Vision Science III….Dynamic Aspects of Accommodation

Still reading in Borish Chapter 4

In real life, the accommodative system is very dynamic. A variety of stimulus occur.

Accommodative Inputs:

Steady-State Inputs: While maintaining a steady focus, the accommodative system shows small fluctuations. These fluctuations are greatest at the midrange of accommodation and decrease at the accommodative range limits. They are thought to be initiated centrally as they are binocular. Are they a form of feedback to help maintain accuracy.?

Step and Pulse Inputs: Step inputs represent an accommodative challenge and show a time constant of 200 to 250 msec to reach 63% of final amplitude. They have an average latency of 370 msecs, taking less time to focus to near, than to change from near to far. Response to a surprise change in accommodation is faster with a latency of 180msec. In observing pulse input where there is a change in stimulus, it is felt that the system operates under continuous feedback as response time approximates stimulus duration. In other words, the response time changes. If this was a sampled system , the response time would be fixed.

Sinusoidal Inputs; Response to sinusoidal inputs reflects the sinusoidal profile where the gain is reduced and the lag increases at higher frequencies. Less effective at higher rate changes.

Ramp Inputs: With ramp stimuli where the accommodation is changed with a constant velocity, slower change results in ramp like accommodation, fast velocity results in exponential change similar to a step input. Dual mode of control of accommodation where there is a constant control and feed back for the slow ramp. And a faster control for the faster moving target.

Dynamic model of accommodation;
Fig: 4-14
This model is set for blur as stimulus:

- Input: target accommodative stimulus level. Target distance. Sums with the accommodative level of the system by the negative feed back loop, this is a dynamic system.

- Dead space operator: Represents the depth of focus,

- Nonlinear switching Element: uses the signal from the derivative controller to set the direction of accommodation. The generated signal is directionally correct and proportional to the magnitude of the blur.

- Derivative Controller: controls speed of response and provide stability

- Nonlinear Saturation Element: Prevents the response velocity from exceeding a certain level. Limits the oscillations of the system.

- Leaky Integrator: Provides for steady state of accommodation, when dark the circuit decays leading to tonic accommodation in 10 to 15 seconds.

- Time Delay: time delays of neural pathways and biomechanical transmission delays.

- Ciliary Muscle lens dynamics: biomechanical characteristics of the focusing plant

- Saturation Element: amplitude of accommodation limited by the lens elasticity.

Disorders of Accommodation:

<u>Accommodative insufficiency:</u>

1. Level of accommodation is lower than expected for the patient's age. (remember presbyopia is normal)
2. Reduction is by 2.00 or more.
3. Symptoms:
    - Blurred vision.
    - Ocular discomfort with reading.
    - Headaches while reading.
    - Watering and rubbing of eyes.
    - Red eyes.
    - Works close to material.
    - Blinks with near work
    - Associated with convergence insufficiency.

4. Associated with physical findings:
   Systemic infection
   Emotional fatigue
   Medication

5. Treatment:
   - Low plus lenses
   - vision therapy
   - Responds well to treatment.
   - Suggestions: Shorten work periods, allow frequent breaks while reading, encourage Harmon distance.

Poorly sustained accommodation:

- May also be called accommodative fatigue.
- Amplitude is sustained only with considerable effort. With time unable to sustain.
- May be first stage of accommodative insufficiency. Amplitude is normal at first, then decreases.
- Symptoms: blur, ocular discomfort, receding accommodation with retesting, headache, diplopia, red watery eyes, squinting, blinking.
- Causes: myasthenia gravis
- Systemic conditions, functional in nature?
- Treatment: low plus lenses with or without VT
- Shorten visual work periods, allow frequent breaks while reading,
- Encourage Harmon distance

Accommodative paralysis:

- Markedly reduced or totally absent accommodative amplitude. Often organic in cause.
- Consider: head trauma

- , Illnesses that affect nervous system such as mono, flu, malaria. Consider medication use.
- Treat with plus lens.

Unequal accommodation;
persistent interocular difference in accommodative amplitude.
From organic

Accommodative excess:

- Persistently higher than expected for the patient's age.
- Often associated with convergence insufficiency.
- Can be an inability to relax accommodation readily.
- This can lead to total spasm of accommodation:

- Symptoms:
- Blurred vision near and far after near work
- Headaches
- Asthenopia
- Avoids near work
- Red eyes, watery eyes
- Fatigues easily
- Poor reading comprehension
- Squinting
- Frowns and blinks
- Nausea with reading

- Causes:
- Refractive error such as Latent hyperopia or uncorrected astigmatism
- Emotional problems
- Early presbyopia

- Treatment:
- Correct refractive error
- Vision therapy

- Plus for near
- Cycloplegia to break spasm

Accommodative infacility:

- Dynamics of accommodation are slowed such as latency, time constant, and peak velocity.
- Inertia of accommodation;

- Symptoms:
- Blurred vision in distance after reading
- Trouble shifting focus
- Headaches
- Watering of eyes

- May be associated with
- Graves's disease
- Measles
- Alcoholism
- Found in people with high near point demands

- Disease can cause accommodative disorders as can medications; tables 4-5,4-6,4-7

- Treatment; low plus lenses, VT with near far accommodative rocks, frequent breaks

Training Accommodative System;

Voluntary accommodation can trained, once learned transferred to a new task.

Testing accommodation can act as training.

- Use of flippers
- Repeated activities jump focus
- plus and minus flippers
- pencil pushups.

Amblyopic patient can be trained. Lag can be reduced, amplitude increased, depth of focus reduced, accuracy of response increased.

Presbyopia: aged eye. Slow normal age-related irreversible reduction in maximal accommodative amplitude.

Begins at ages 40-45, peak onset 42 to 44.

Risk factors for onset:

1. Refractive error: hyperopes onset earlier due to greater demand at corneal plane for accommodation.
2. Ambient Temperature: warmer temperature causes earlier myopia

Symptoms begin when accommodative amplitude is twice as large as demand.

1. blurred vision or else discomfort with near focus
2. drowsiness
3. Longer arms needed.
4. accommodative spasm may occur
5. asthenopia with resulting accommodative spasm
6. diplopia from increased accommodation driving convergence

Primary factors to presbyopia;

1. Elasticity of lens capsule decreases, less ability to shape the lens. Accounts for the amount of presbyopia found in a 45 yr old.
2. The elasticity of the lens shifts becoming stiffer. 44% of the loss of accommodation.
3. The lens size/volume increases with age, making the lens capsule less able to
   Deform the lens. 55% of the loss in accommodation is related to the increased lens size along with the decreased elasticity of the lens capsule.

   Charts p 110 are interesting.

   Other factors in presbyopia;

   1. Zonules are moved forward by lens growth causing less mechanical force.
   2. Less zonular fibers with aging reducing the biomechanical force.
   3. Increase in bridges between the lens capsule and lens, more resistance between lens fibers during accommodation making lens harder to move.
   4. Changes in the ciliary muscle anatomy. Less inward and forward movement of the muscle and ciliary muscle ring. Reduces the amount of ciliary body movement.
   5. Choroid loses elasticity.

1. Zonular elasticity remains the same.
2. The ciliary muscle contractile power increases to age 45, then shows a slight decrease. This slight decline does reflect the 100% loss in accommodation.

3. neural control remains constant

Remember the models of accommodation:
Need chart p 4-10

Tonic accommodation decreases 0.04 D. per year….1.80 at 20 to 0.90 at 50. Aging biomechanics most likely the cause.

Depth of Focus: this remains relatively constant if measured objectively, however subjectively determined depth of focus increases suggesting that we are move tolerant of blur with aging.

Gain: does not change with age suggesting that the underlying neural pathways remain the same.

Accommodative Amplitude: Decreases around 0.30 D per year over presbyopia

Accommodative Adaptation: decreases with age 0.035D per year.

AC/A ratio: Response AC/A shows a modest increase which may be from

a. a true gain change in cross-link gain from accommodation to vergence to compensate for the lenses reduced responsitivity
b. Age related increase in ciliary muscle fore to compensate for the increased stiffness of the choroid.
c. More accommodation effort to obtain a unity change in accommodation

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Stimulus A/C ratio decreases with age to zero at 55.

Dynamic Model of Accommodation

Latency: Both positive and negative accommodation latency increases with age. Neurological?

Time-Constant…. The time to reach 63% of final response amplitude remains
unchanged. However at the upper nonlinear range the time constant is prolonged. This occurs in all ages though.

Peak Velocity: Peak velocity / amplitude relationship remains constant. The velocity increases in proportion to the amplitude.

Accommodative Micro fluctuations: decrease in amplitude and frequency form age 20 to 50. Aging biomechanics of the lens is thought to be cause of this.

Two theories of Presbyopia:

Helmholtz-Hess-Gullstand theory gives all the loss in accommodation to biomechanical changes in the lens capsule and lens. The ciliary muscle remains powerful.

Donders-Duane-Fincham theory gives the loss to accommodation as being due to ciliary muscle and none to lens and lens capsule.

Morgan combined these two theories in that most of the accommodative range is covered by the HHG theory with biomechanical changes, but at the high end where extra effort is required and lacking the DDF model takes over with the decrease in accommodation being due to weakened ciliary muscle.