Outline: Vergence Eye Movements: Classification

I. **Describe with 3 degrees of freedom**- Horiz, Vert, torsion

II. **Quantifying units- deg, PD, MA**

III. **Measurement of Vergence:- Objective & Subjective phoria**

IV. **Stimuli for *Horizontal* vergence**

  Maddox classification for horizontal vergence

    Tonic- orthophorization

    Proximal- spatiotopic- coarse adjustment

    Fusional or disparity- fine adjustment

    Cross link- Accommodative convergence- open-loop.

  Effects of prisms and lenses on the horizontal phoria:

    Concomitant and non-concomitant

V. **Stimuli for *Vertical* vergence**

  Disparity in tertiary gaze

  Cross coupling with gaze direction and distance

VI. **Neurological control- Near Response cells-**

  pre-motor nuclei Mesencephalic Reticular formation.

  Burst, tonic and pause cells

Outline: Vergence Eye Movements

I. Describe with 3 degrees of freedom

II. Quantifying units

III. Measurement

- **Objective**
- **Subjective**

IV. Maddox classification for horizontal vergence

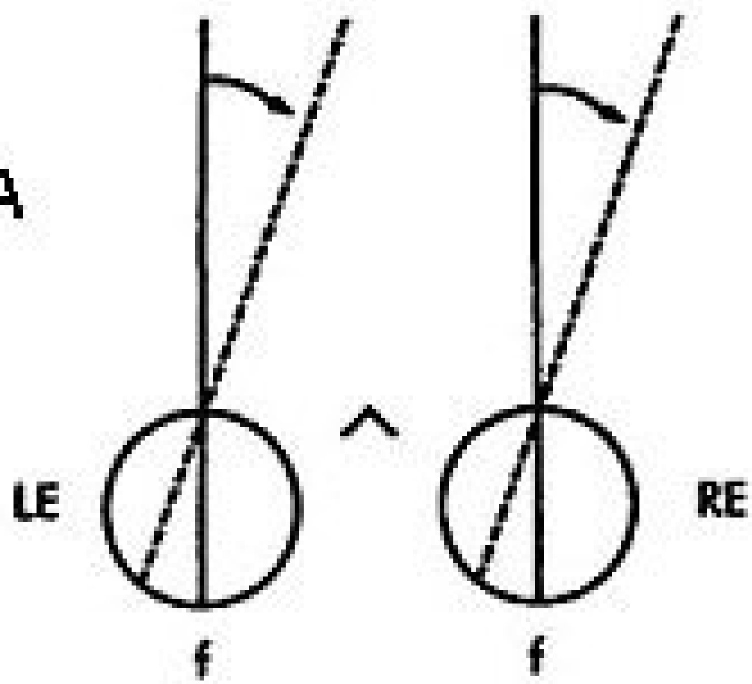
V. Neural control

Two classes of binocular eye movements:

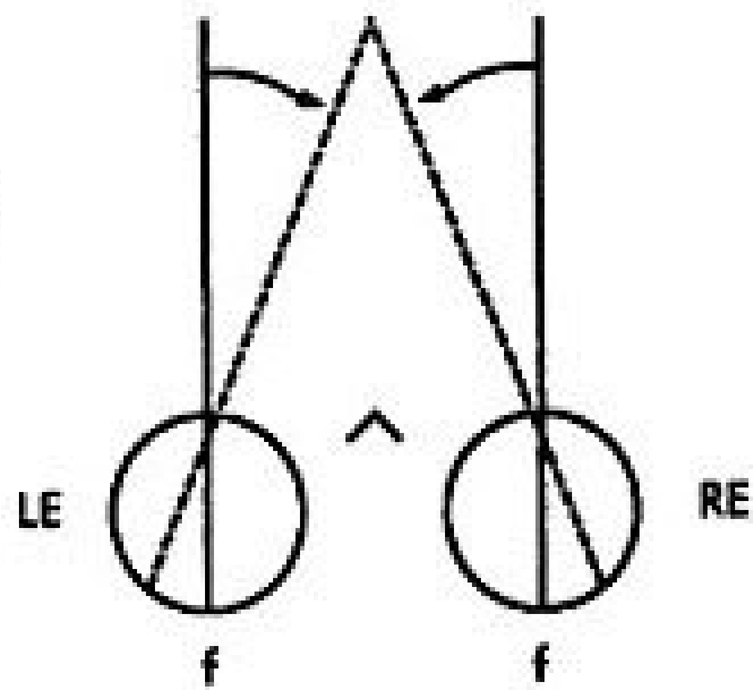
Version movement
Same direction
Conjugate rotation

Vergence movement
Opposite direction
Disjunctive rotation

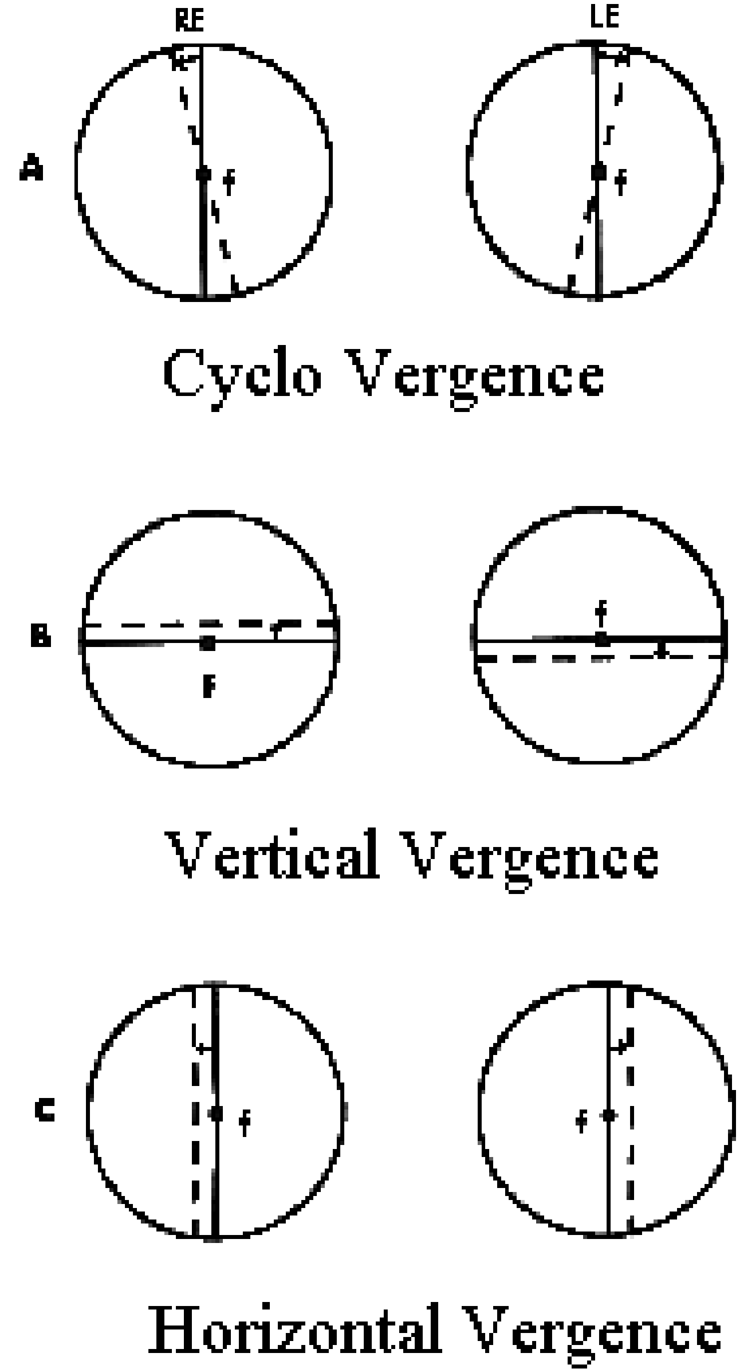
A



B



Vergence has three degrees of freedom



Units for quantifying vergence:

1) Degrees

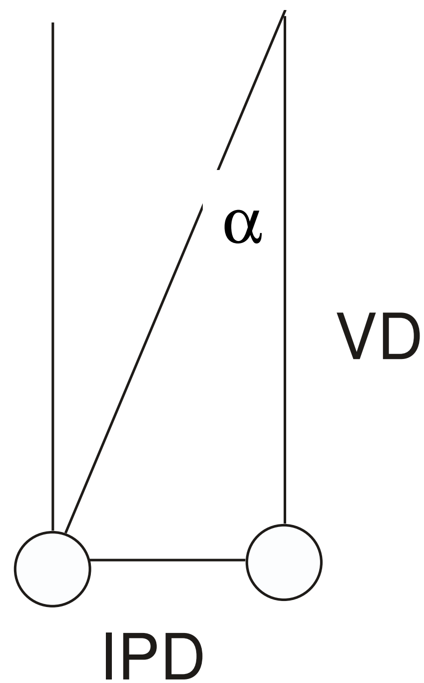
2) Prism Diopters (Δ) = 100 x tan Degrees

3) Meter Angle (MA) = 1/VDm

Δ = MA x IPD cm

e.g. 15Δ= 2.5 x 6.0 cm

MA units are quantitatively similar to Diopter units of accommodation.
MA are independent of the inter-pupillary distance.
MA only apply to symmetrical convergence



Δ = 100 x tan α

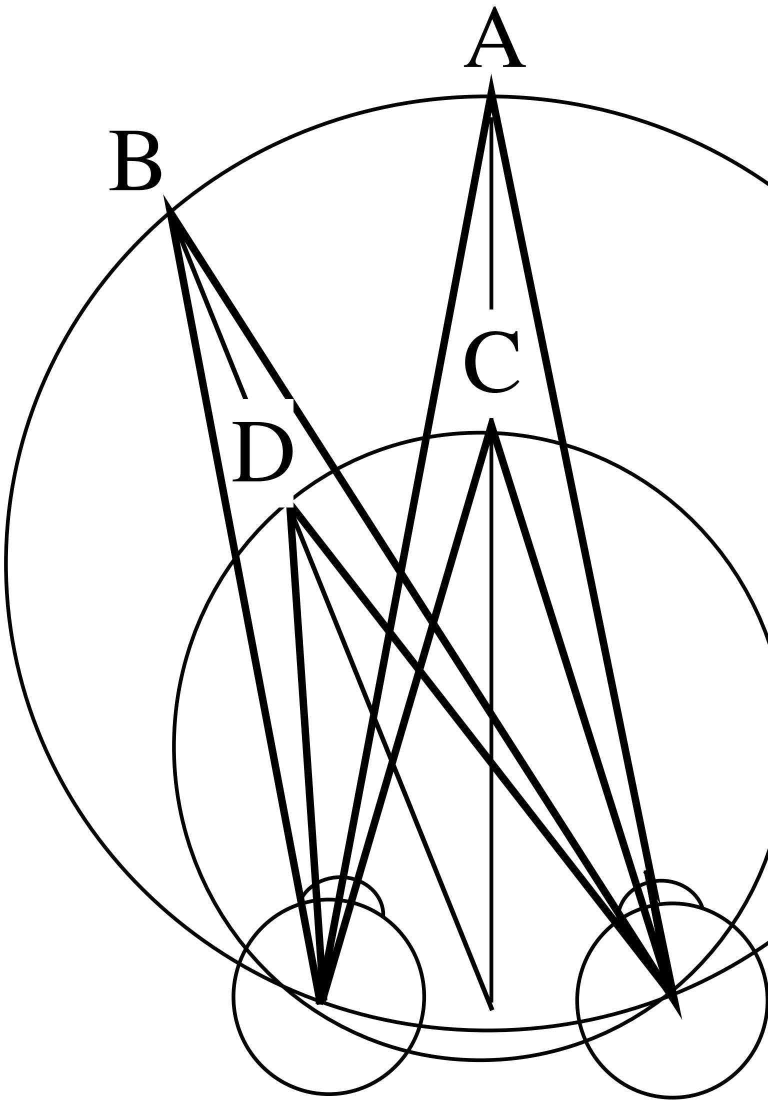
tan α = IPD / VD

by substitution

Δ = 100 X IPD m / VD m ; IPD m X 100 = IPD cm

Δ = IPD cm / VD m

Iso-Vergence Circle
Iso-Version Lines

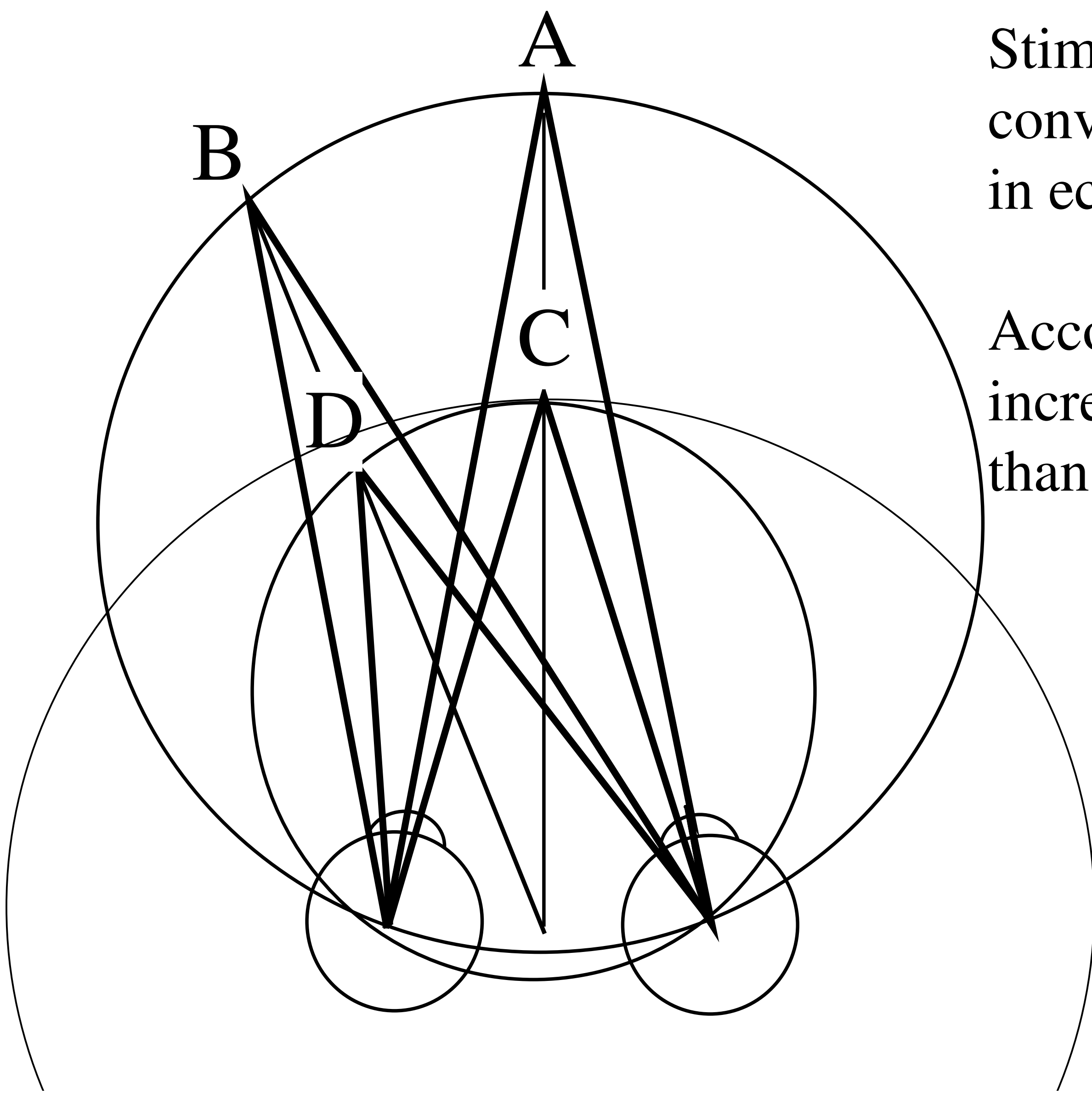


Points A and B have the same **Vergence** angle. So do Points C and D. They lie on an iso-vergence circle

Points A and C have the same **Version** angle. So do Points B and D. Iso-version lines

This shows the Iso-Vergence Circle and Iso-Version lines in the visual plane.

Iso-Vergence & Iso-Accommodation Circles



Stimuli to accommodation and convergence are not matched in eccentric gaze.

Accommodation stimulus increases faster with azimuth than does the vergence stimulus

The ideal AC/A decreases w/ azimuth

Four Maddox Components of Horizontal Vergence

Maddox proposed that horizontal vergence was composed of a linear sum of these four components.

1) Tonic convergence-
(Adaptable Resting level)

2) Proximal convergence-
(Spatio-topic Gaze shifter)

3) Disparity (fusional) convergence-
(Retino-topic Gaze refiner & maintainer)

4) Accommodative convergence
(Coordinator of voluntary and involuntary)

Anatomical Position of rest (APR) = 5 deg divergence
occurs at birth, death, deep anesthesia or deep sleep

Physiological Position of rest (PPR) = approximately zero vergence with far fixation.

Tonic vergence moves the eyes from APR to PPR
tonic adapts to the PPR during the first 6 weeks of life

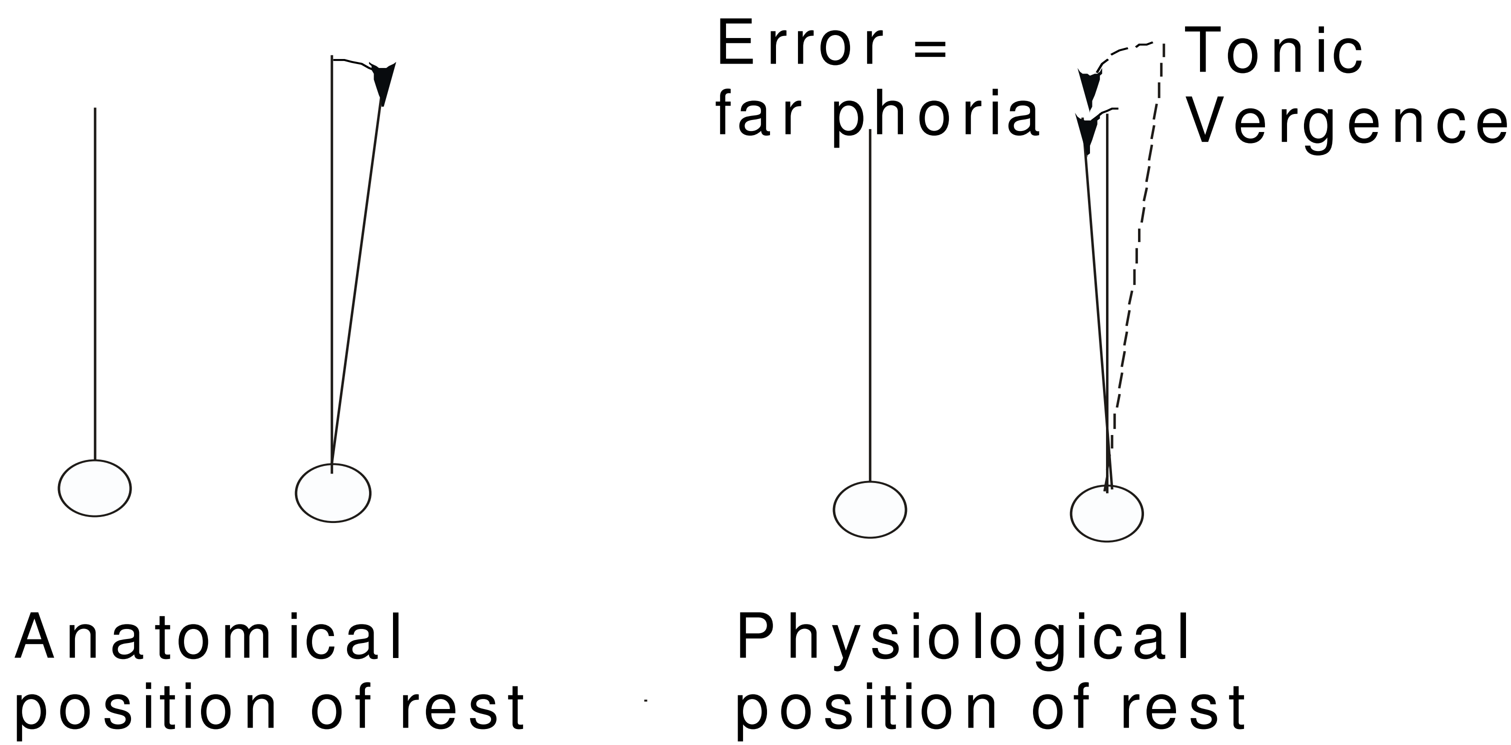
Distance Phoria = PPR deviation from zero

Tonic Vergence Estimates:

Anatomical Position of Rest (5 degrees divergence)

Physiological Position of rest (Approximately zero vergence with far fixation)

Error of Physiological Position of Rest = Distance Phoria



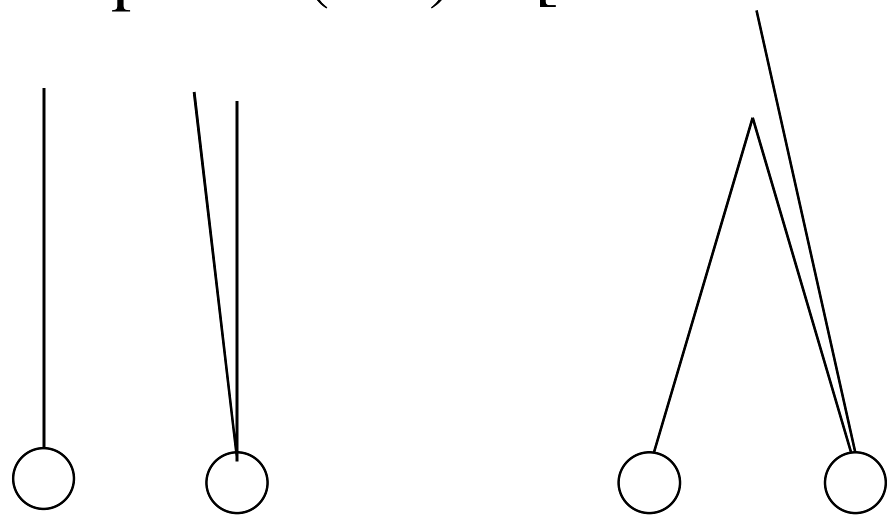
Tonic Vergence estimated from Phoria = Vergence error

Phoria = [Vergence Response – Vergence Stimulus (Demand)]

Convergence Response (CR) = [Phoria + Vergence Stimulus]

Eso +

Exo -



5 PD Eso Phoria

Demand = 0

CR = 5 PD

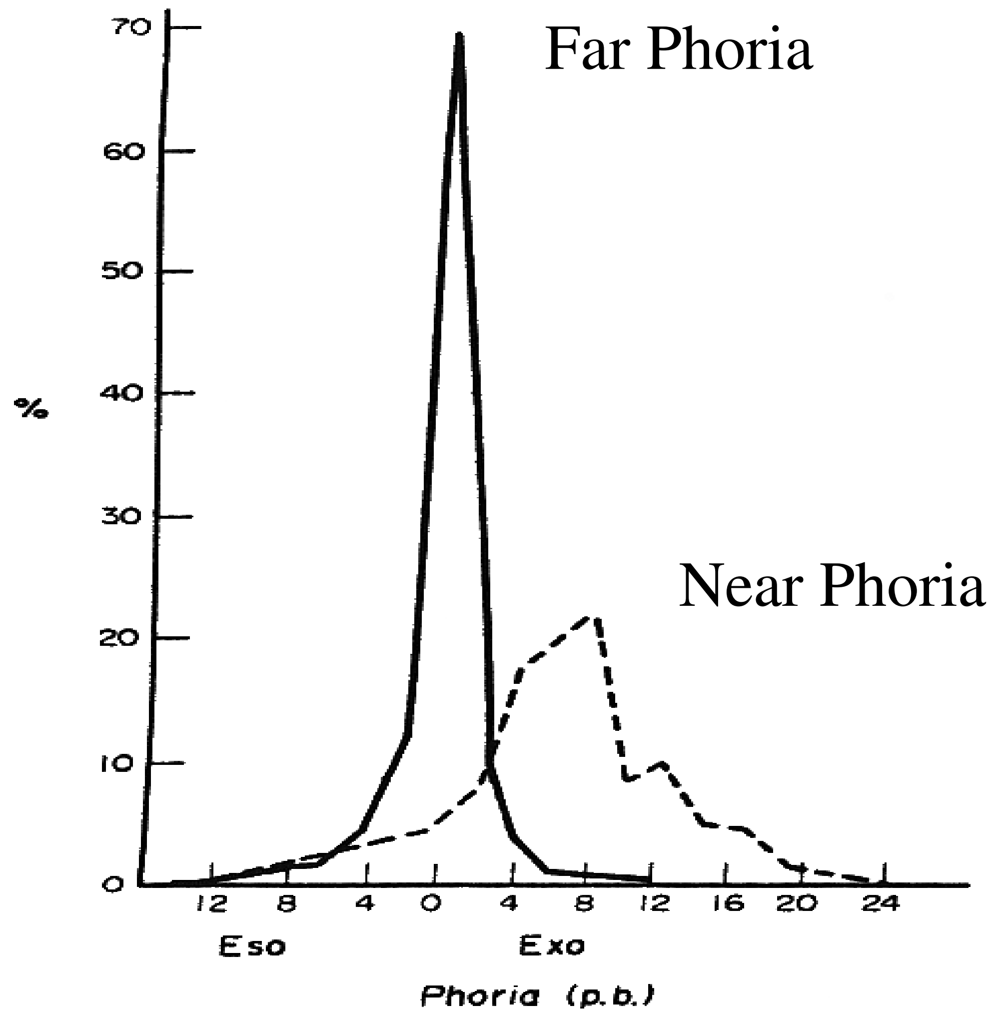
5 PD Exo Phoria

Demand = 15 PD

CR = 10 PD

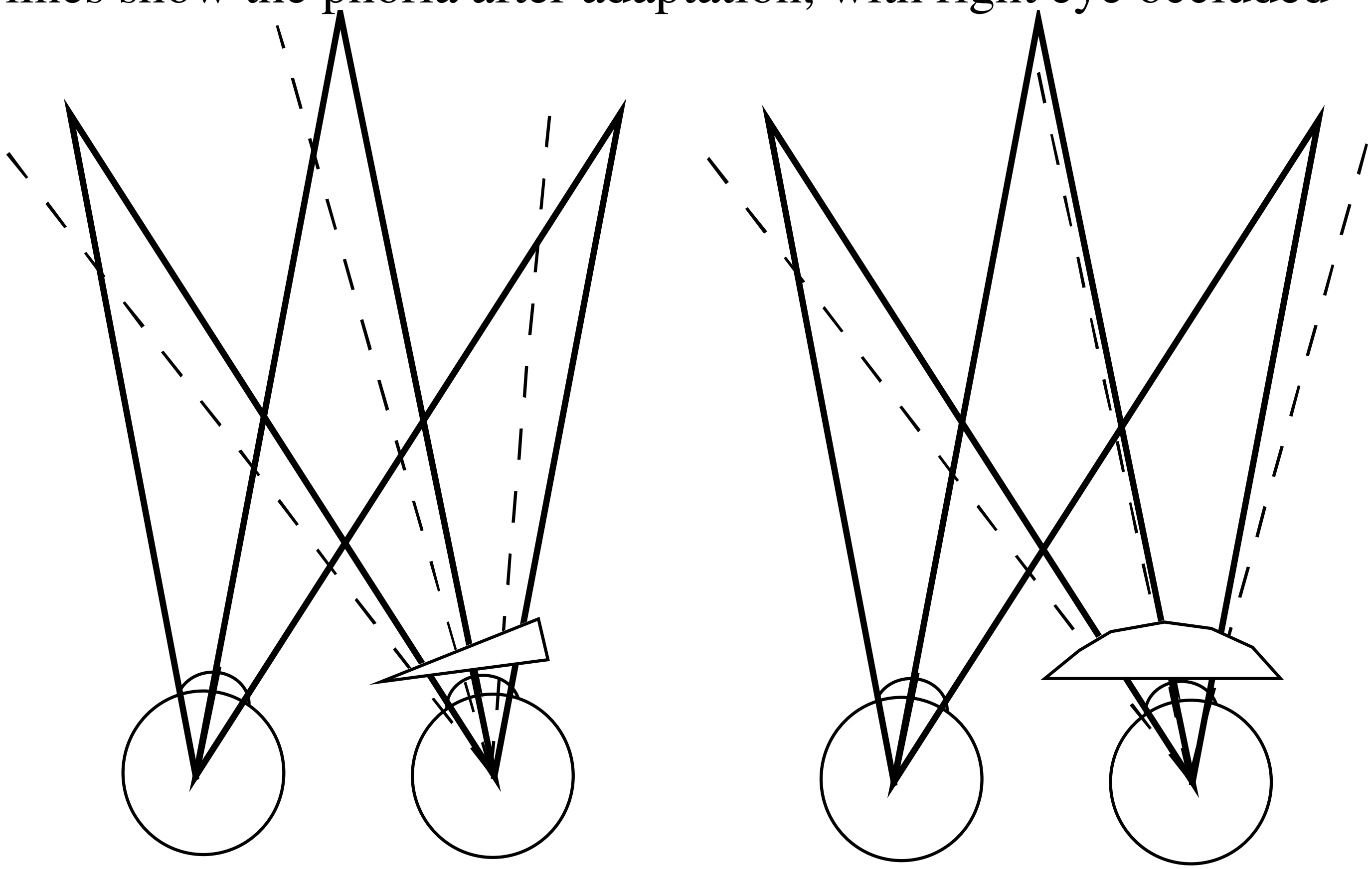
Orthophorization:
Distribution of Phorias in the population is not normal, it is peaked near zero. Peaking (kurtosis) results from adaptation.

TONIC VERGENCE ESTIMATE



Phoria Adaptation: concomitant and non-concomitant

Solid lines show orthophoric alignment before adaptation
Dashed lines show the phoria after adaptation, with right eye occluded

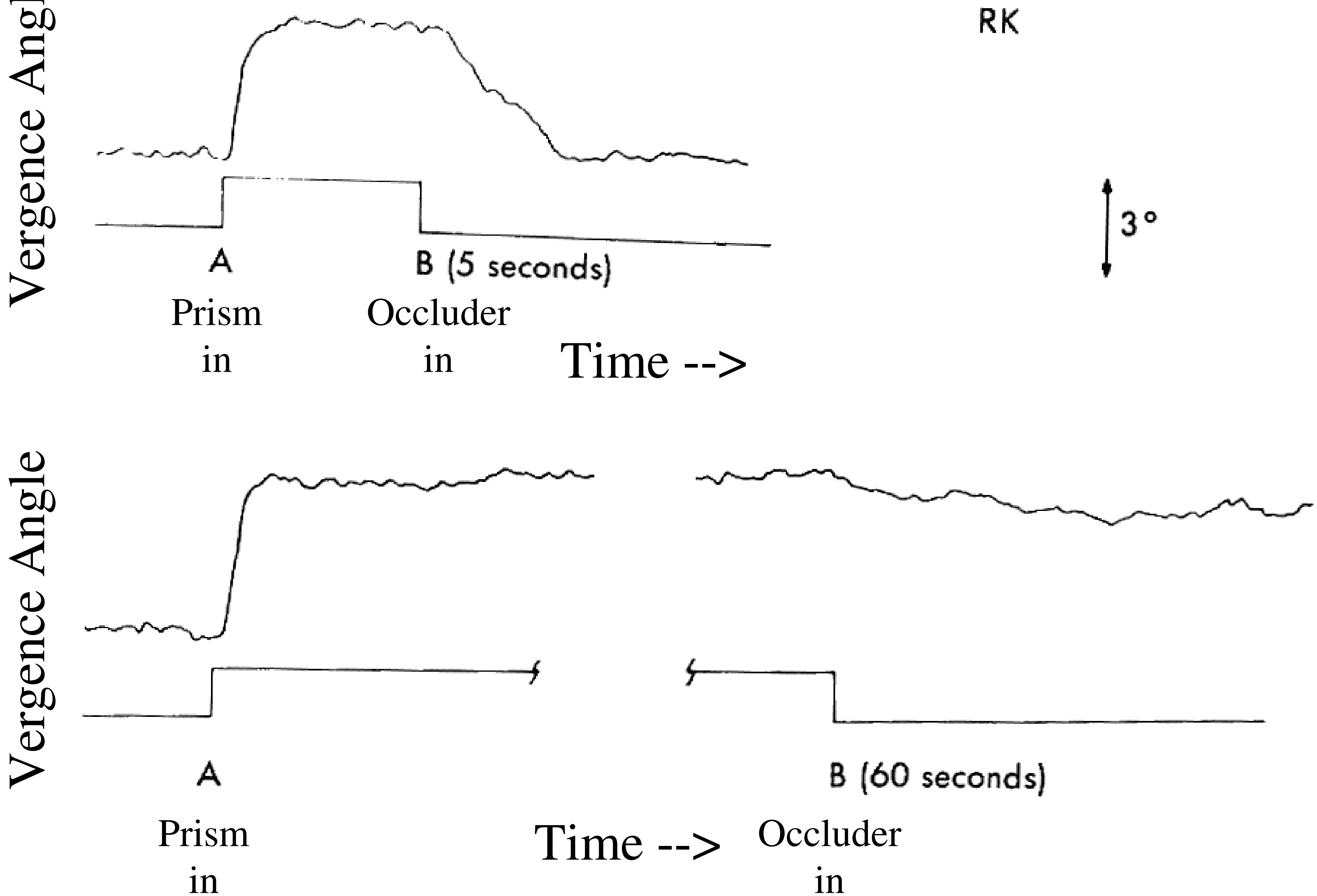


Prism adaptation produces ***concomitant*** change in phoria

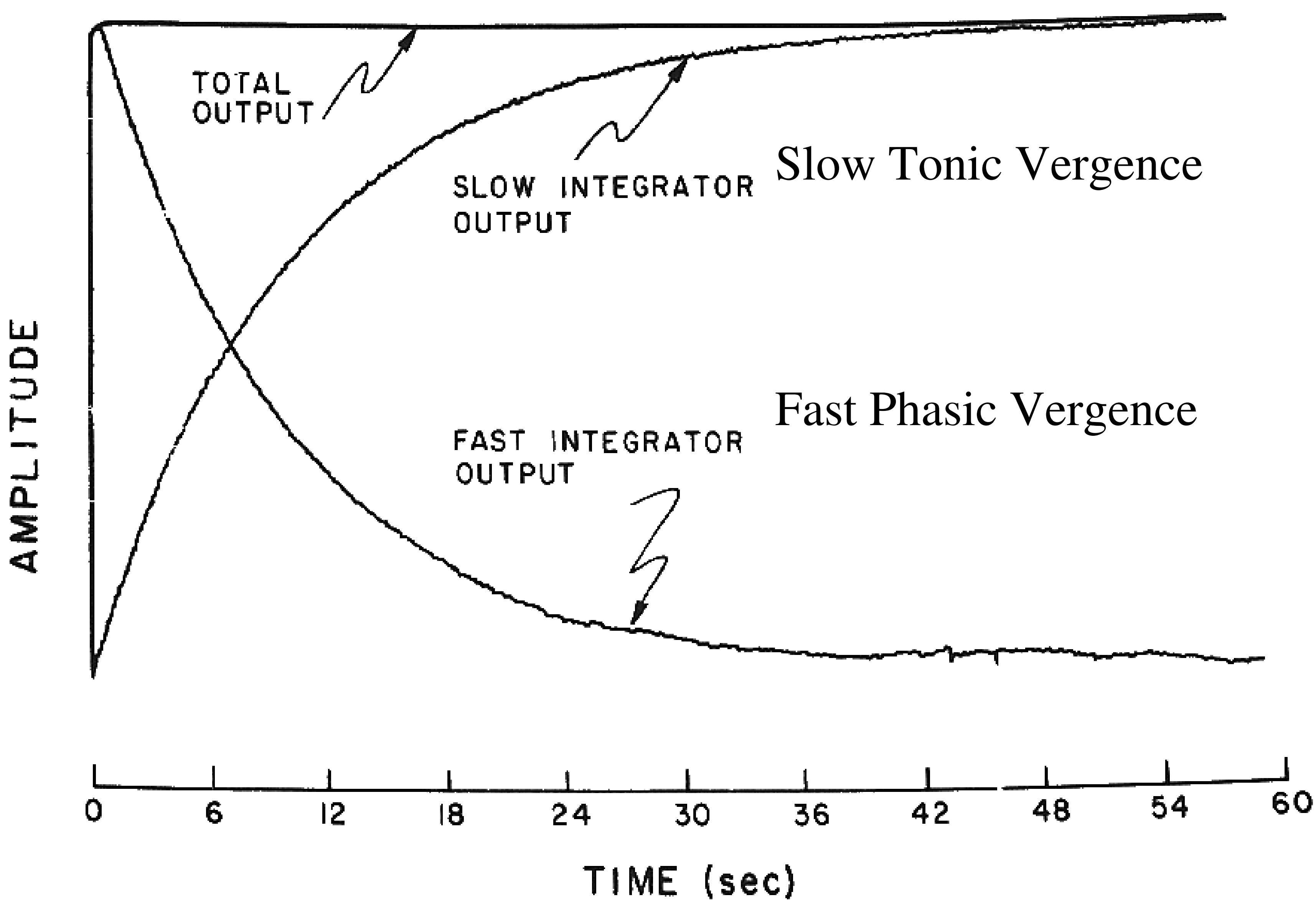
Anisometropic spectacle adaptation produces ***non-concomitant*** change in phoria. It also compensates for muscle paresis- Spread of Comitance

Horizontal disparity vergence and Prism Adaptation

Adaptation occurs in about 60 seconds



Model of temporal interactions between phasic and tonic components of vergence



Subjective measures of vergence using diplopia
Red Lens, Maddox Rod, neutralize with prism.

Normally, disparity produces diplopia
which is nulled by fusional vergence. Disparity equals
the unfused vergence error (phoria).

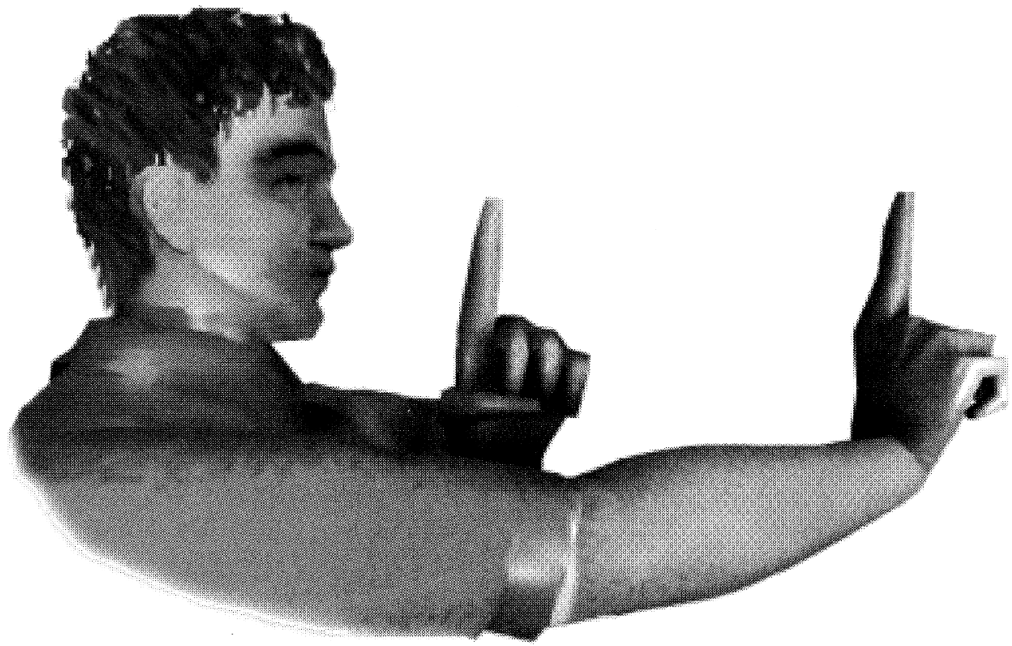
Quantify the phoria by measuring diplopia. Disrupt fusion with
a red lens or vertical prism over one eye to produce diplopia.

Esophoria is produced by uncrossed disparity

Exophoria is produced by crossed disparity

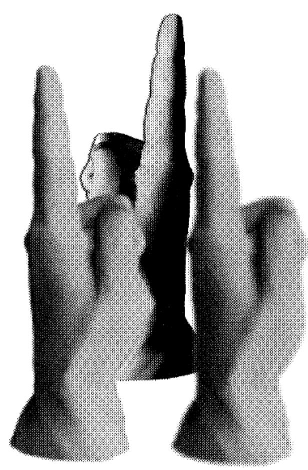
Divergence corrects esophoria
Convergence corrects exophoria

Illustration of crossed and uncrossed diplopia

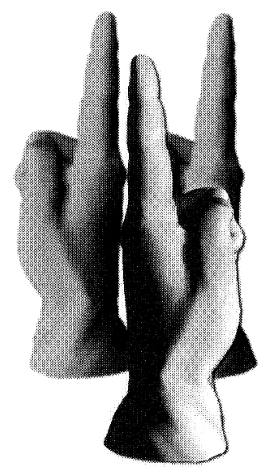


A. Position for observing physiological diplopia

Near crossed diplopia- Exo error

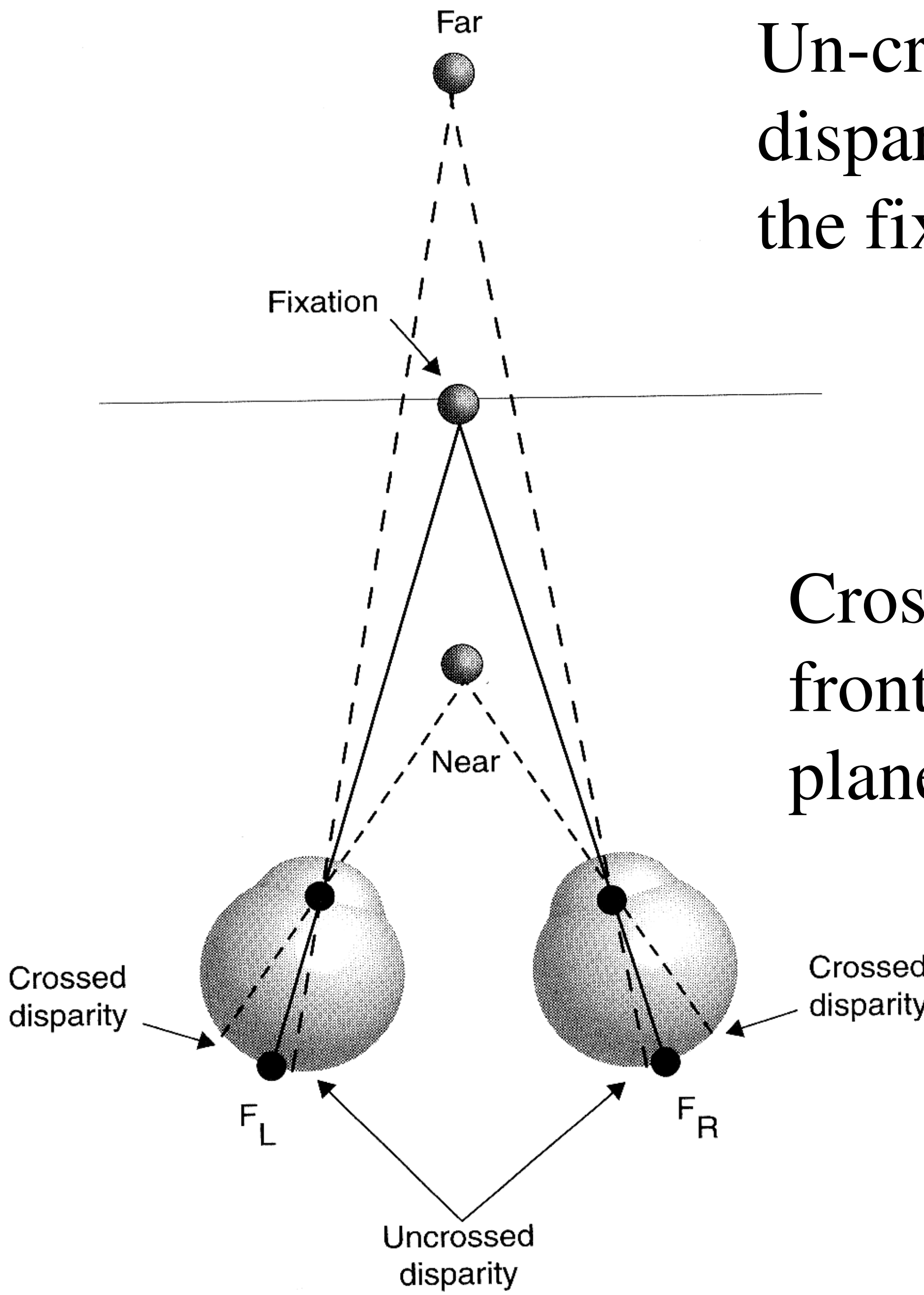


B. When focused on the distal finger, the near finger is seen as



C. When focused on the near finger, the distal finger appears

Far uncrossed diplopia- Eso error

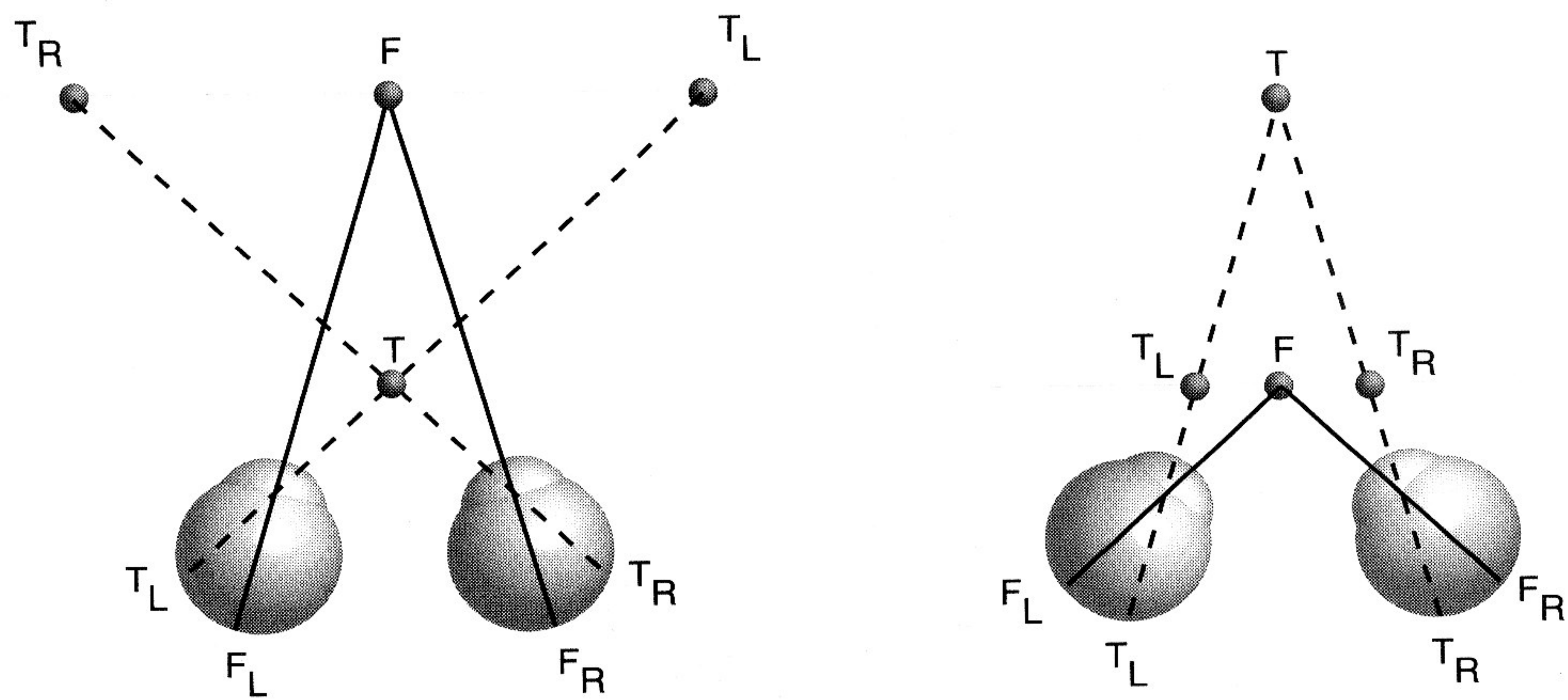


Un-crossed disparity behind the fixation plane

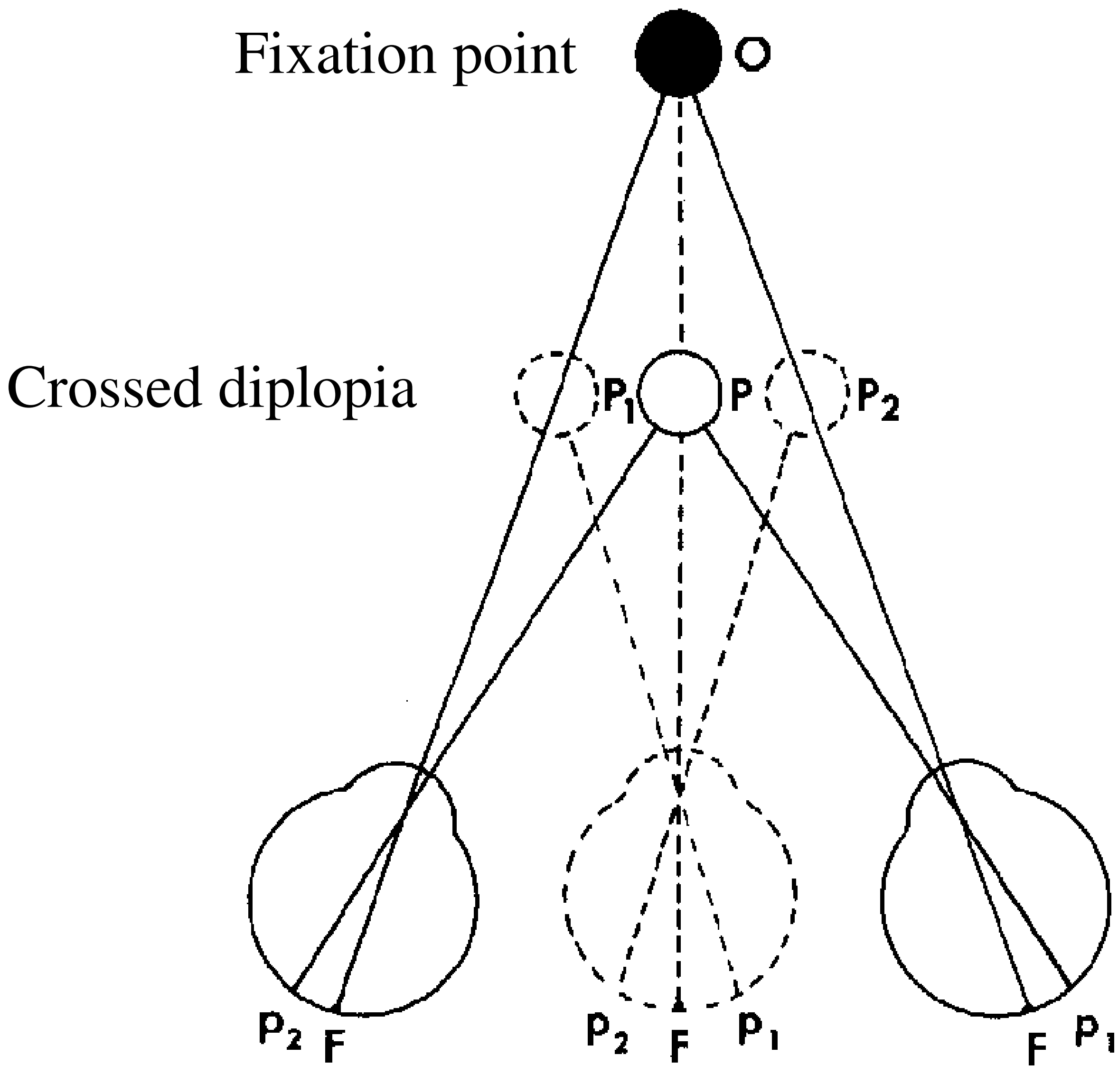
Crossed disparity in front of the fixation plane

A. Crossed Diplopia

B. Uncrossed Diplopia



Diplopia used for subjective measures of vergence error: Fixate the black spot and view the open spot in crossed diplopia. Close left eye and right spot disappears.



Proximal Vergence-Perceptual distance cues for gaze shifts
Dynamic gaze-shifting response (analogous to a saccade)

Proximal vergence is a voluntary gaze shift from one target distance to another in response to perceived distance.

Horizontal proximal vergence is under voluntary control.

Vertical and cyclo-vergence are not controlled voluntarily. Instead they are cross-coupled with voluntary horizontal proximal vergence.

And all three vergence directions respond to disparity.

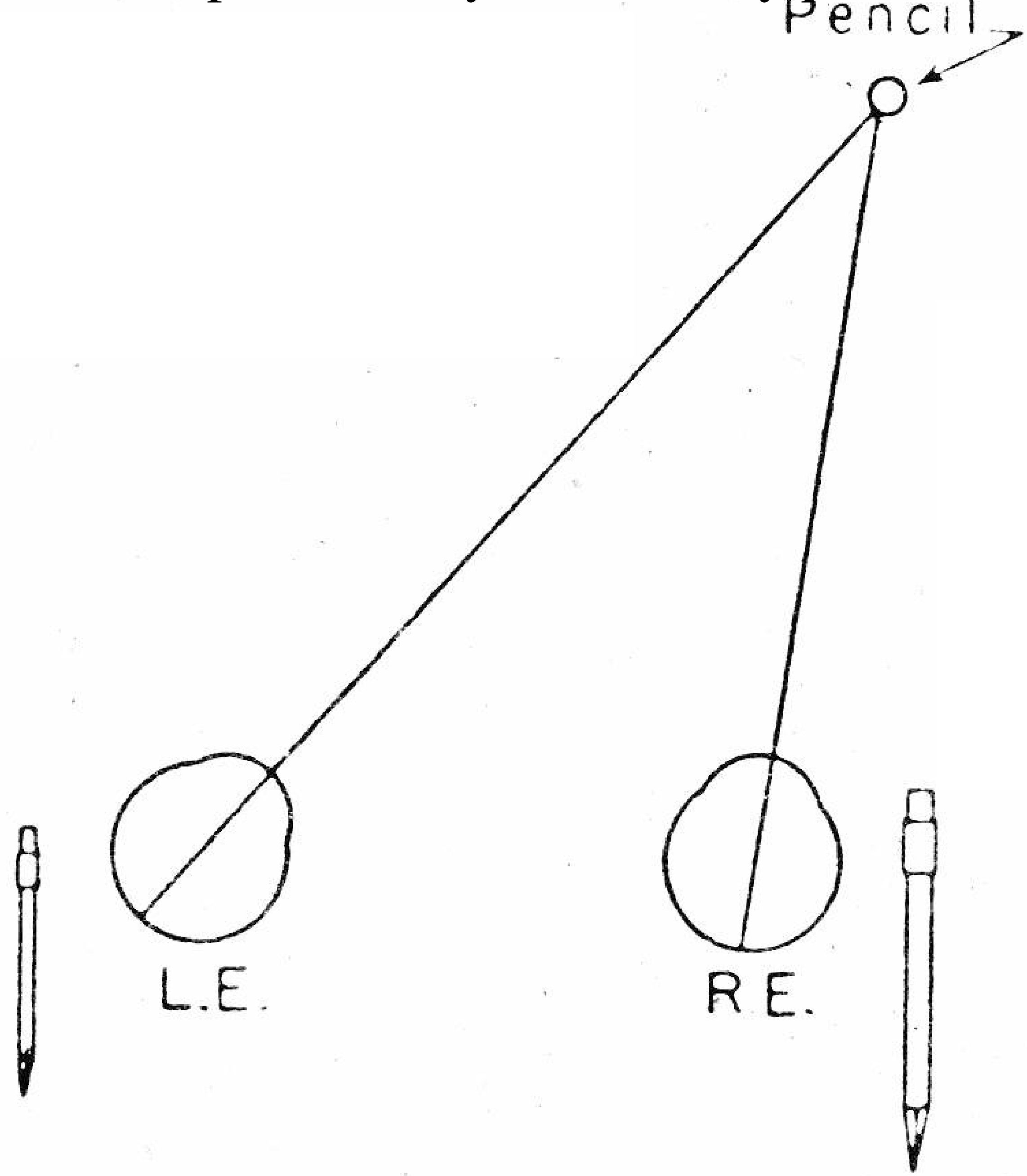
Three components of disparity vergence stimulated by retinal (disparity) cues.

Horizontal vergence – horizontal disparity

Vertical vergence – vertical disparity

Cyclo vergence- cyclo disparity

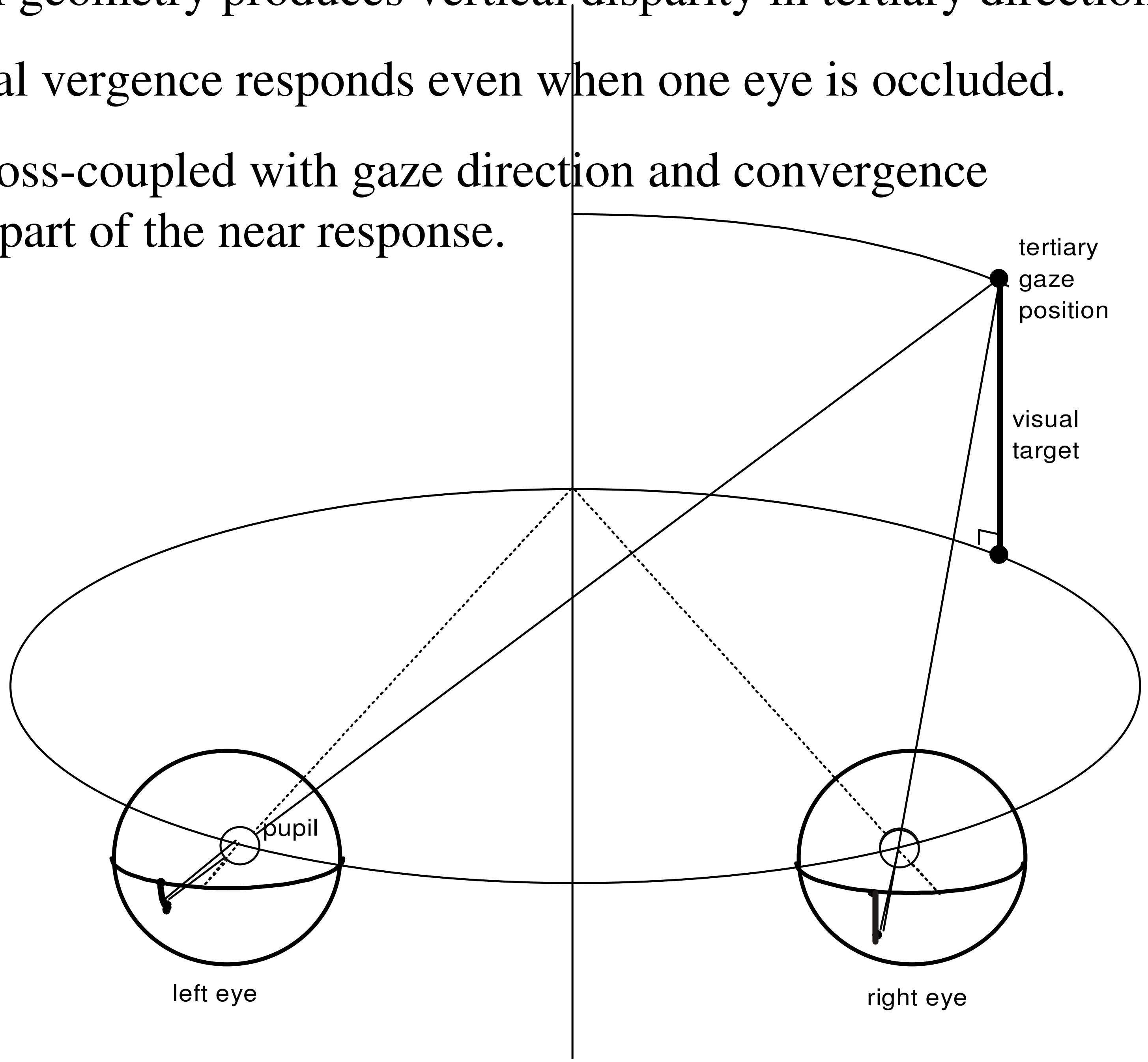
Vertical disparities are produced by near tertiary points in space



Spatial geometry produces vertical disparity in tertiary directions.

Vertical vergence responds even when one eye is occluded.

It is cross-coupled with gaze direction and convergence and is part of the near response.

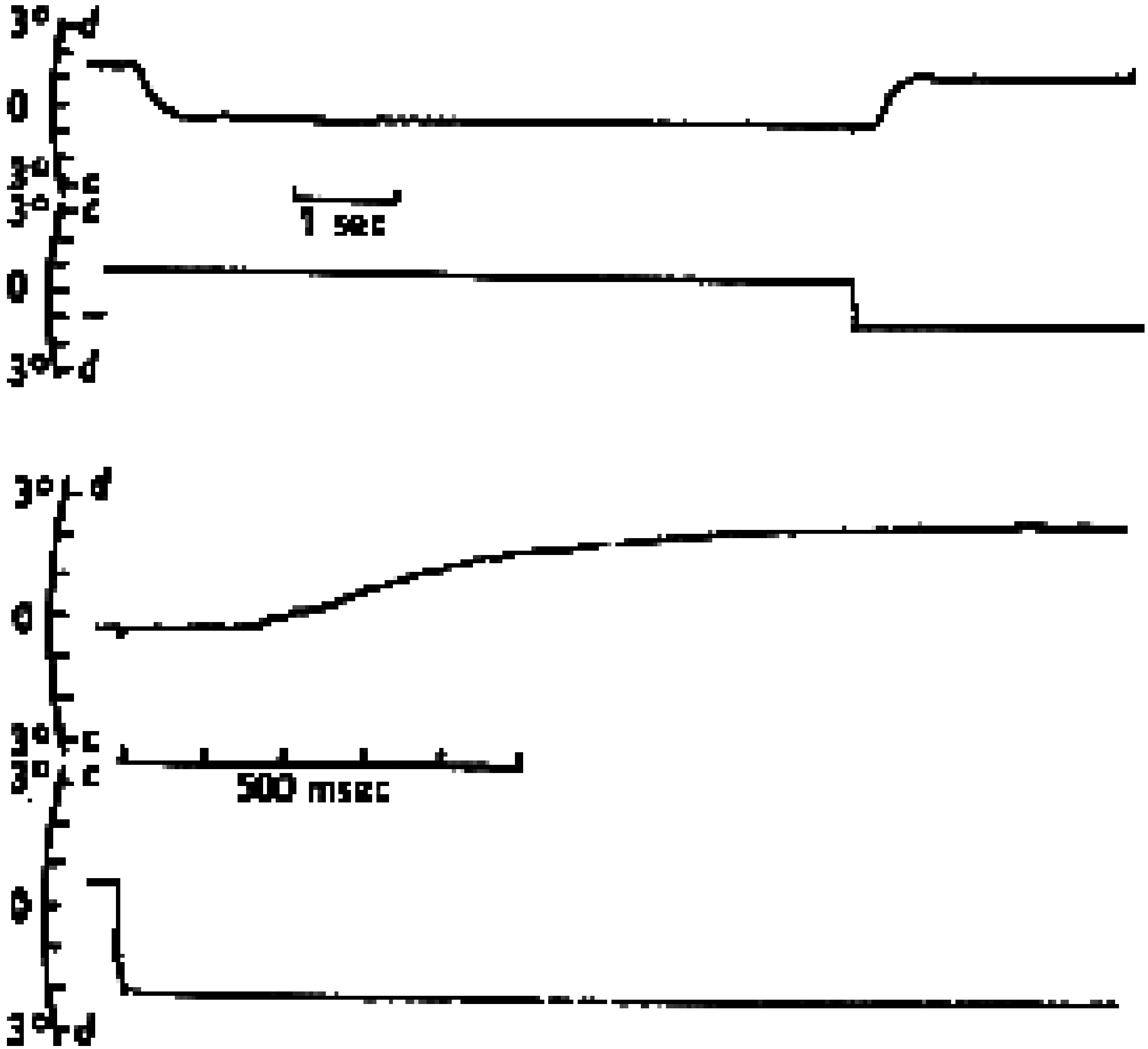


Two Classes of Dynamic Vergence:

1) Gaze shifting responses to proximal stimuli (saccade like coarse adjustment to perceived distance, refined by disparity vergence)

2) Smooth tracking (pursuit like fine adjustment to perceived motion in depth. It is refined by disparity vergence).

Disparity vergence response to small step disparity

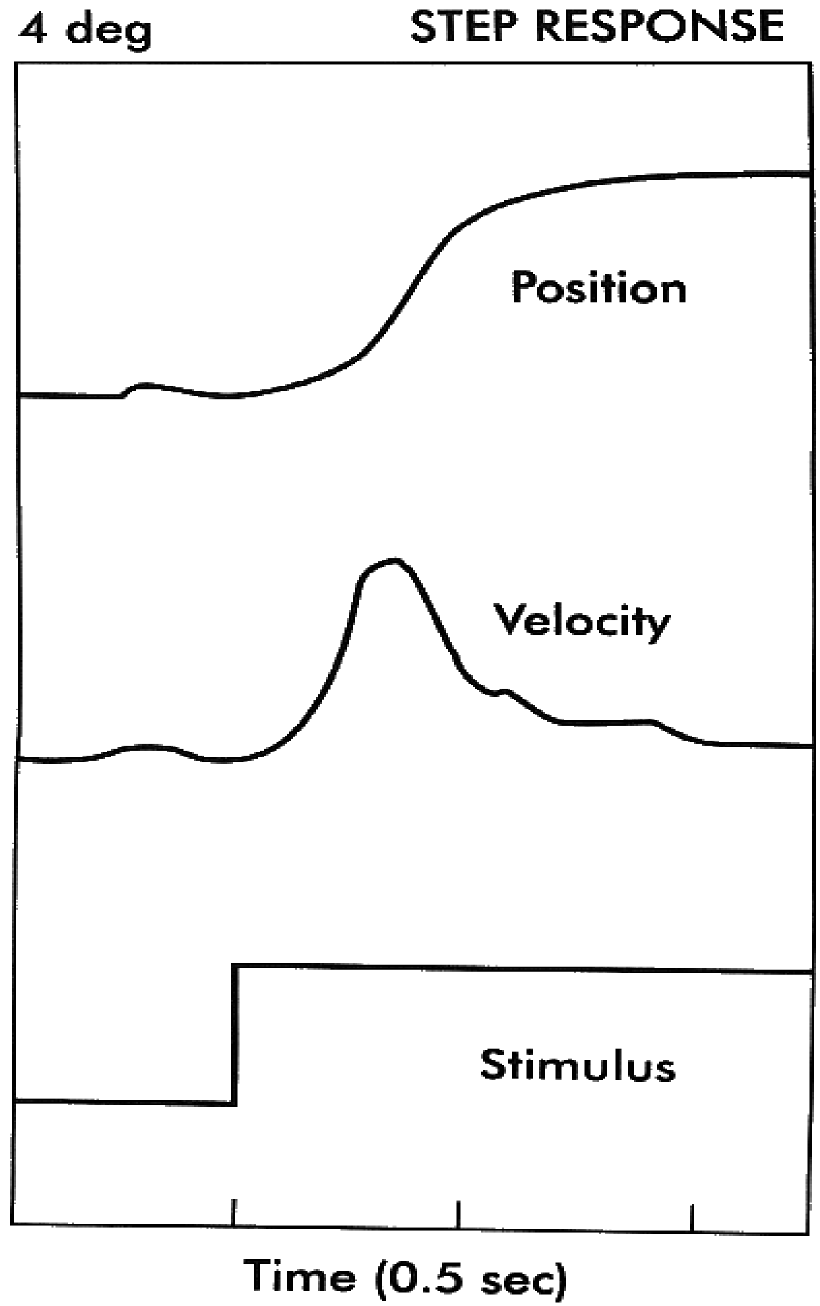


150 ms latency (half the latency as for accommodation)

Vergence step response

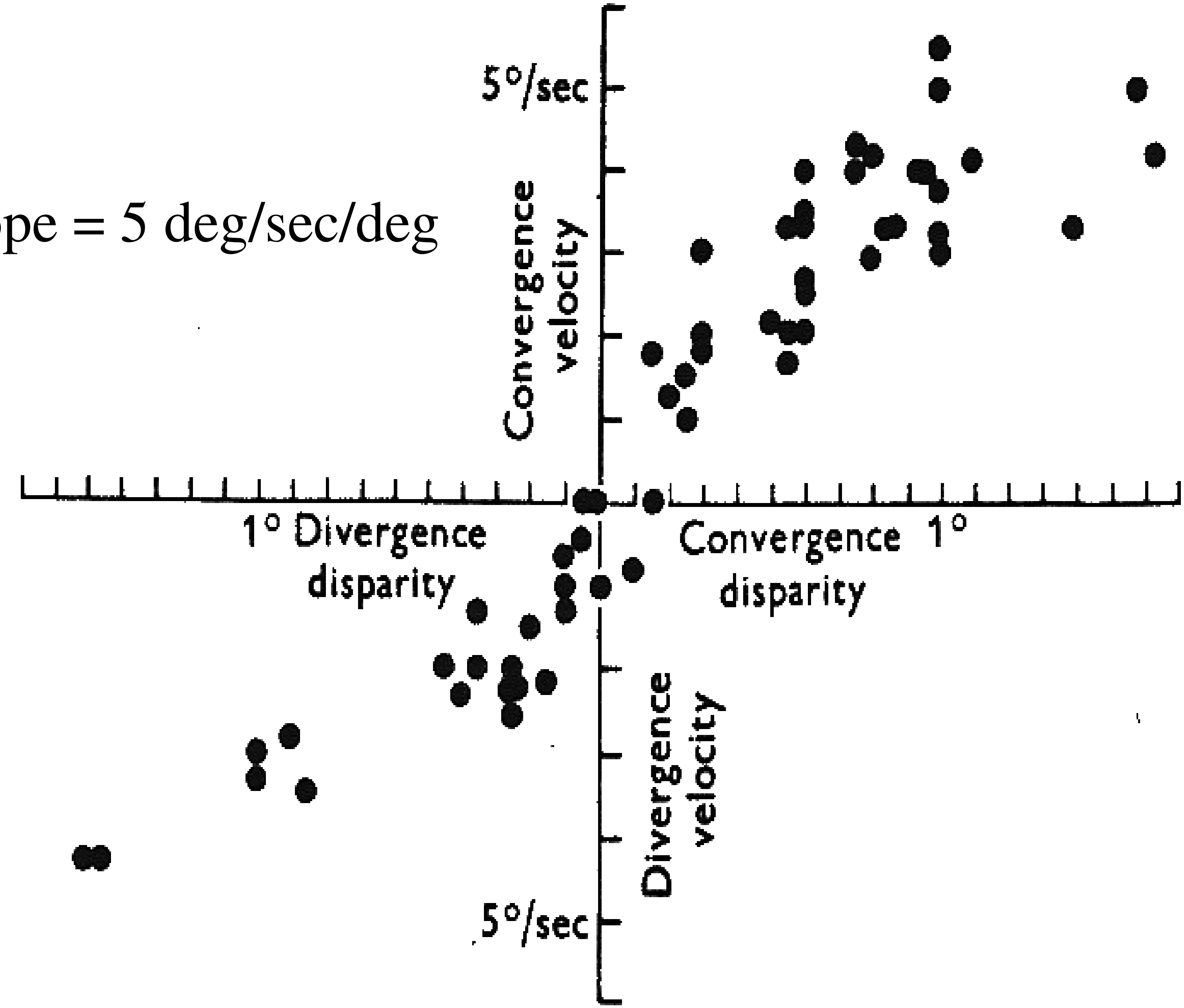
Peak velocity increases proportionally with response size.

Velocity is highest at the beginning of the vergence response and it decelerates to the end point.



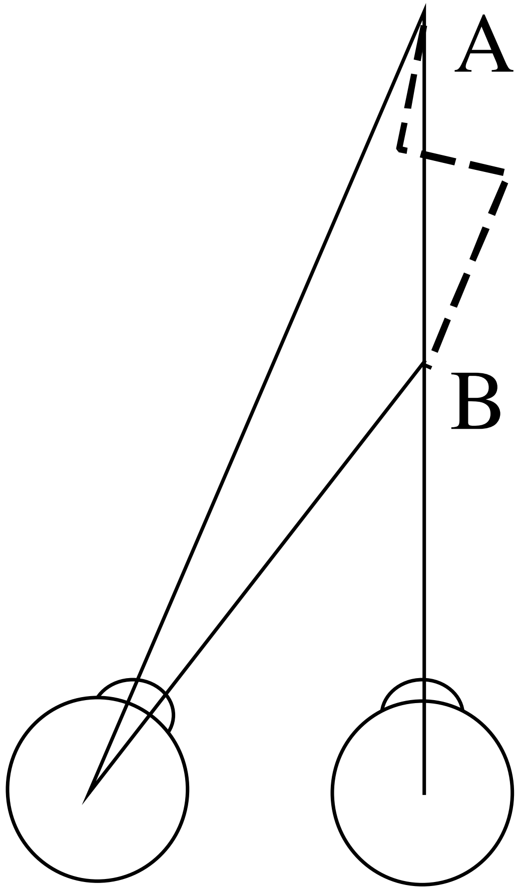
Response velocity is proportional to step disparity stimulus

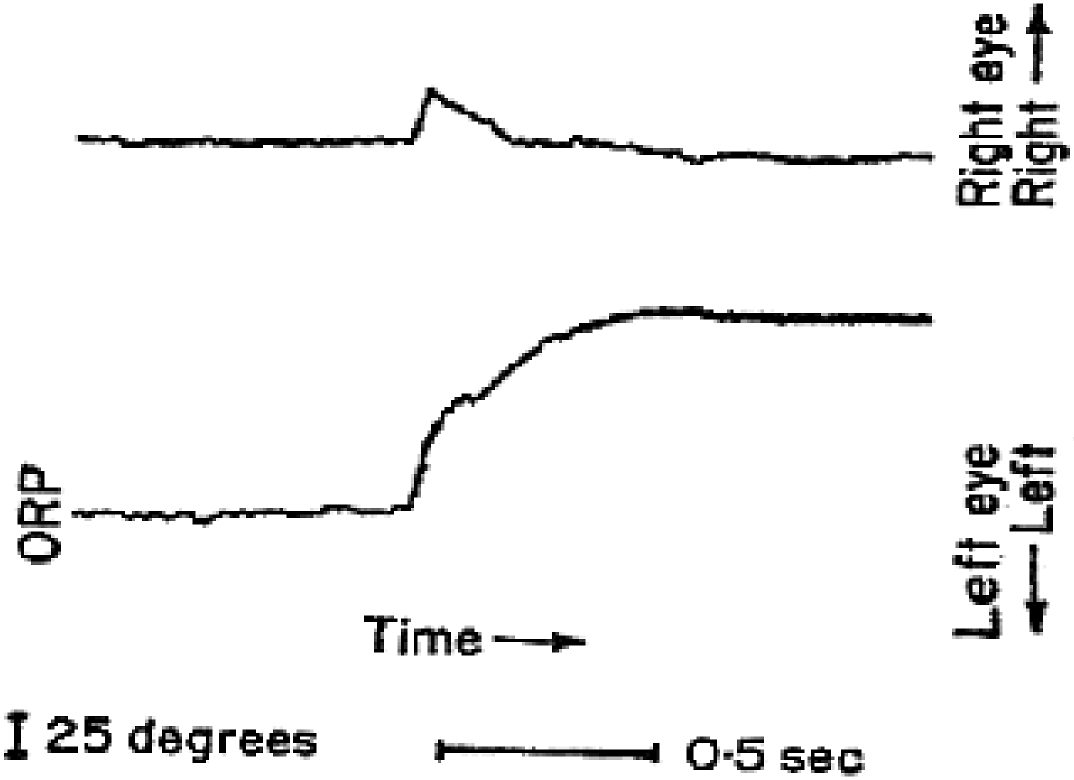
Slope = 5 deg/sec/deg



Disparity Vergence along the line of sight (Asymmetric vergence)

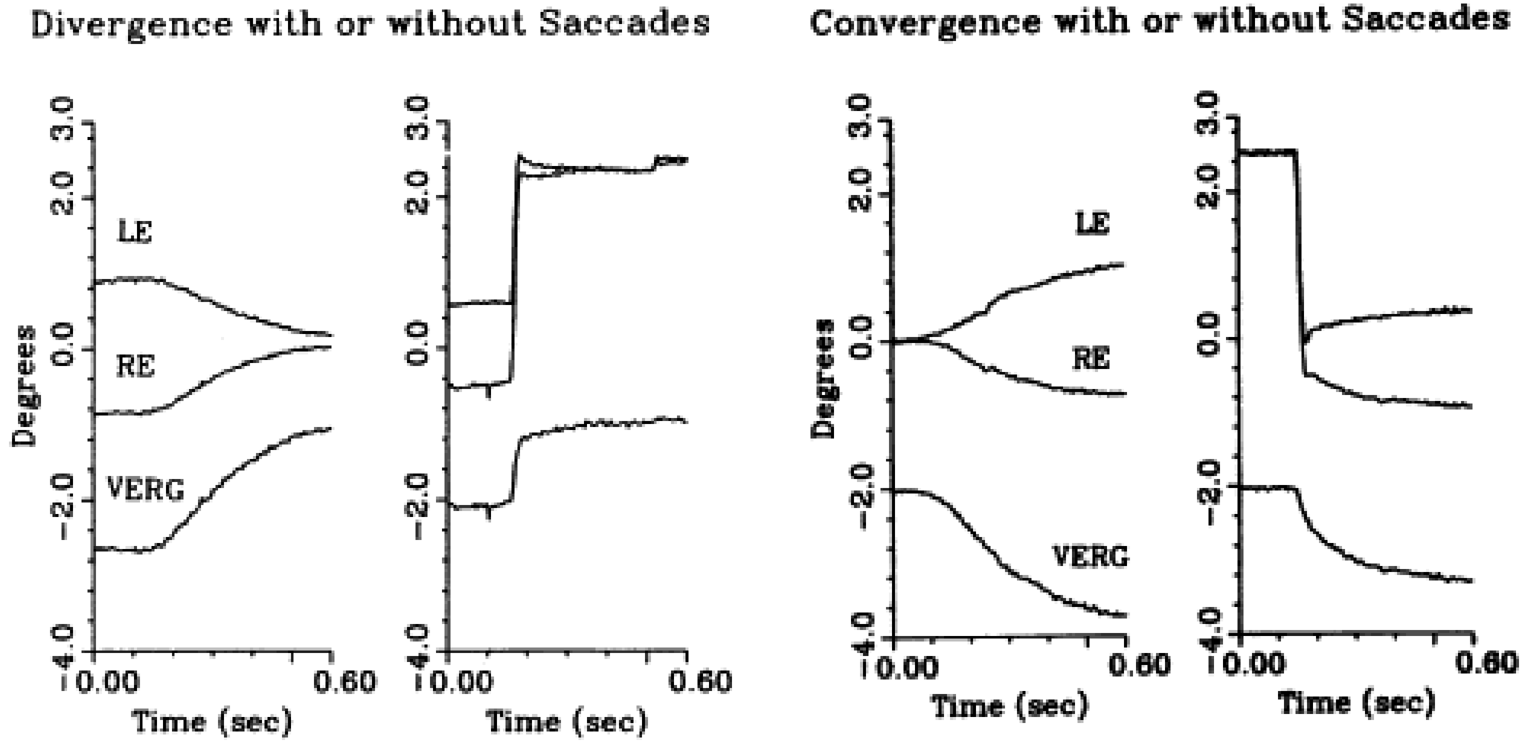
Can we move one eye while the other eye remains still?



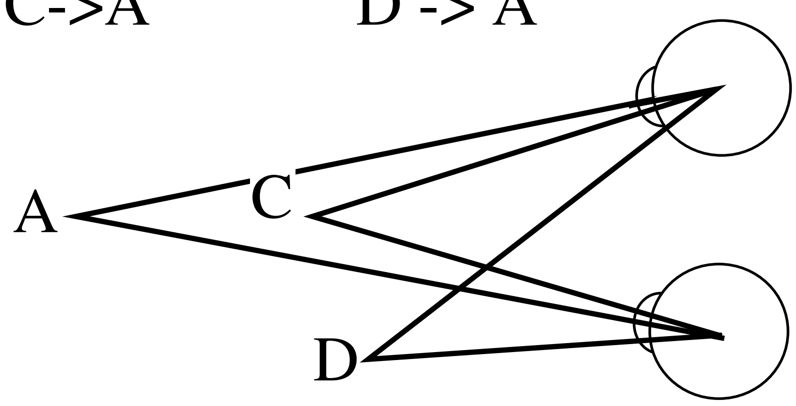


Hering's law says we can not.

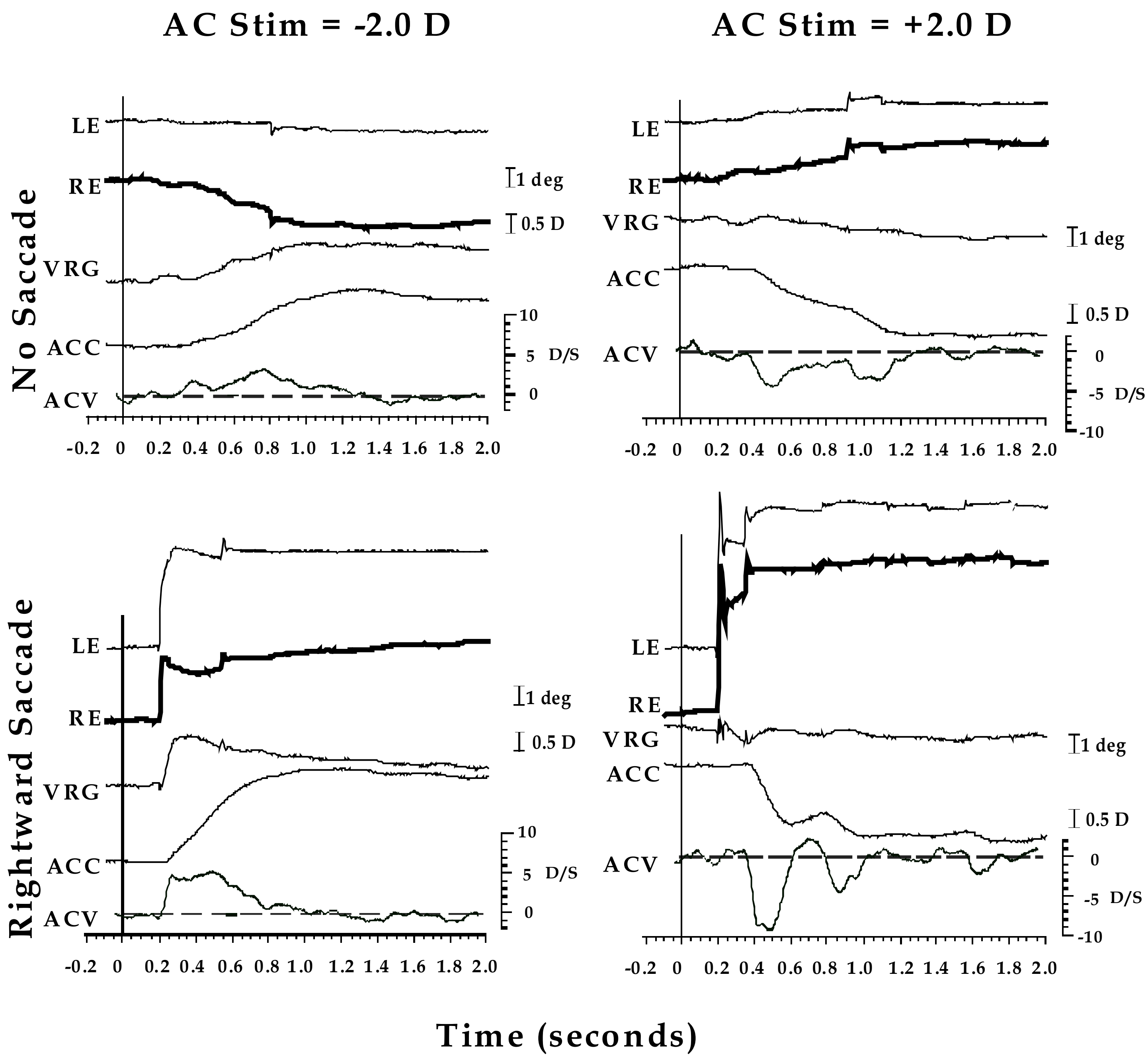
Velocity interactions between saccades and vergence



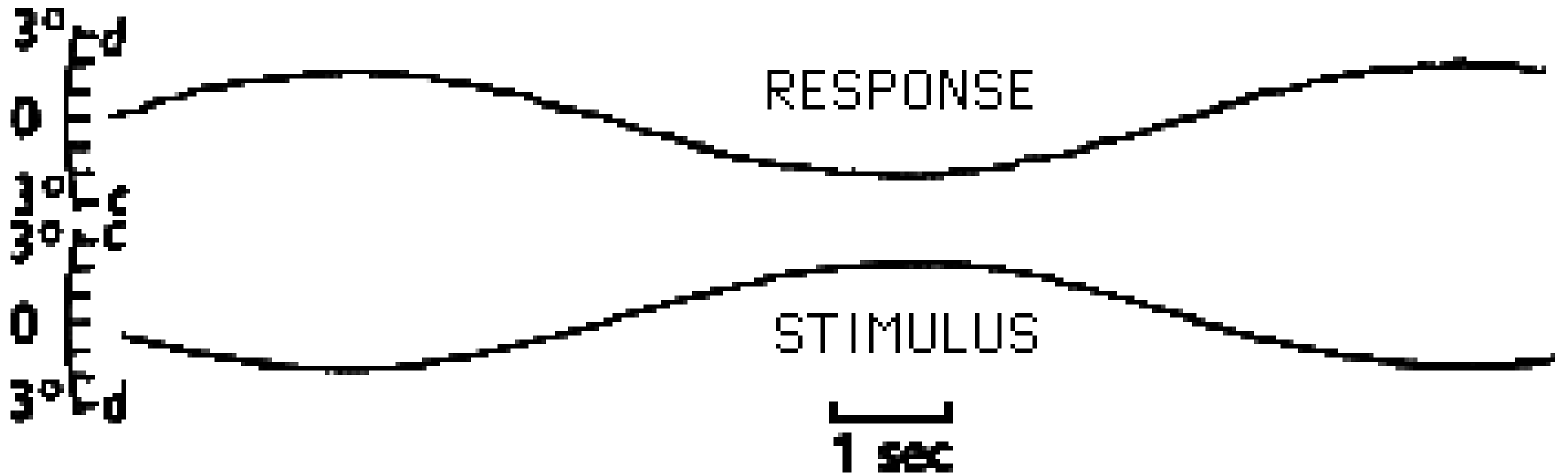
C->A D -> A A->C A->D

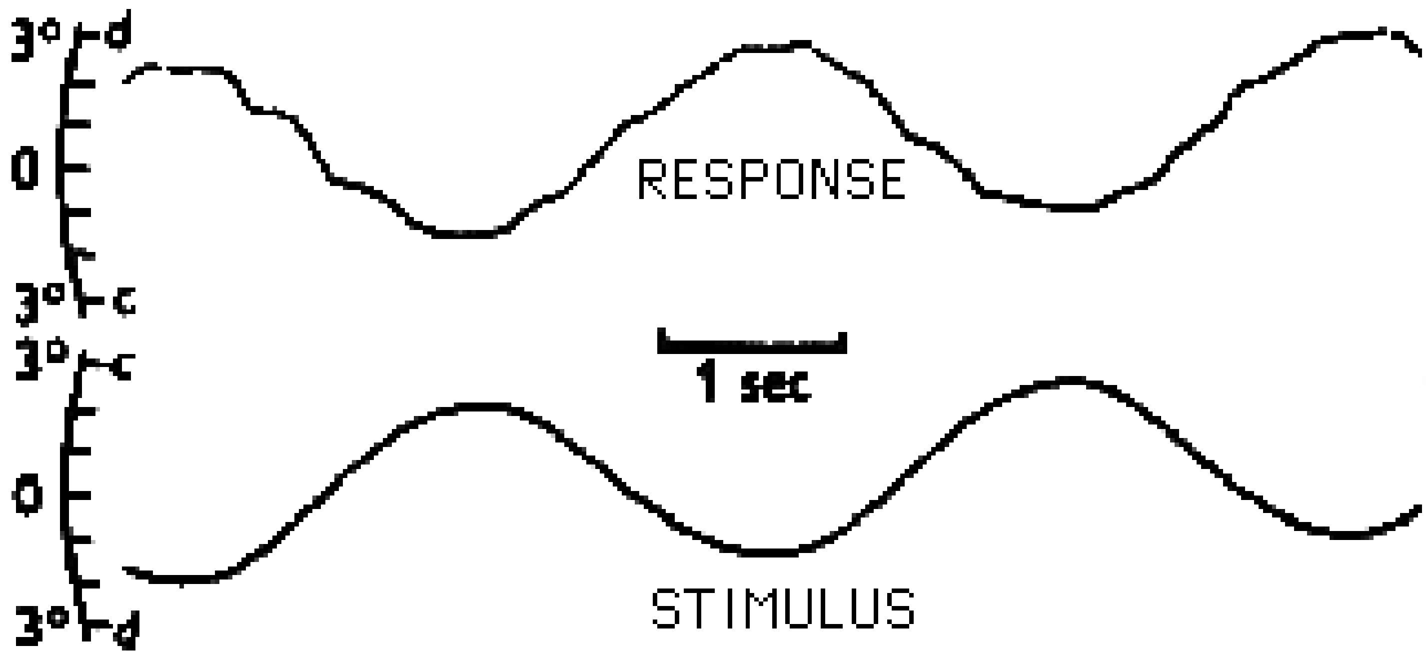


Saccades increase the velocity of accommodation and shorten latency



Smooth vergence pursuit tracking with prediction

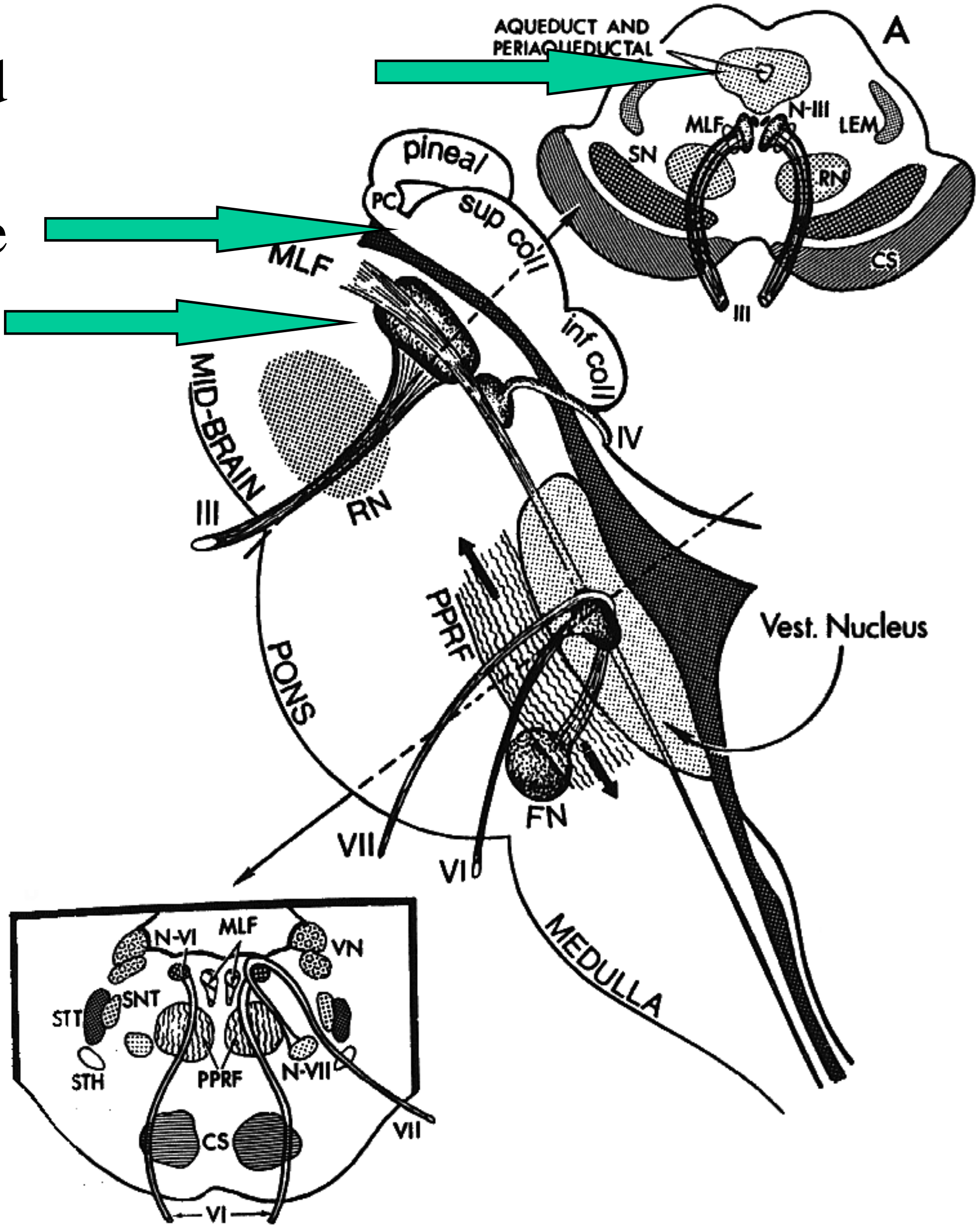




Brainstem nuclei for the near response: Supra-oculomotor nucleus

Vergence-related Near-Response cells found here

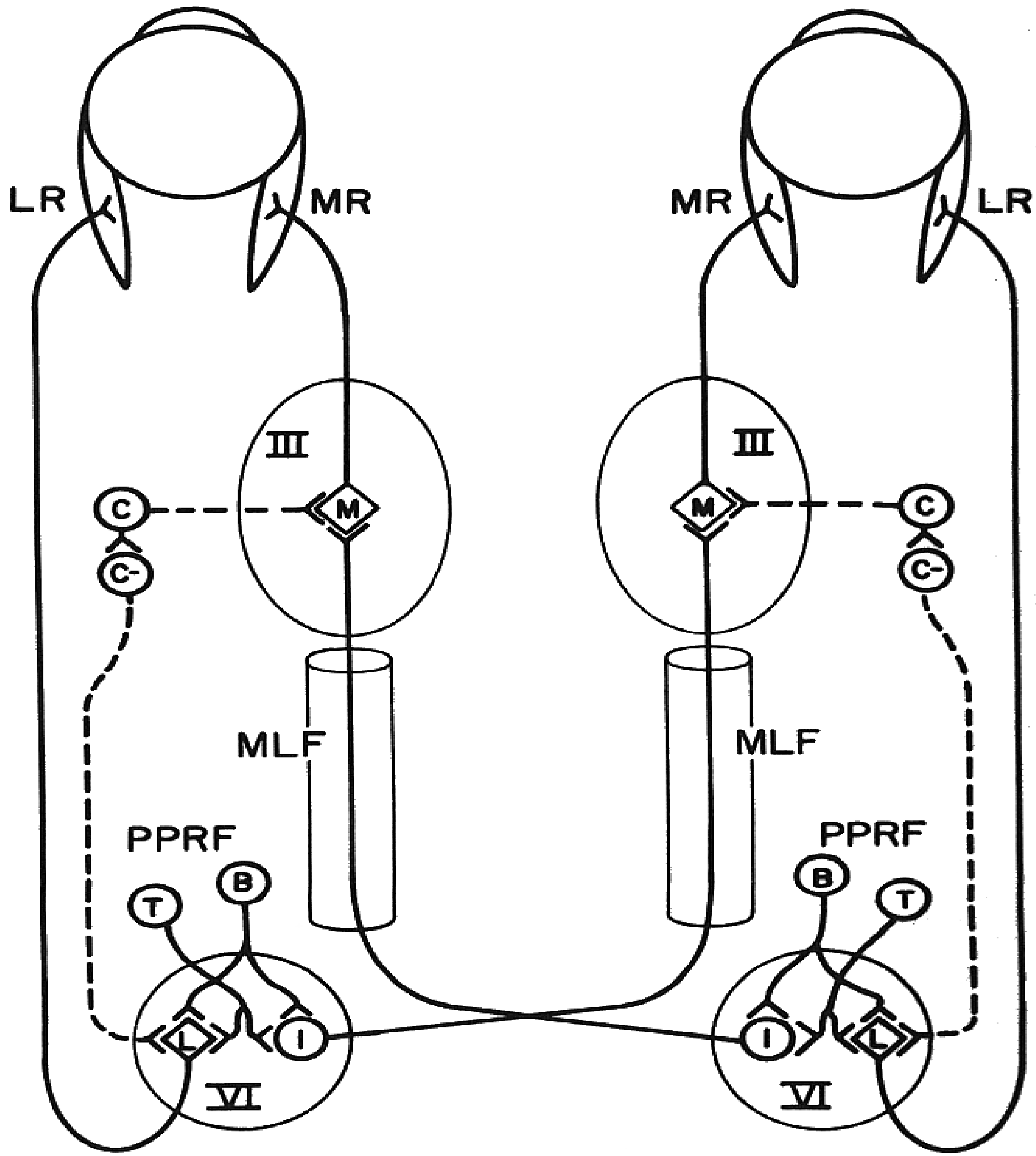
III Nucleus



Types of vergence cells in Pre-motor nuclei:
Superior Oculomotor Nucleus

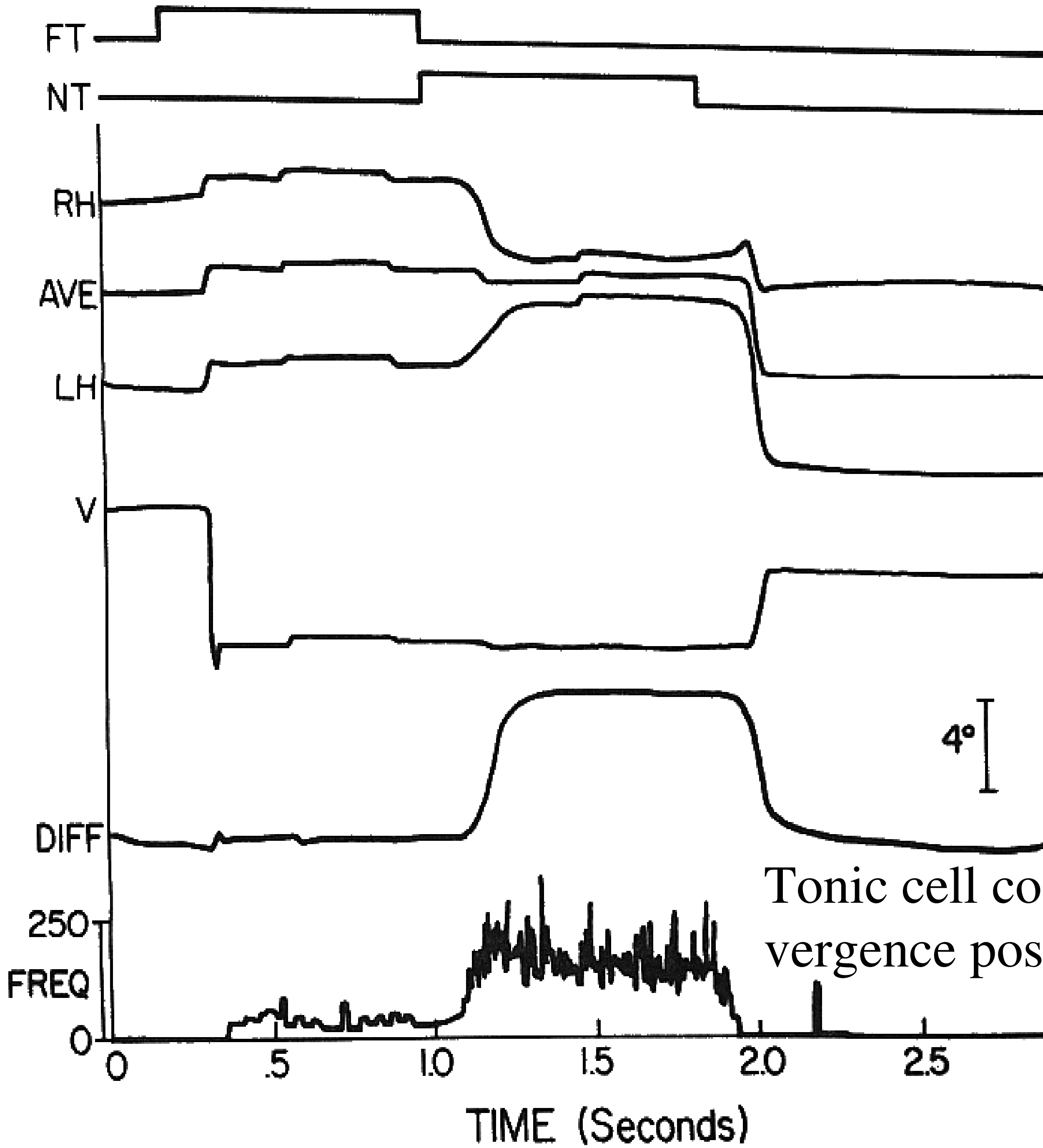
Tonic– Position cells

Phasic– Velocity cells



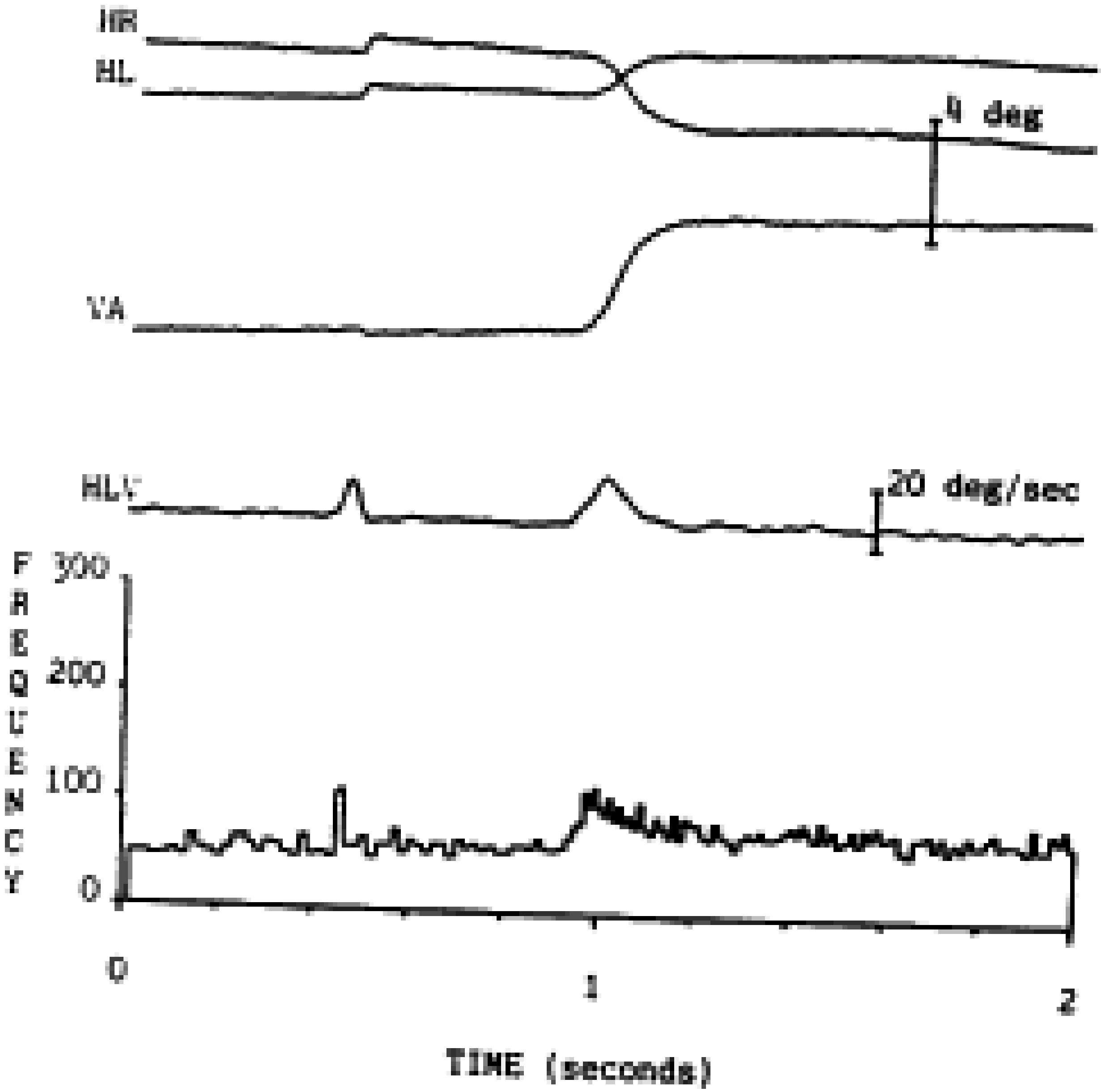
Final common pathway

Phasic or burst (B) and Tonic (T) cells in superior oculomotor nucleus



Tonic cell coding
vergence position activity

Phasic Velocity Cell:
Medial Rectus Motoneuron activity during Convergence



Lunch time

Dynamics of Accommodation:

Latency (300 ms) & response time (1 sec)