Neuroscience of Looking

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14 January 2019

A class in the course

Introduction to Neuroscience: Systems Neuroscience

Organized by Nachum Ulanovsky

Theoretical approaches to looking

Orienting response

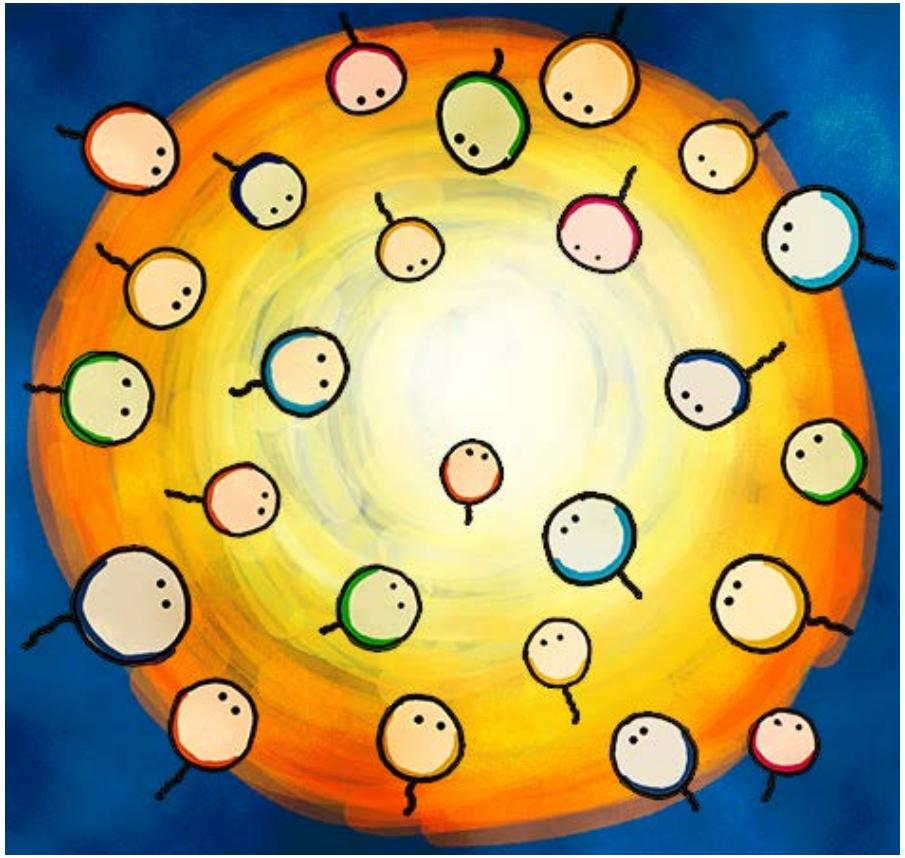
Attention

Mind-body

Orienting: phototaxis

‘Early’ evolution

Bacteria



http://2012.igem.org/Team:Peking/Project/Phototaxis

Plants

https://www.fast-growing-trees.com/images/D/Cold-Hardy-Tea-Plant-3-450W.jpg

Moths

http://en.es-static.us/upl/2012/10/moths-light-e1503921825511.jpg

Attention Human psychology & mind-body

Everyone knows what attention is. It is the taking possession by the mind, in clear and vivid form, of one out of what seem Several simultaneously possible objects or trains of thought… It implies withdrawal from some things in order to deal effectively with others….

James, 1980
The Principles of Psychology, pp. 403-404

The spotlight metaphor of attention

Mind-body: intention & attention

- Intention: plan
  - Subjective (accessible only to subject)
  - Exists in working memory
  - Ends in either:
    - Execution (becomes behavior, objective, accessible to all)
    - Cancellation (remains hidden forever in subjective existence)
- Intended action
- Attention: same, but acts on sensation
  - Observed only indirectly (because percepts are subjective)
  - (Concept can be extended)

Ilya Repin
1844-1930, Russian

<u>Unexpected Visitors</u>

1884 - 1888
Oil on canvas
167.5 x 160.5 cm

Tretyakov Gallery
Moscow, Russia

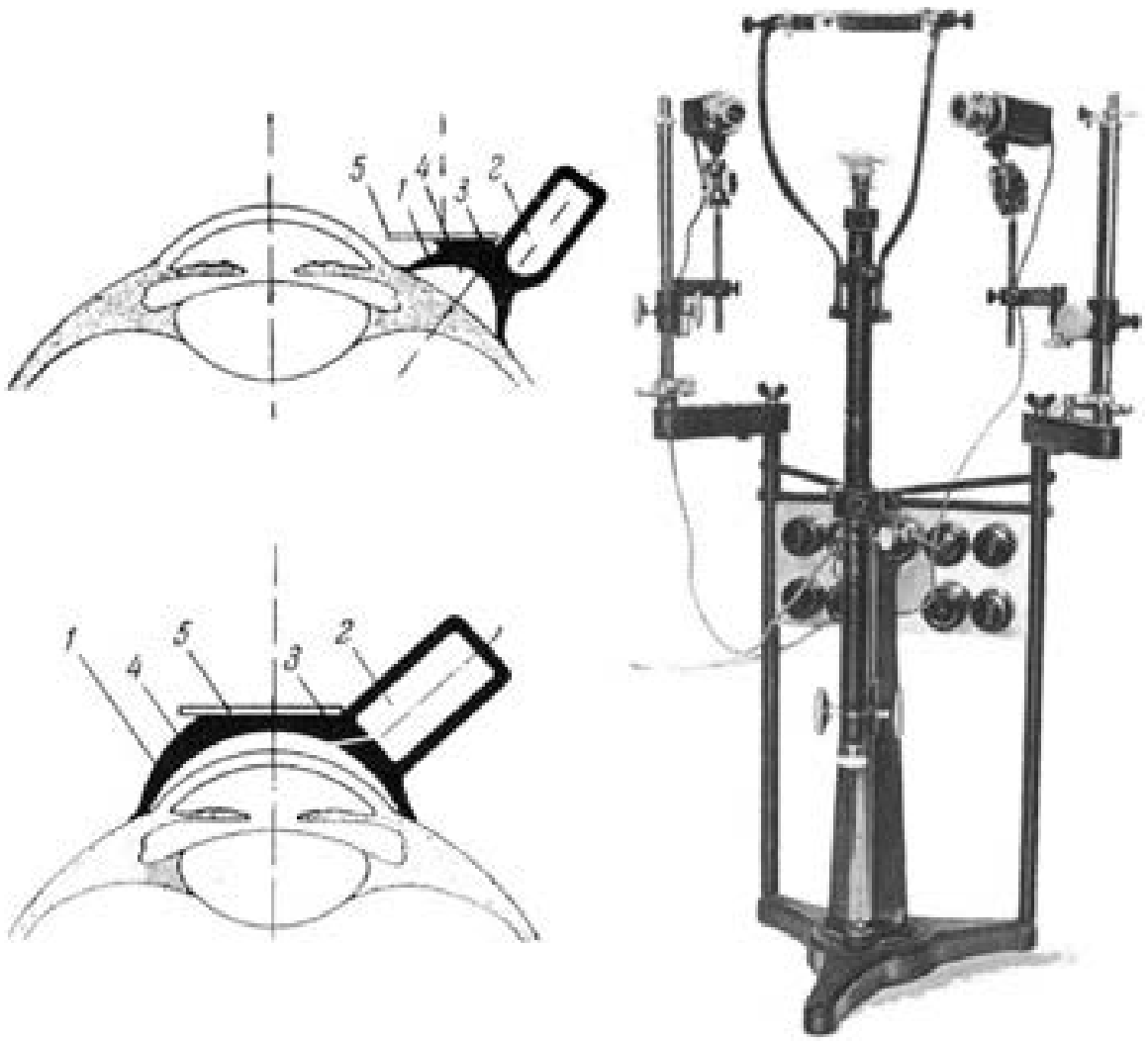
Alfred Lukyanovich Yarbus (Альфред Лукьянович Ярбус)

- Moscow, 1914 – 1986
- PhD on visual illusions
- From 1957 **USSR Academy of Sciences**
- Lab leaders Bongard (Soviet AI) Smirnov
- **Vadim Invanovich Chernishev**, technician, made the suction cups (together with Yarbus)
- PhD in Biology 1964
- Book 1965, English 1967
- Faced resentment due to credit
- 1975-1980 papers on vision inspired by analog electrical engineering

(a)

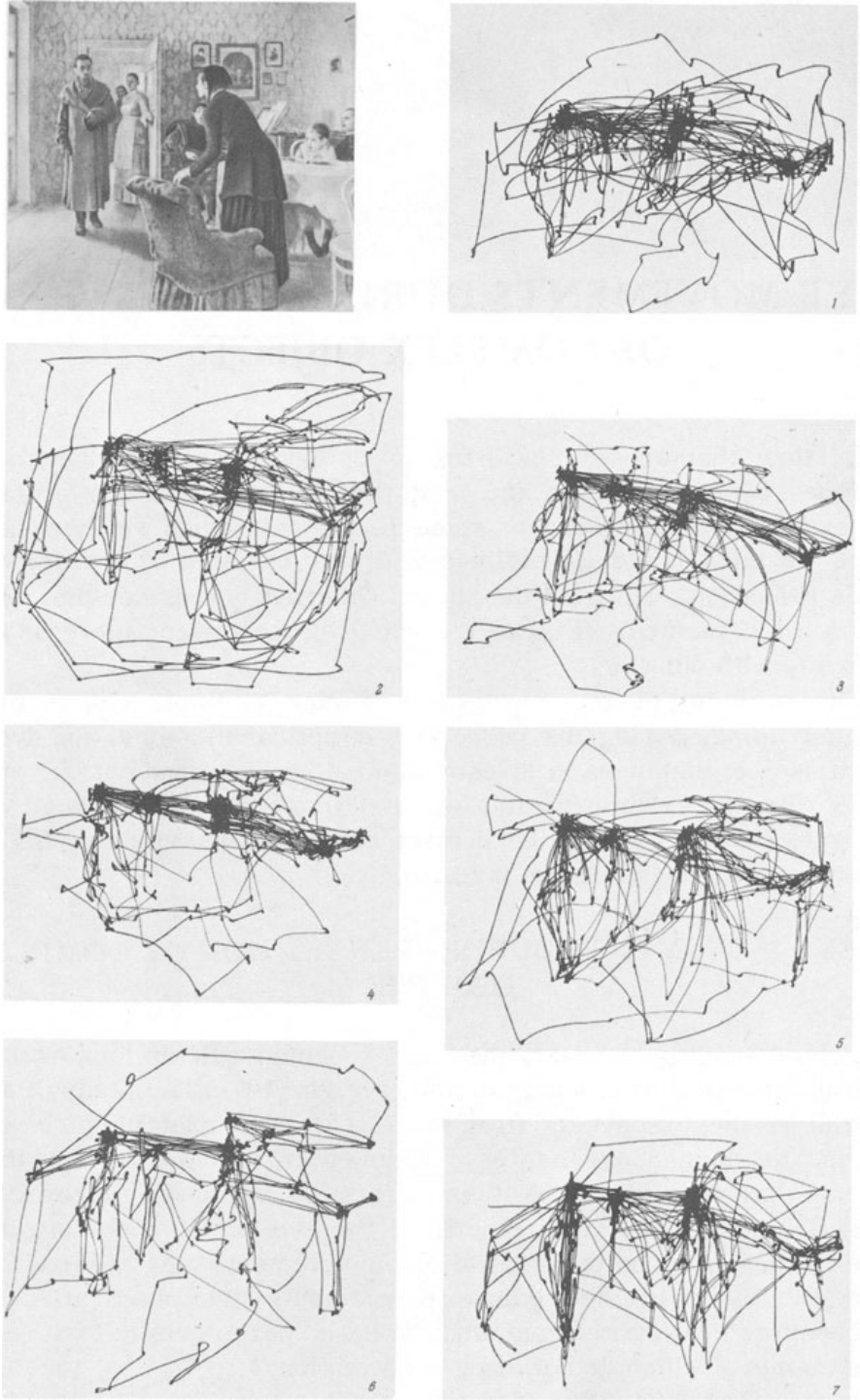
WWII (1944?)

Iperception. 2010; 1(1): 7–27.
Published online 2010 Jul 12. doi: 10.1068/i0382
Yarbus, eye movements, and vision
Tatler, Wade, Kwan, Findlay, and Velichkovsky



(b)

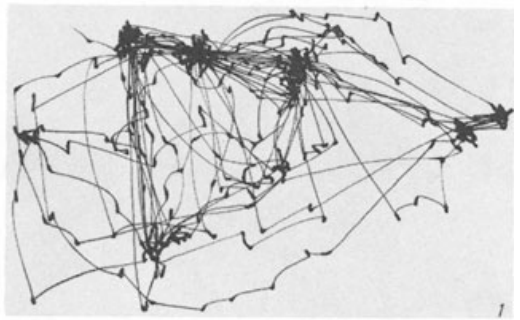
Yarbus
Records of
the eye movements
of
seven different subjects

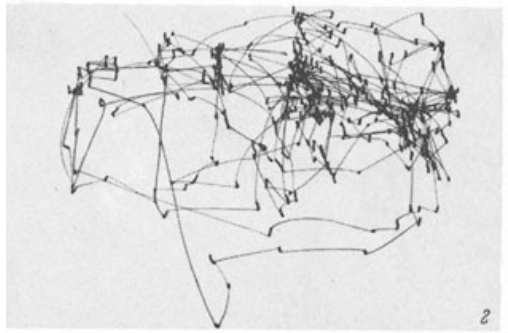


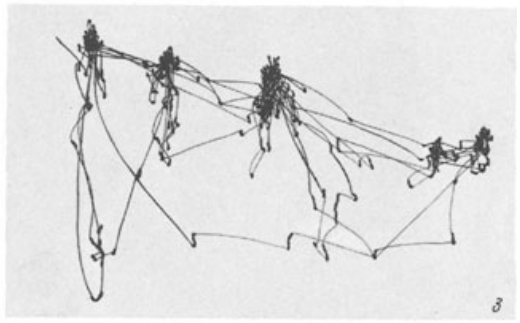
Estimate the material circumstances of the family in the picture

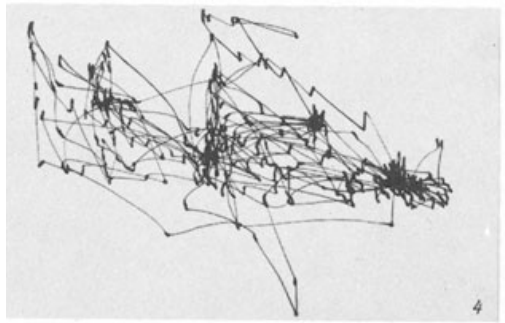
Surmise what the family had been doing before the arrival of the “unexpected visitor”

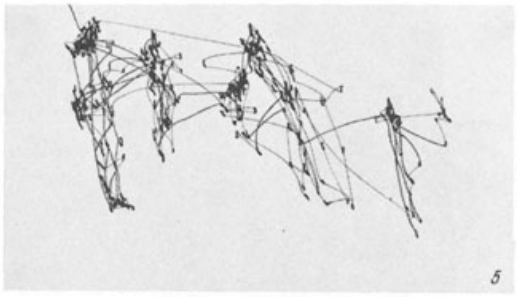
Remember the position of the people and objects in the room

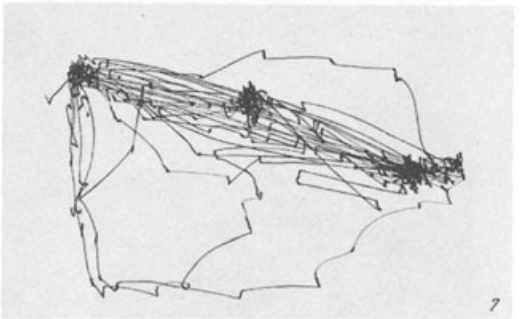












Give the ages of the people

Remember the clothes worn by the people

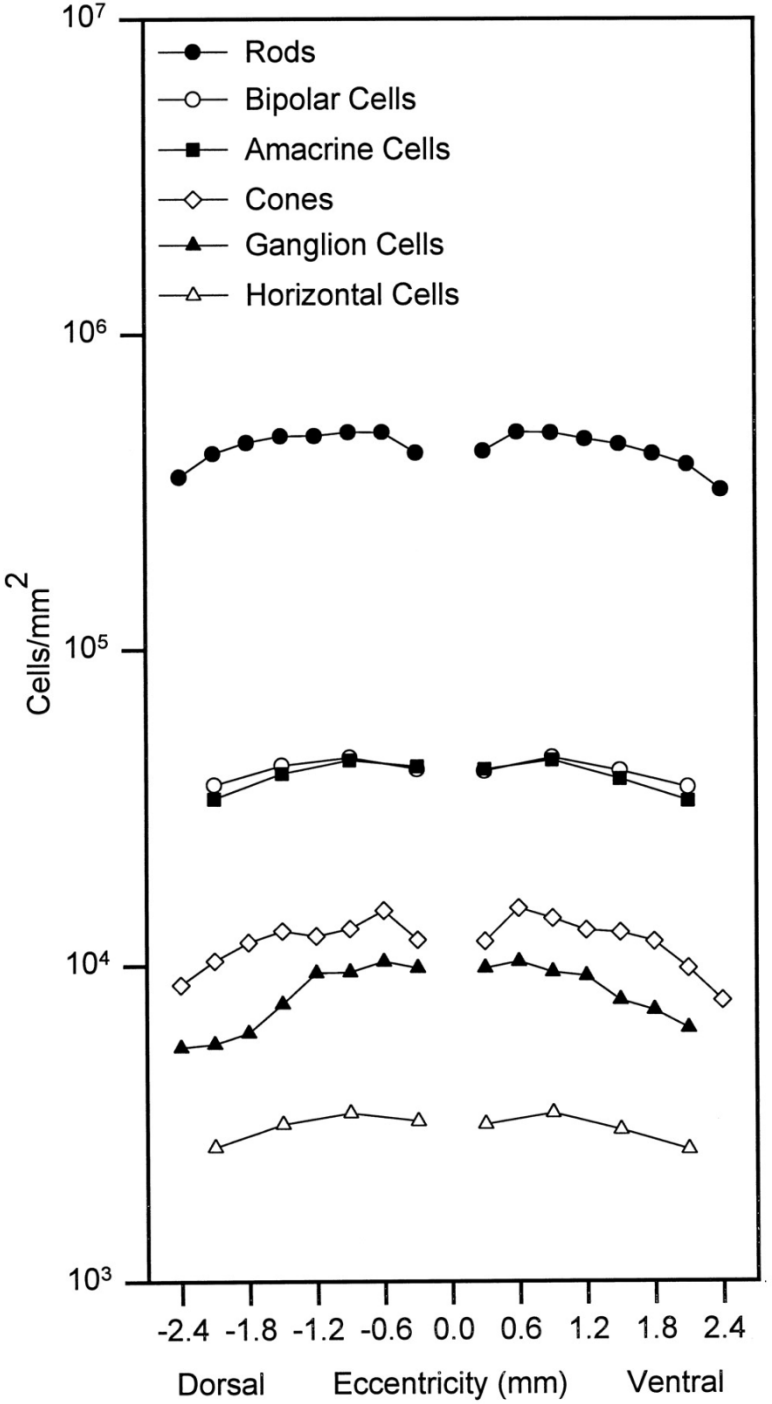
Estimate how long the “unexpected visitor” had been away from the family

Archaic eye movements (with simple retina)

VOR Vestibulor-ocular movement

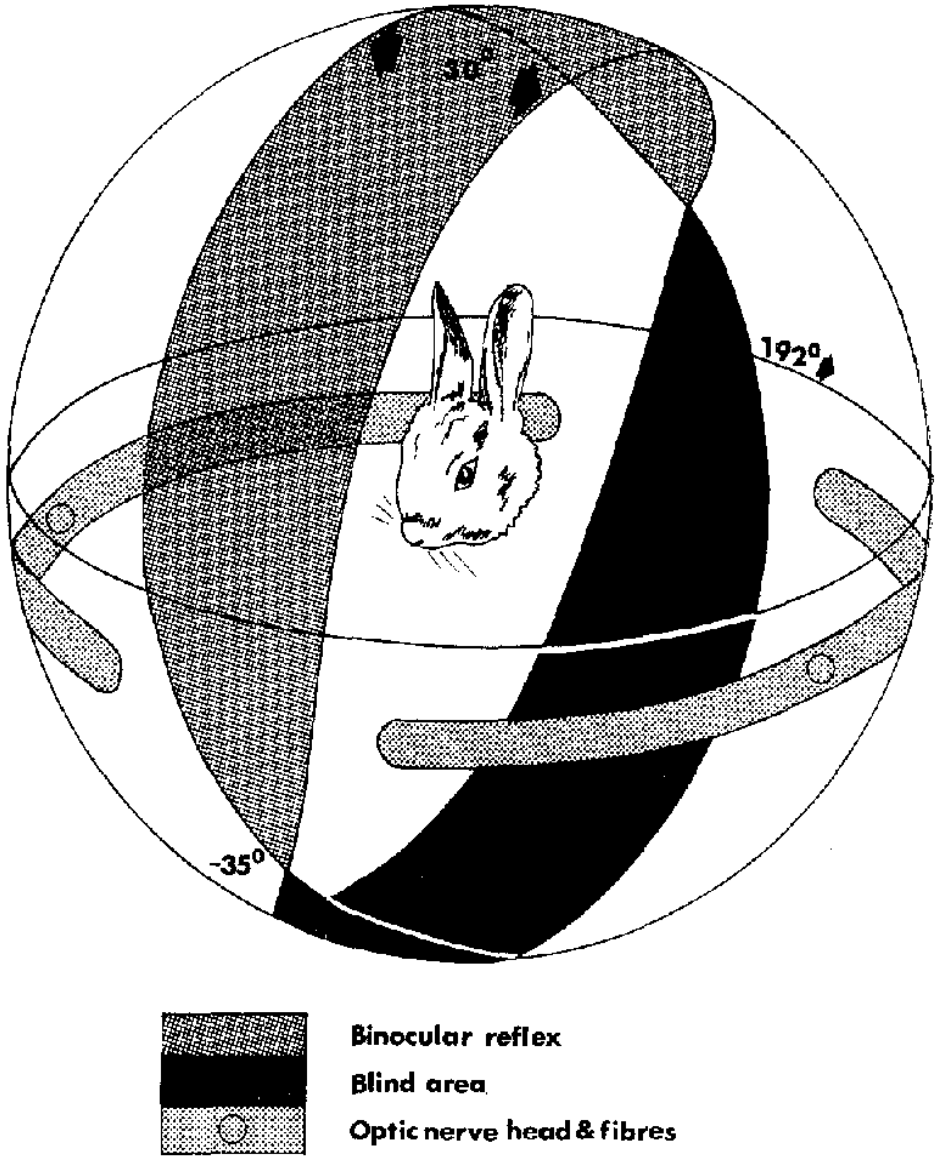
OKN Opto-kinetic nystagmus

Mouse retina Density of Photoreceptors: no big change

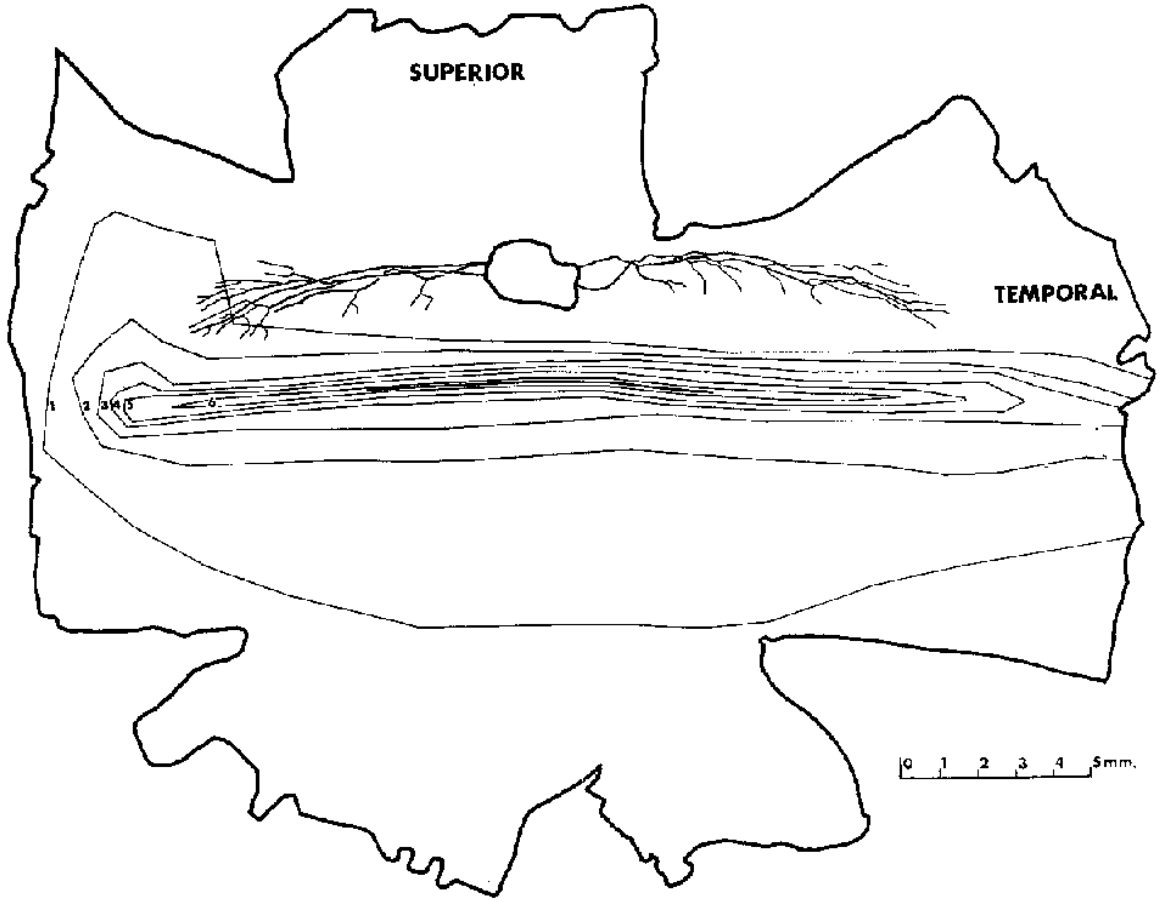


The Major Cell Populations of the Mouse Retina
Chang-Jin Jeon, Enrica Strettoi and Richard H. Masland
Journal of Neuroscience 1 November 1998, 18 (21) 8936-8946

Rabbit Visual space



Flat mount of retina – topographic map of ganglion cell density

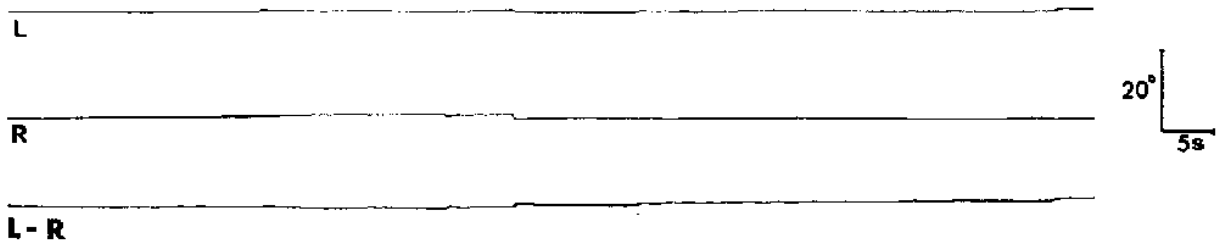


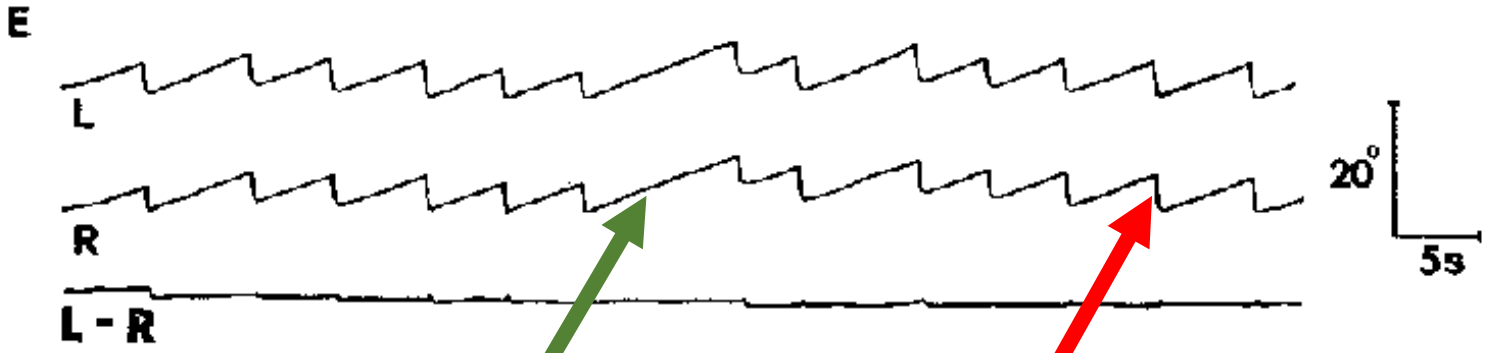
A. Hughes 1971

Rabbit: OKN

Collewijn 1971

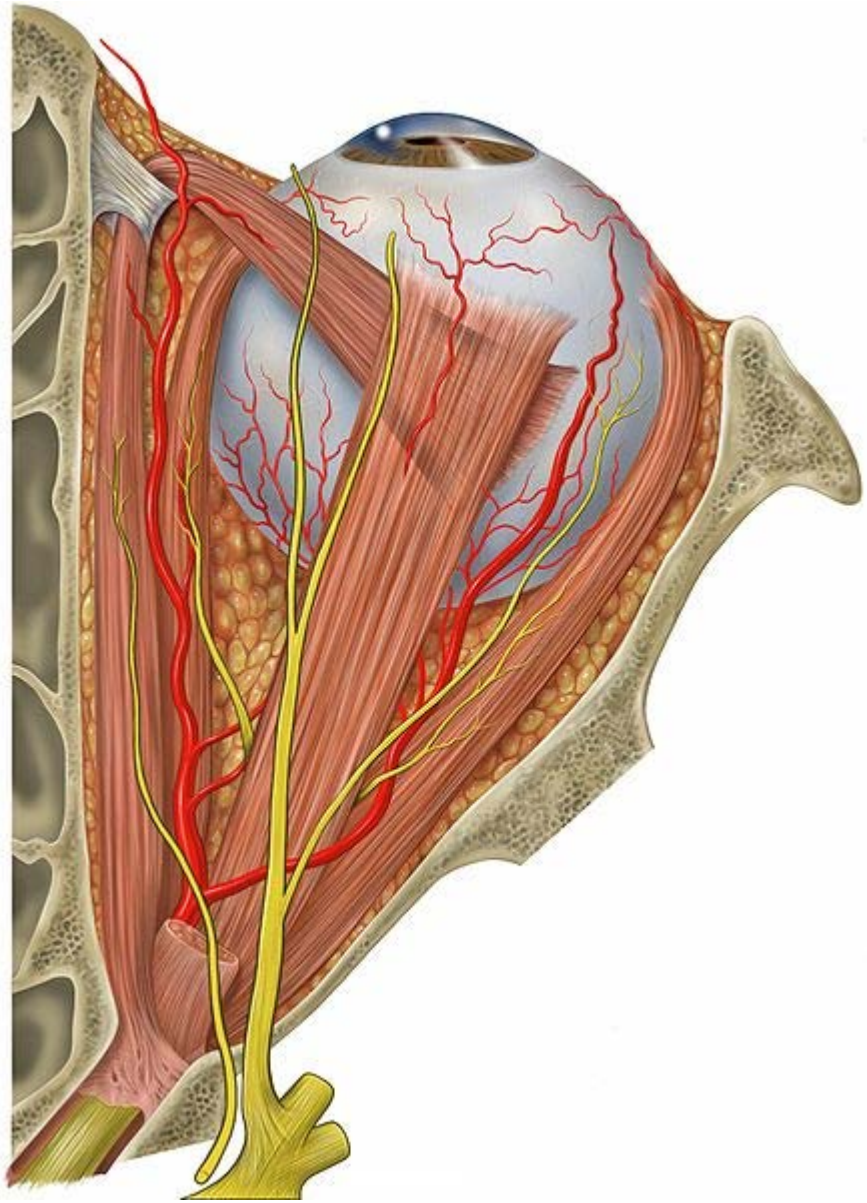
Resting, bright light

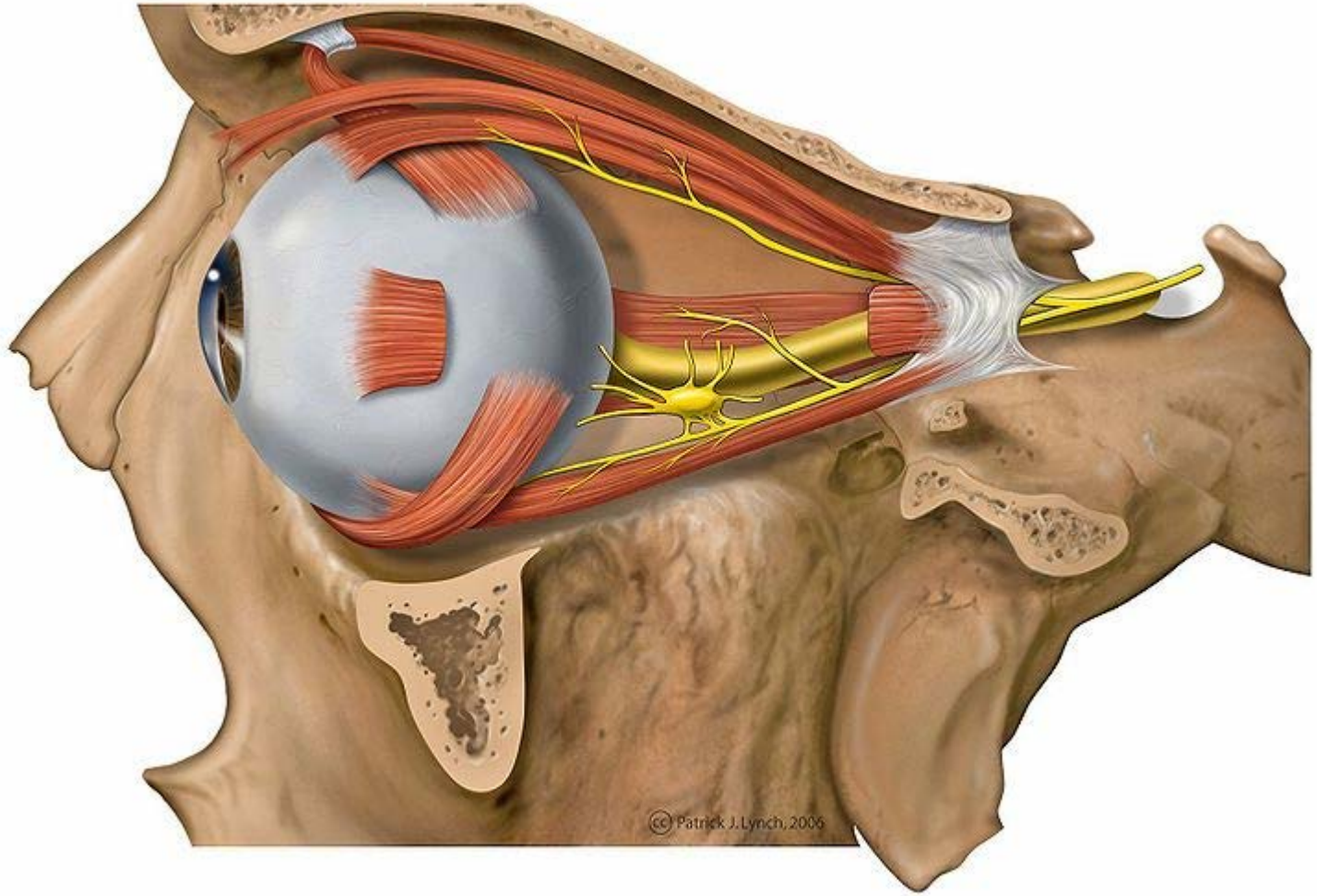




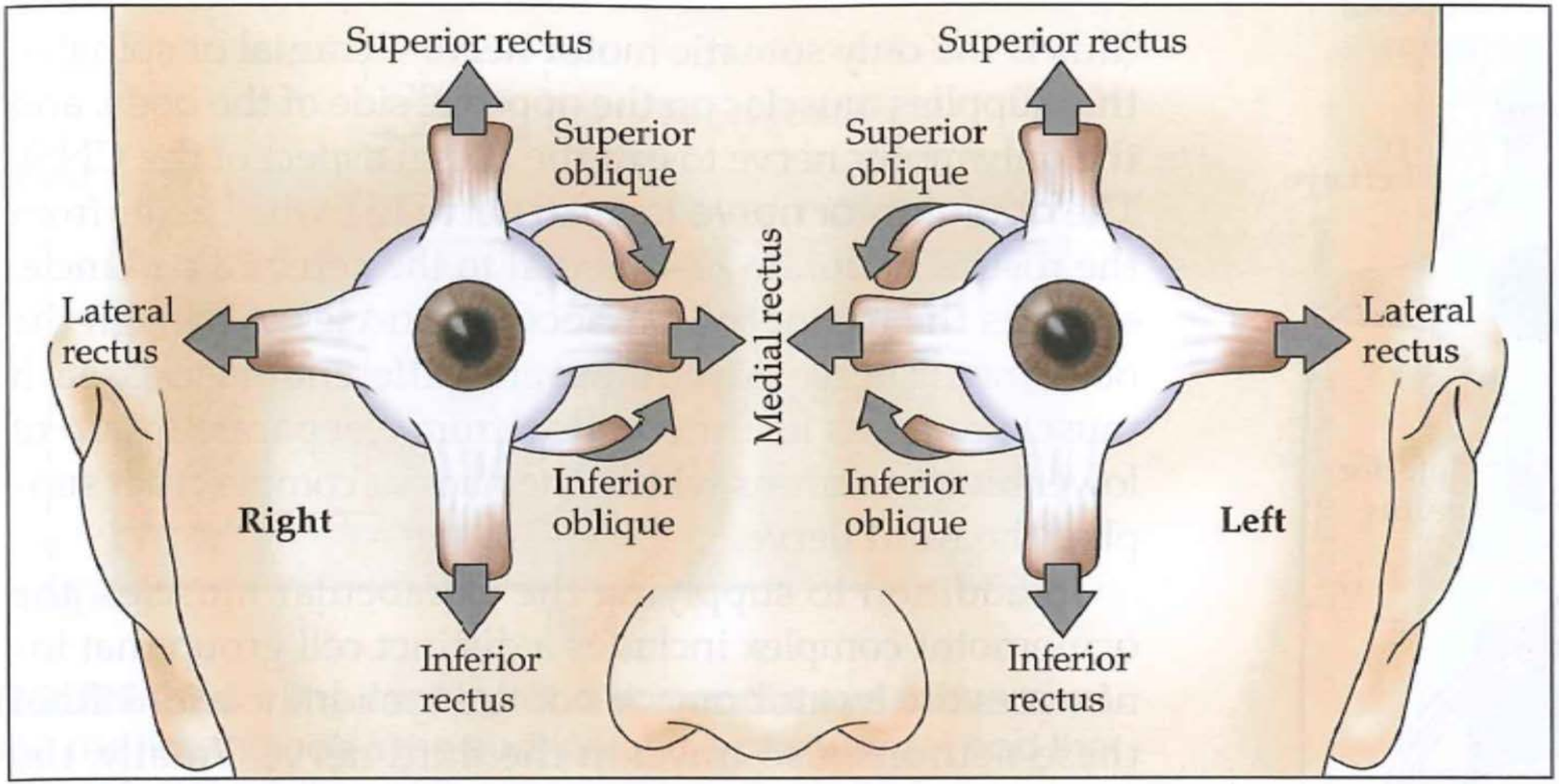
Slow phase

Fast phase

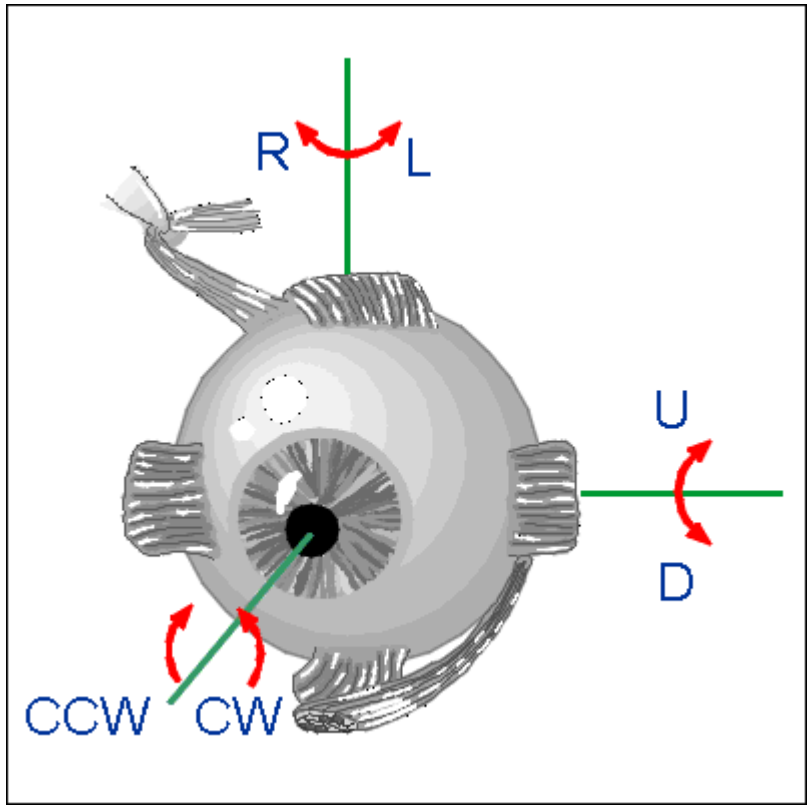



©Patrick J. Lynch, 2006

The extraocular muscles

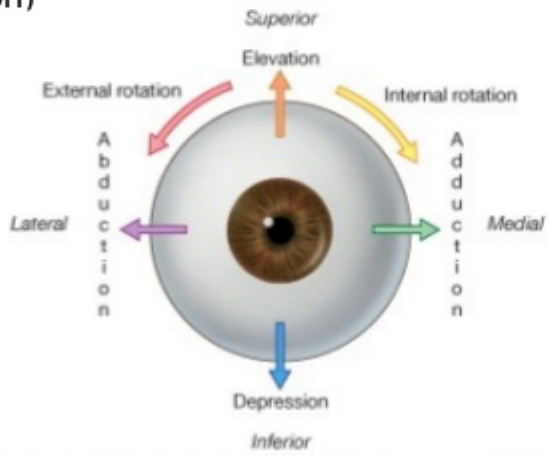


Rotation of the eye: dimensions and directions

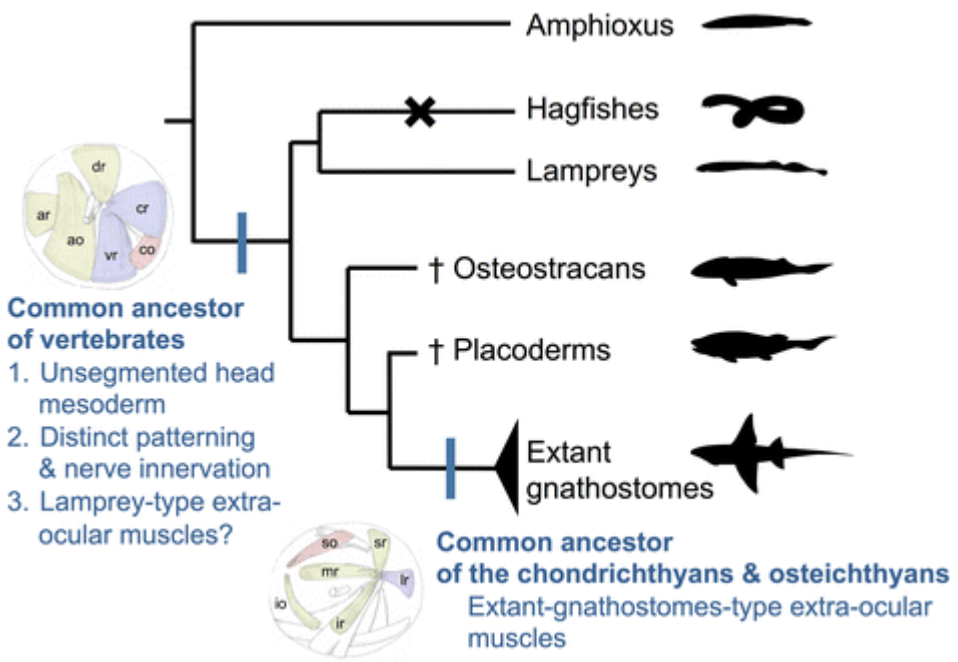


Movements of Eyeball

- **Along vertical axis** : Lateral rotation (Abduction) & Medial rotation (Adduction)
- **Along Transverse axis**: Elevation & Depression
- **Along anteroposterior axis**: Intortion (cornea moves medially from 12 O'clock position) & Extortion (cornea moves laterally from 12 O'clock position)



The six extraocular muscles in evolution



(Suzuki et al Zoological Letters 2016)

Listing’s Law

- Torsion fixed function of (Horizontal,Vertical)
- H,V fully specify direction of gaze
- Listing’s law not always valid

Cone density map Fovea evolves in primates

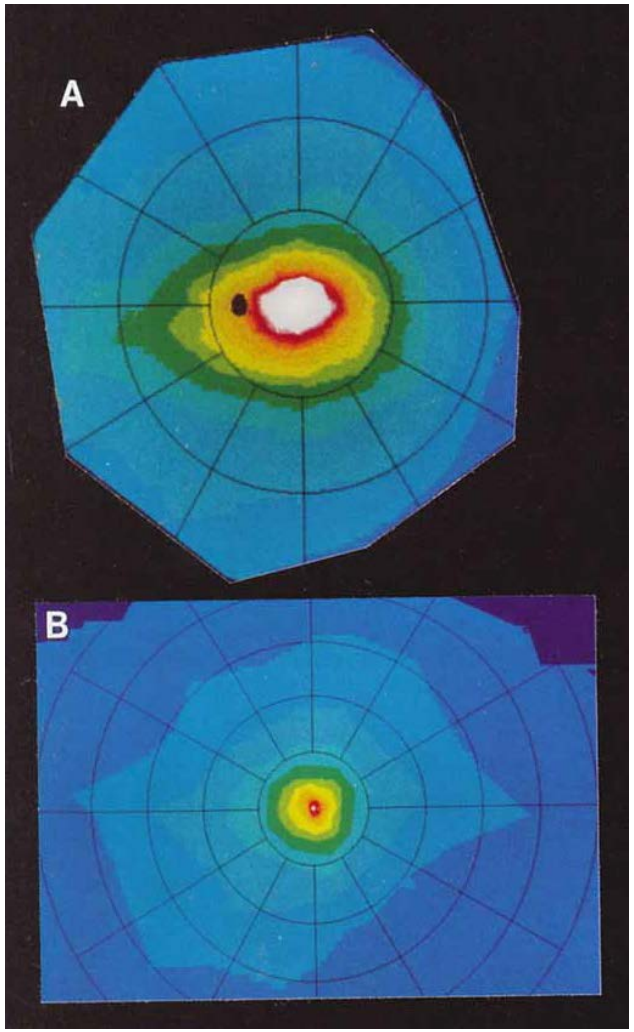
THE JOURNAL OF COMPARATIVE NEUROLOGY 288:165–183 (1989)

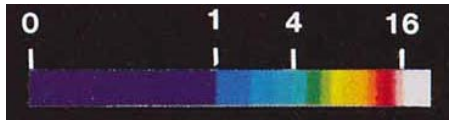
Photoreceptor Topography of the Retina in the Adult Pigtail Macaque (*Macaca nemestrina*)

ORIN PACKER, ANITA E. HENDRICKSON, AND CHRISTINE A. CURCIO

Entire retina

Center



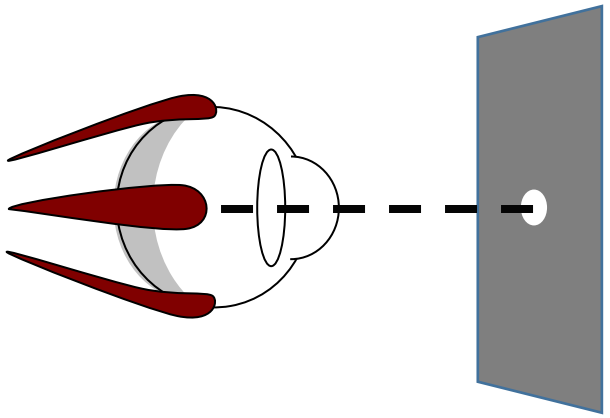


Cones per unit area

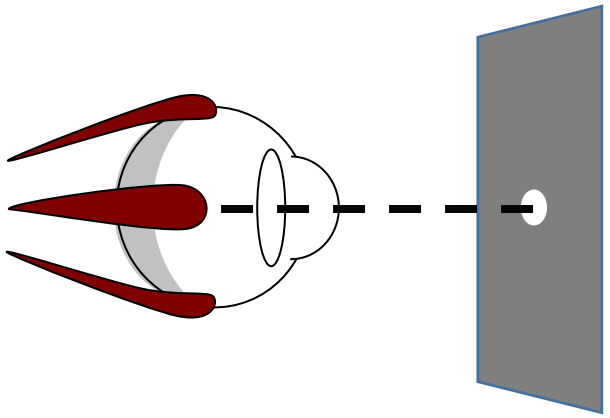
Eye movements with fovea

- Fixation
- Smooth pursuit
- Saccades

- Stay
- Stay*
- Change



Pre-saccadic
Fixation



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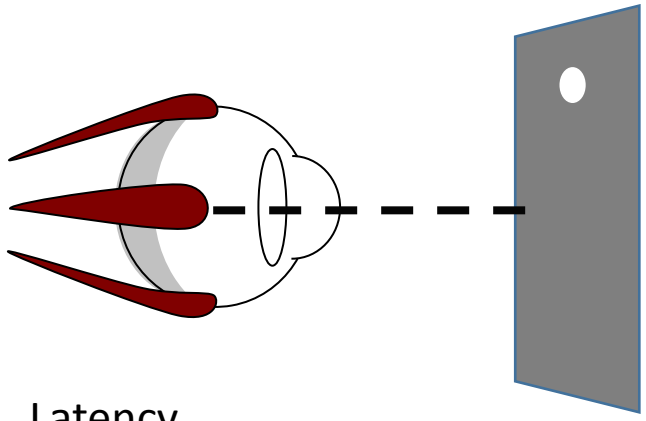
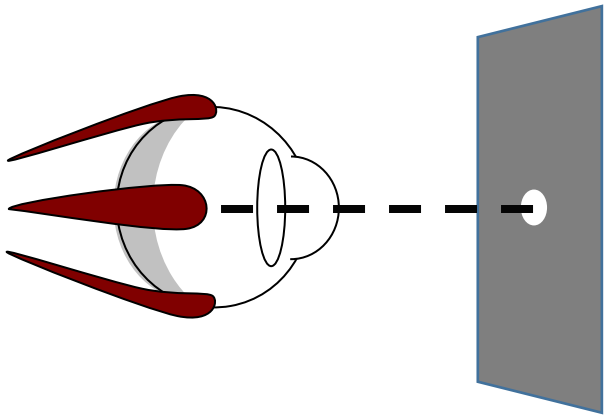
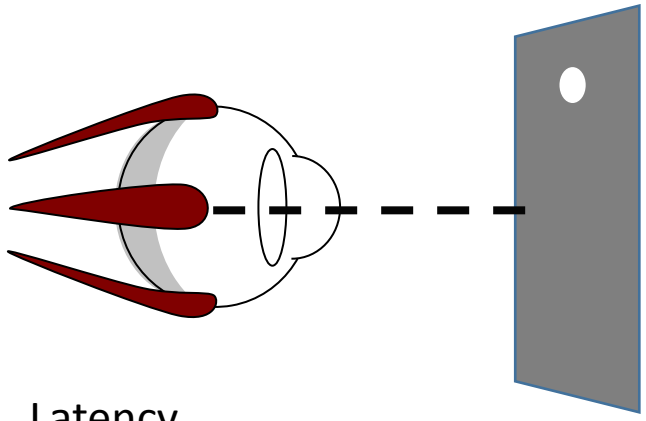


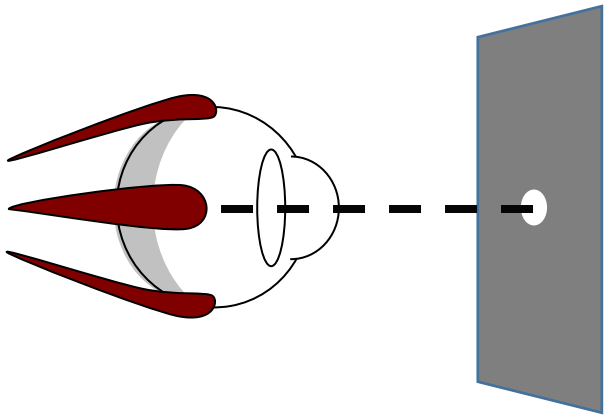
Latency



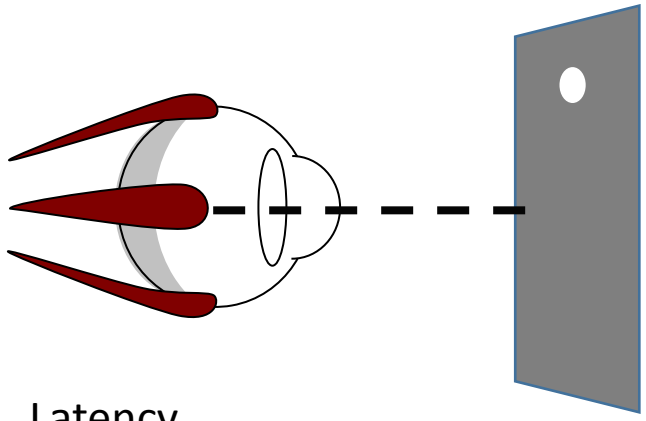
Pre-saccadic
Fixation



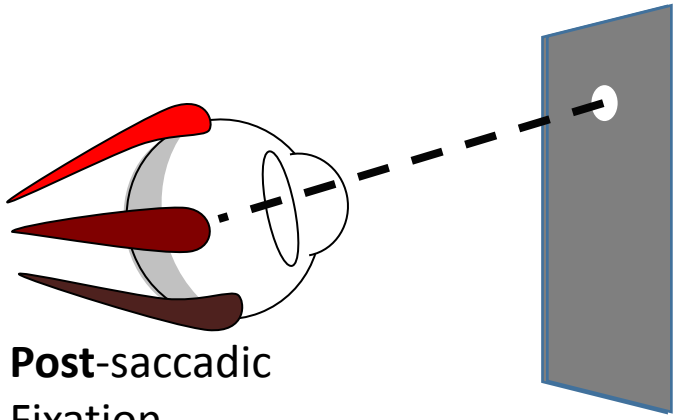
Latency



Pre-saccadic
Fixation

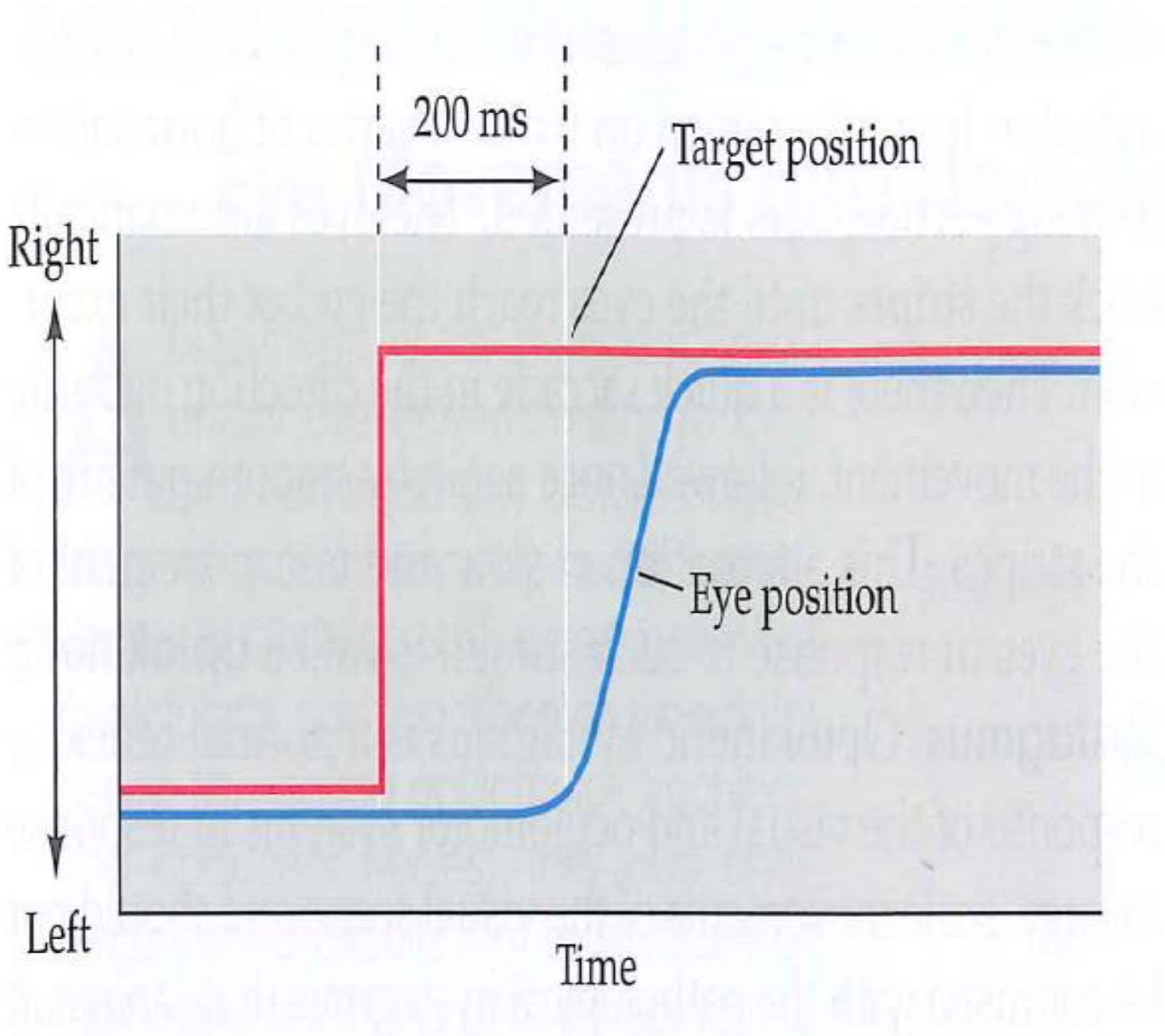


Latency

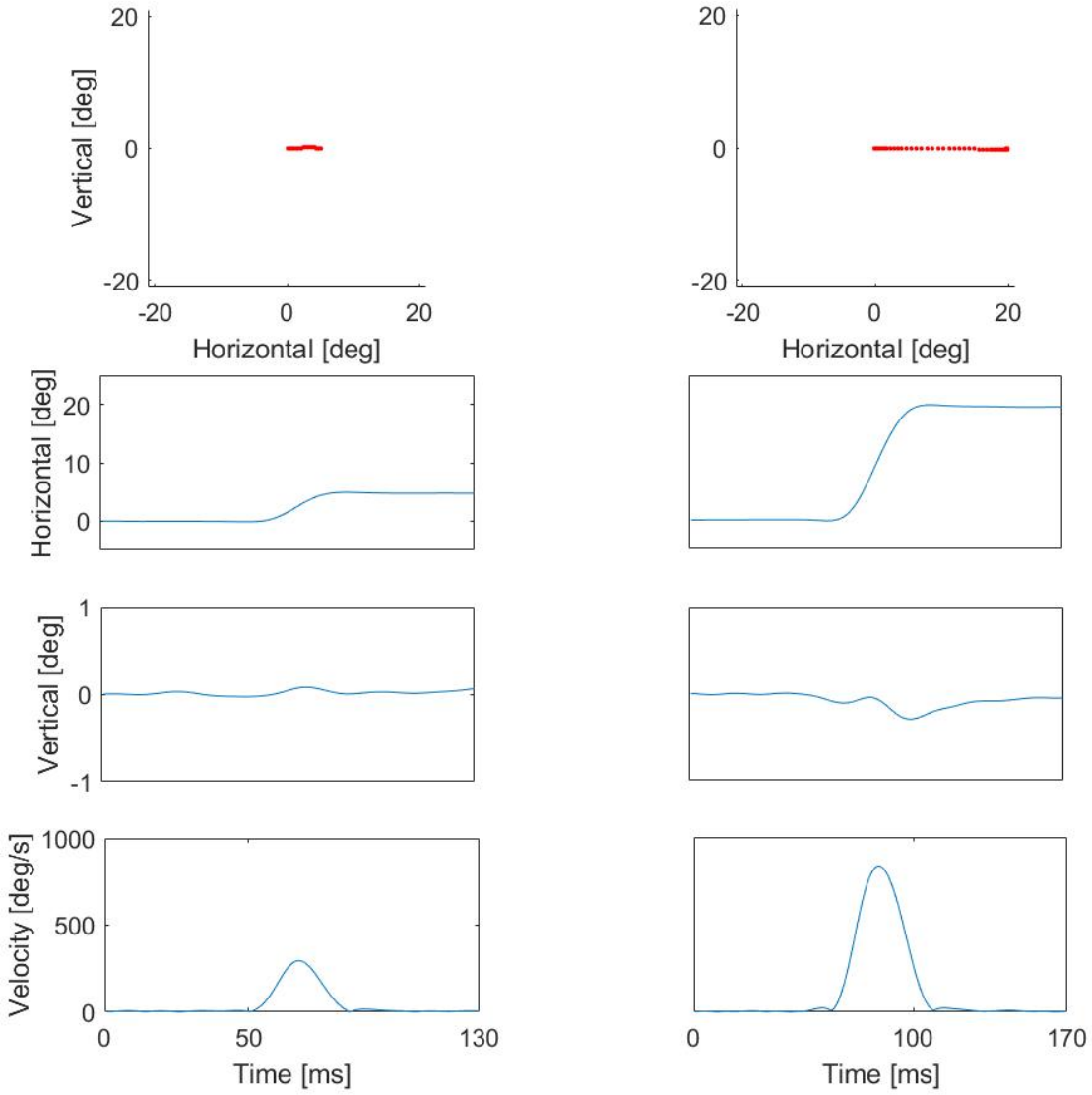


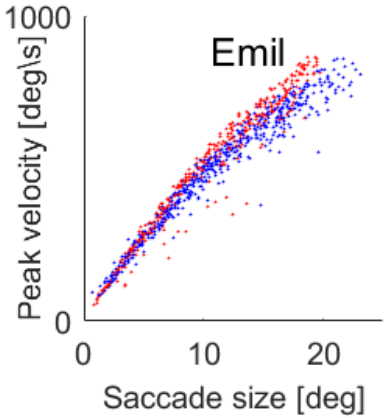
Post-saccadic
Fixation

Saccade – timecourse



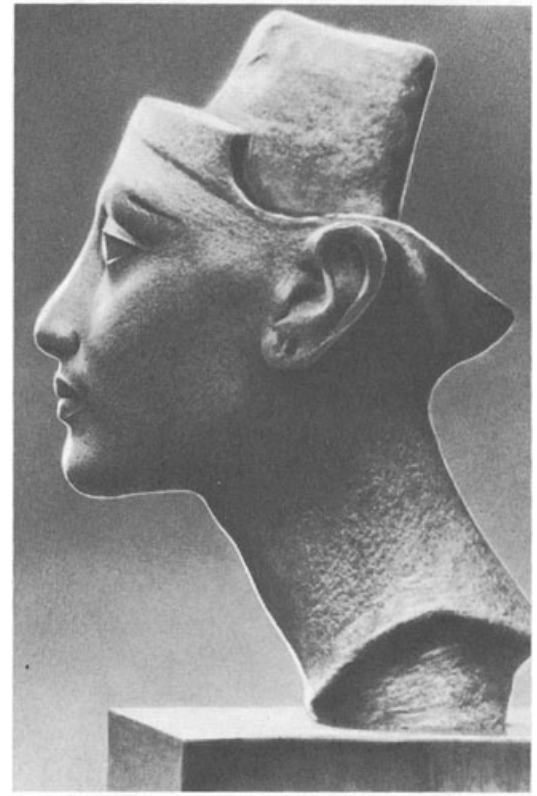
Saccades – velocity and main sequence

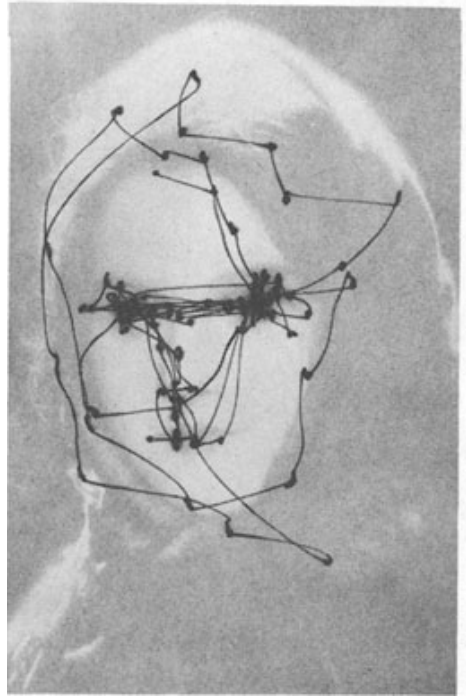


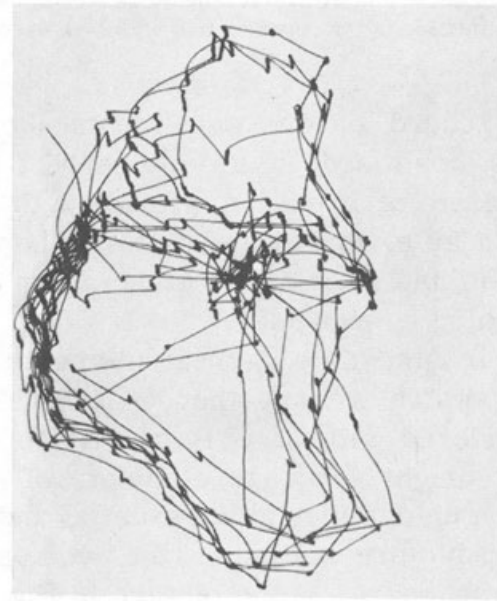


Saccades

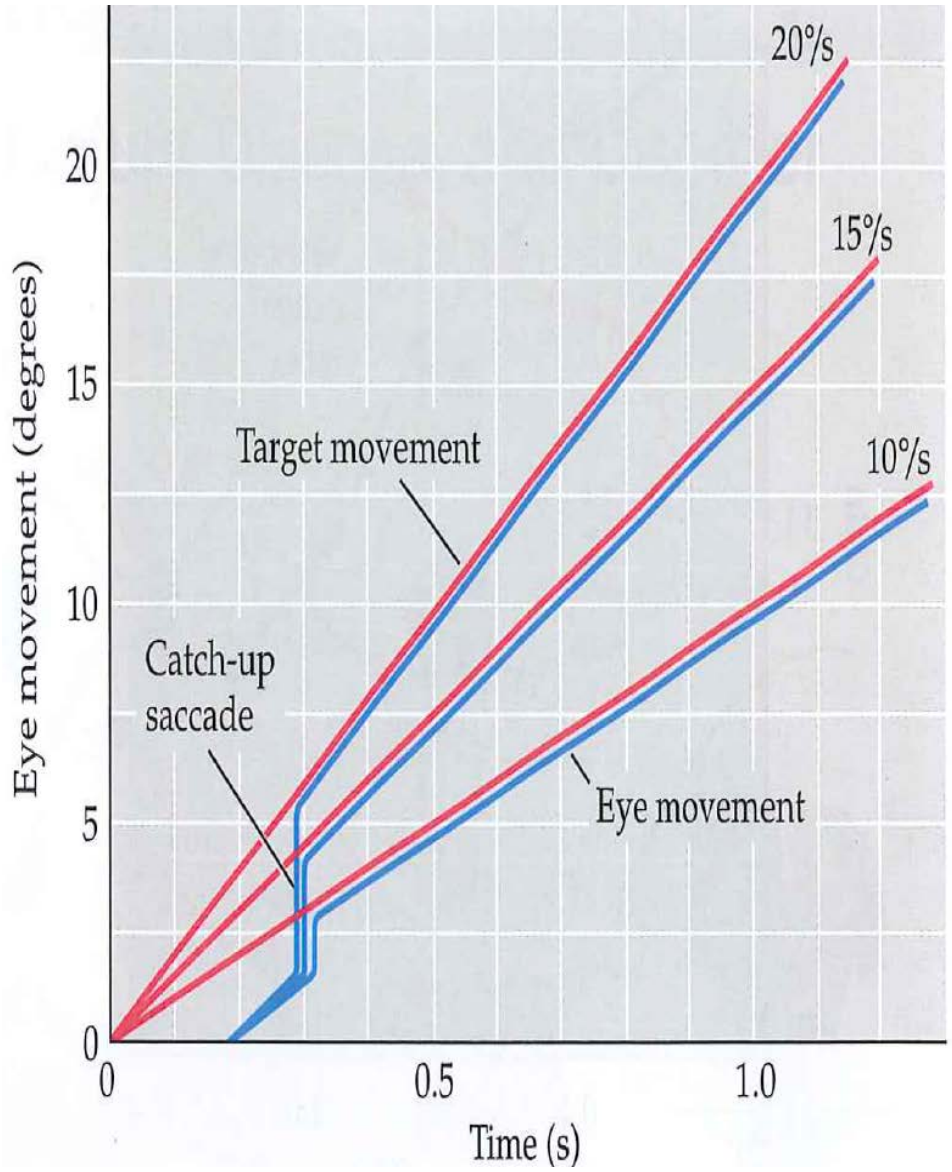
- Saccades occur all the time:
  - 2-5 per s during waking hours
  - Also during sleep
- Over life time, similar number of saccades to heartbeats
- Every saccade requires deliberation and choice
- Vision builds up trans-saccadically
  - Memory
  - Stability of perception
- Relationship to attention



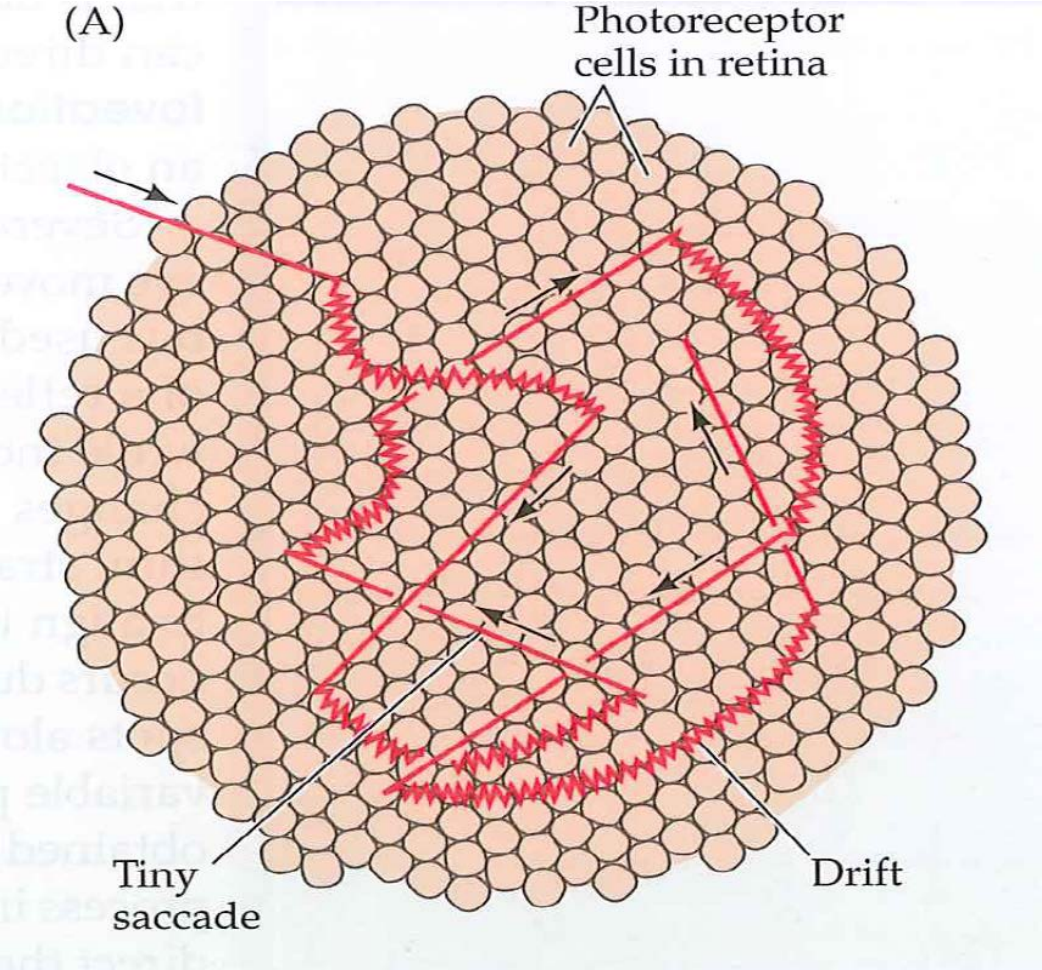




Smooth pursuit eye movements - only primates!



Fixation movements – functional?



Drift
Microsaccades

Is drift motor error?
Are microsaccades useful for vision?

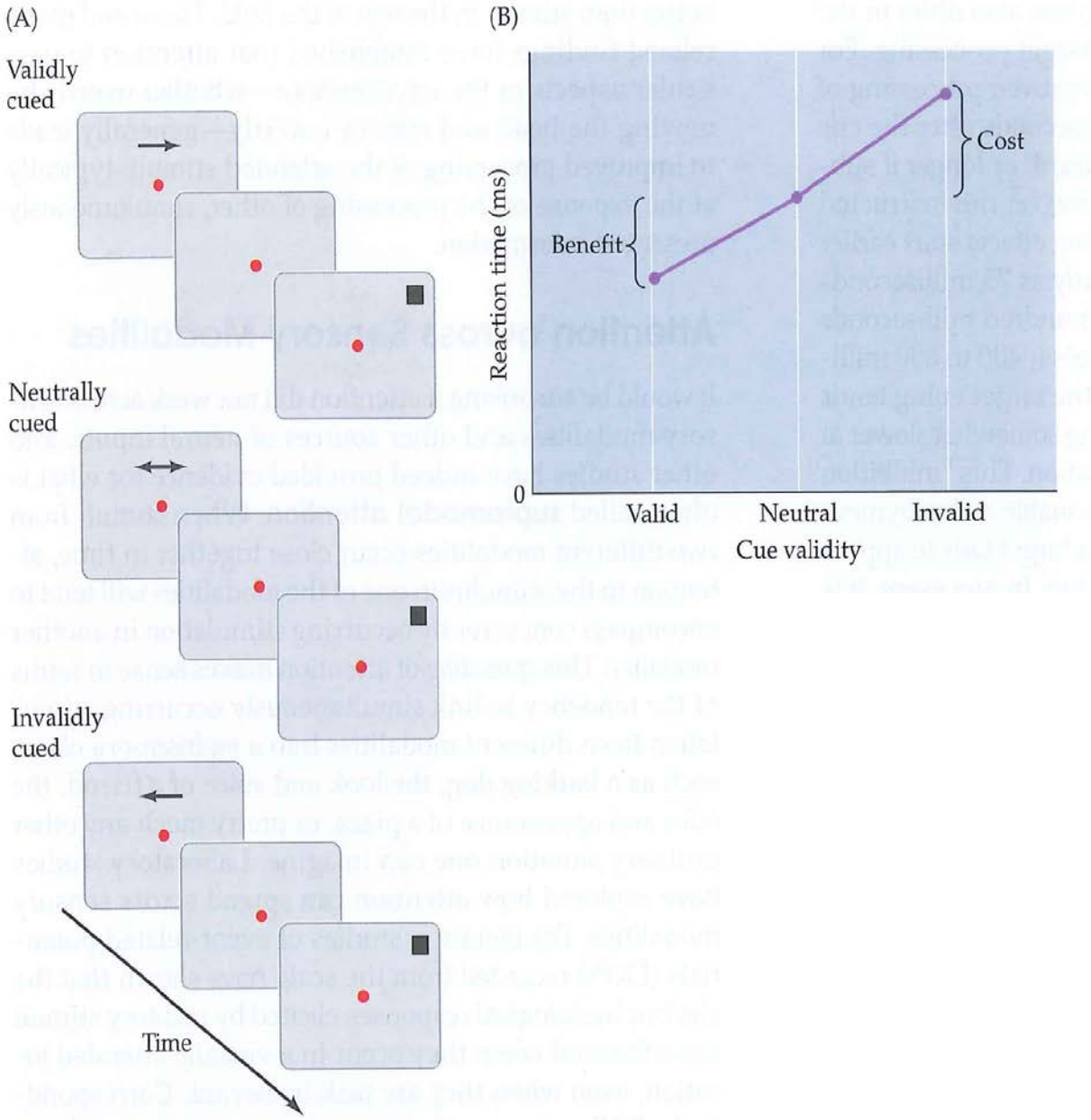
Answer not necessarily unique!

Other movements

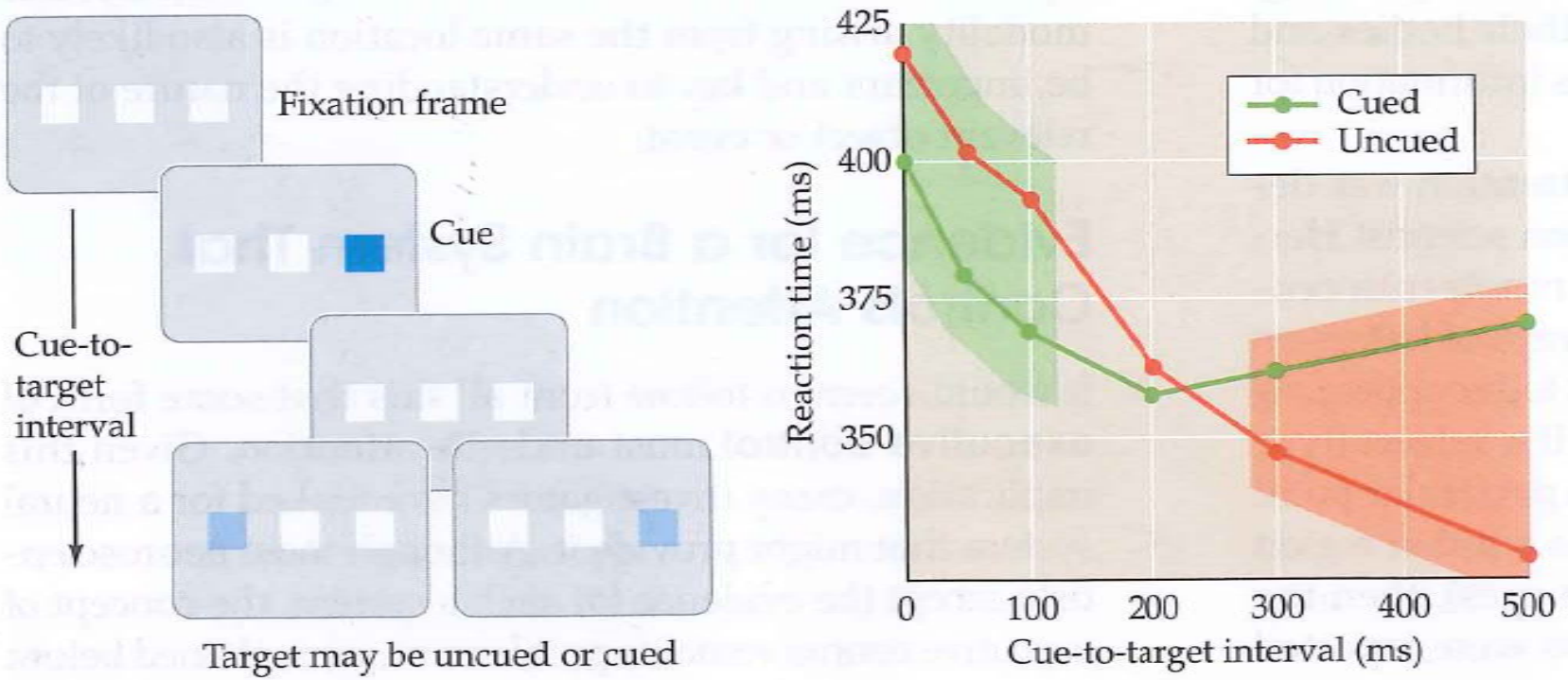
Convergence/Divergence

Accomodation

Posner Endogenous attention

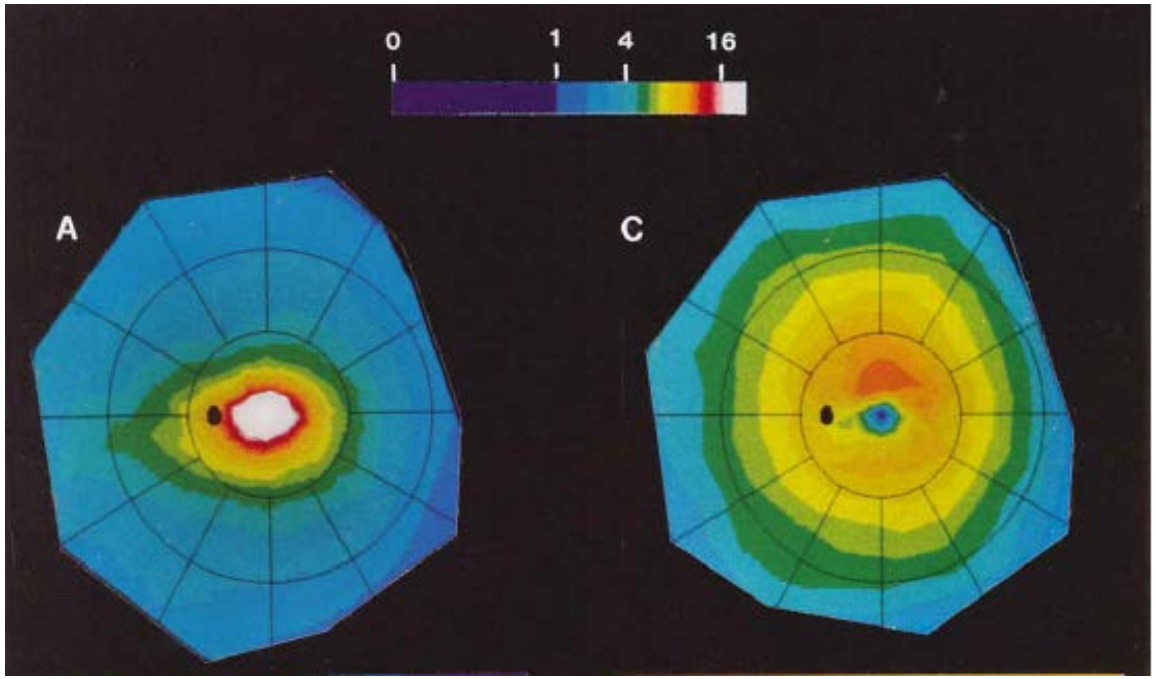


Posner Exogenous attention

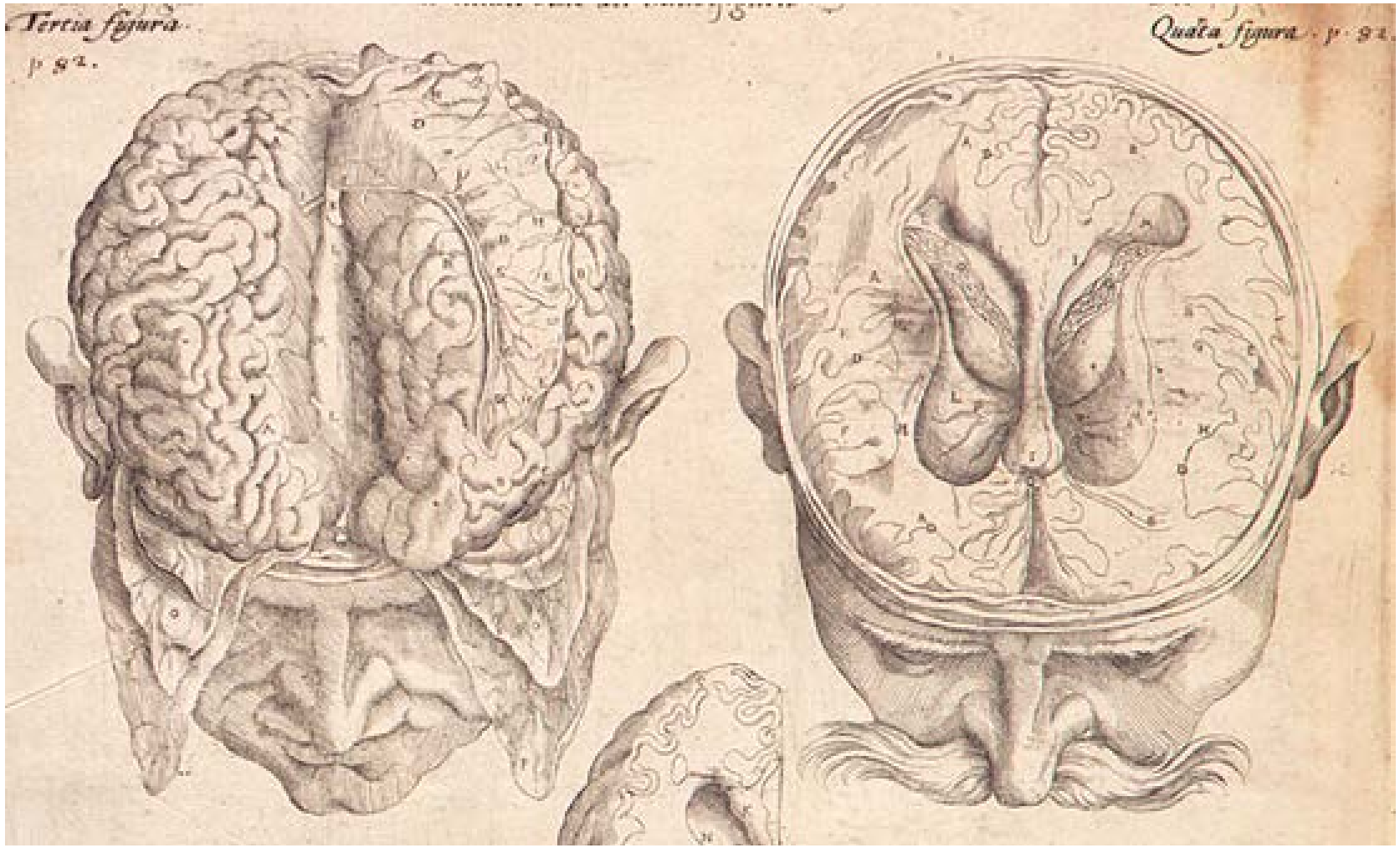


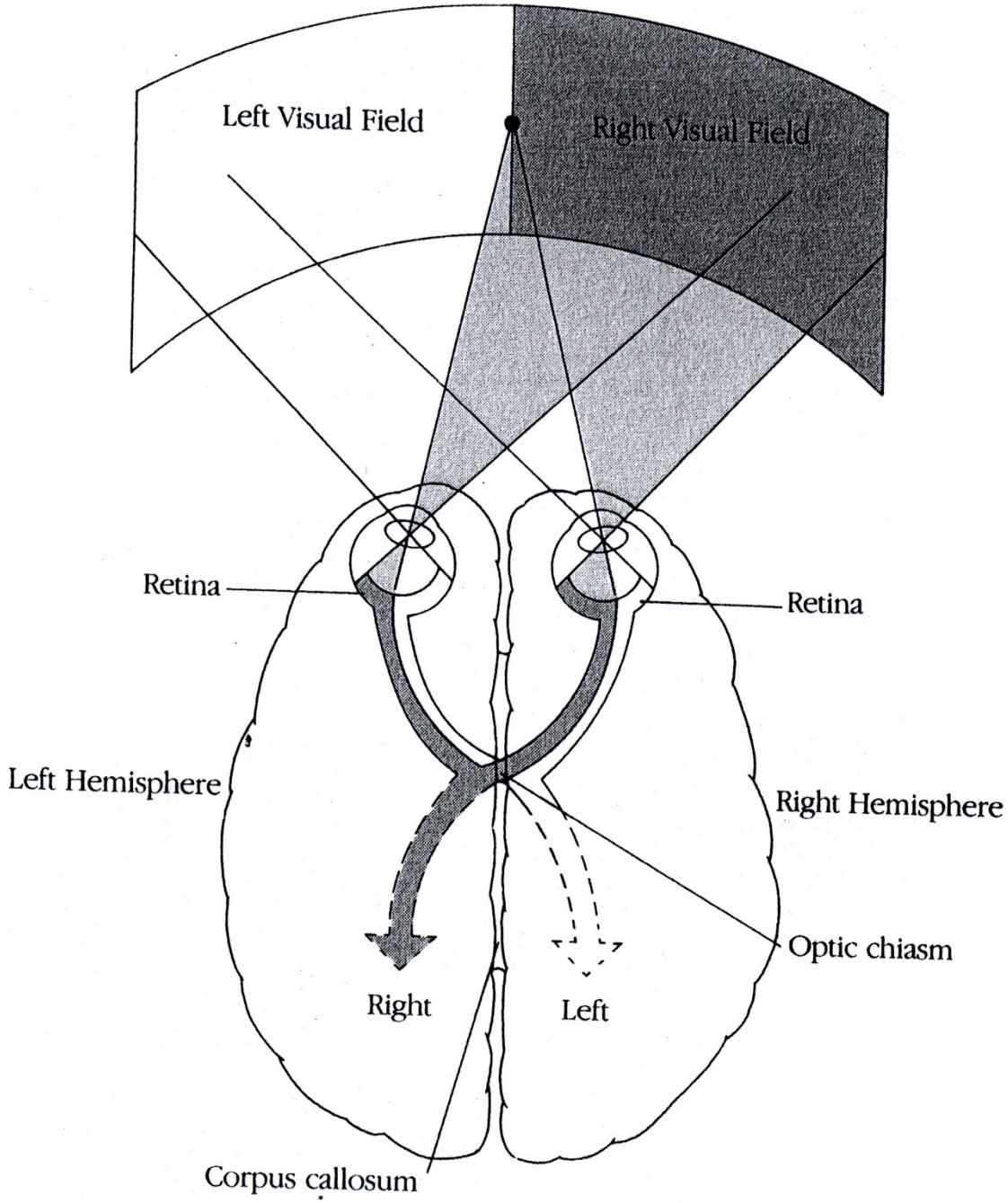
Saccades and attention

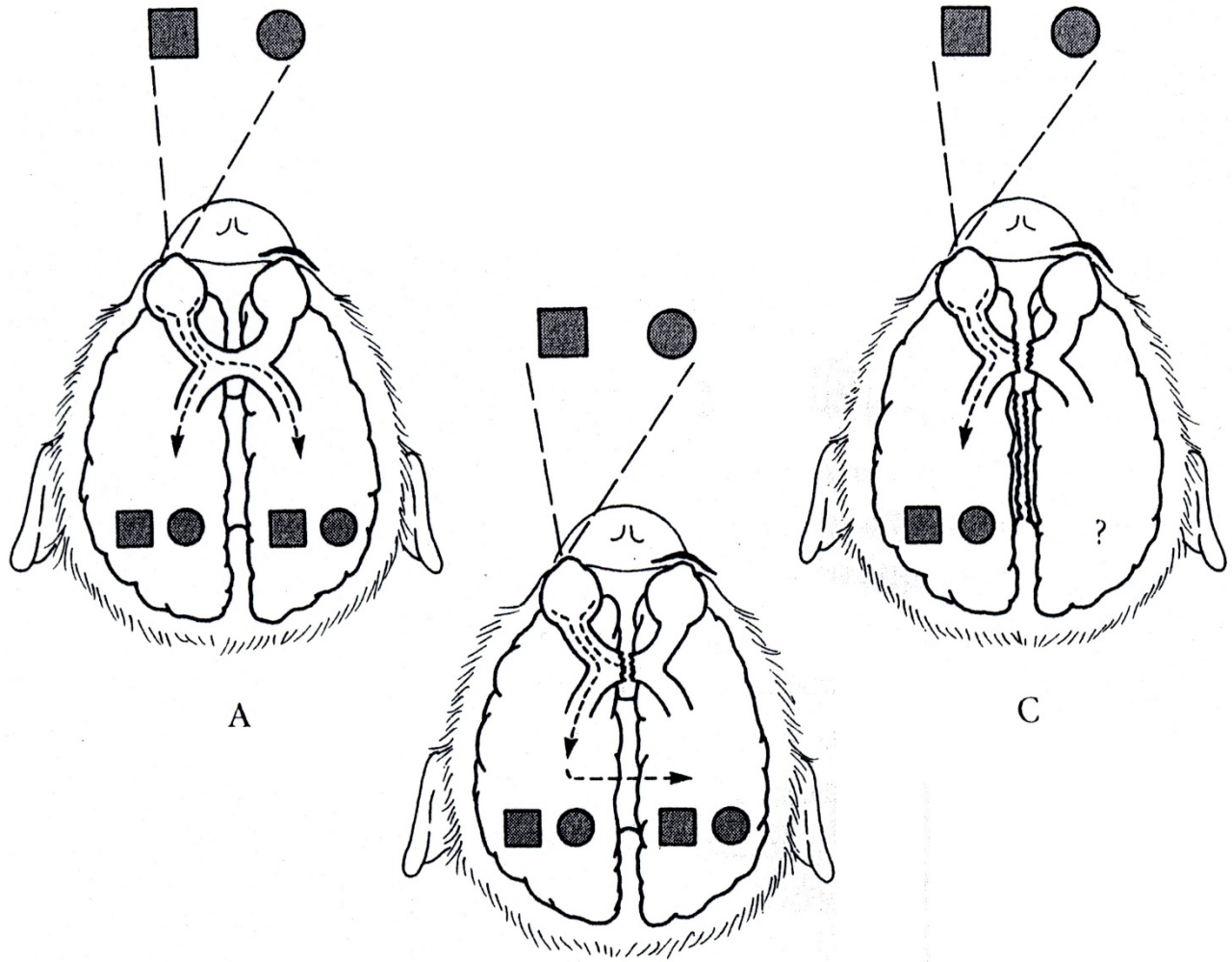
- When making a saccade, attention is directed to the saccade's target. This appears to always happen, whether we want it or not.
- At least some allocations of covert attention are reflected in the pattern of microsaccades.

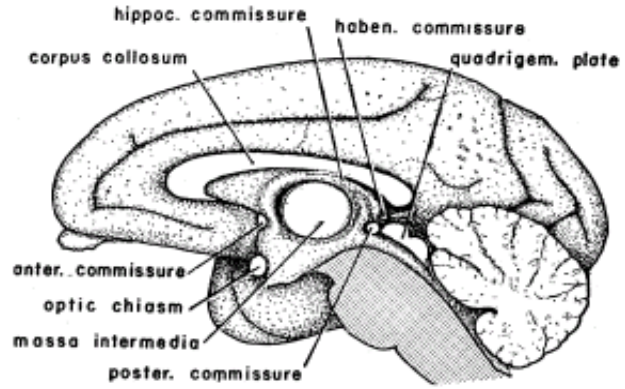


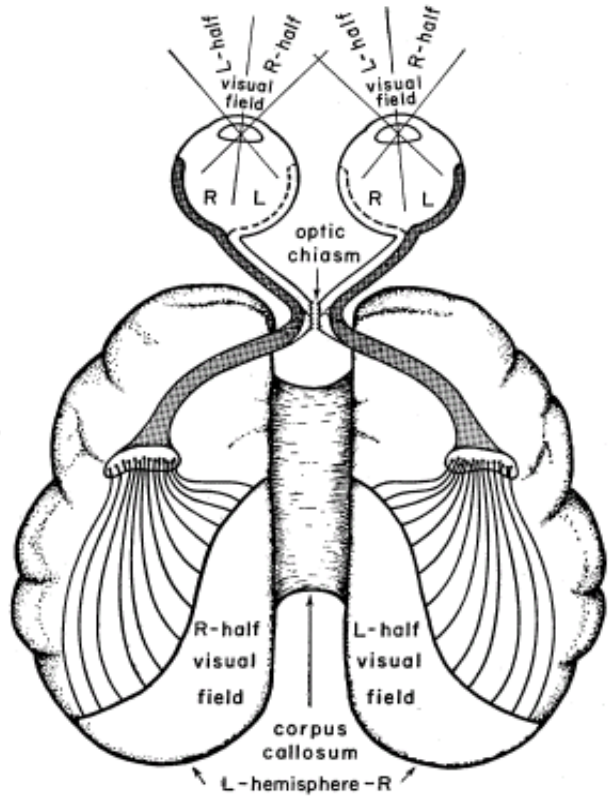
Packer Hendrickson Curcio J Comp Neurol 1989


Tertia figura.
p. 82.
Quarta figura. p. 82.

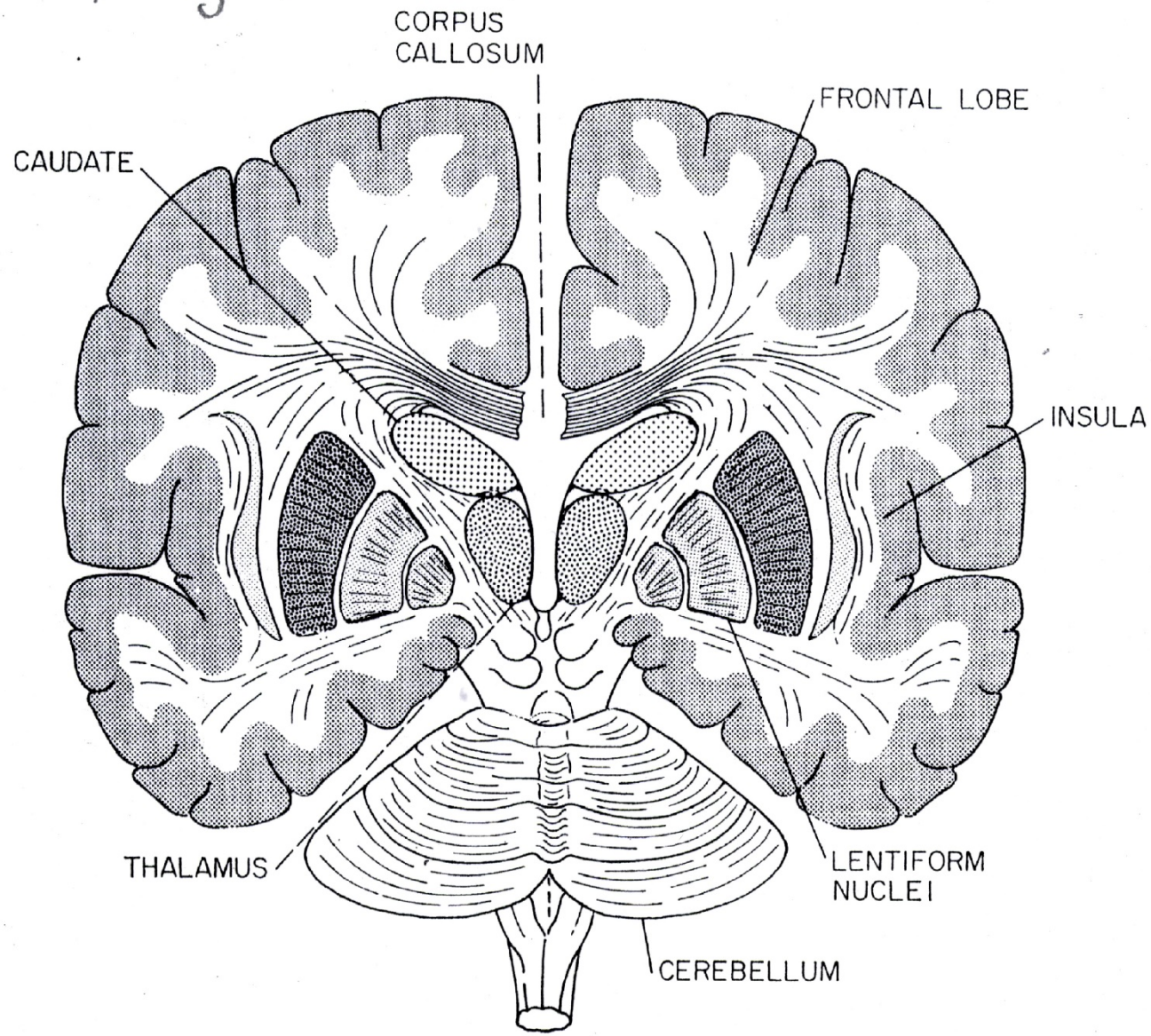

Left Visual Field
Right Visual Field
Retina
Retina
Left Hemisphere
Right Hemisphere
Optic chiasm
Right
Left
Corpus callosum


?
A
B
C


hippoc. commissure
haben. commissure
corpus callosum
quadrigem. plate
anter. commissure
optic chiasm
massa intermedia
poster. commissure


L-half visual field
R-half visual field
L-half visual field
R-half visual field
R
L
R
L
optic chiasm
R-half visual field
L-half visual field
corpus callosum
L-hemisphere-R

Sperry (1974)


CORPUS
CALLOSUM
FRONTAL LOBE
CAUDATE
INSULA
THALAMUS
LENTIFORM
NUCLEI
CEREBELLUM

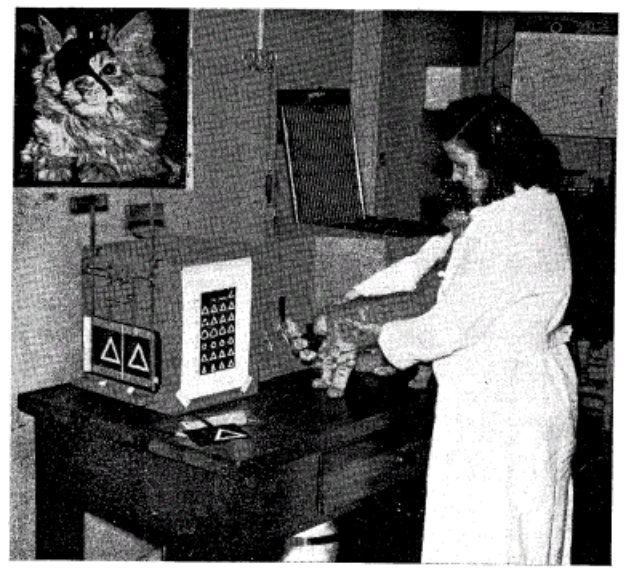


Fig. 3. Visual training apparatus. The cat, placed in the darkened box, obtains a food reward by pushing on the correct one of two translucent patterns interchanged in doors at the end of the box. Inset shows enlargement of the cat wearing the eye patch devised by Myers. Made of rubber, it is simply turned inside out to cover the other eye.

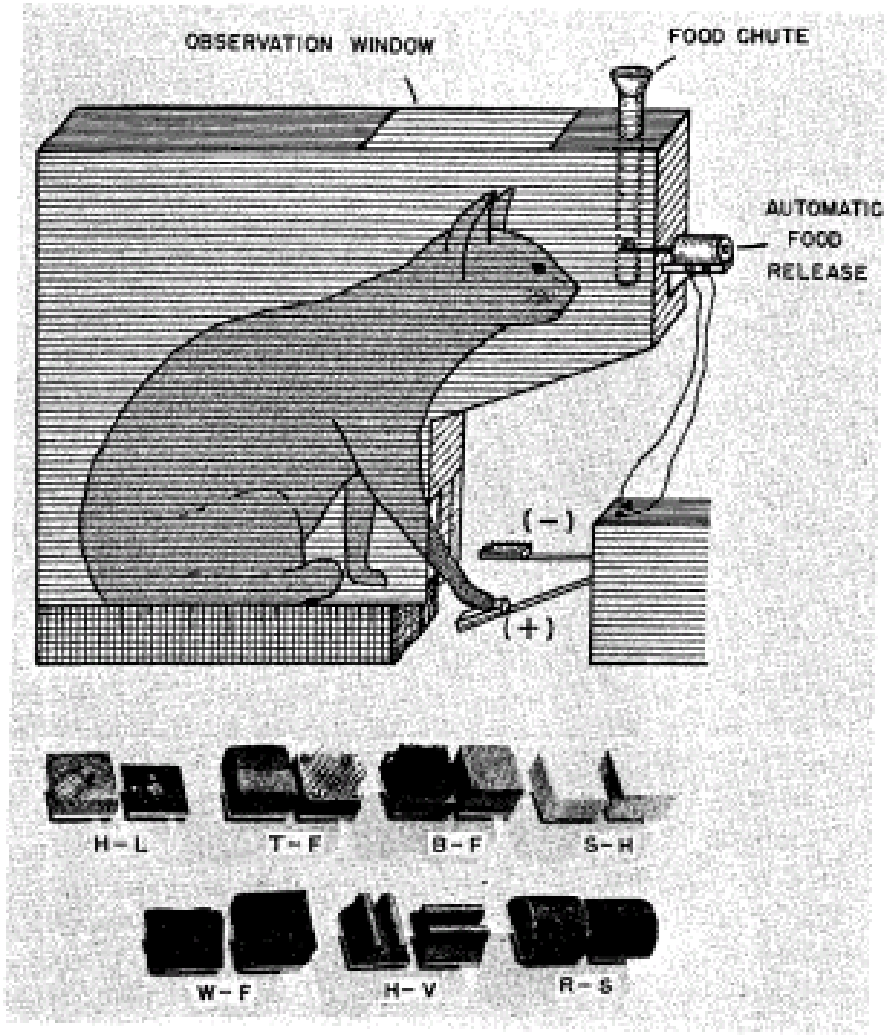
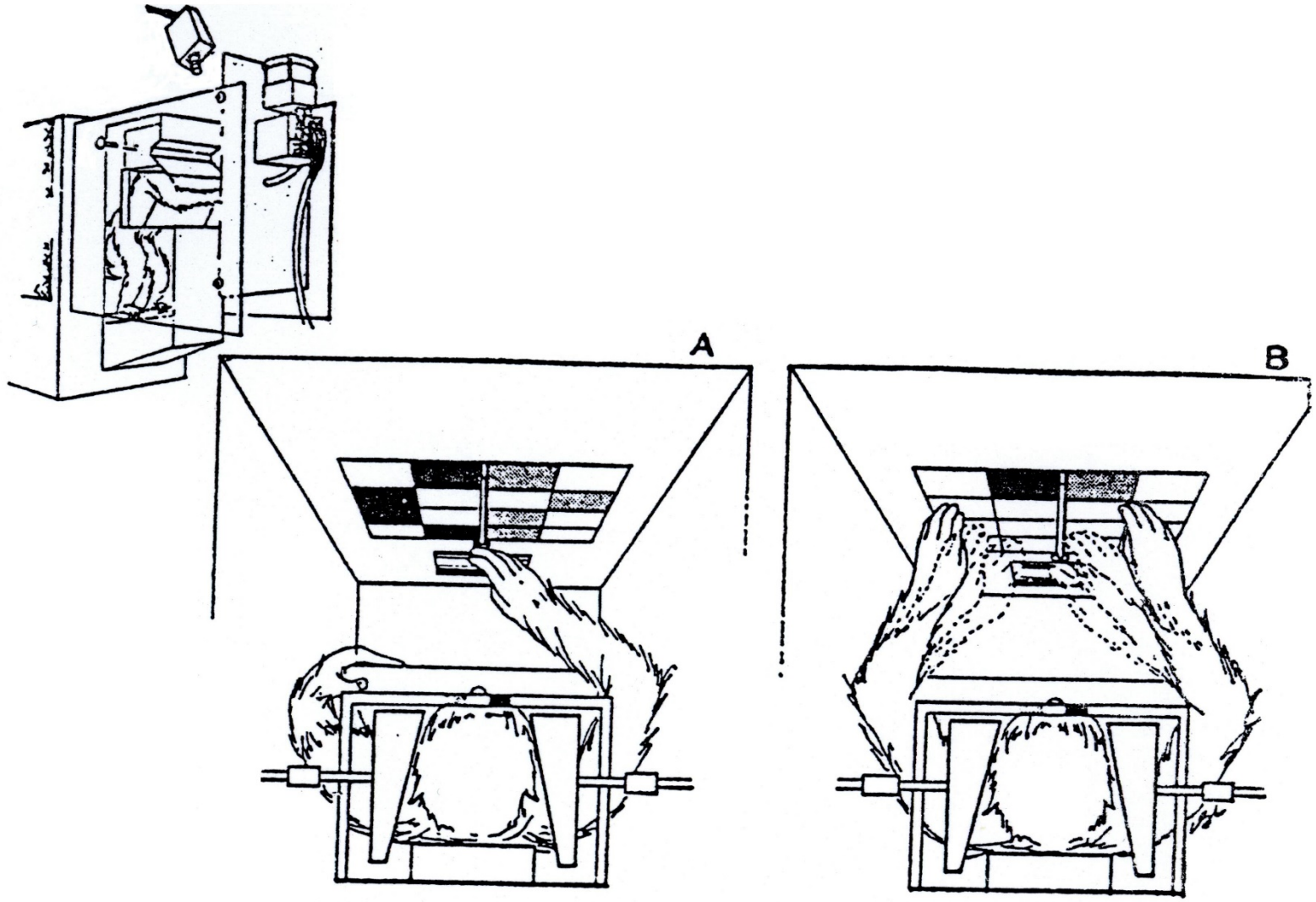
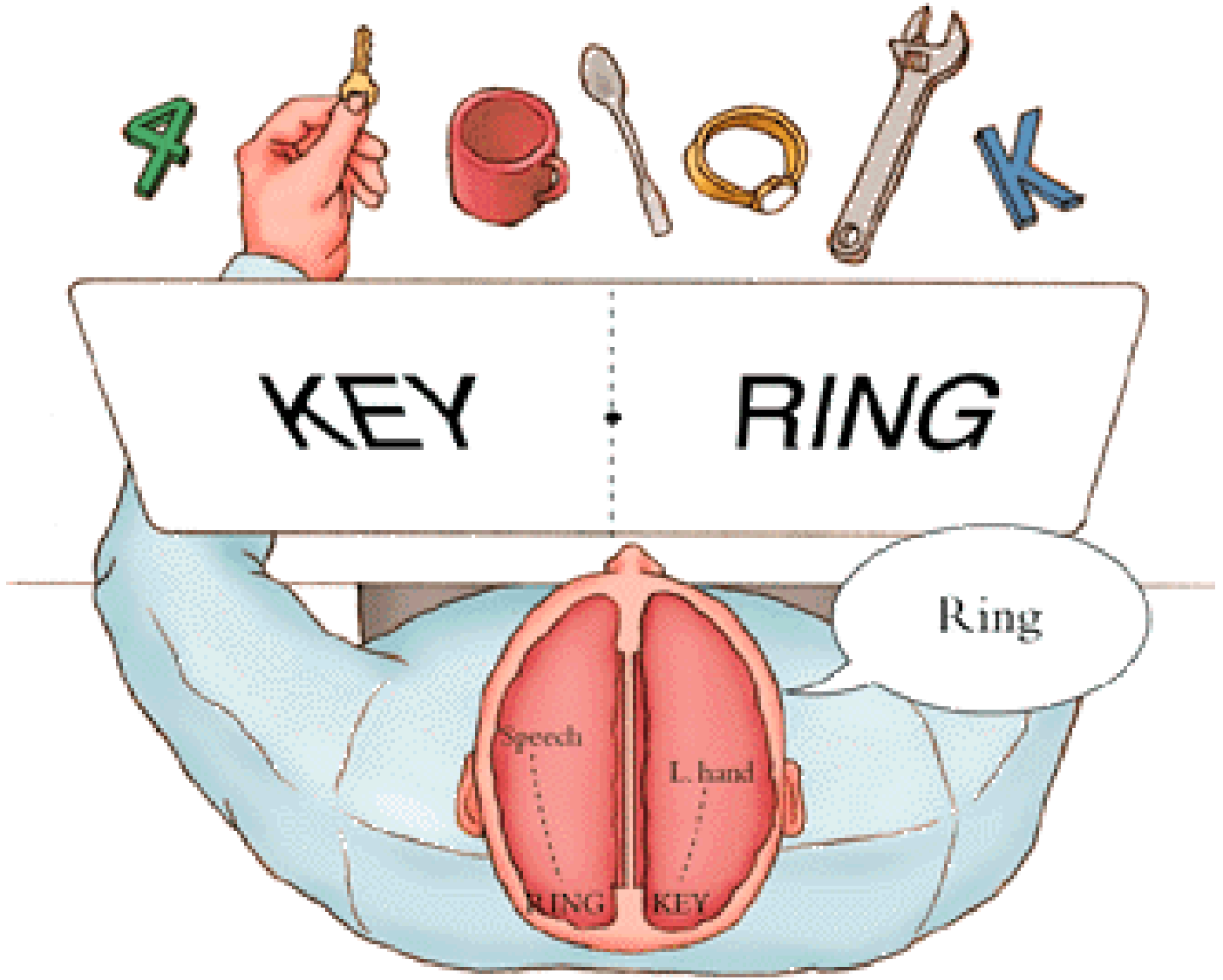
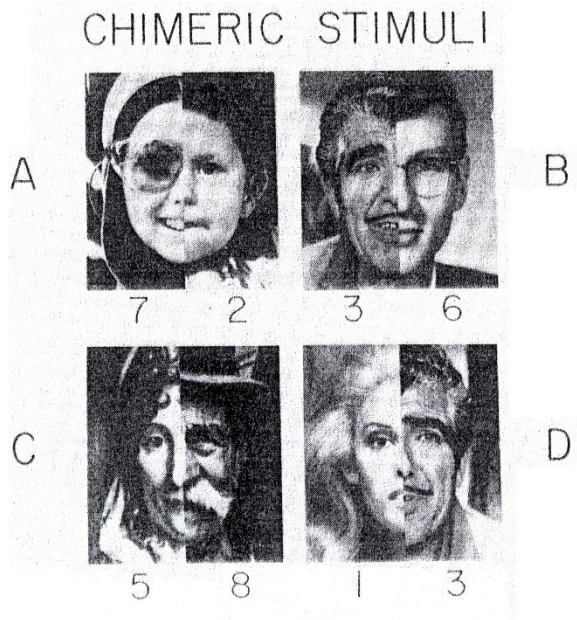


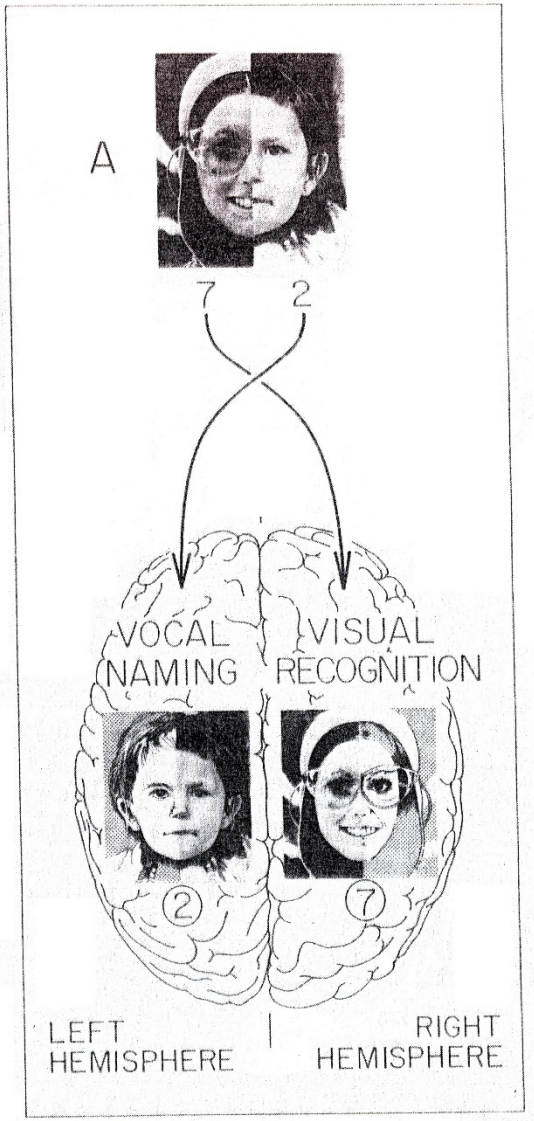
Fig. 5. Simplified diagram of the pedal-pressing apparatus for training in tactile discrimination. Pairs of interchangeable pedal mountings are shown at bottom (*7*, *15*).


A
B

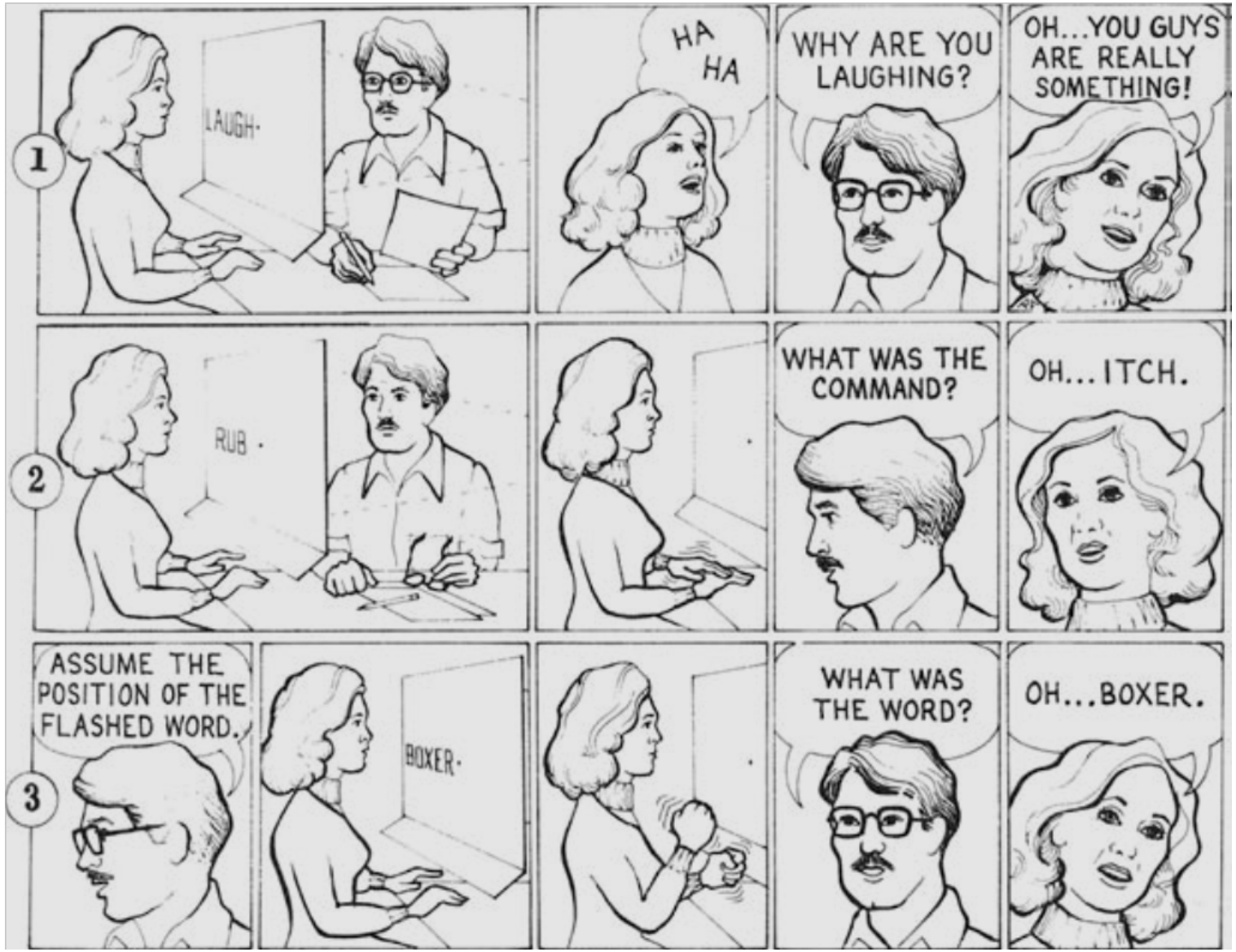

KEY
RING
Ring
Speech
L. hand
RING
KEY


1
2
3
4
5
6
7
8


CHIMERIC STIMULI
A
B
C
D
7 2
3 6
5 8
1 3


A
7 2
VOCAL NAMING
VISUAL RECOGNITION
②
⑦
LEFT HEMISPHERE
RIGHT HEMISPHERE

Split Brain: confabulation



Gazzaniga 1978: The integrated mind

FIGURE 41. When a series of commands were presented to the right hemisphere, each evoked a response. Although the left hemisphere did not know what the command was, it attempted to account for the response. When the command was *laugh* or *rub,* the left hemisphere instantly " filled in." When the response was less equivocal, the reason generated for the action was quite accurate, as with the word *boxer.*

Split Brain: Language in the right hemisphere

Gazzaniga 1978: The integrated mind

FIGURE 29. Using the methods developed by Pre mack for the chimpanzee, the global aphasic also learned to "write" simple sentences. Here, while the examiner carries out a simple act of stirring the water, the subject is about to arrange the appropriate symbols in a way that effectively says, "Mike stirs water."

Split Brain: Unity of the mind

Gazzaniga 1978: The integrated mind