ACCOMMODATION

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THIS CHAPTER INCLUDES A REVIEW OF:

- Definitions
- Accommodation
- Steady-State (Static) Accommodative Stimulus Response Function
- More Vision Science

DEFINITIONS

Source: Benjamin, W. Borish's Clinical Refraction. WB Saunders, Philadelphia. 2006.

ACCOMMODATION	It is the process whereby changes in the dioptric power of the crystalline lens occur so that an in-focus retinal image of an object of regard at different distances is obtained and maintained at the fovea, that area of high resolution at the macula.
DEPTH OF FOCUS	It is the variation in image distance from a lens or optical system, which can be tolerated without incurring an objectionable lack of sharpness in terms of focus. This lack of focus will stimulate accommodation.
DEPTH OF FIELD	It is the free space dioptric interval that defines the depth of field. The linear distance in object space for which the eye cannot detect blurring when focused on a given object. Stimulus to accommodate: The dioptric amount by which accommodation would have to change for an object to be conjugate to the retina.
LAG OF ACCOMMODATION	It is the extent to which the near response is less than the dioptric stimulus to accommodate. It is normal to have an accommodative lag of 0.50D to 0.75D, which is under-accommodation that is still within the depth of focus. The accommodative system changes focus by the minimum amount to place the object just within the eye's depth of field/focus.
LEAD OF ACCOMMODATION	The extent to which the accommodative response is greater than the dioptric stimulus to accommodate. It is not normal to have a lead of accommodation. Remember the system is set to be efficient.

NEAR POINT OF ACCOMMODATION	The closest point of focus, conjugate to the retina with exertion of maximal accommodation. The maximum amount of accommodation is represented in space.
FAR POINT OF ACCOMMODATION	The farthest point of focus, conjugate to the retina with exertion of minimum accommodation. Note: It is not possible to have zero accommodation – there is always some degree of accommodation exerted.
AMPLITUDE OF ACCOMMODATION	The difference, expressed in dioptres, between the far point and the near point of accommodation with respect to the spectacle plane, the entrance pupil or some other reference point of the eye.
RANGE OF ACCOMMODATION	The linear distance from the near point of accommodation to the far point of accommodation.
CONSENSUAL ACCOMMODATION	Simultaneous accommodation of the two eyes. Occurs in accordance with Hering's Law of Equal Innervation.
PRESBYOPIA	The "aged eye". Slow, normal, naturally occurring, age-related and irreversible reduction in maximal accommodative amplitude. This results in recession of the near point.
PROXIMAL ACCOMMODATION	Accommodation due to the influence of knowledge of the apparent nearness of an object. There is no 'real' dioptric stimulus to accommodation and is more psychological in nature.
CONVERGENCE ACCOMMODATION	Accommodation induced by the innate neurological linking and action of disparity vergence, which is approximately 0.40D per meter angle.
TONIC ACCOMMODATION	Accommodation found in the absence of blur, disparity and proximal inputs as well as any voluntary or learned accommodation. No stimulus is needed; it reflects baseline neural innervation from the midbrain. Mean tonic accommodation in young adults is approximately 1.00D. Tonic accommodation represents the normal tonus of the ciliary body in its resting state.
EMPTY FIELD ACCOMMODATION OR DARK FIELD ACCOMMODATION	Accommodation, which occurs in the absence of optical stimuli such as in low levels of illumination or when viewing a clear cloudless sky.
REFLEX ACCOMMODATION	Automatic adjustment of the refractive state to obtain and maintain a sharply defined and focused retinal image in response to a blur input.

ACCOMMODATION

THEORIES OF ACCOMMODATION	Accommodation could happen due to : • The interval of Sturm (due to astigmatism) causing a change in focus - accounts for 1.00 D • Pupil size causing accommodation - accounts for 1.00D. • Changes in corneal curvature resulting in a change in focal point. • The variation in focal point causing the antero-posterior position of the lens to change. • The axial length of the eye changing and leading to accommodation. • Or changes in the shape and therefore in the power of the crystalline lens to allow objects at various distances to be focused on the retina, which is the currently recognized theory of accommodation. Interesting to note that vision alone is not needed to stimulate accommodation. It is also stimulated due to proximity, drugs such as glaucoma medication, auditory stimulus, aberration, convergence as well as voluntary effort.

FOUR COMPONENTS OF ACCOMMODATION	1. **Reflex Accommodation:** Largest component of accommodation for both monocular and binocular situations. 2. **Vergence Accommodation:** Second major component of accommodation. Driven by the link between accommodation and vergence. 3. **Proximal Accommodation:** Stimulated by perceptual cues, no retinal-based visual feedback loop of blur. 4. **Tonic accommodation:** The accommodation remaining in the absence of stimuli. It is stimulated by base-line innervation from the midbrain. The average degree of accommodation is 1.00Dand this amount changes with age.
INNERVATION OF ACCOMMODATION	For Blur-driven accommodation: • Retinal cones are stimulated by the lack of focus. • Blur signals are transmitted through the magno-cellular layer of the lateral geniculate nucleus (LGN) to the visual cortex. • The signal is also transmitted to parieto-temporal areas for processing. • The supranuclear signal travels on to the midbrain to the oculomotor /Edinger-Westphal nucleus where motor command is formulated. • The motor command is transmitted to the ciliary muscle via the oculomotor nerve (CN III), the ciliary ganglion, and the short ciliary nerve. • A change in state of contraction of the ciliary muscle occurs. • The crystalline lens changes shape to attain an in-focus retinal image and clarity of vision. • The zonular tension decreases causing the anterior surface of the lens to steepen thereby increasing plus power. The Z axis lengthens and the lens moves forward. • The lens sinks towards gravity. • When relaxing accommodation, the zonules tighten causing a flattening of the lens and the focus moves further away.
ACCOMMODATION MEASUREMENT IN INFANTS	Accommodation measurement in infants shows some general trends but infants are not very cooperative in stating their results. • Accommodation during the first month is near 5.00D. • Then between 2 and 3 months it begins to behave more like an adult eye. • Tonic accommodation appears to be the same in infants and young adults (approx.1.40D). • Preterm babies show larger amounts of accommodation. • The speed of accommodation is adult-like by age of 3 months. • The linearity of the accommodative response relative to the stimulus to accommodation improves throughout infancy. A gap in testing exists for children aged between 1 and 4.5 years, as they are difficult to assess. Assessment of Children between the ages 5 to 10 provides more data (Benjamin, W. Borish's Clinical Refraction. WB Saunders, Philadelphia. 2006) • Amplitude decreases with age • Lag of accommodation shows slow but progressive increase with age • Facility of accommodation improves with age

QUESTION:
Do testing results of this age group reflect real findings or maturity and cooperation of the individual?

STEADY-STATE (STATIC) ACCOMMODATIVE STIMULUS RESPONSE FUNCTION

1. INITIAL NONLINEAR ZONE	This zone denotes the response to a 0 to 1.50D stimulus. This is the result of a small tonic input and depth of focus where the system's response is not 0D, but 0.25D to 0.33D. This represents the lead of accommodation where the system sets up for the least amount of work to place the depth of focus at the far target. Hyperfocal refraction and hyperfocal distance correspond to the point where the eye is still conjugate and still has a clear focus.
2. LINEAR MANIFEST ZONE	This is the response mid-region over which a change in stimulus produces a relatively large and proportional change in the accommodative response. The slope of the linear response region ranges from 0.70D to1.0D. The lag of accommodation is apparent in this portion.
3. NONLINEAR TRANSITIONAL ZONE	As the accommodative stimulus increases above the upper linear manifest zones, progressively smaller changes in accommodation occur. This indicates a soft saturation in the system. More error in accommodation occurs due to the biomechanical limits of the crystalline lens.
4. NONLINEAR LATENT ZONE	Further increases in the level of accommodative stimulus fail to produce additional change in accommodation. This means that hard saturation has occurred and it extends 2.00D beyond the non-linear transitional zone. This is the functional presbyopic zone. The system continues to try.
5. MYOPIC NONLINEAR DEFOCUS ZONE	In this zone, further amounts of uncompensated retinal defocus cause the system to reduce its effectiveness and lead to a gradual decrease in accommodative response sending the system towards its tonic level.
6. HYPEROPIC NONLINEAR DEFOCUS ZONE	Stimulation beyond optical infinity produces a non-compensated hyperopic retinal defocus that sets the system into a tonic focus that is greater than the 0.25 expected for infinity. This also sends the system back to the tonic level of 1.00D. BLUR sets off accommodation, but the system is also error controlled. The direction of the accommodation is controlled by a variety of factors. The system without influence is 50% accurate in terms of accommodation direction. The effect of a variety of characteristics affects the response. Real life is a composite of factors and the accommodative system is able to work well within it.

MORE VISION SCIENCE

HUNG'S STEADY-STATE (STATIC) MODEL	The input of distance in both dioptres and metre angles stimulates the reflex, proximal and vergence portions of the accommodative systems. It is only the proximal system that does not follow the retinal path.
THE THRESHOLD DEAD SPACE OPERATOR	This is the system component that tolerates error. It sets the level of the perceived blur required to drive the system.
GAIN	This is the mechanism that controls the speed of response of the system.
ADAPTIVE LOOP	Once the initial fast system response is complete, the adaptive loop is activated and allows the system to sustain the response for a prolonged time.
CROSS-LINK GAIN	This gain multiplies the response output of the direct pathway gain taking into account the AC/A and CA/C ratios. High gain would result in esotropia, reduced gain might cause exotropia.
TONIC INPUT	This is the midbrain baseline neural innervation. There is no visual feedback involved.
SUMMING JUNCTION	This is the summation area of tonic, proximal and crosslink output to drive the system
PERIPHERAL APPARATUS	The output of the summing junction proceeds to the cortical and subcortical centres to activate the neural signal to innervate the ciliary muscle and lens for accommodation as well as the extraocular muscles for vergence. A negative feedback pathway controls the system until a steady state is achieved.

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