DYNAMIC ASPECTS OF ACCOMMODATION

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THIS CHAPTER INCLUDES A REVIEW OF:

- Accommodative Inputs
- Dynamic Model of Accommodation
- Disorders of Accommodation
- Training the Accommodative System
- Presbyopia (aged eye)

INTRODUCTION

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

ACCOMMODATIVE INPUTS

STEADY-STATE INPUTS	While maintaining a steady focus, the accommodative system shows small fluctuations. These fluctuations are greatest at the mid-range of accommodation and decrease at the accommodative range limits. It is thought that they may 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 msecs to reach 63% of the final amplitude. They have an average latency of 370 msecs; taking less time to focus to near than to change focus from near to far. The response to a surprise change in accommodation is faster with a latency of 180msec. In observing a pulse input where there is a change in the stimulus, it is felt that the system operates under continuous feedback as the response time approximates stimulus duration. In other words, the response time changes. If we were to consider a sampled system, the response time would be fixed.
SINUSOIDAL INPUTS	The response to sinusoidal inputs reflects the sinusoidal profile where the gain is reduced and the lag increases at higher frequencies. It is less effective as the higher rate changes.

RAMP INPUTS	With ramp stimuli, accommodation is changed with a constant velocity where slower velocity results in ramp-like accommodation and faster velocity results in an exponential change that is similar to a step input. This is a dual mode of accommodative control where there is a constant control and feedback for the slow ramp as well as a faster control for the faster moving target.

DYNAMIC MODEL OF ACCOMMODATION

This model assumes that blur is the stimulus:

- **Input:** The stimulus change required for accommodation.
- **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 the speed of the response and provides 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. In dark conditions, the circuit decays leading to tonic accommodation in 10 to 15 seconds.
- **Time delay:** Refers to the time delay of neural pathways and biomechanical transmission delays.
- **Ciliary muscle lens dynamics:** Biomechanical characteristics of the focusing plant.
- **Saturation element:** The point at which the amplitude of accommodation is limited by the lens elasticity.

DISORDERS OF ACCOMMODATION

- Accommodative Insufficiency
- Poorly Sustained Accommodation
- Accommodative Paralysis
- Unequal Accommodation
- Accommodative Excess
- Accommodative Infacility

ACCOMMODATIVE INSUFFICIENCY	• Level of accommodation is lower than expected for the patient's age. • Remember: Accommodative insufficiency due to presbyopia is normal • Defined by an accommodative reduction of 2.00D or more. **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 **Associated with physical findings** • Systemic infection • Emotional fatigue • Medication **Treatment** • Low plus lenses • Vision therapy • Responds well to treatment. • Suggestions: Shorten work periods, allow frequent breaks while reading, encourage Harmon distance (optimal visual reading distance).

POORLY SUSTAINED ACCOMMODATION	• May also be called accommodative fatigue. • Amplitude is sustained only with considerable effort. Difficult to sustain with time. • May be the first stage of accommodative insufficiency. Amplitude is normal at first but then decreases. **Symptoms** • Blur • Ocular discomfort • Receding accommodation with retesting • Headache • Diplopia • Red watery eyes • Squinting • Blinking. **Causes** • Myasthenia gravis • Systemic conditions **Treatment** • Low plus lenses with or without Vision Therapy (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.
	• Cause:
	  – Head trauma
	  – Illnesses that affect nervous system such as Infectious Mononucleosis, flu, malaria.
	  – Medication use.
	• Treat with plus lens.

UNEQUAL ACCOMMODATION	This is a persistent interocular difference in accommodative amplitude.
ACCOMMODATIVE EXCESS	• Persistently higher level of accommodation than would be expected for the patient's age. • Cause: – Often associated with convergence insufficiency. • Can be an inability to relax accommodation readily. • This can lead to total spasm of accommodation: **Symptoms** • Blurred near vision • Blurred distance vision after near work • Headaches • Asthenopia • Avoids near work • Red, watery eyes • Fatigues easily • Poor reading comprehension • Squinting • Frowns and blinks • Nausea with reading

ACCOMMODATIVE EXCESS (contd)	**Causes** • Refractive error such as latent hyperopia or uncorrected astigmatism • Emotional problems • Early presbyopia **Treatment** • Correct refractive error • Vision therapy • Plus lenses for near • Cycloplegia to break spasm
ACCOMMODATIVE INFACILITY	• Dynamics of accommodation are slowed: – Reduced latency – Reduced time constant – Reduced peak velocity. • Inertia of accommodation **Symptoms** • Blurred vision in distance after reading • Trouble shifting focus • Headaches • Watering of eyes **Causes - May be associated with:** • Graves's disease • Measles • Alcoholism • Found in people with high near point demands **Treatment** • Low plus lenses • VT with near/far accommodative rocks • Frequent breaks

NOTE: Disease and medications can cause accommodative disorders,
e.g. the use of topical cholinergic drugs, trauma, brain tumours, myasthenia gravis.

TRAINING THE ACCOMMODATIVE SYSTEM

Voluntary accommodation can be trained. Once learned it could be transferred to a new task.

Testing accommodation can act as training:

- Use Of Flippers
- Repeated Activities – E.g. Jump Convergence Exercises
- Plus And Minus Flippers
- Pencil Push-ups.

Accommodative training helps:

- Improve accommodation in amblyopic patients
- Reduce Lag
- Reduce depth of focus
- Increase amplitude
- Increase accuracy of response.

PRESBYOPIA (AGED EYE)

Slow, normal, age-related, irreversible reduction in maximal accommodative amplitude.
It begins between age 40 and 45 with peak onset occurring somewhere between age 42 and 44.

RISK FACTORS FOR ONSET	1. Refractive error: • Hyperopes - onset is earlier due to greater demand at corneal plane for accommodation. 2. Ambient Temperature: • Warmer climate causes earlier onset of presbyopia
SYMPTOMS	Symptoms begin when accommodative amplitude is less than twice the demand. 1. Blurred vision or discomfort with near focus 2. Drowsiness 3. Longer arms needed 4. Asthenopia 5. Resulting accommodative spasm 6. Diplopia from increased accommodative effort causing increased convergence
PRIMARY FACTORS THAT LEAD TO PRESBYOPIA	1. Elasticity of lens capsule decreases so there is less ability to shape the lens. This accounts for the amount of presbyopia found in a 45-year-old. 2. The elasticity of the crystalline lens shifts, becoming stiffer. This accounts for 44% of the loss of accommodation. 3. The crystalline lens size/volume increases with age, making it more difficult for the lens capsule to deform the lens. 55% of the loss in accommodation is related to the increased lens size along with decreased elasticity of the lens capsule.
OTHER FACTORS AFFECTING PRESBYOPIA	1. Zonules are moved forward because of lens growth, causing less mechanical force. 2. Ageing reduces the biomechanical force of the zonular fibres. 3. Increased resistance between the lens fibres during accommodation makes it more difficult to move the lens. 4. Changes in the ciliary muscle anatomy. 5. Decreased inward and forward movement of the ciliary muscle ring which reduces the amount of ciliary body movement. 6. Choroid loses elasticity.
PHYSICAL FEATURES OF PRESBYOPIA	1. Zonular elasticity remains the same. 2. The contractile power of the ciliary muscle increases until age 45 and then shows a slight decrease. This slight decline greatly contributes to the loss in accommodation. 3. Neural control remains constant

IMPACT OF PRESBYOPIA ON MODELS OF ACCOMMODATION	**Tonic Accommodation:** This decreases by 0.04 D per year so that it is approx. 1.80D at age 20 and 0.90D at age 50. The most likely cause for this is ageing biomechanics. **Depth of Focus:** This remains relatively constant if measured objectively, however subjectively, the determined depth of focus increases. This suggests that we are more tolerant of blur with age. **Gain:** This does not change with age suggesting that the underlying neural pathways remain the same. **Accommodative Amplitude:** This decreases by approx. 0.30 D per year from the onset of presbyopia **Accommodative Adaptation:** This decreases with age by approx. 0.035D per year. **AC/A ratio:** The response AC/A ratio shows a modest increase, which may be due to: a. A true gain change in cross-link gain from accommodation to vergence to compensate for the reduced responsiveness of the lens. b. The age-related increase in ciliary muscle force to compensate for the increased stiffness of the choroid. c. A greater accommodative effort exerted to obtain a unity change in accommodation **Stimulus AC/A ratio:** decreases with age to zero at 55.
DYNAMIC MODEL OF ACCOMMODATION	**Latency:** Both positive and negative accommodative latency increases with age. This would possibly be due to some neurological process or developmental changes between birth and adulthood.. **Time-Constant:** The time required to reach 63% of the final response amplitude remains unchanged with age. However, at the upper nonlinear range, the time constant is prolonged. This is seen at all ages though. **Peak Velocity:** Peak velocity / amplitude relationship remains constant. The velocity increases in proportion to the amplitude. **Accommodative Micro fluctuations:** This is a decrease in amplitude and frequency from age 20 to 50. This is thought to be caused by the ageing biomechanics of the lens.
THEORIES OF PRESBYOPIA	**Helmholtz-Hess-Gullstand (HHG) Theory:** This theory attributes all the loss in accommodation associated with presbyopia to biomechanical changes in the lens capsule and lens. The ciliary muscle remains powerful. **Donders-Duane-Fincham (DDF) Theory:** This theory attributes the total loss of accommodation associated with presbyopia to a weakening of the ciliary muscle and none to the lens and lens capsule. **Morgan Theory:** Morgan combined these two theories believing that most of the accommodative loss is due to the biomechanical changes as suggested by the HHG theory 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 a weakening of the ciliary muscle.

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