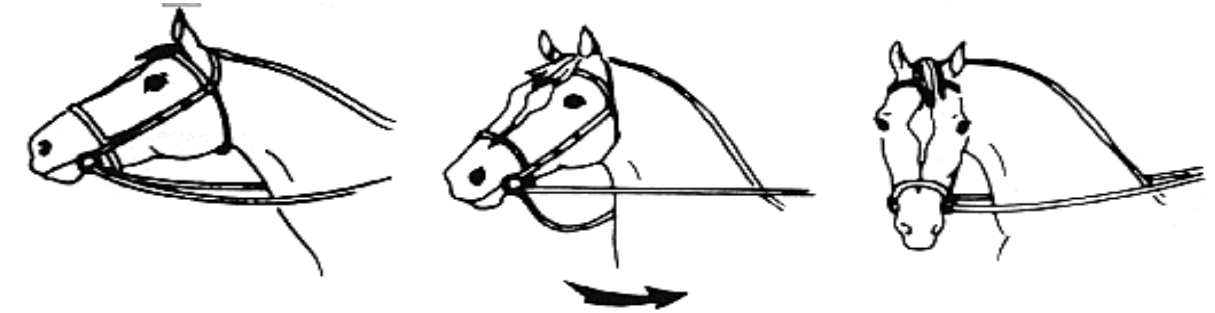
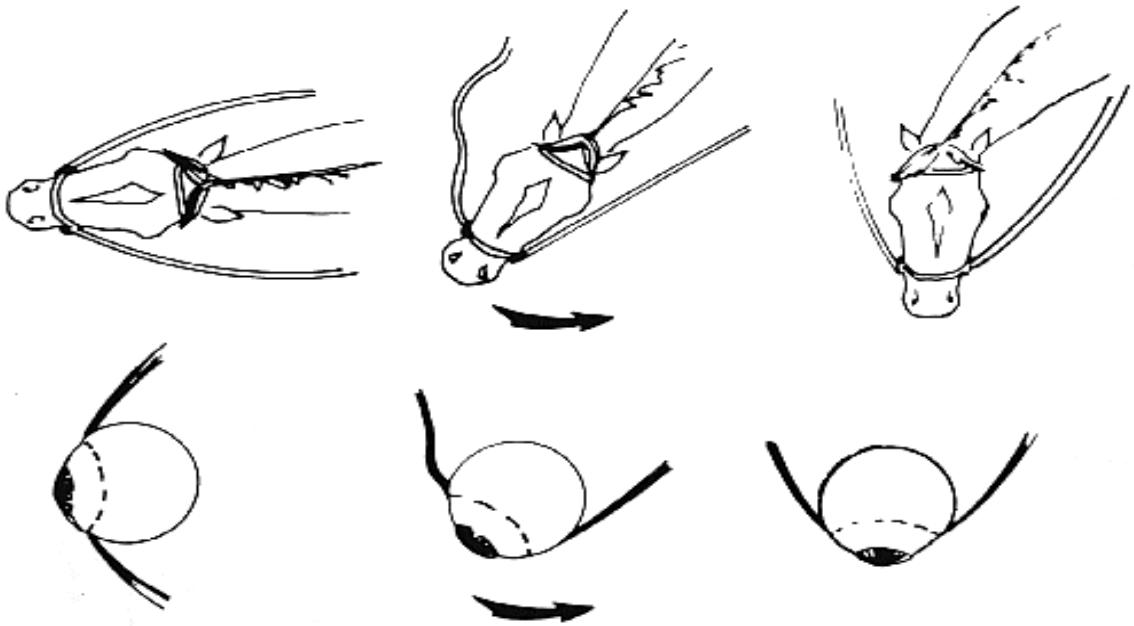
Derivation of "Saccade"



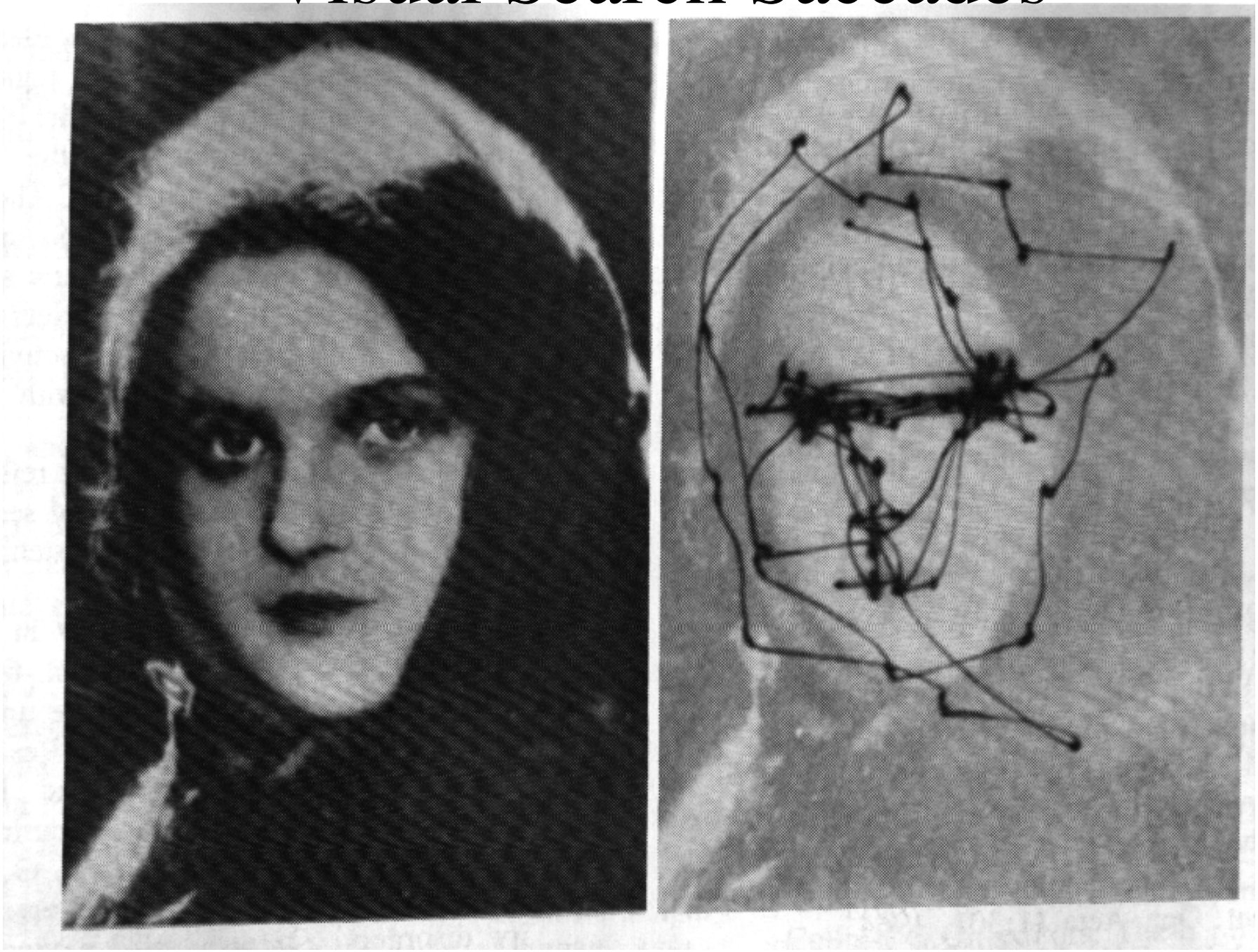
Saccade



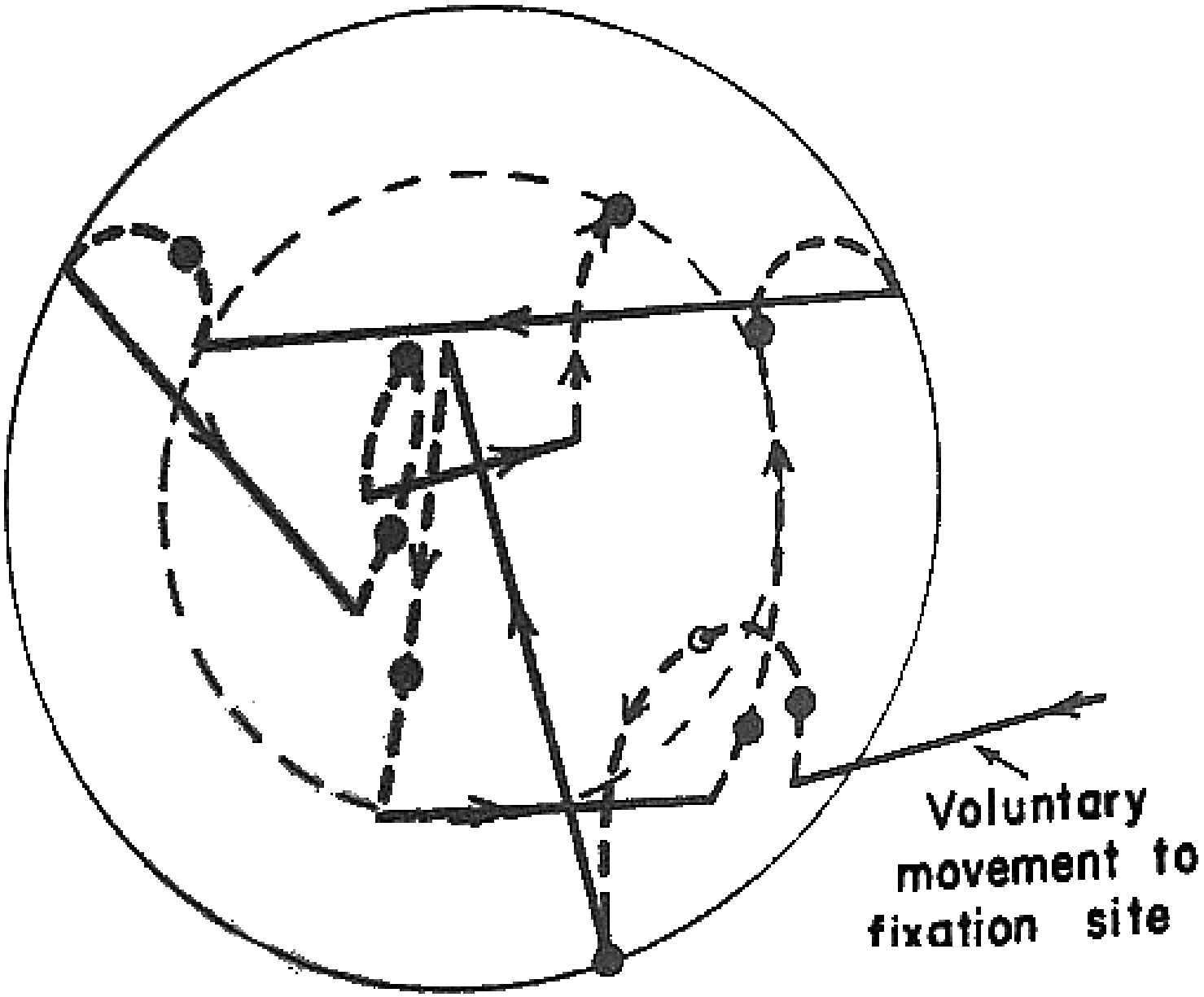
Saccade

Saccade Tasks

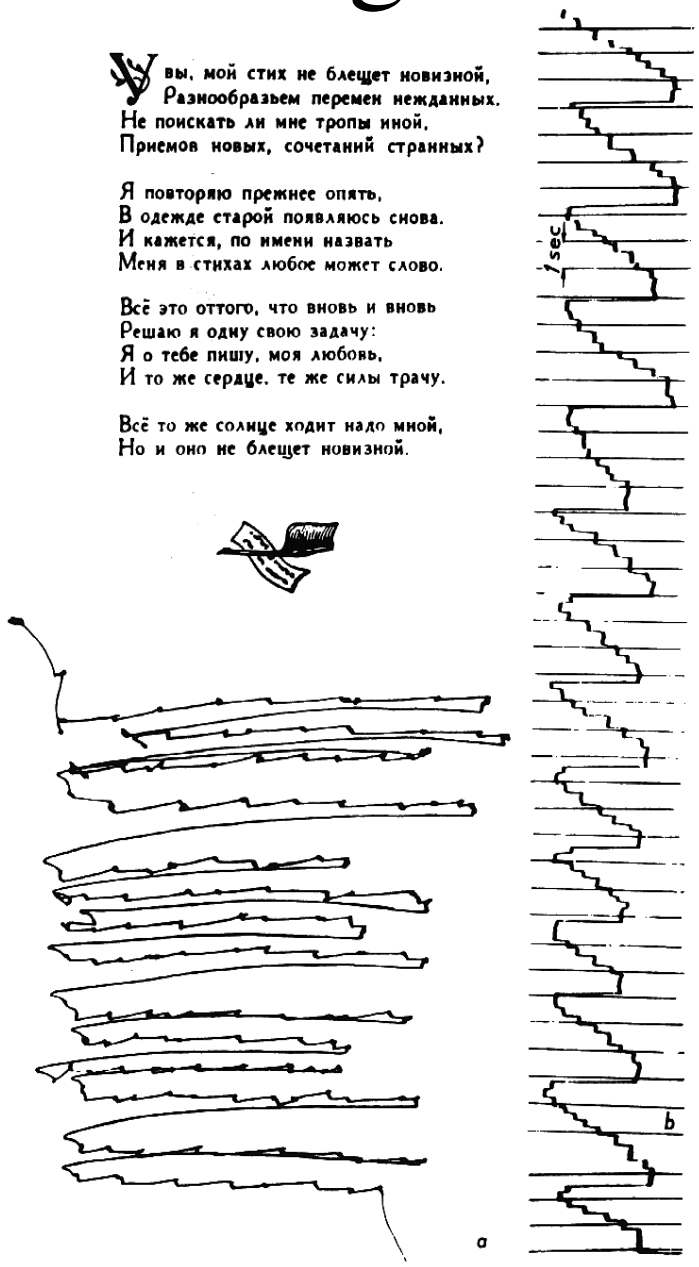
Visual Search Saccades



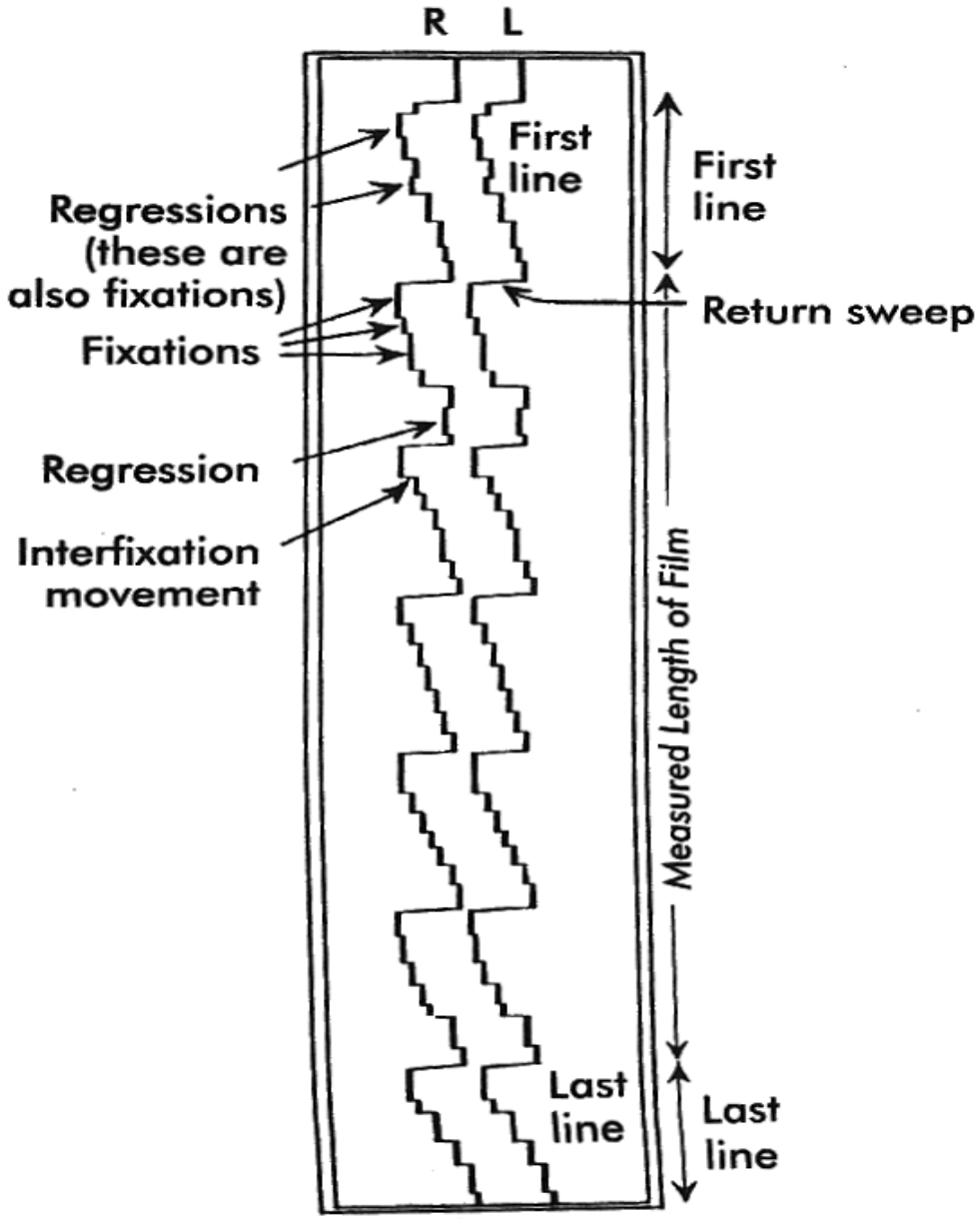
Micro-Fixation Saccades



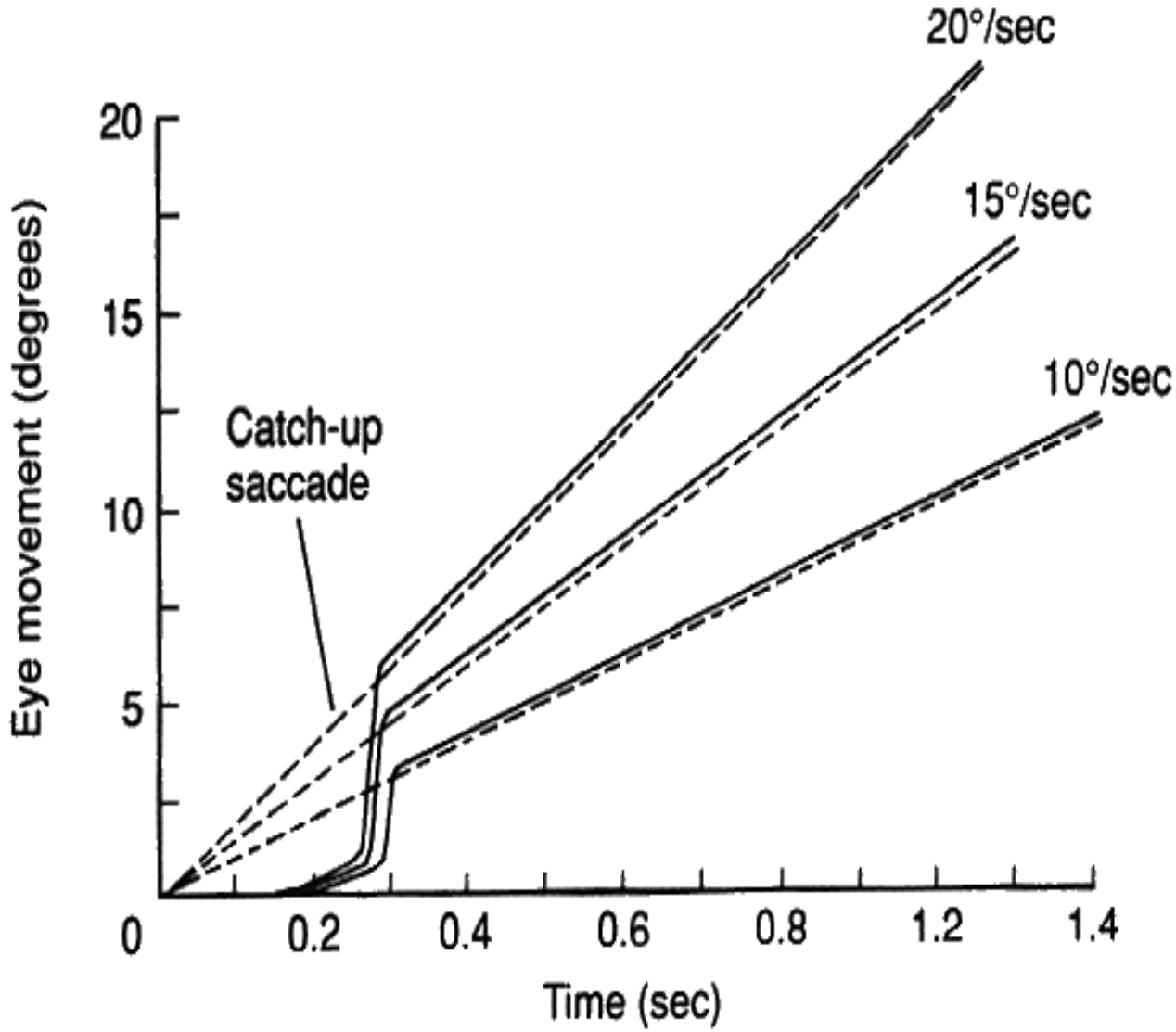
Reading Gaze Shifts



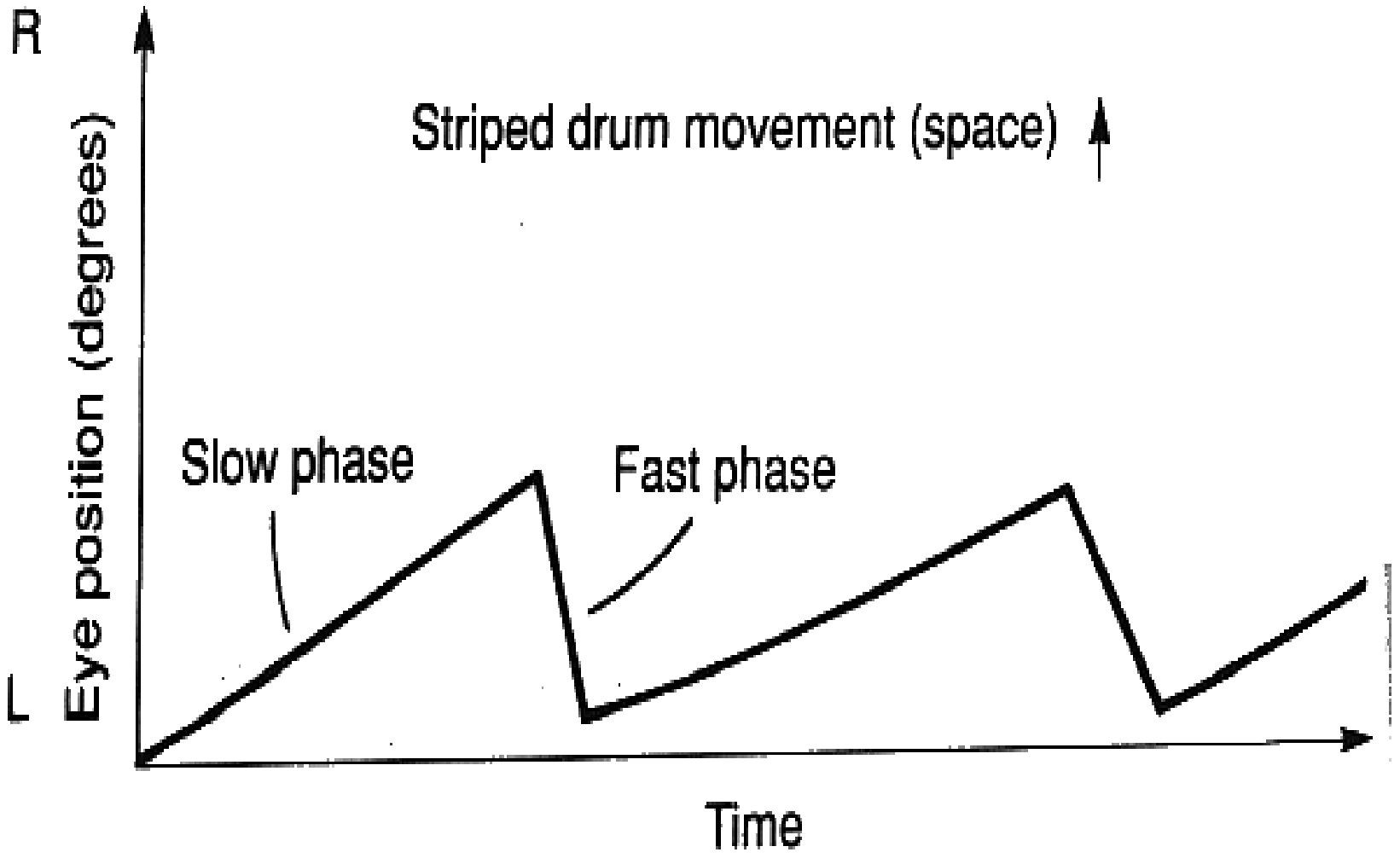
Reading Gaze Shifts



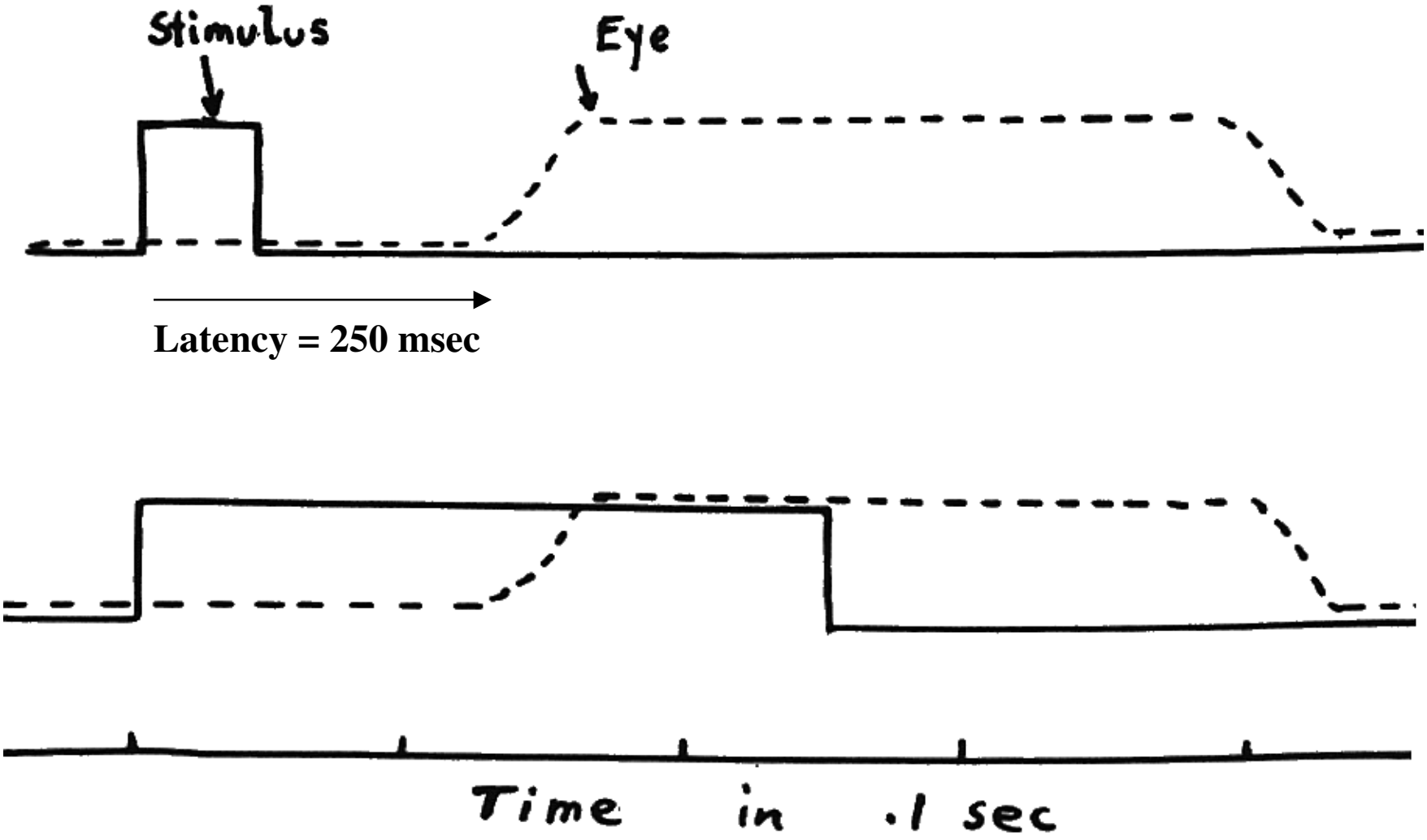
Catch-up Saccades



Saccadic Fast Phase



Ballistic nature of saccades. Pulse and step are pre-programmed



Prediction can reduce saccade latency to zero.

Vision During Saccades is very reduced.

Demo:Watch eye movements in a mirror

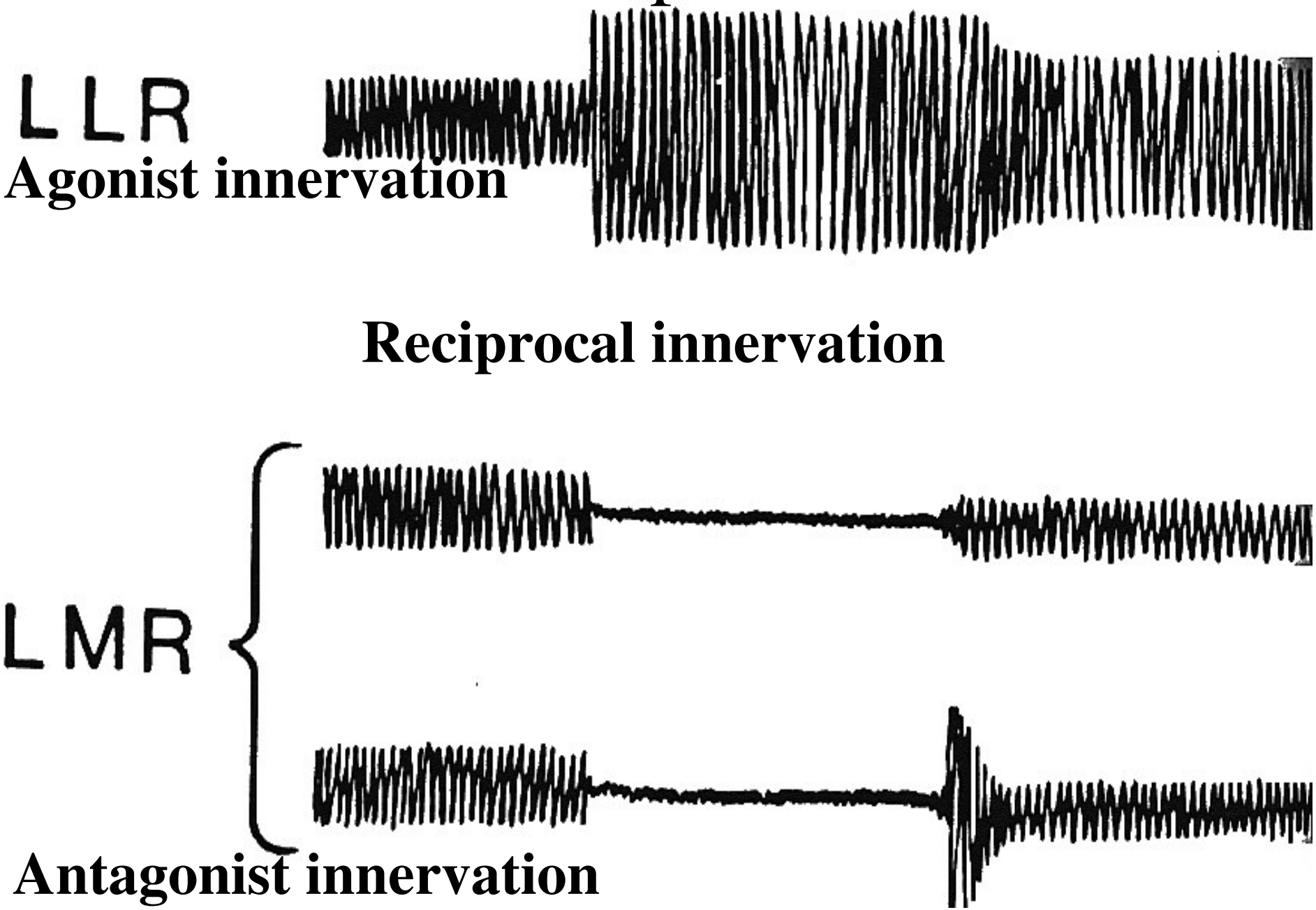
Explination:
Smearing of the retinal image
Shearing of the retina
Backward masking- second target erases the first

Saccades are characterized by their high velocity that comes at the cost additional force to needed to overcome muscle viscosity. Analogous to stealing second base in baseball.

A pulse component of the saccade provides this extra force that is absorbed by the muscle. Pulse height sets velocity and width sets amplitude.

A step component follows the pulse to hold the eye in its new position. This force counteracts the spring force of the antagonist.

Pulse and Step Innervation

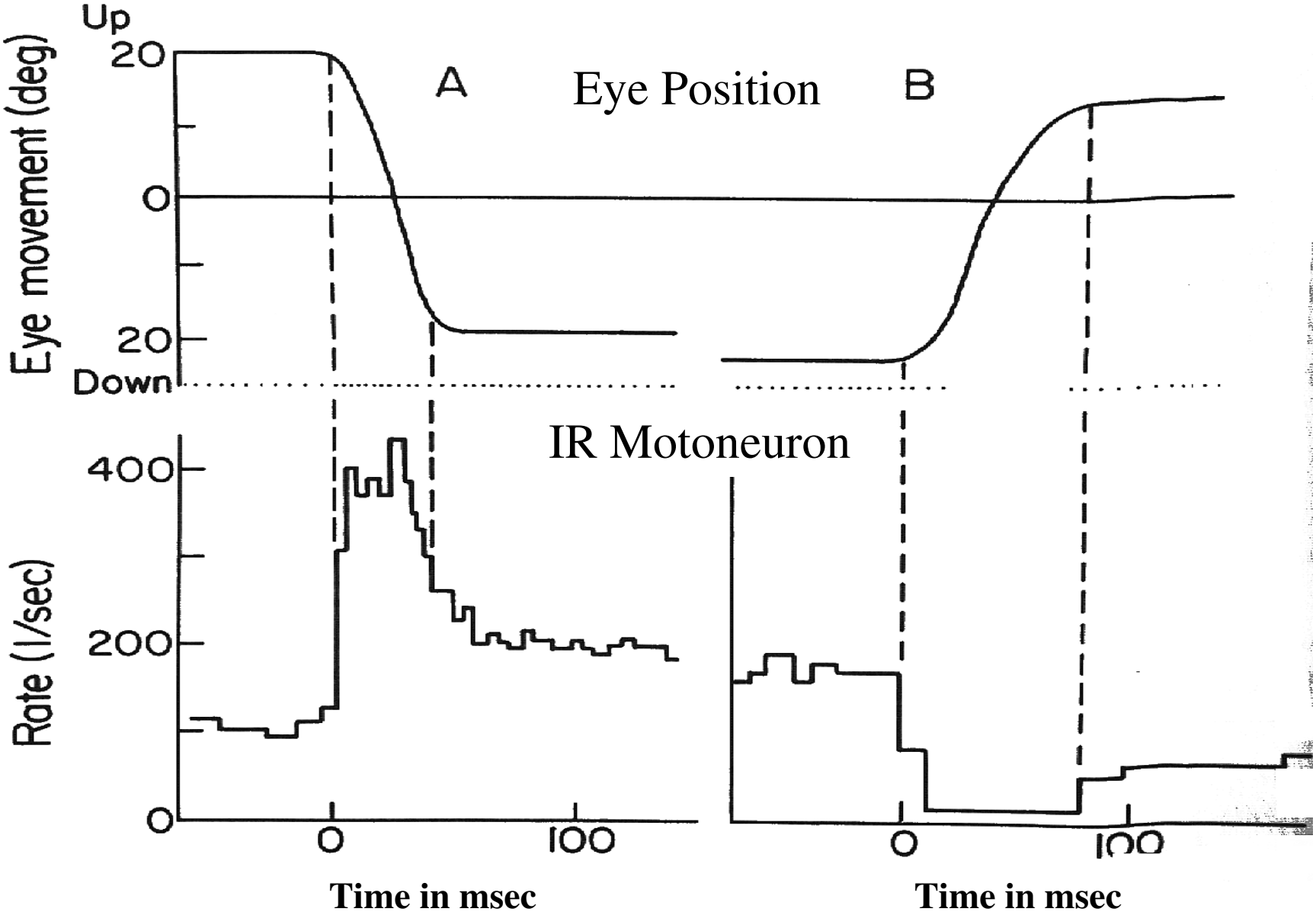


Agonist innervation

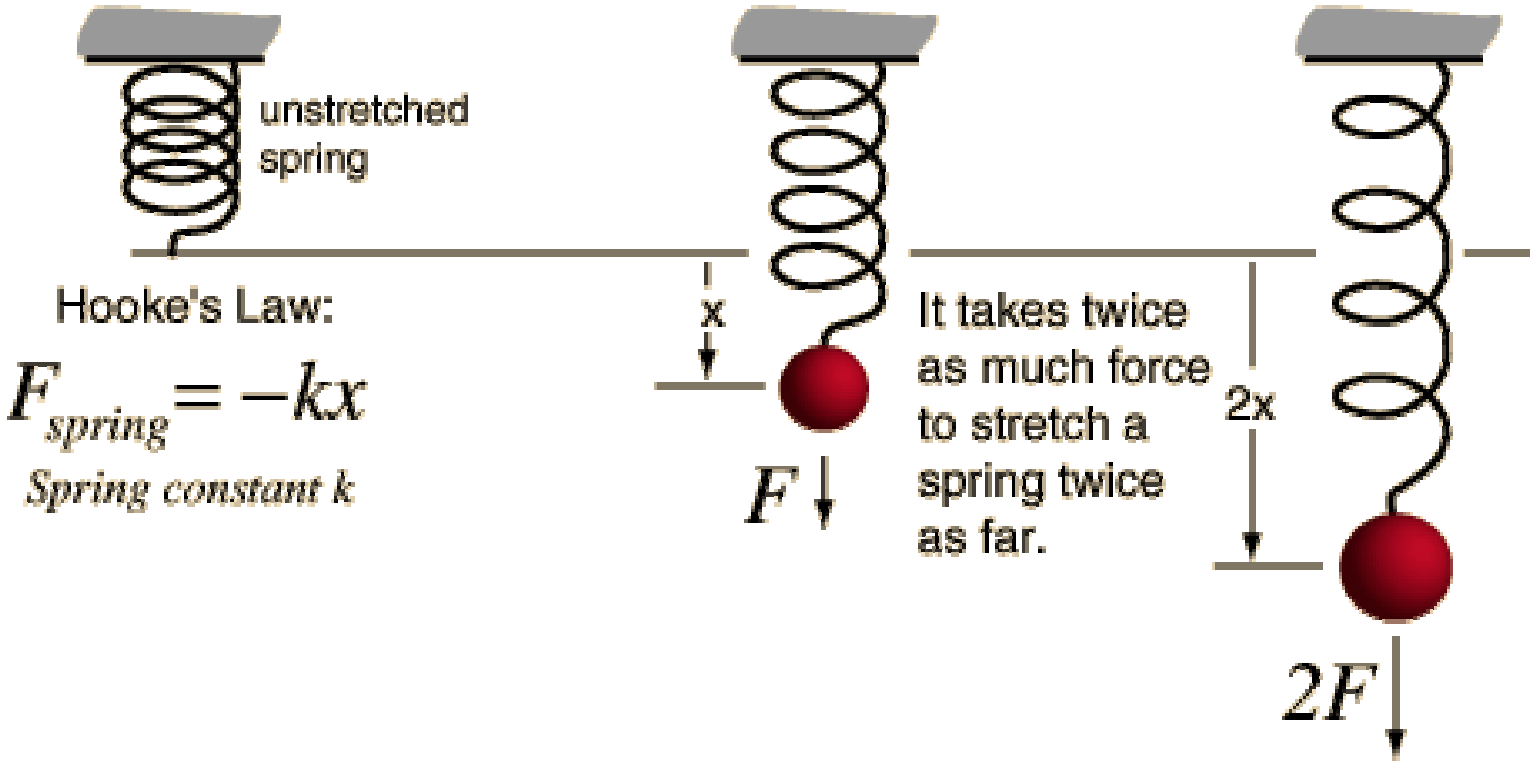
Reciprocal innervation

Antagonist innervation

Pulse-Slide-Step components of saccade generation



Step innervation changes muscle stiffness maintains eye position



Muscle innervation increases the spring constant (K) or muscle stiffness. This increases the restoring force applied to the eye and antagonist muscle.

Hooke's Law: Force exerted by a spring equals the product of its length (L) and spring-stiffness constant (K) or elasticity.

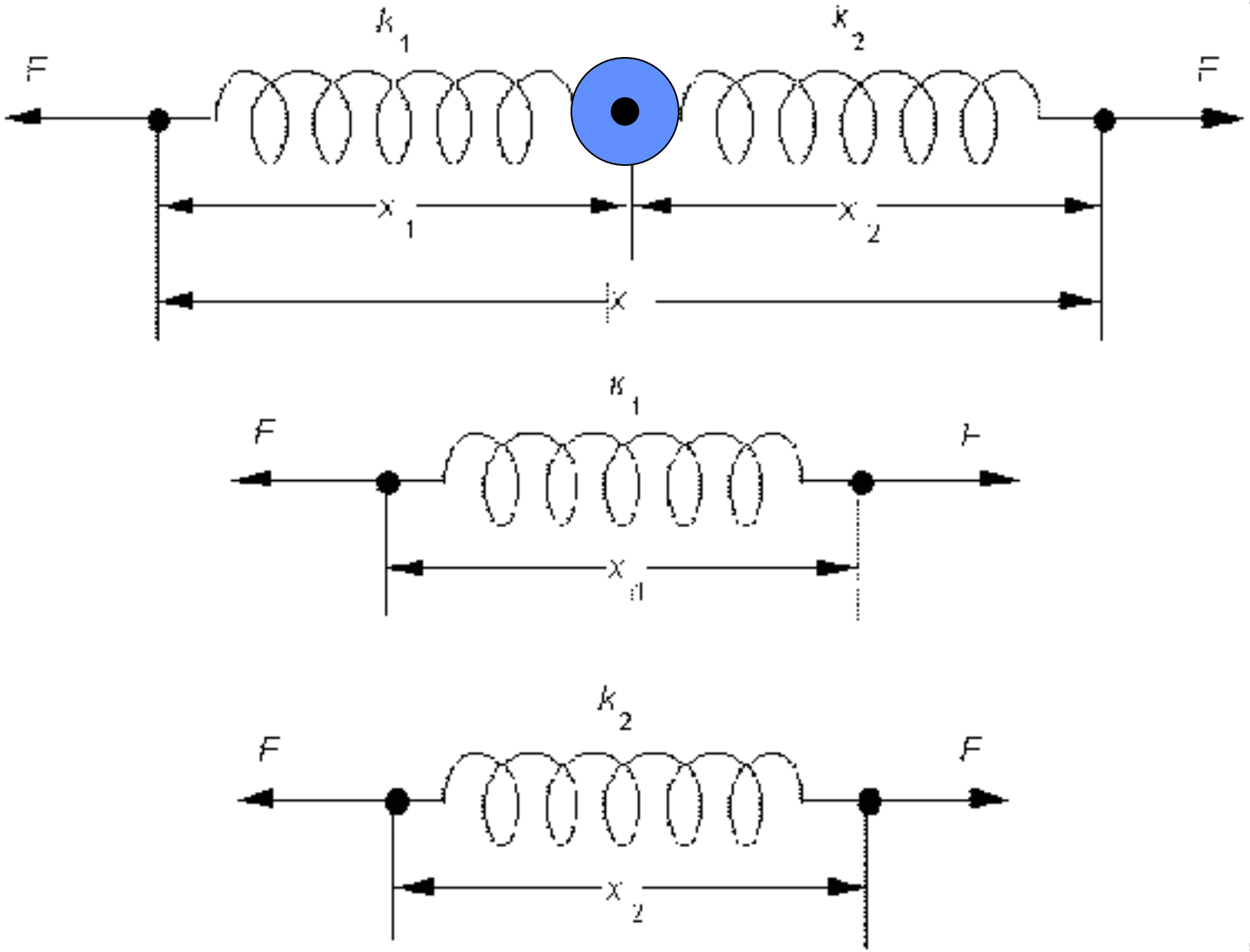
$F = L \times K$

Innervation increases the spring stiffness and force of the agonist against the antagonist.

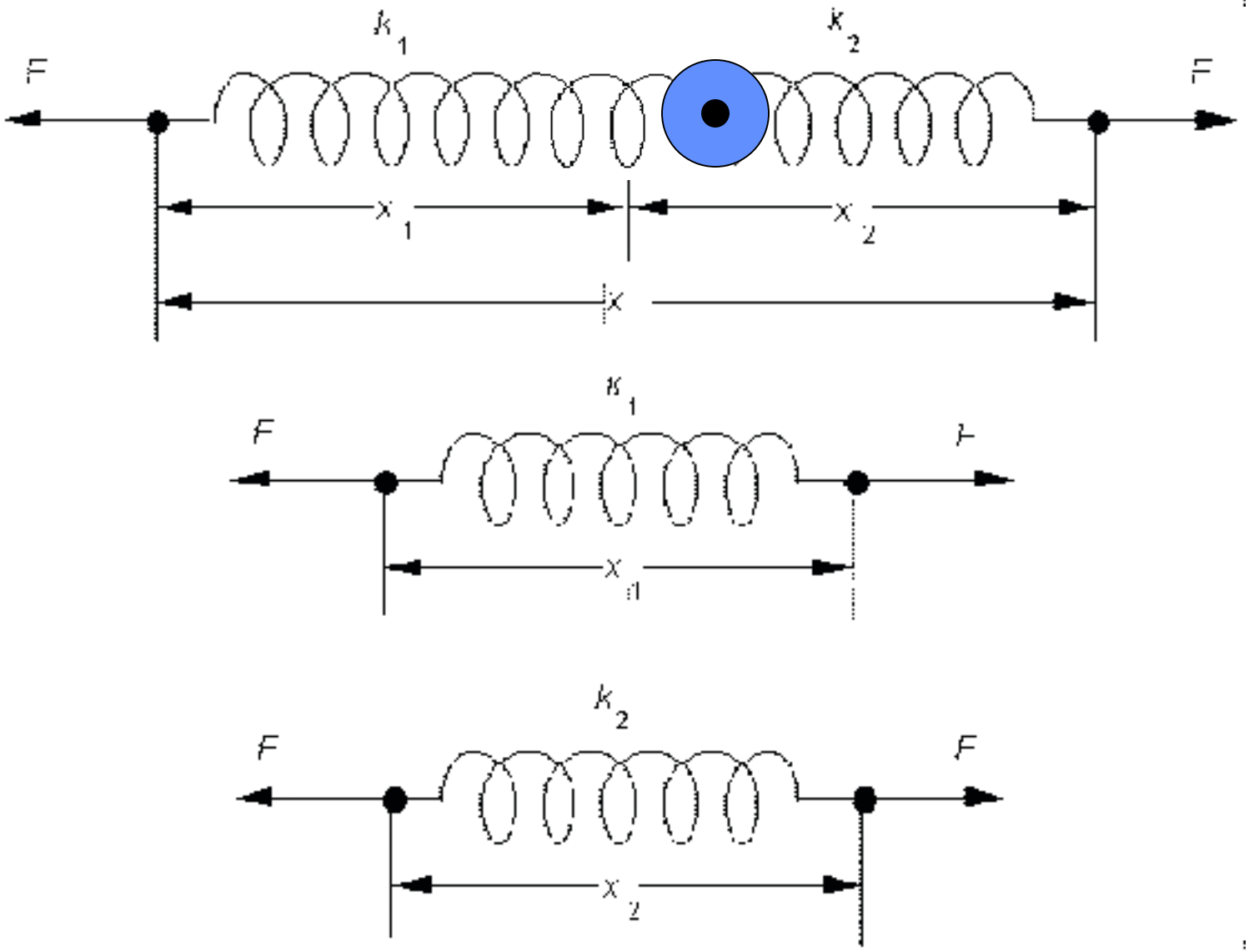
The length of the antagonist increases when stretched by the agonist until their forces become equal.

Force exerted by the agonist and antagonist is smallest in primary position.

$$X_1 * K_1 = F = X_2 * K_2$$



$$X_1 * K_1 = F = X_2 * K_2$$



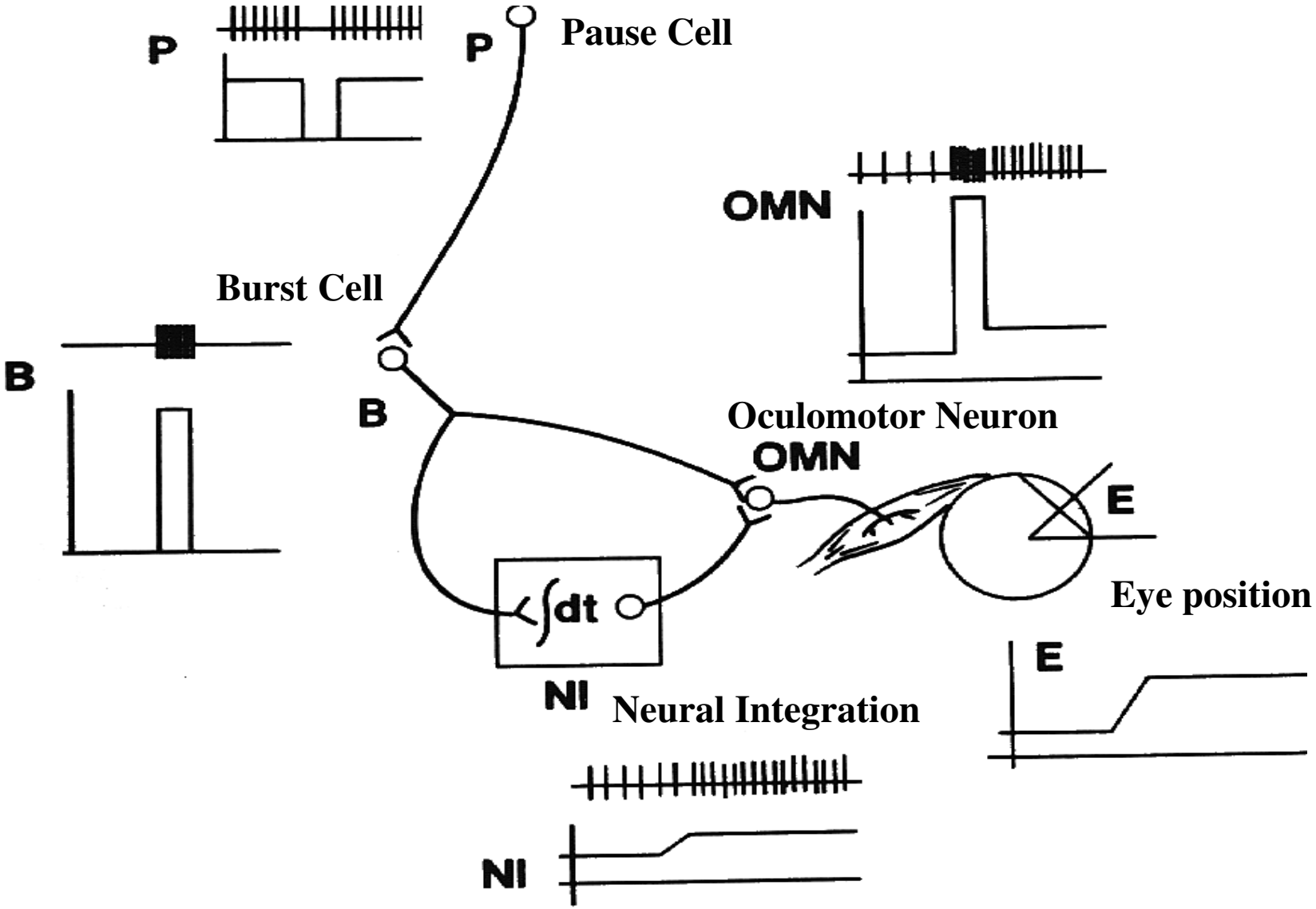
Burst Cell determine the velocity of a saccade
Overcome viscosity to achieve high velocity

Tonic cells maintain the new eye position at the end of a saccade

Neural Integration transforms burst activity into tonic cell activity

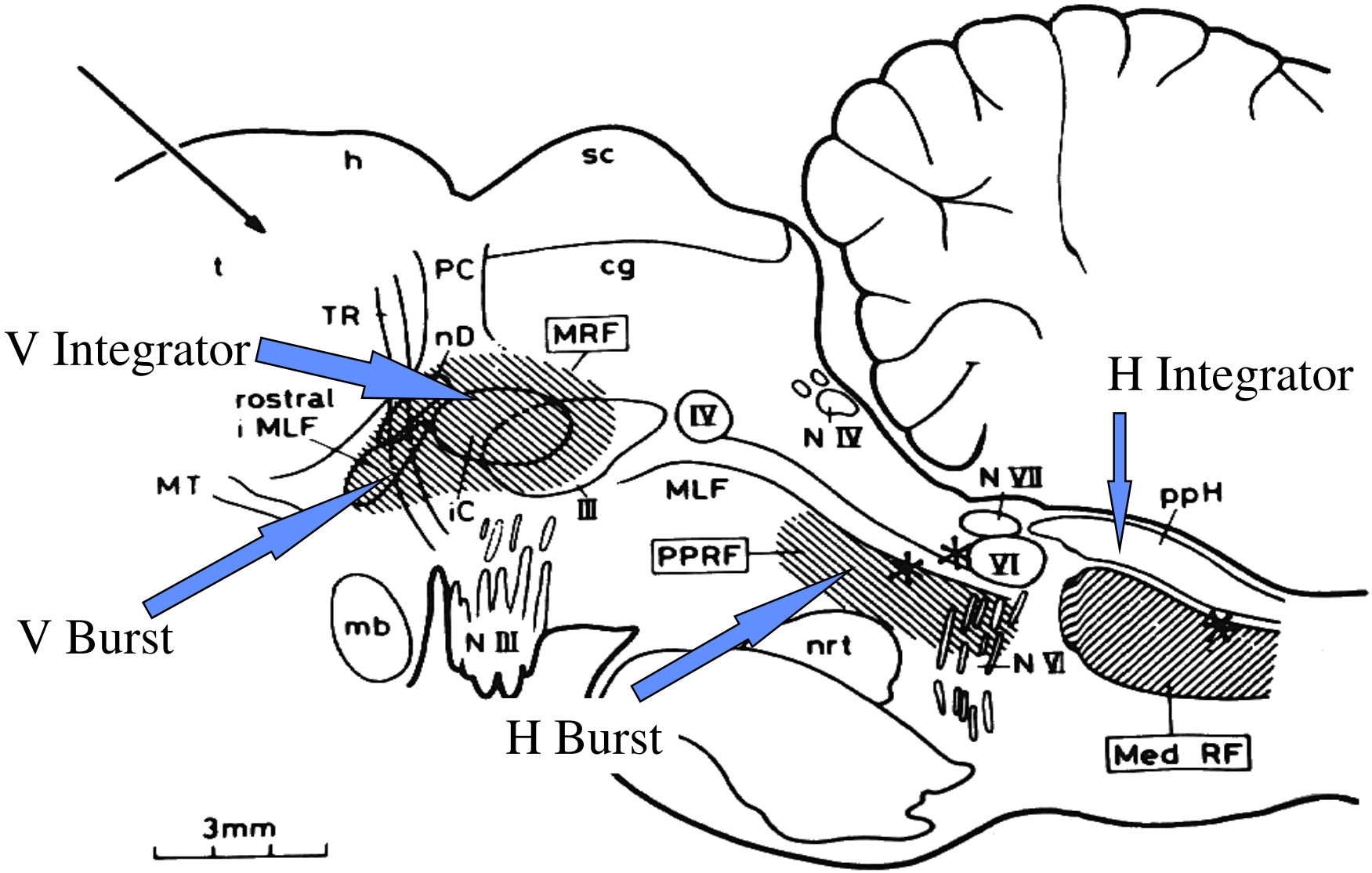
Pause Cell determine the duration of a saccade
Triggers the burst cell activity like a car clutch

Pause, Burst and Integration circuit

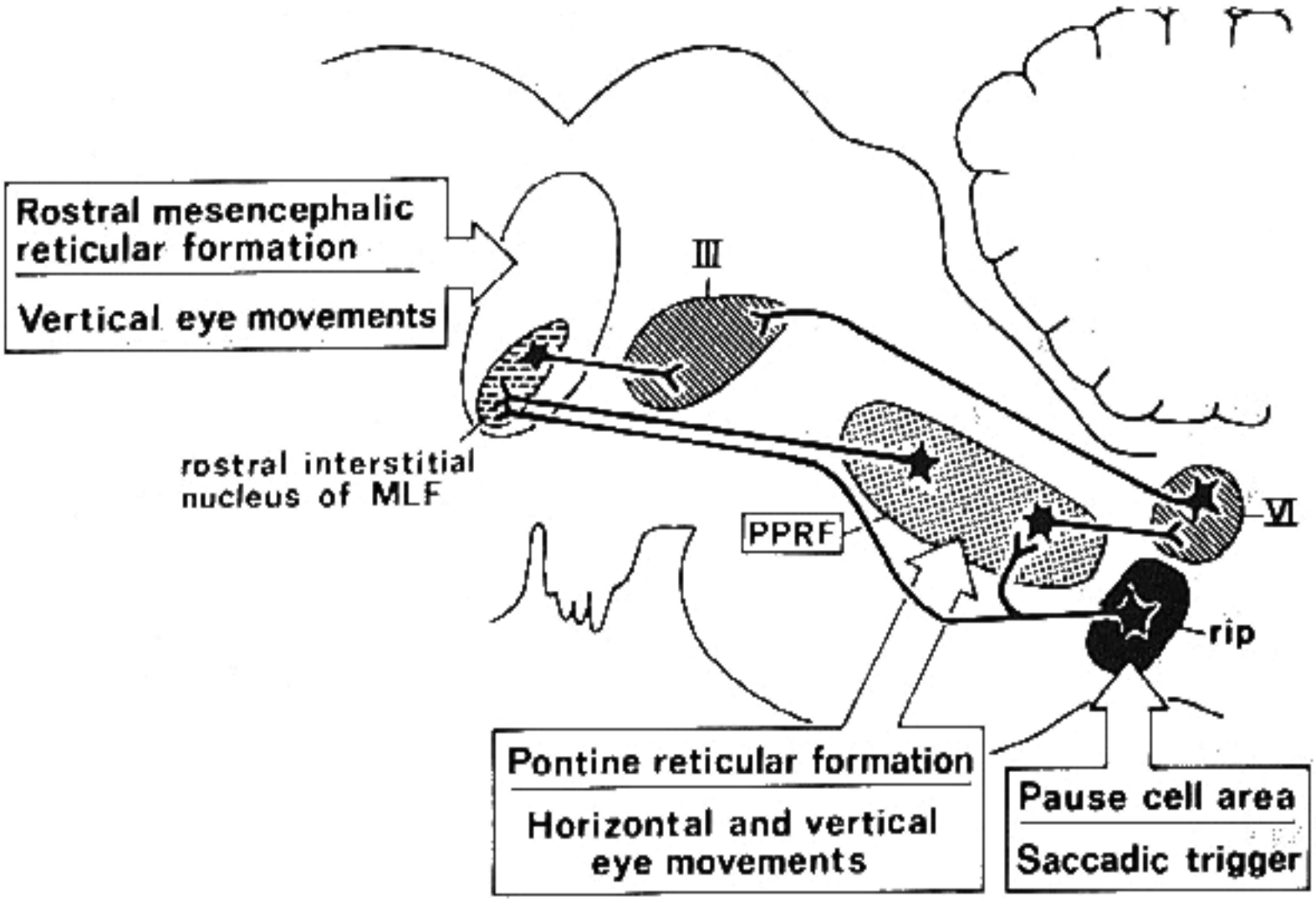


Pre-motor sites include PPRF and Prepositus for horizontal saccades & riMLF and nucleus of Cajal for vertical saccades

Brainstem Burst and Integrator regions



Brainstem burst and pause cell areas- Schematic



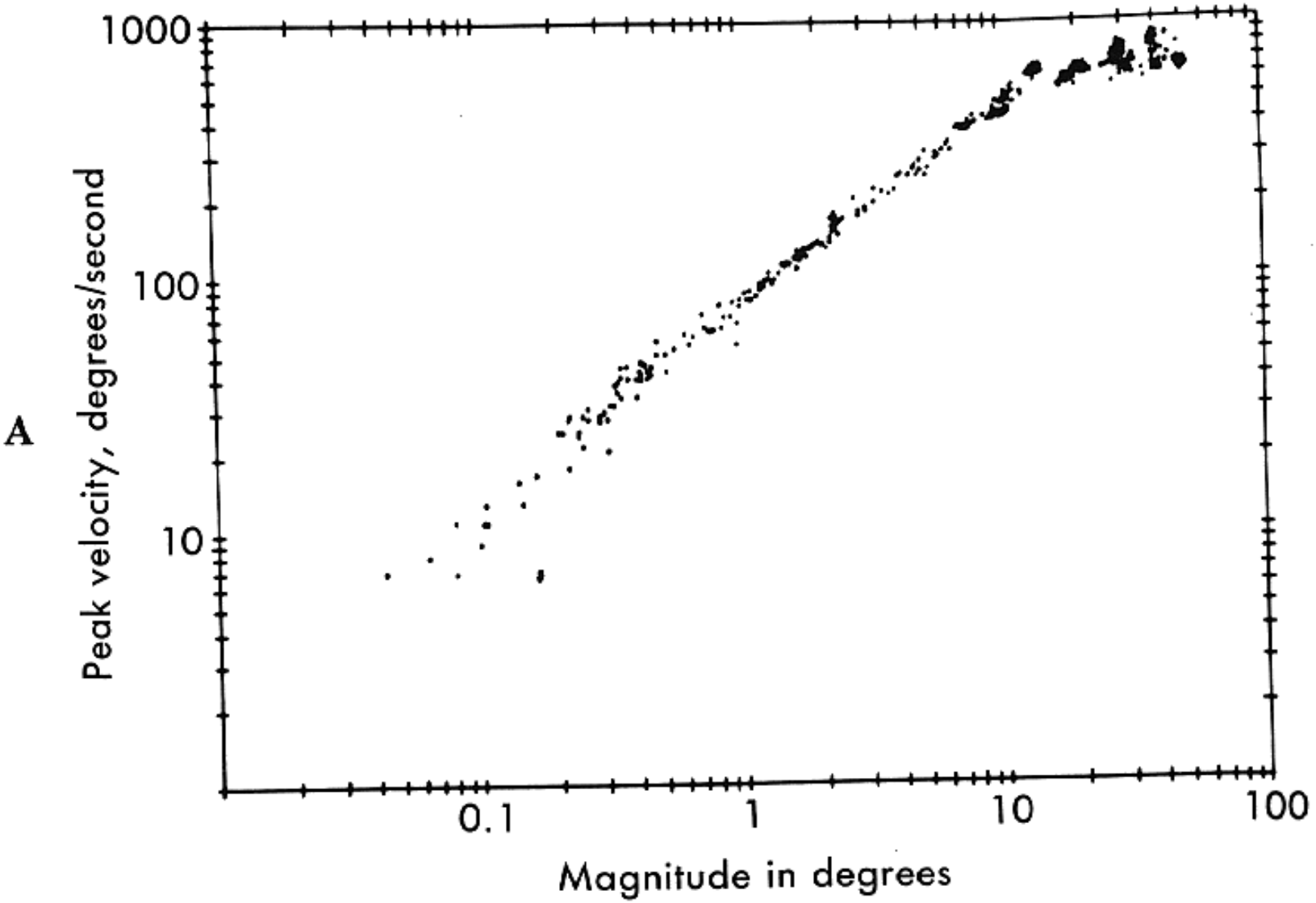
Amplitude of a saccade is determined by the duration and amplitude of the pulse.

Main sequence diagram plots velocity or duration as a function
Of saccade amplitude.

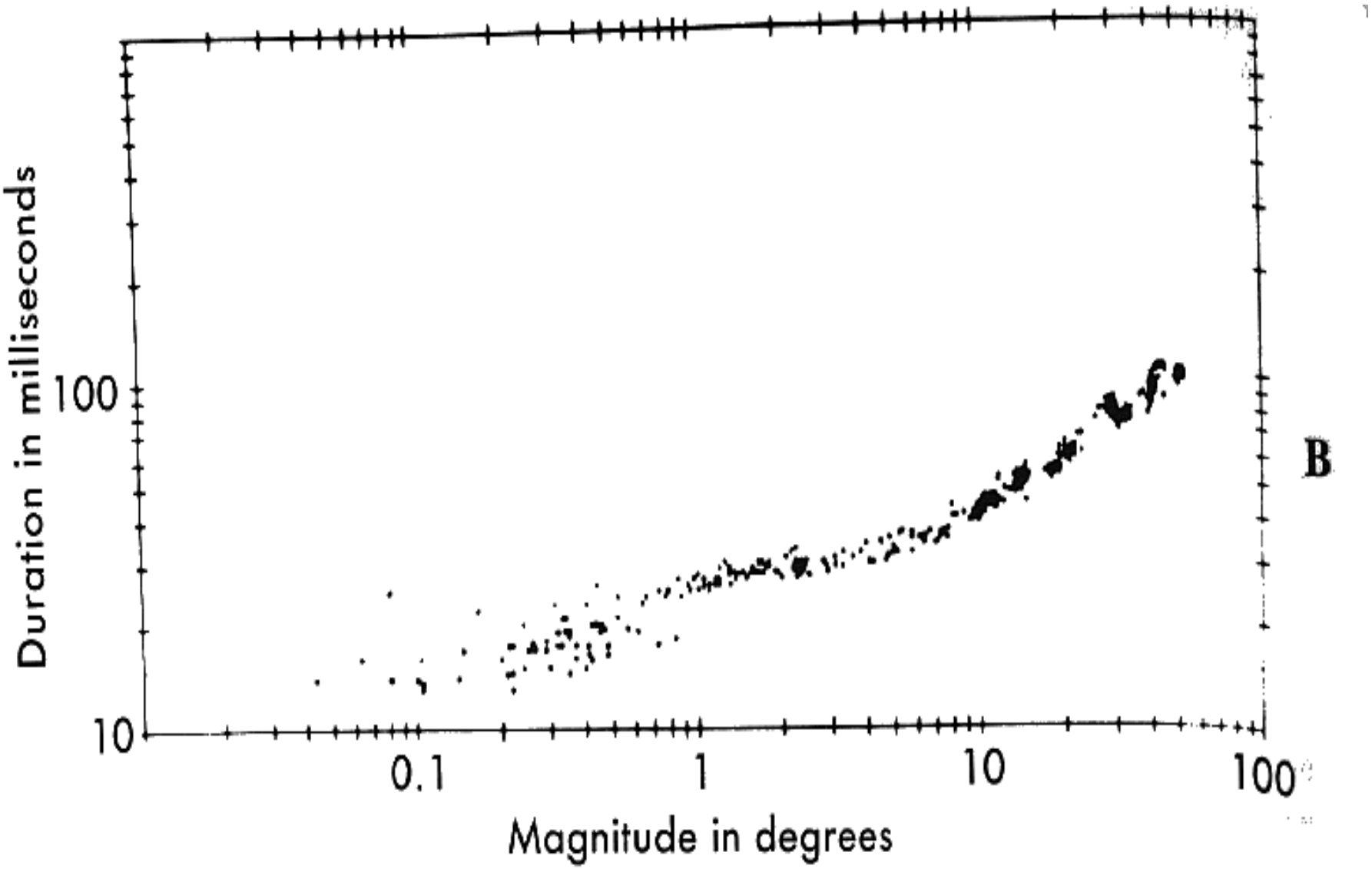
10 deg saccade lasts 50 msec. Saccades are rarely longer than 100 msec

Main sequence reflects the activity of Burst neurons.

Main Sequence Curve- peak velocity



Main Sequence Curve- Saccade duration

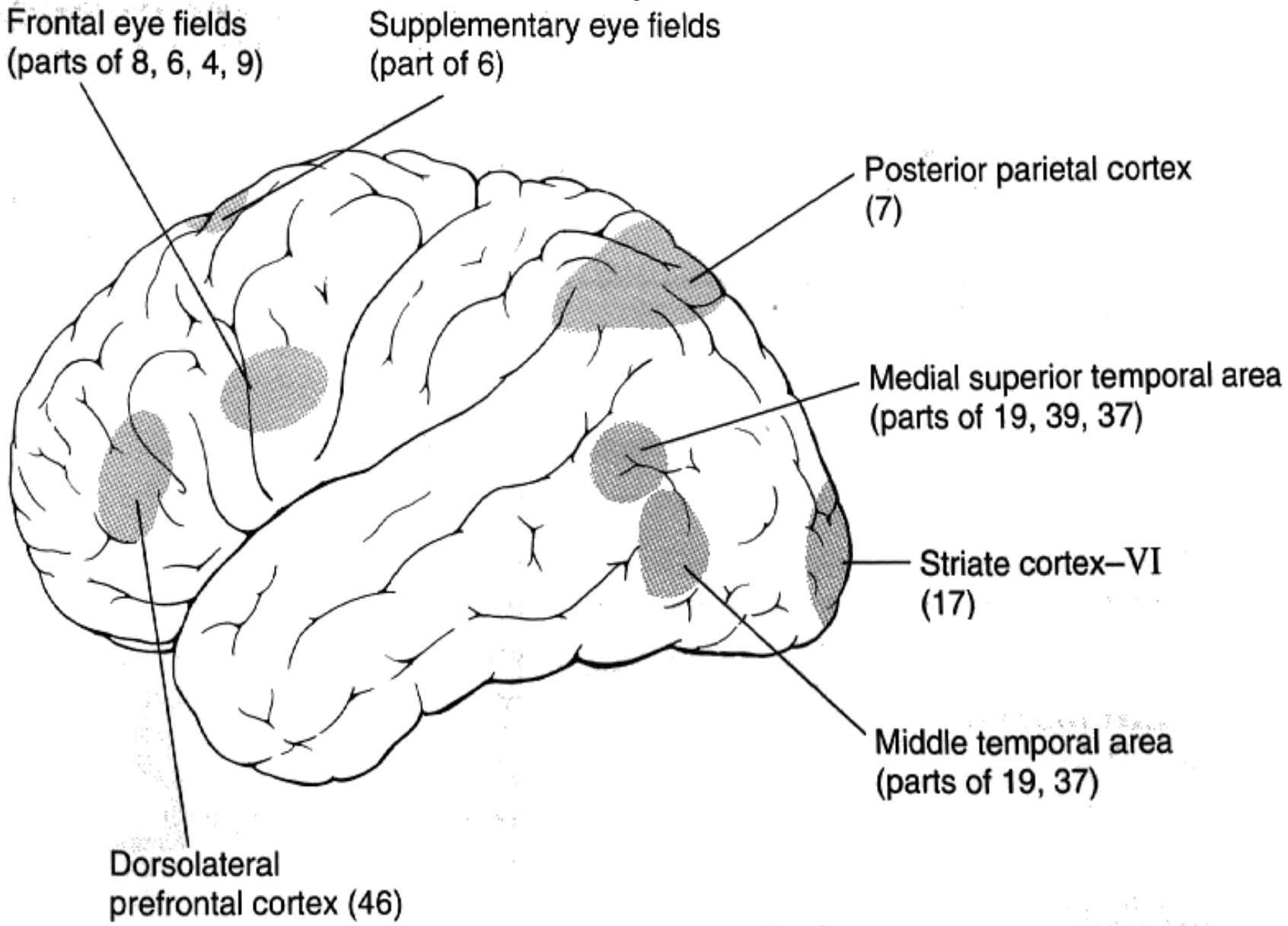


Supra-nuclear sites

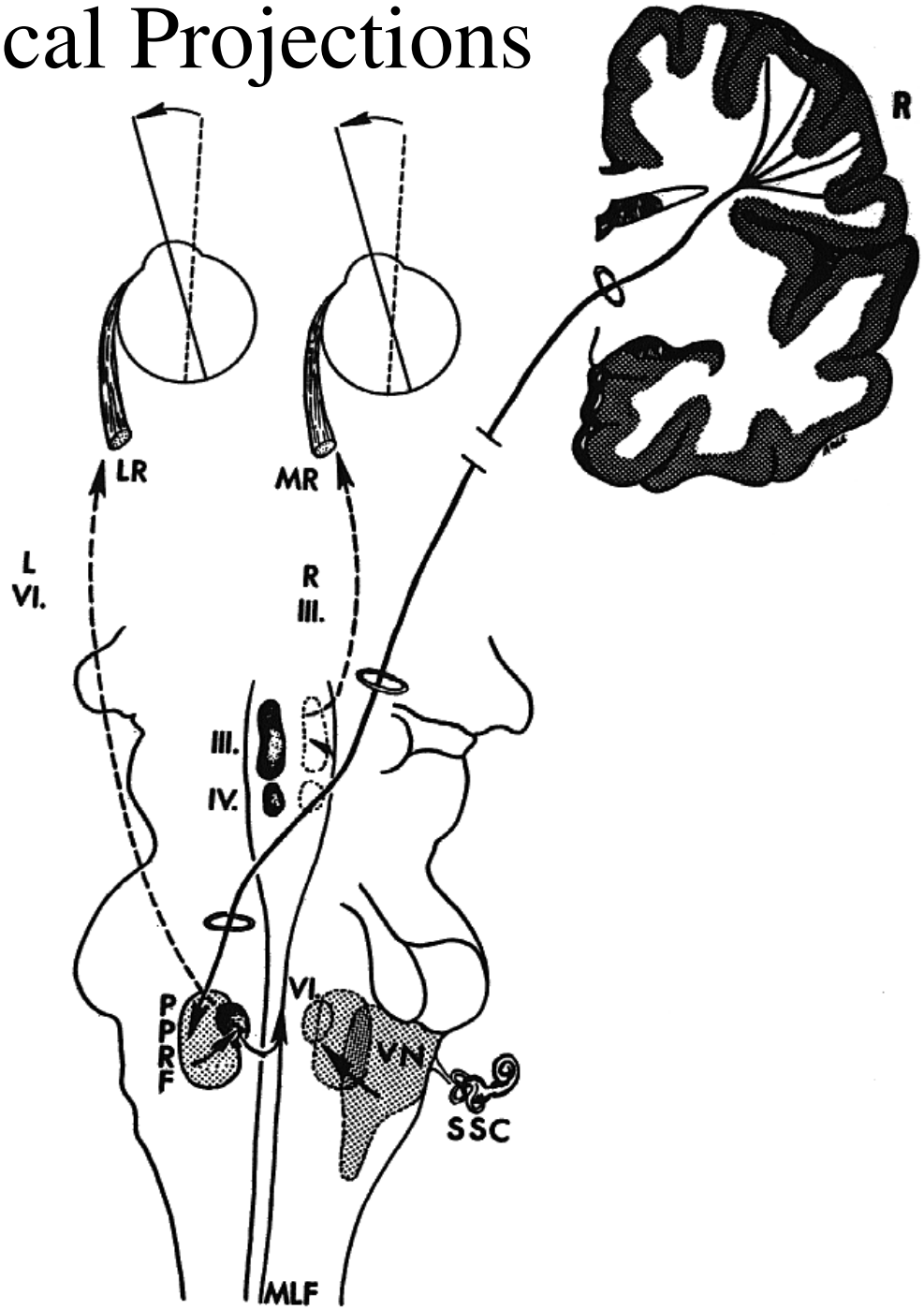
Frontal eye fields (Area 8)

Superior Colliculus

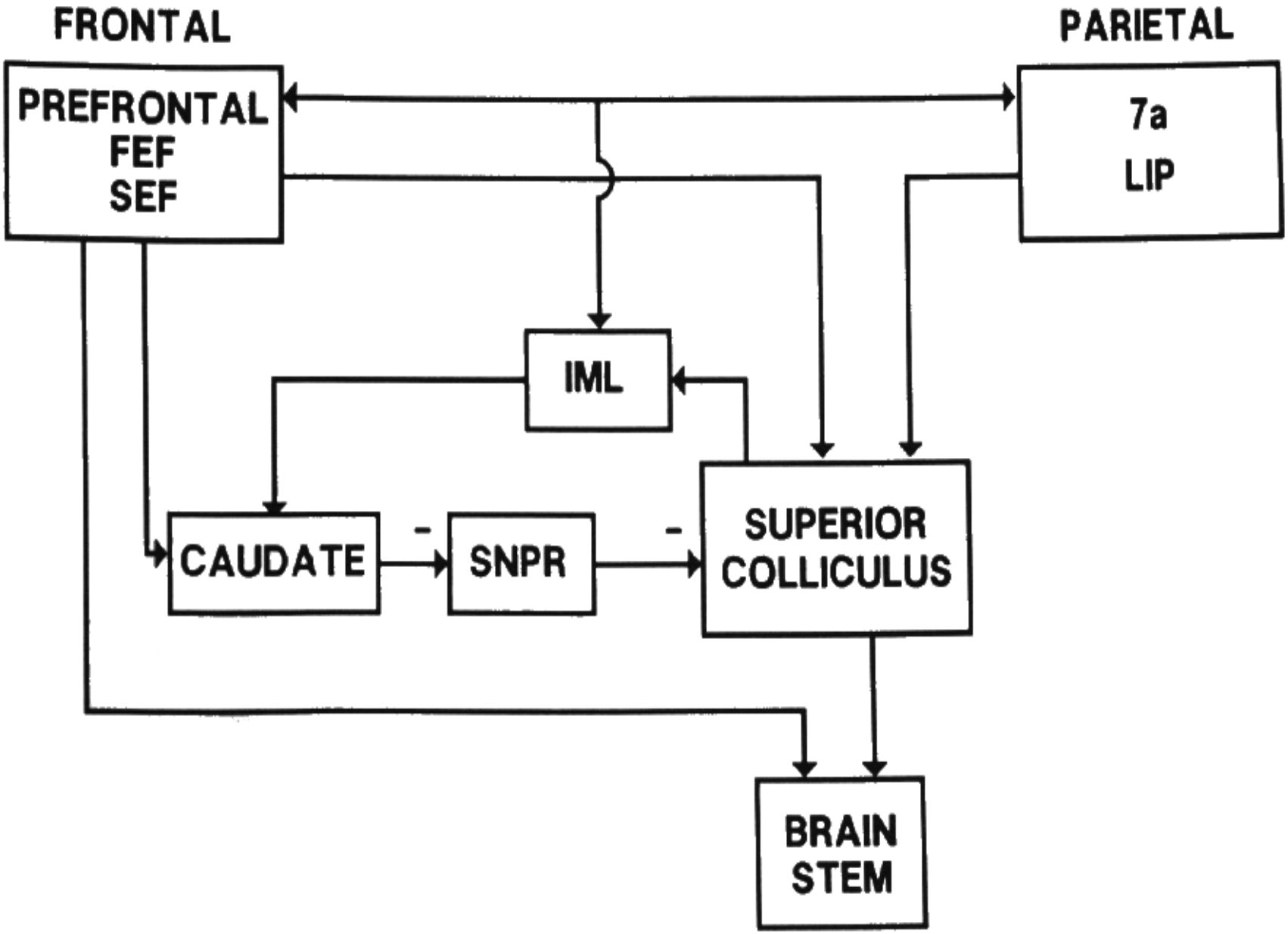
Frontal Eye Fields



Cortical Projections

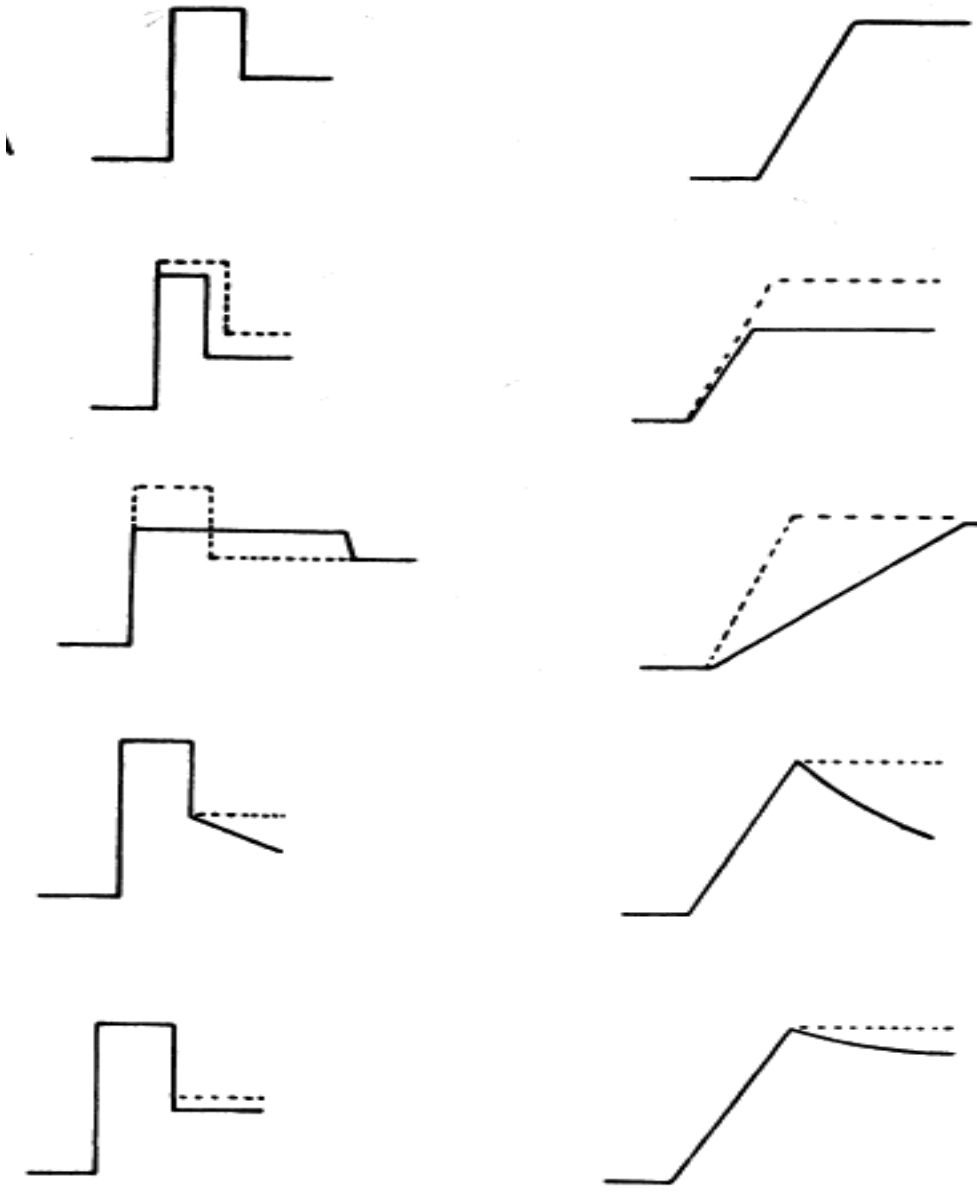


Saccade Pathways Schematic



Saccade amplitude abnormalities related to pulse and step

Innervation **Motor response**



Normal Saccade

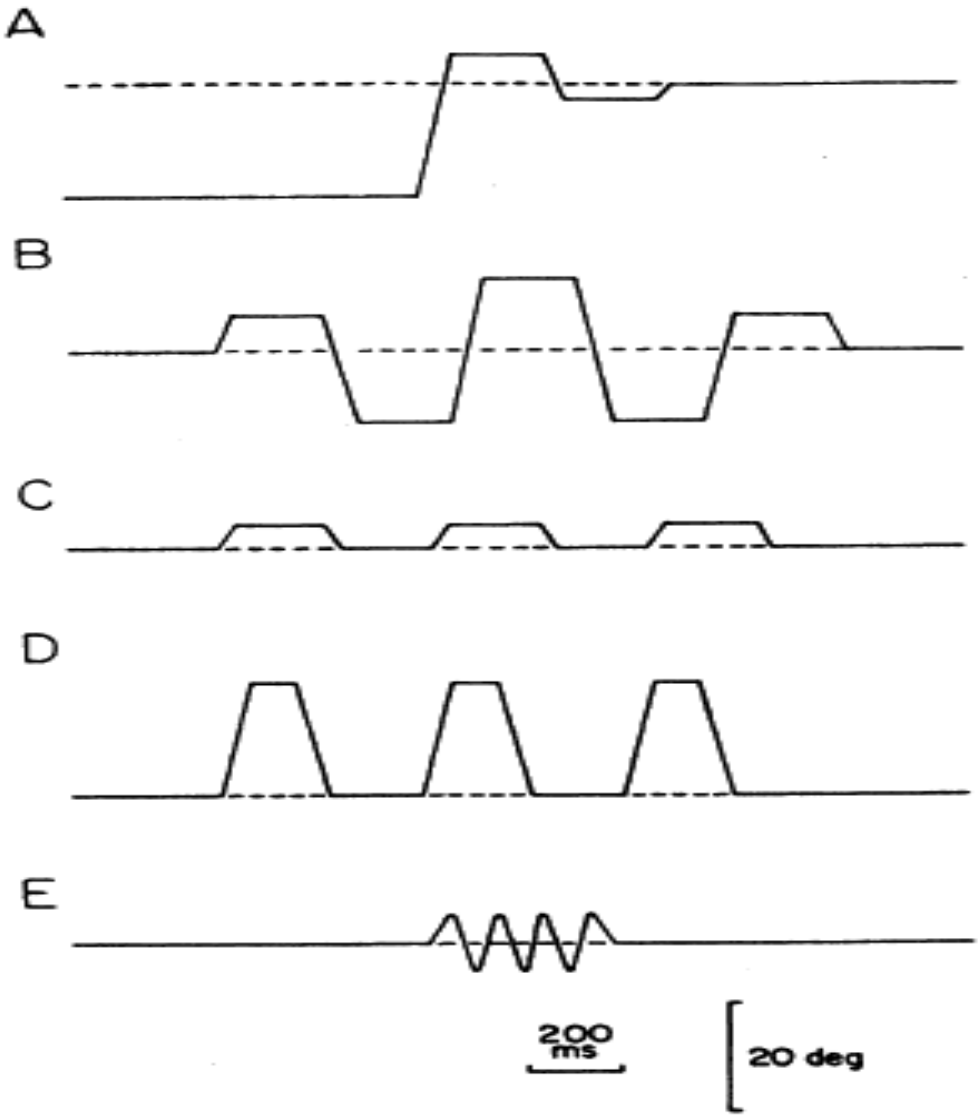
Hypometric Saccade

Slow Saccade-Glissade

Gaze-evoked Nystagmus (leaky integrator)

Pulse-Step mismatch

Inappropriate Saccades
Saccadic Oscillations- Dysmetria, Jerks and Flutter



Dysmetria- (inaccurate size)

Macrosaccadic Oscillations

Square Wave Jerks

Macro Square Wave Jerks

Ocular Flutter

Parinaud's Syndrome- no downward vertical saccades

Square Wave Jerks

Slow Saccades

Macro Saccadic Oscillations

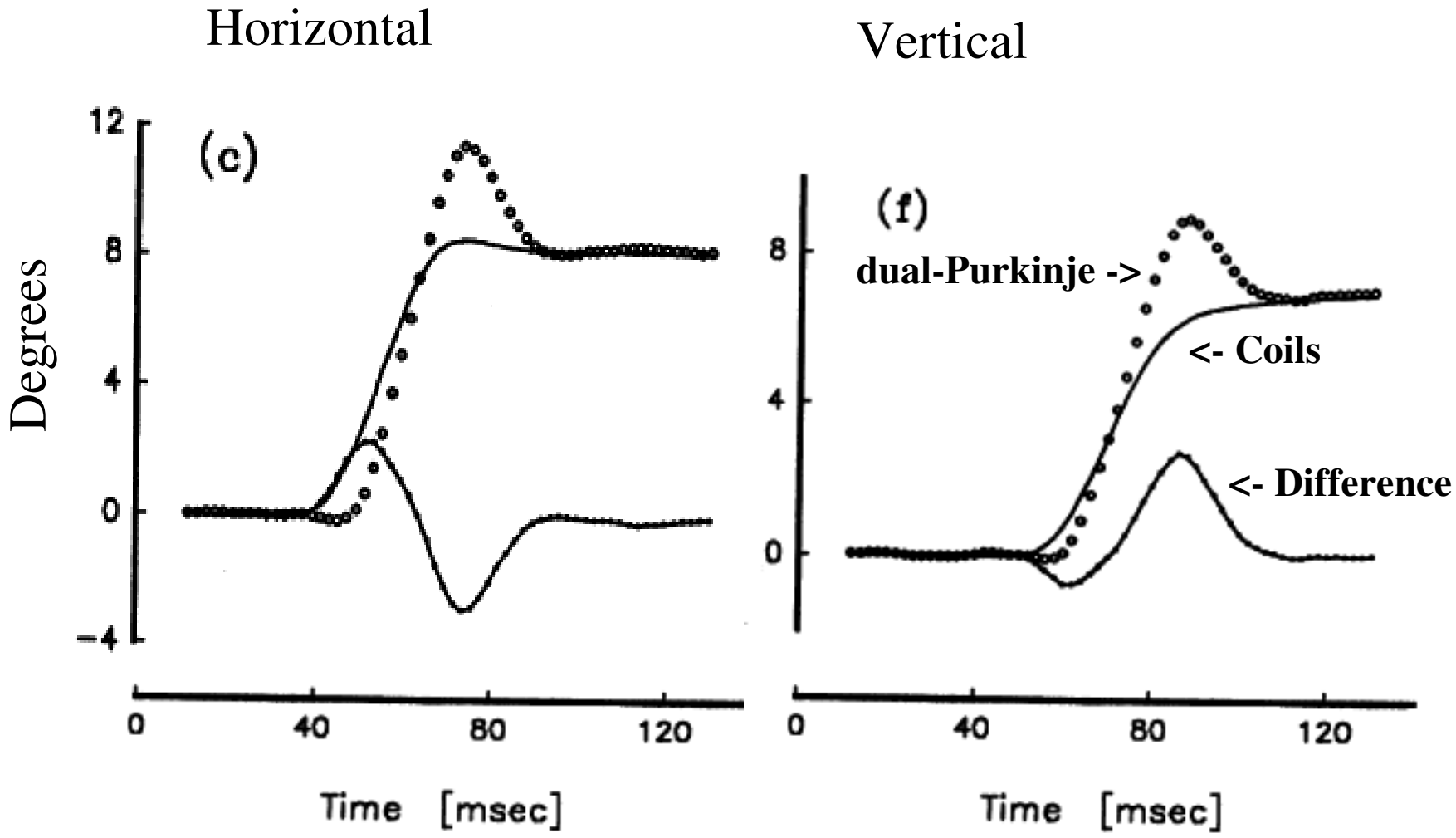
Hypermetric Saccades

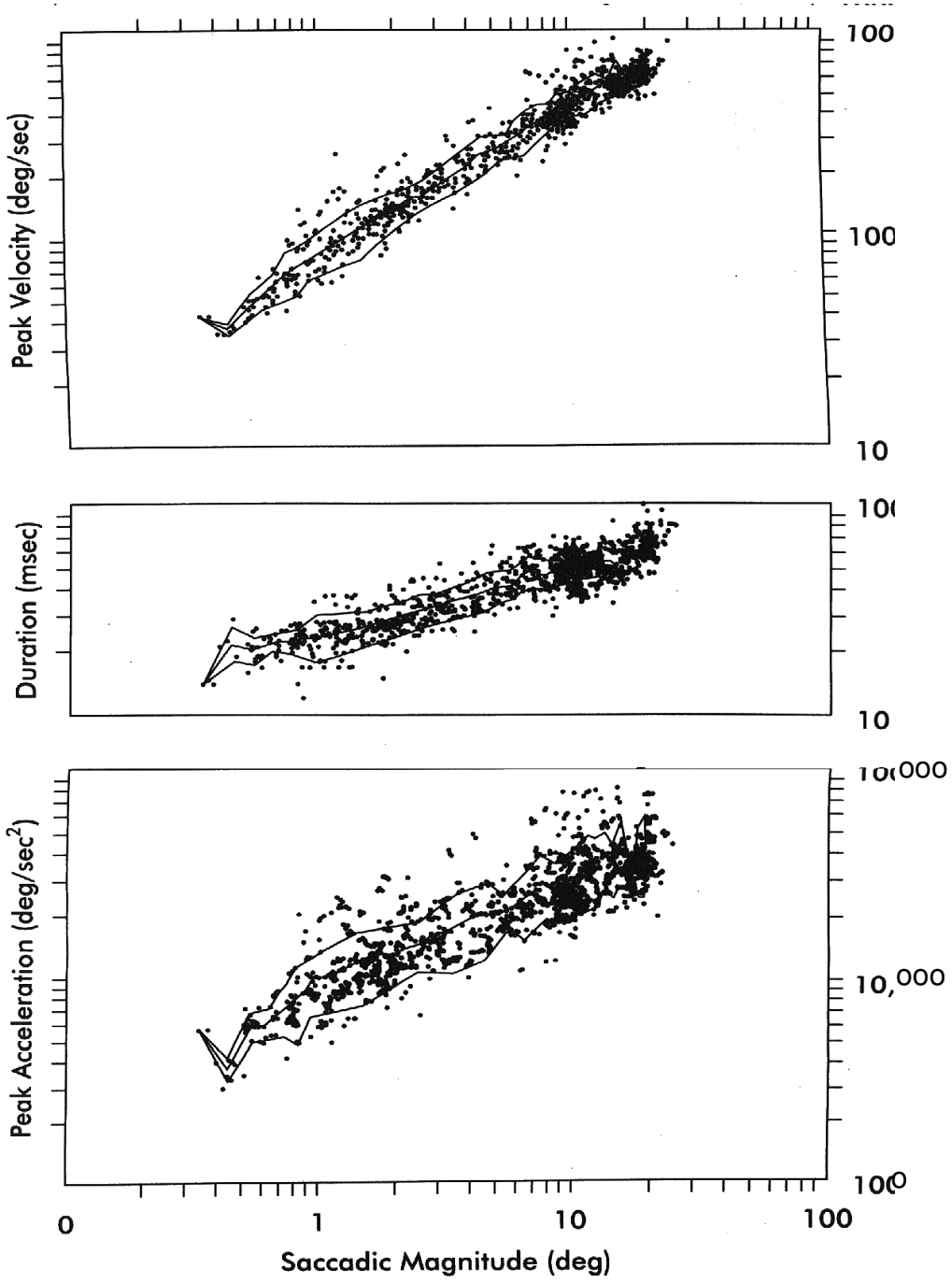
Adult Opsoclonus Movie

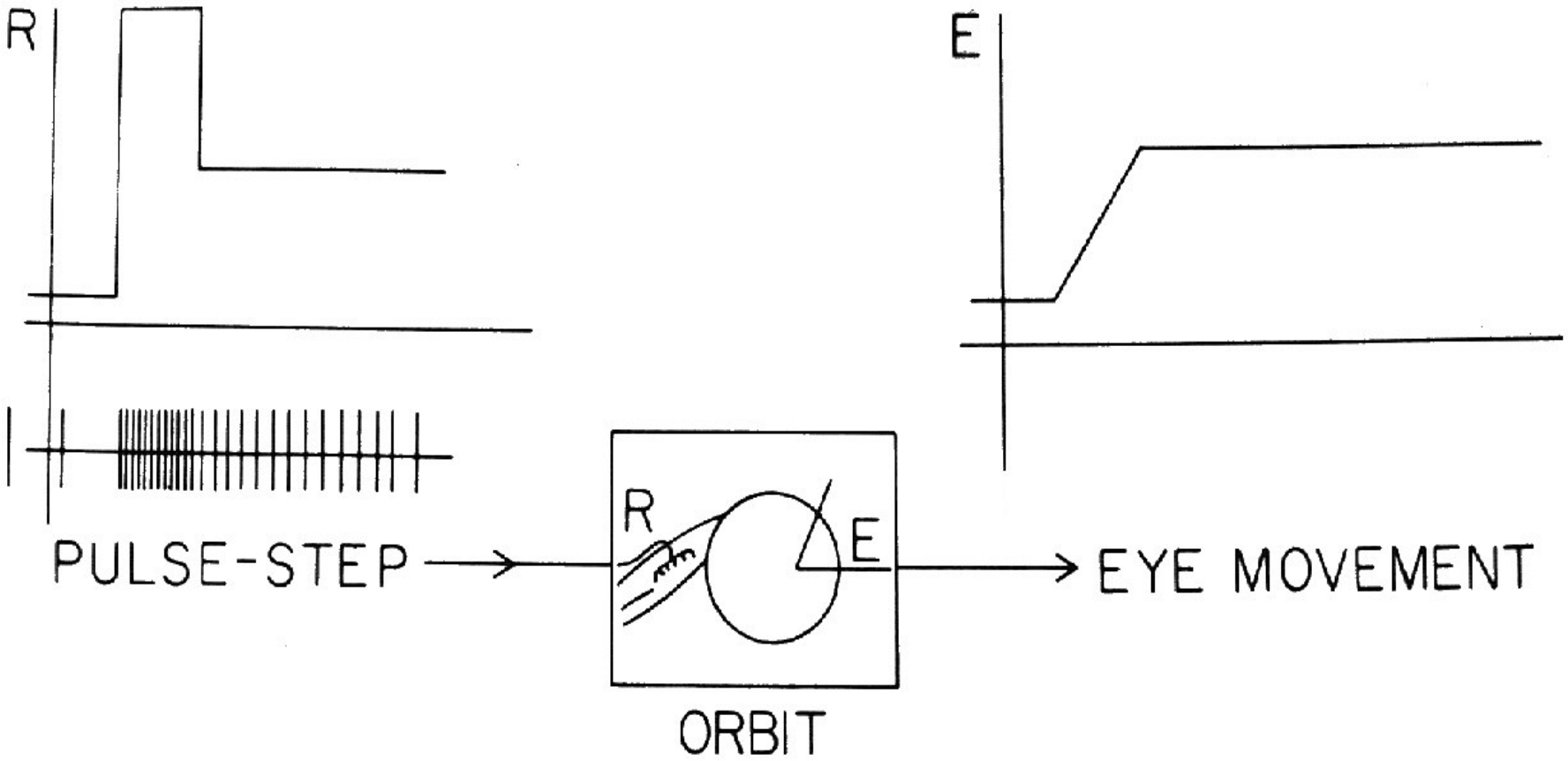
Infant Opsoclonus Movie

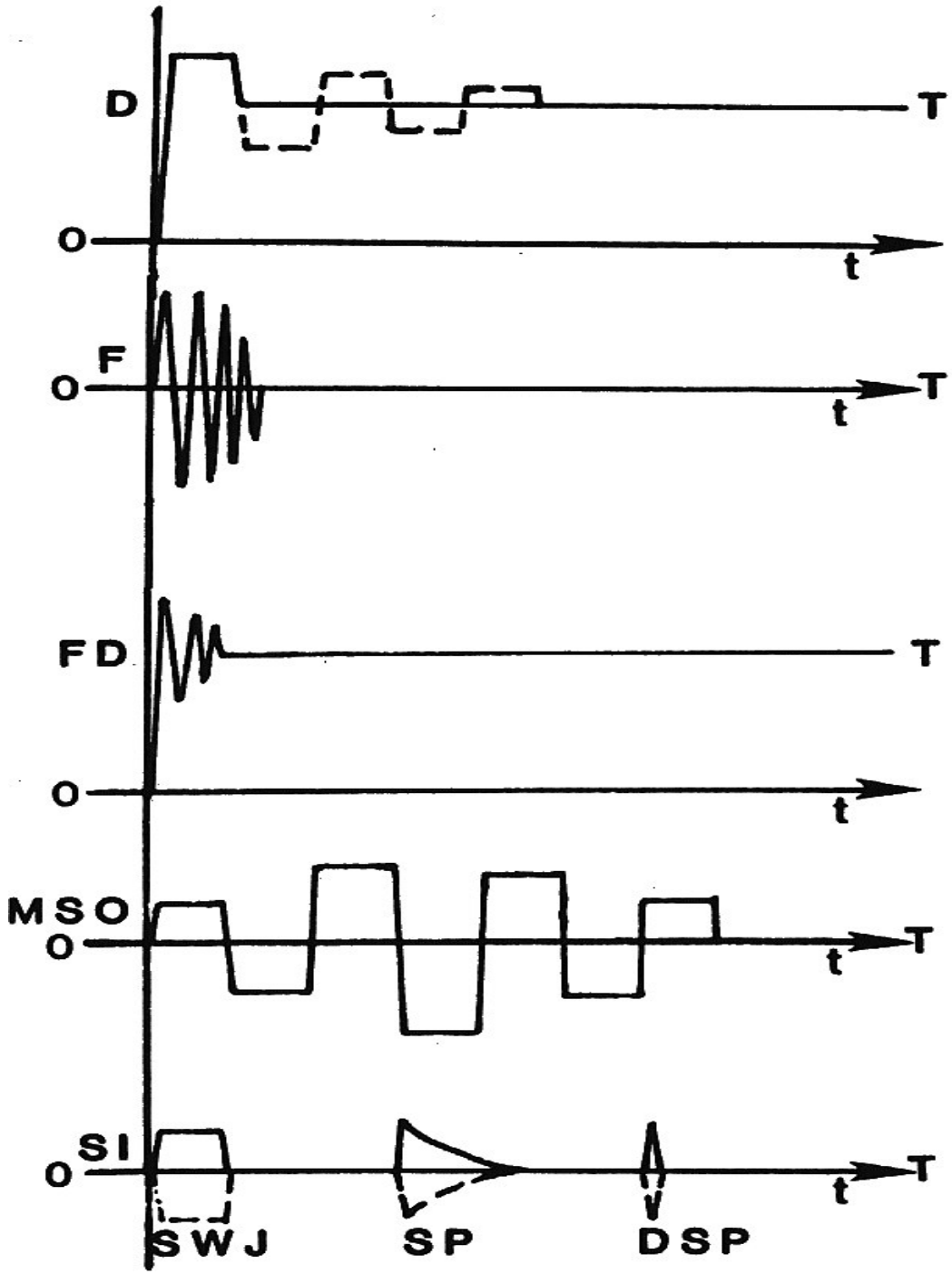
Spasmus Nutans

Saccade measured with coils and dual-Purkinje trackers




Peak Velocity (deg/sec)
100
100
10
Duration (msec)
10
Peak Acceleration (deg/sec^2)
10,000
10,000
0
1
10
100
Saccadic Magnitude (deg)


R
E
PULSE-STEP
R
E
EYE MOVEMENT
ORBIT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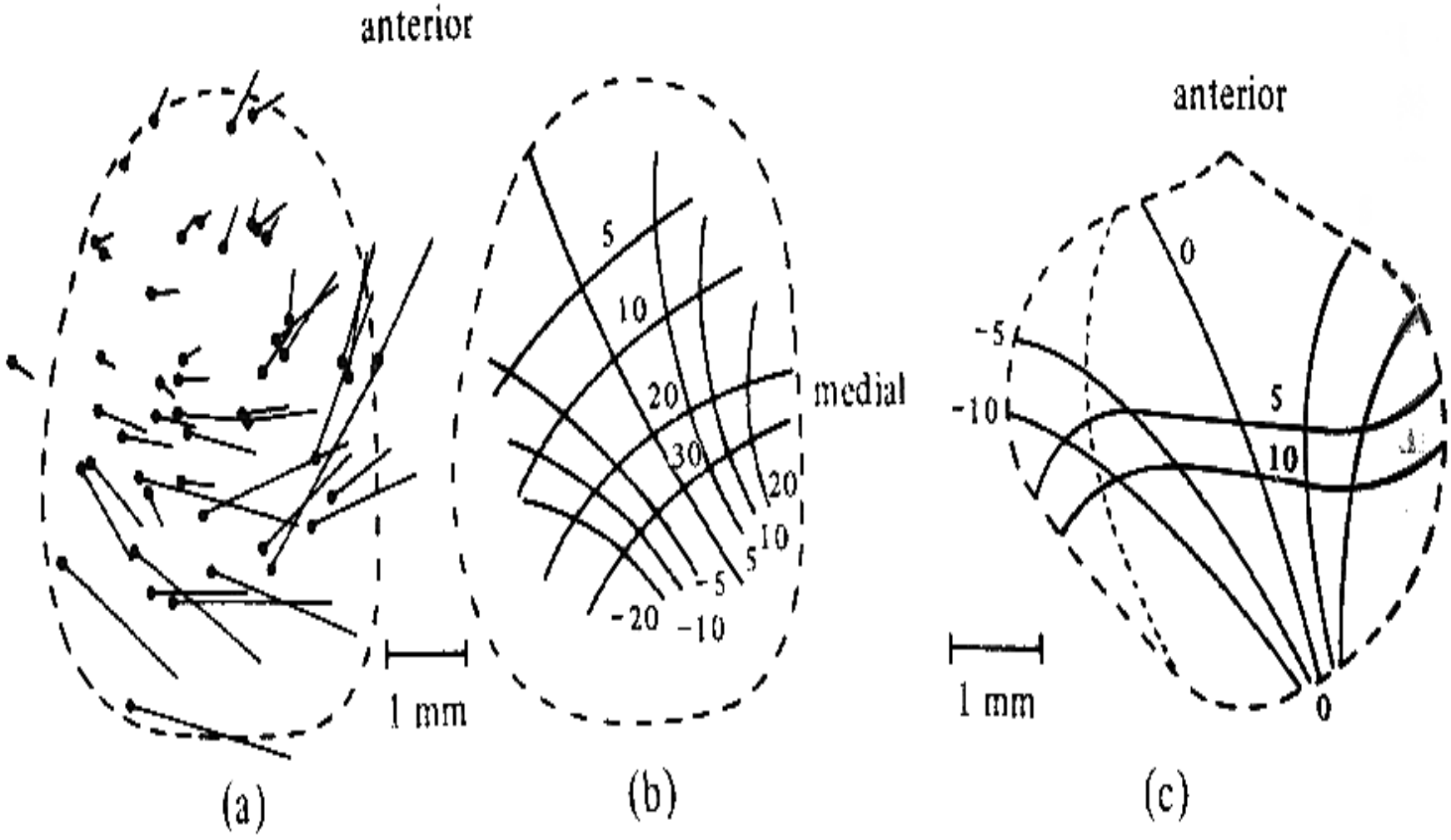
anterior
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(a)
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10
20
30
20
10
5
-5
-10
-20
medial
(b)
anterior
0
-5
-10
5
10
1 mm
0
(c)

Spasmus Nutans