accurate
  - Athletes with good initial test scores on pursuits could improve to a final level that normal subjects could attain with training.

*******So what's this all mean??? Who cares?

What are some situations in life where an enhancement of pursuits tracking ability would be tremendously helpful?

VII. Saccadic overlay

- Increased number and amplitude of these corrective saccades in hyperactive kids…WHY?
- Also see more of this in elderly patients…WHY?

VIII. Aging effects on Pursuits

- Reduced closed-loop gain (e.g. how accurate the pursuit is) of about 25%, which becomes progressively worse as the target velocity increases. May be due to age-related degradation of the motion information at numerous sites in the visual pathway.
  - the older you get, the worse your pursuit mvts are, and e.g. the harder it is for you to track moving objects. Think about how this would affect the activities of your daily life: driving, watching your favorite basketball or baseball team play, bird watching, etc, etc, etc. All of these can become much harder.

- Increased overall saccade frequency. Why???
- Reduced overall acceleration→ not only is it more difficult to track with a pursuit once you're looking at the target, but its also harder for your eyes to catch up to it in the first place.
- Increased velocity latency→ indicative of a delay in processing.
- Increased square wave jerks.
  Increased visual distractibility→ e.g. if there is lots of background "stuff," then its easier to lose your place.

In Summary and in introduction:

Versional Eye movements: are yoked movement of the two eyes in the same direction; This occurs in

1. Vestibulo- optokinetic system
2. saccadic system
3. pursuit system

These three systems work together with inputs going to the "neural integrator" which sends appropriate signals to the cranial nerve nuclei subnuclei, which in turn signal the extramural muscles to move the globes….

The neural integrator is a variety of CNS structures which work together:

1. cerebellum
2. pontine reticular
3. periphypoglossal nuclei

Horizontal Versions:

1. 1. The Horizontal Gaze Center exists with in the PONS, near to the sixth cranial nerve nuclei (the Parapontine Reticular Formation, or PPRF, is another name for the "horizontal gaze center).

2. The horizontal gaze centers are responsible for the commands which reach the cranial nerve nuclei and produce a horizontal versional movement.

3. The PPRF sends input into the abducens (VI) nerve nucleus

a. two separate neuron populations within the abducens nucleus respond to the command to execute a horizontal movement
   1. neurons supply the ipsilateral lateral rectus muscle by way of axons within the ipsilateral abducens nerve
   2. neurons supply the contralateral medial rectus muscle by way of t he contralateral medial longitudinal fasiculus (MLF) into the oculomotor nerve subnucleus which then sends an axon up to the oculomotor nerve

   3. The abducens nucleus also receives constant input from the vestibular nerve nuclei, from the periphypoglssal nuclei and from the burst cells of the pons…. Thus the abducens nucleus integrates all these inputs.

See diagram

Testing pursuit:

Evaluate pursuit by monitoring patients eyes as they follow a small object in vertical and horizontal versions . Observe for catch up saccades or absence of pursuit.

Evaluate the patients ability to suppress the VOR. Patient is on a rotating stool and fixates thumb. A normal patient can suppress the induced VOR by maintaining fixation on the thumb, even in darkess or with the eyes closed. …..this may help rule out a malingering patient if they cannot maintain fixation as even a blind person can.