

What can we learn from barn owls or Why study an exotic animal



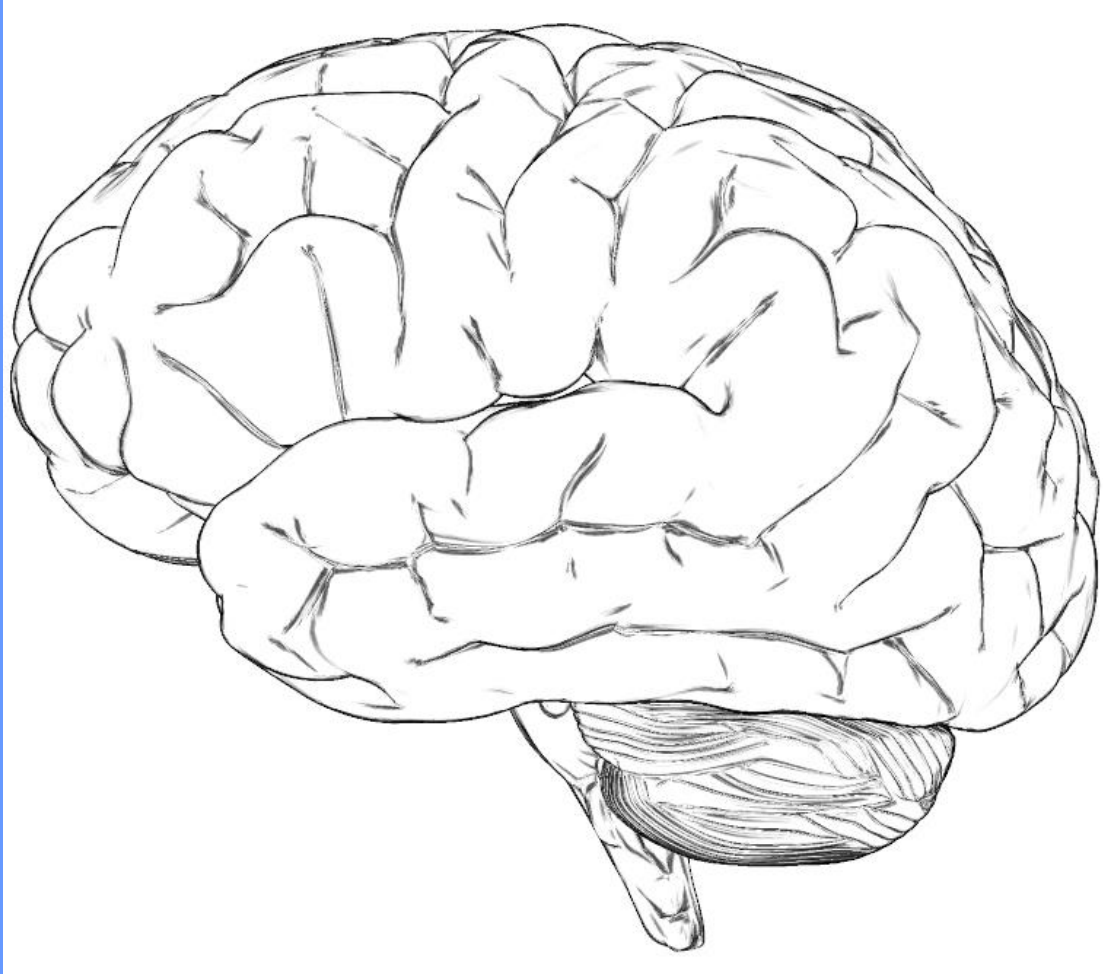
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<https://yoramg.technion.ac.il/>



Neuroscience – The quest for understanding how the brain works



Which level shall we study the brain?

Brains have been shaped through evolution to optimize adaptive control of behavior



The appropriate level of investigation

If we want to explain how the brain works in the natural environment, the answer needs a level of explanation that is above that of molecular biology. The appropriate level is that of behavioral neuroscience.

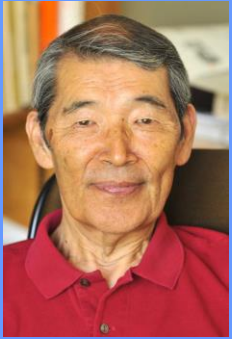


Which model system?

Animals that lend themselves to combined behavioral and neurophysiological work.

Specialist or Generalist?





Mark Konishi 1933-2020



- **Sound localization**
- **Sensory maps plasticity and development**
- **Spatial attention**
- **Multisensory integration**
- **Spatial processing**

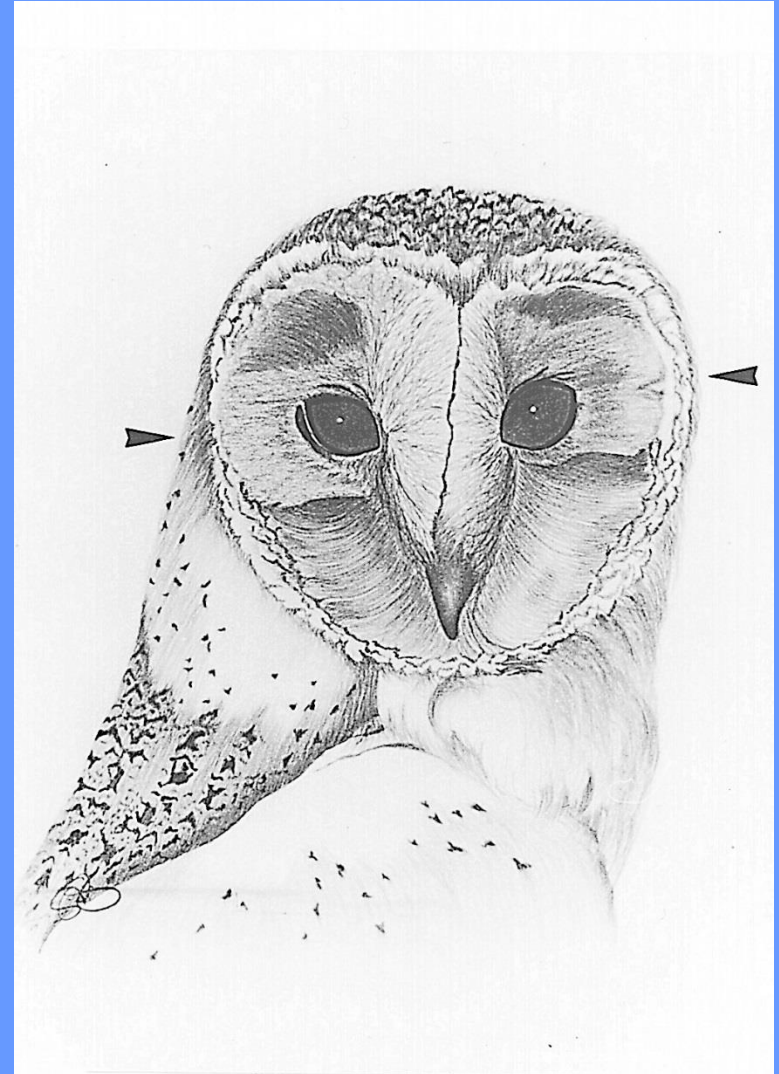
Barn owls as model system for sound localization

- Facial ruff serves as a sound amplifier



Barn owls as model system for sound localization

- Facial ruff serves as a sound amplifier
- Asymmetric ears allow for an increased spatial resolution in the vertical plane



artist: Susan Mauersberg

Barn owls as model system for sound localization

- Facial ruff serves as a sound amplifier
- Asymmetric ears allow for an increased spatial resolution in the vertical plane
- Comb-like structures at the leading edge of the wing reduce noise during flight



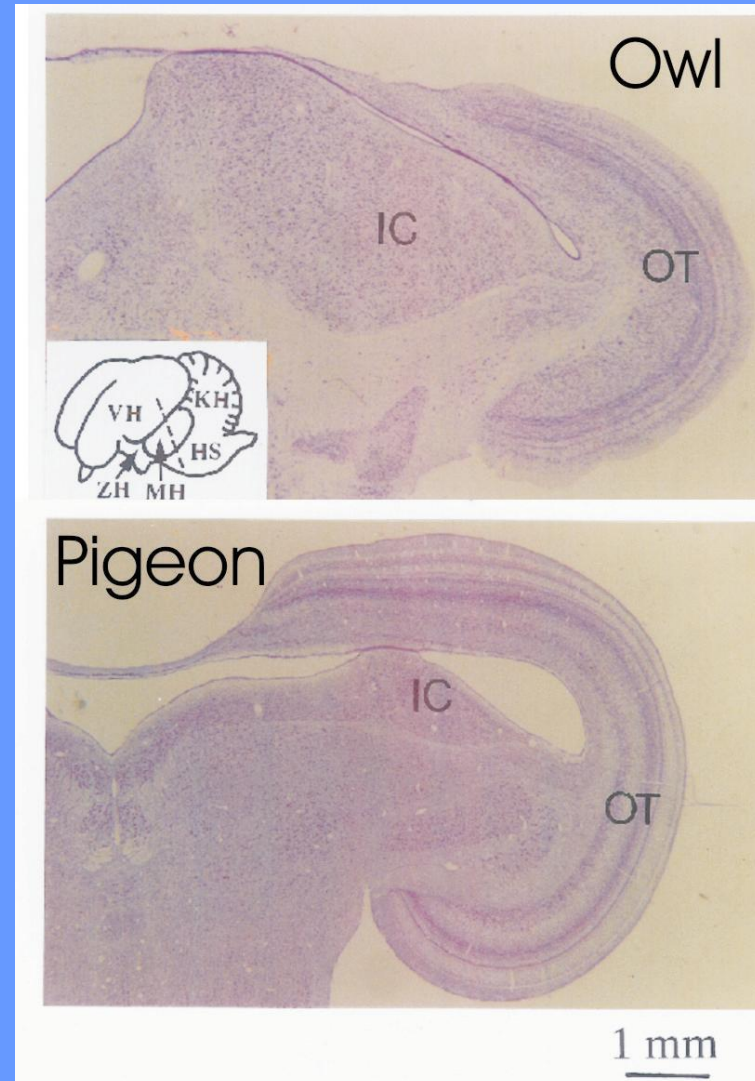
Barn owls as model system for sound localization

Facial ruff serves as a •
sound amplifier

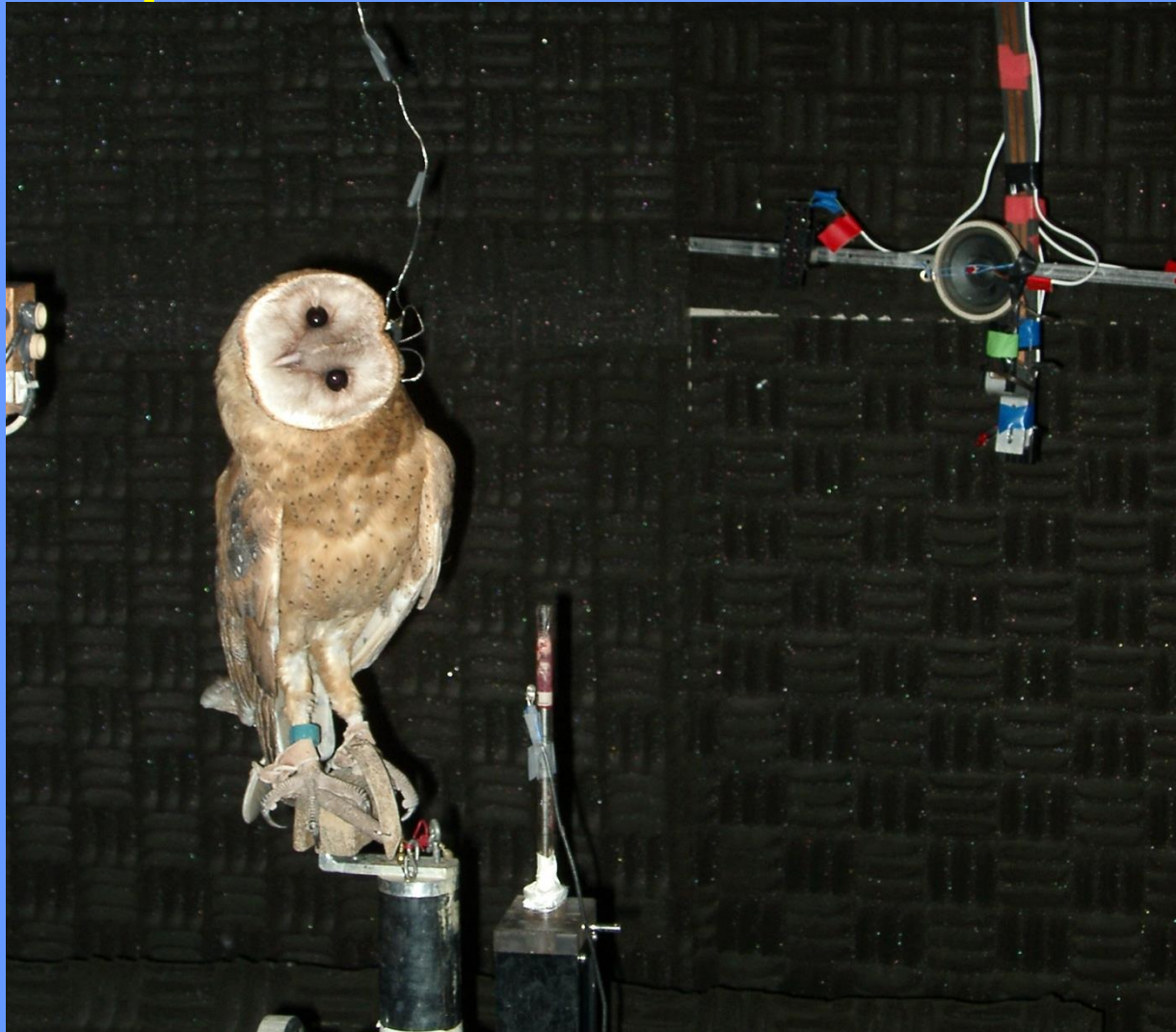
Asymmetric ears allow for •
an increased spatial
resolution in the vertical
plane

Comb-like structures at the •
leading edge of the wing
reduce noise during flight

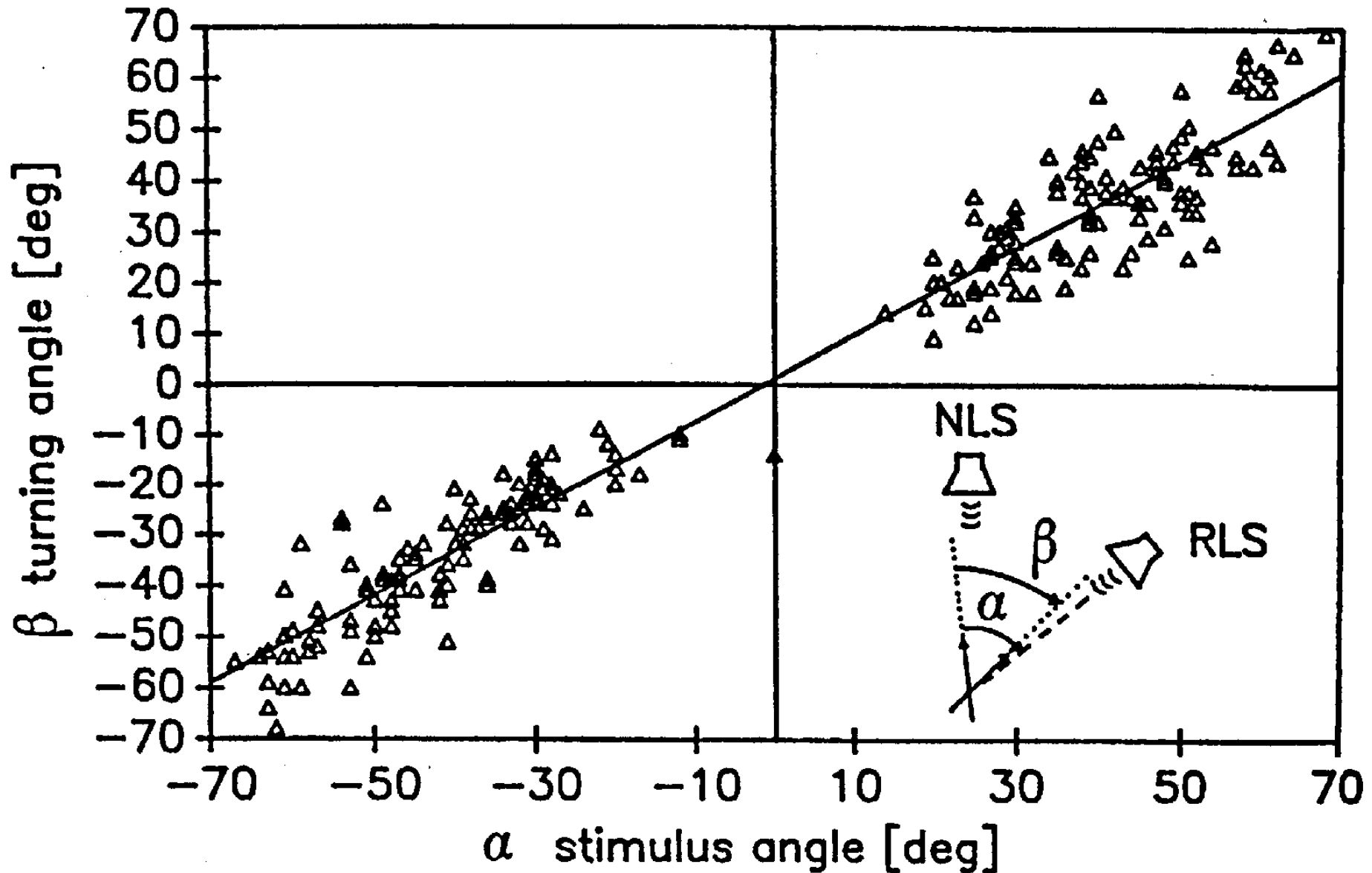
Brain structures involved •
in the analysis of sound
are enlarged



Performing a psychoacoustic experiment with an owl



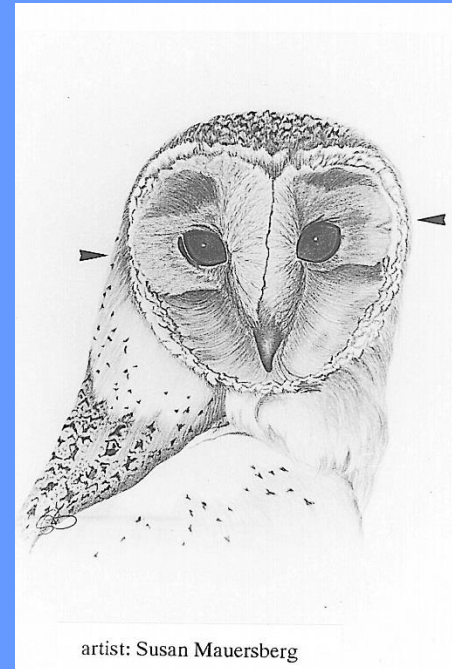
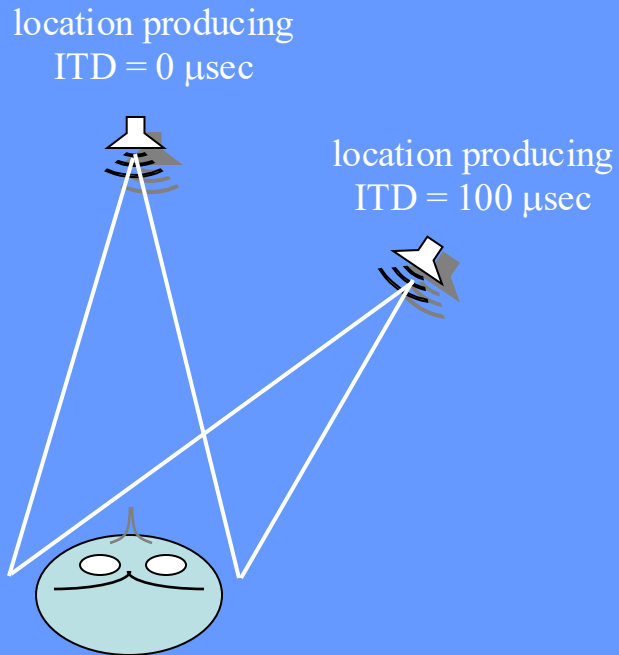
Sound-localization with free-field stimuli



- The auditory localization cues:

- ITD - horizontal

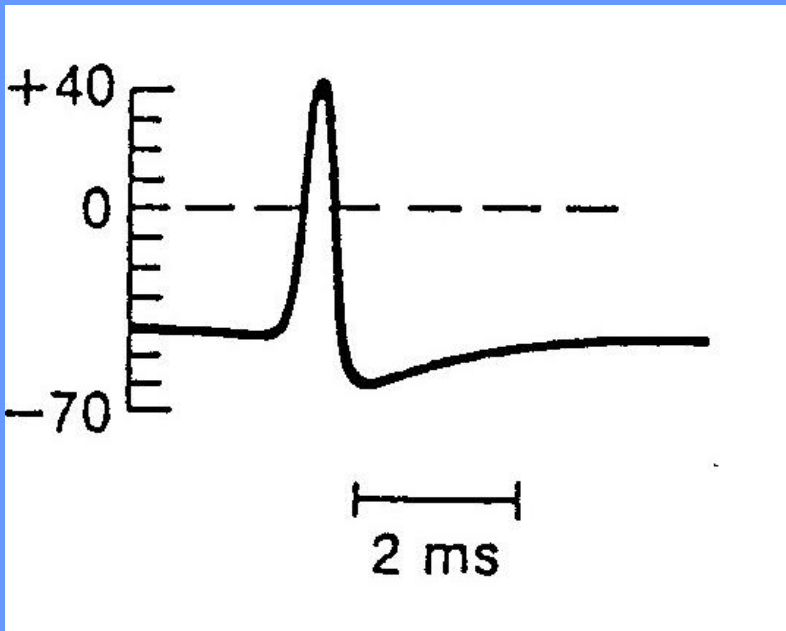
- ILD - vertical



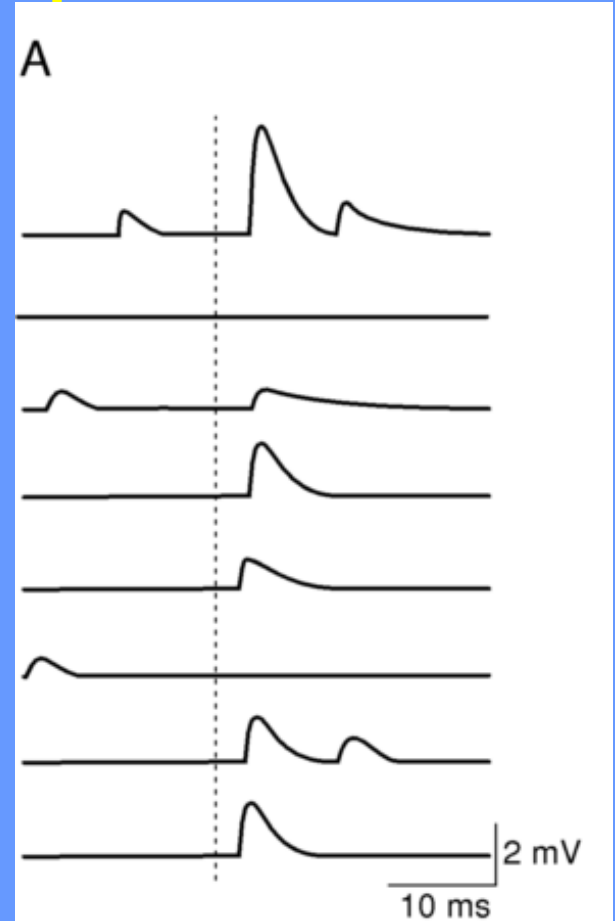
**Precision of sound localization in barn owls
may be as good as 3 deg which corresponds to
6-10 μ s.**



Action potential



Postsynaptic potentials



These signals are the “language” of neural processing.

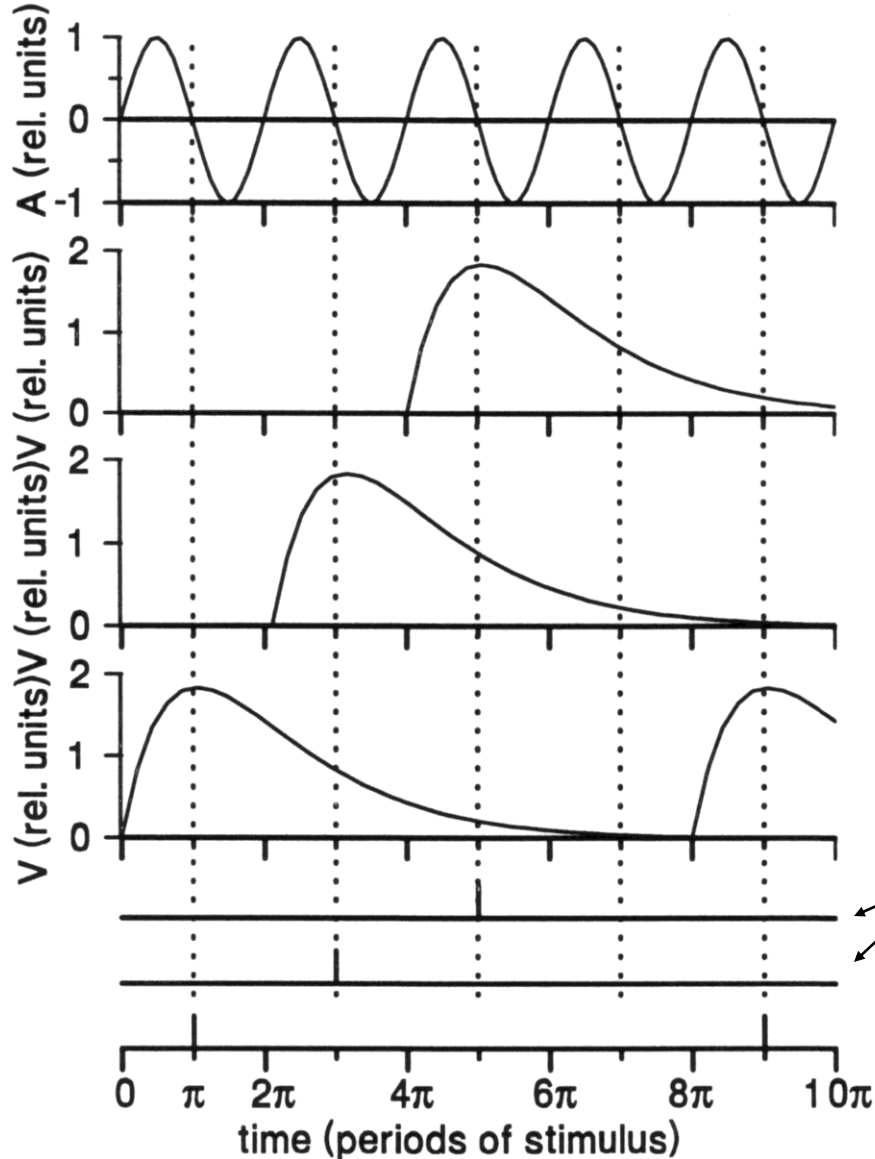
Durations of events

- Typical duration of action potential: 1ms
- Typical duration of post-synaptic potentials: 5-10 ms
- Precision of sound localization by interaural time difference: 6-10 μ s

What has to be explained is

Factor of 500-1000

The principle of phase locking as a means to conserve time



Sinusoidal signal

Presumed resulting post-synaptic potential

Registered signal in computer

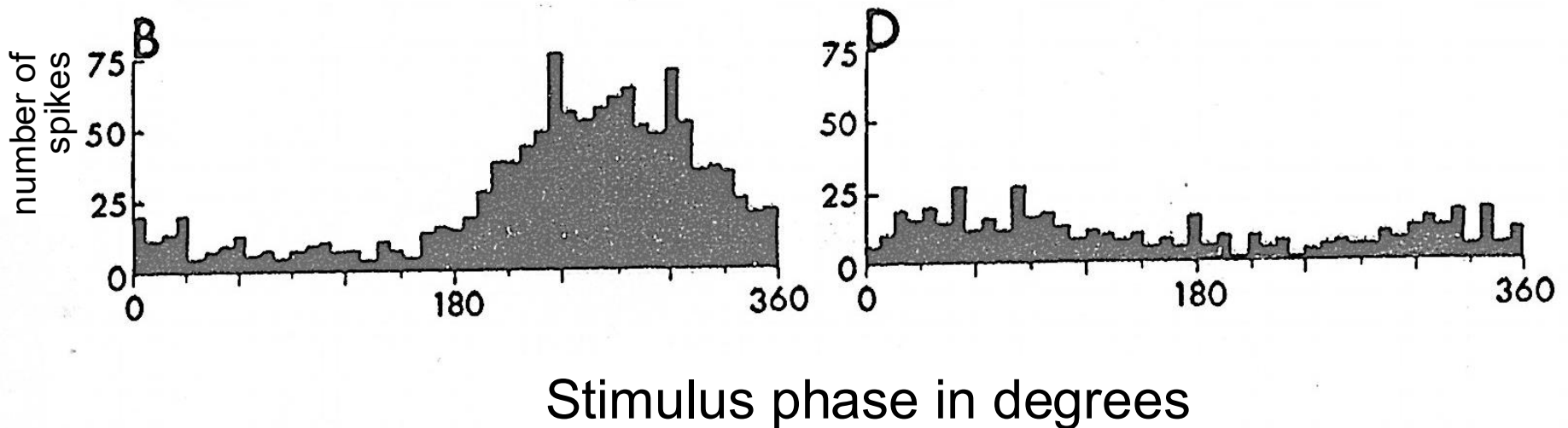
Note that in this example the response always occurs at a phase of 180 degrees.

Phase locking in the barn owl

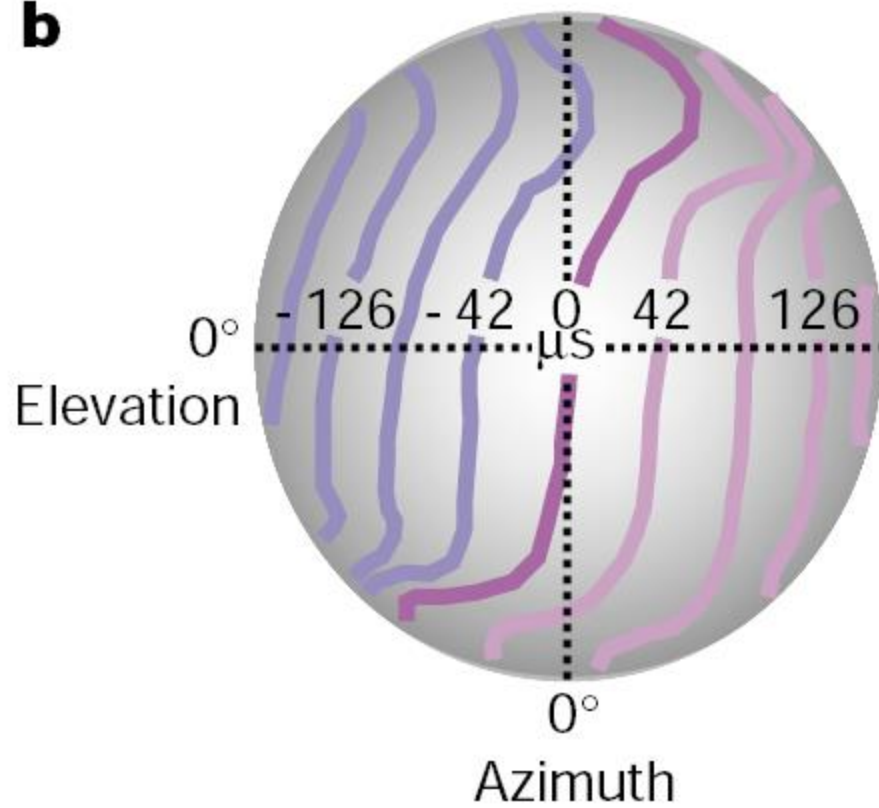
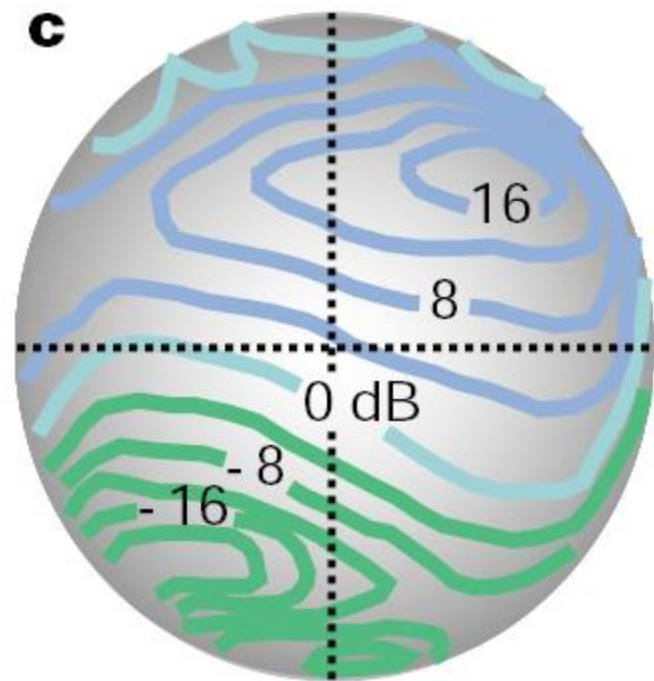
Phase locking can be measured by plotting spike arrival times with respect to the period of the stimulus tone.

5 kHz Period 200 μ s

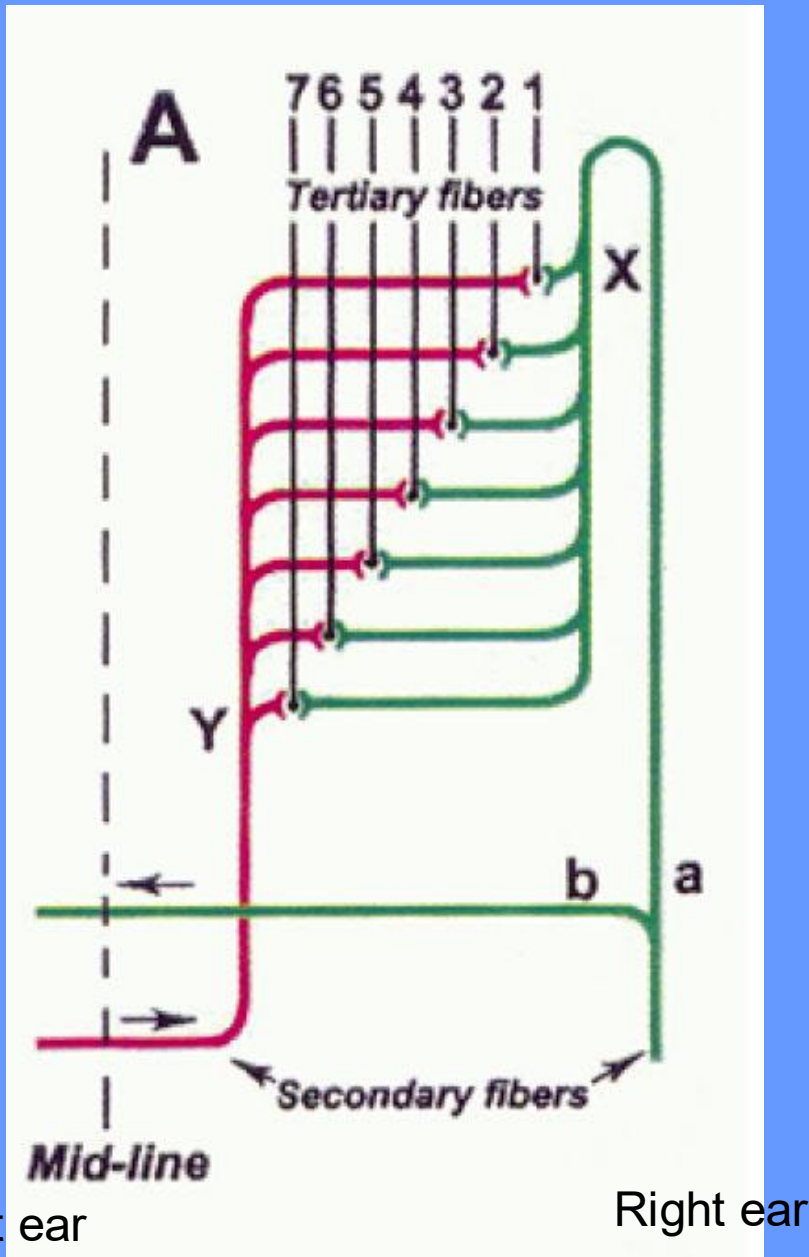
9 kHz Period 111 μ s



Precision of phase locking is 35 μ s at 5 kHz (Koeppel (1997)).

b**c**

Jeffereess model (1948)

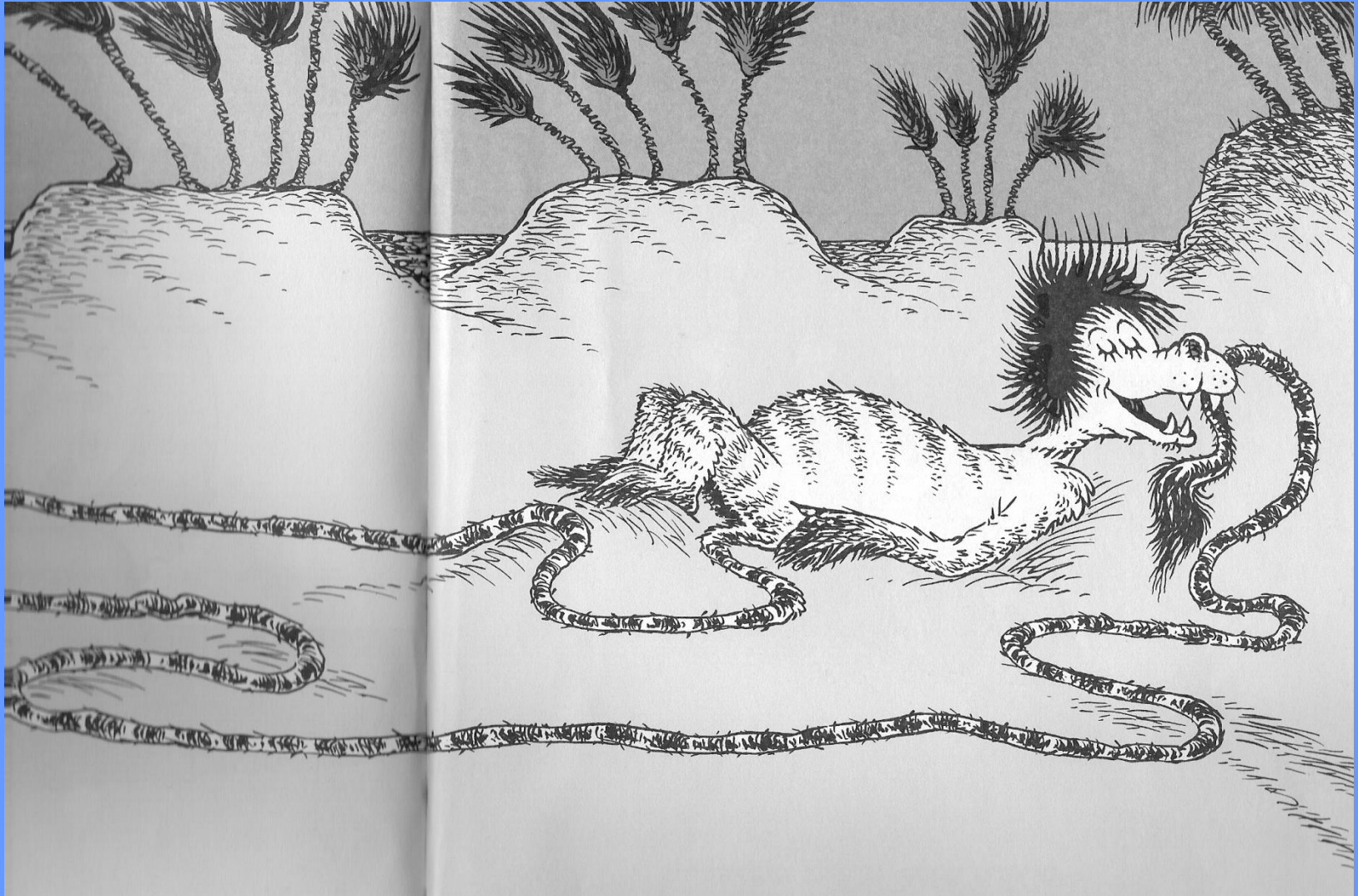


$$A_i + N_i = A_c + N_c$$

$$A_i - A_c = N_i - N_c$$

ITD

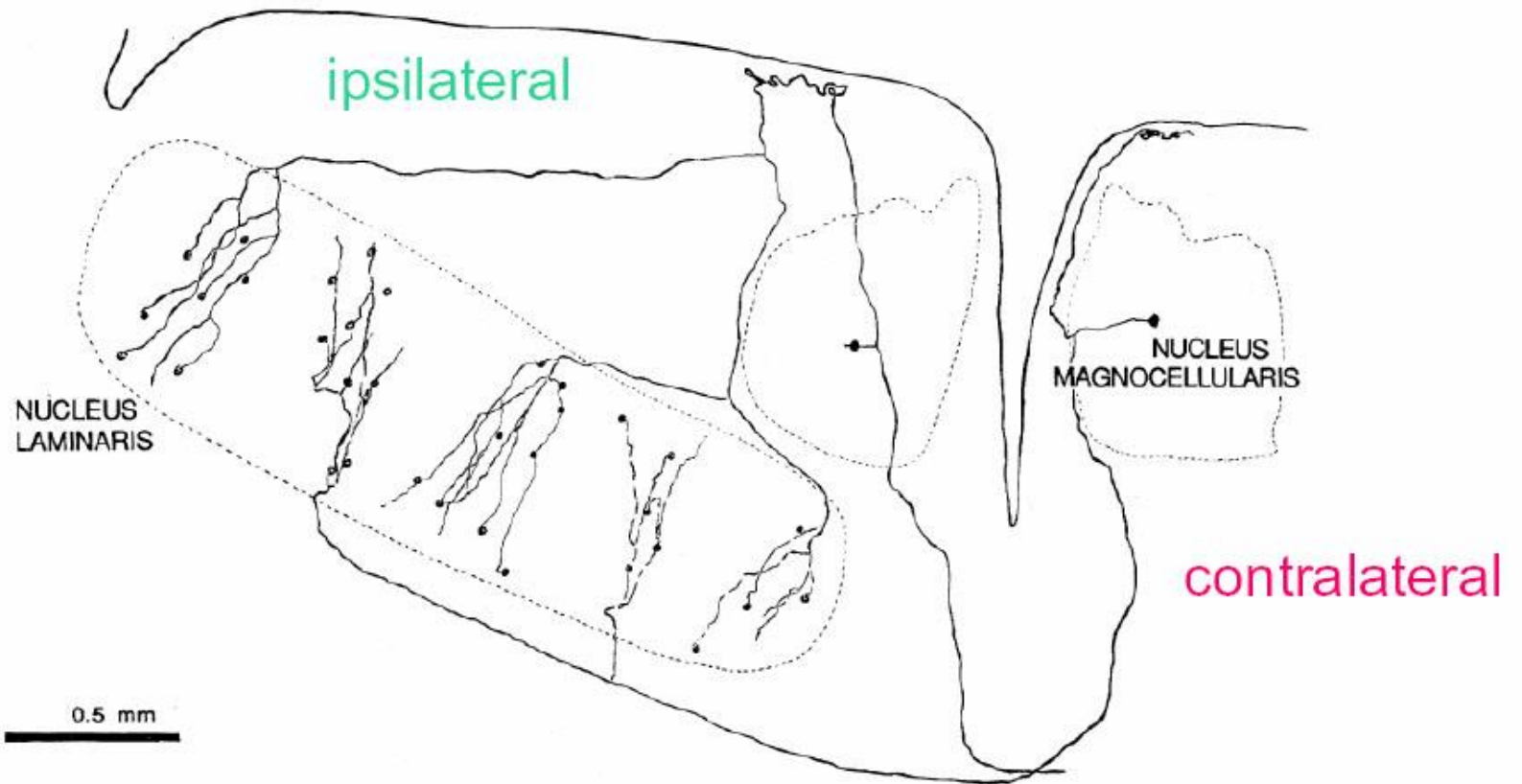
Delay lines



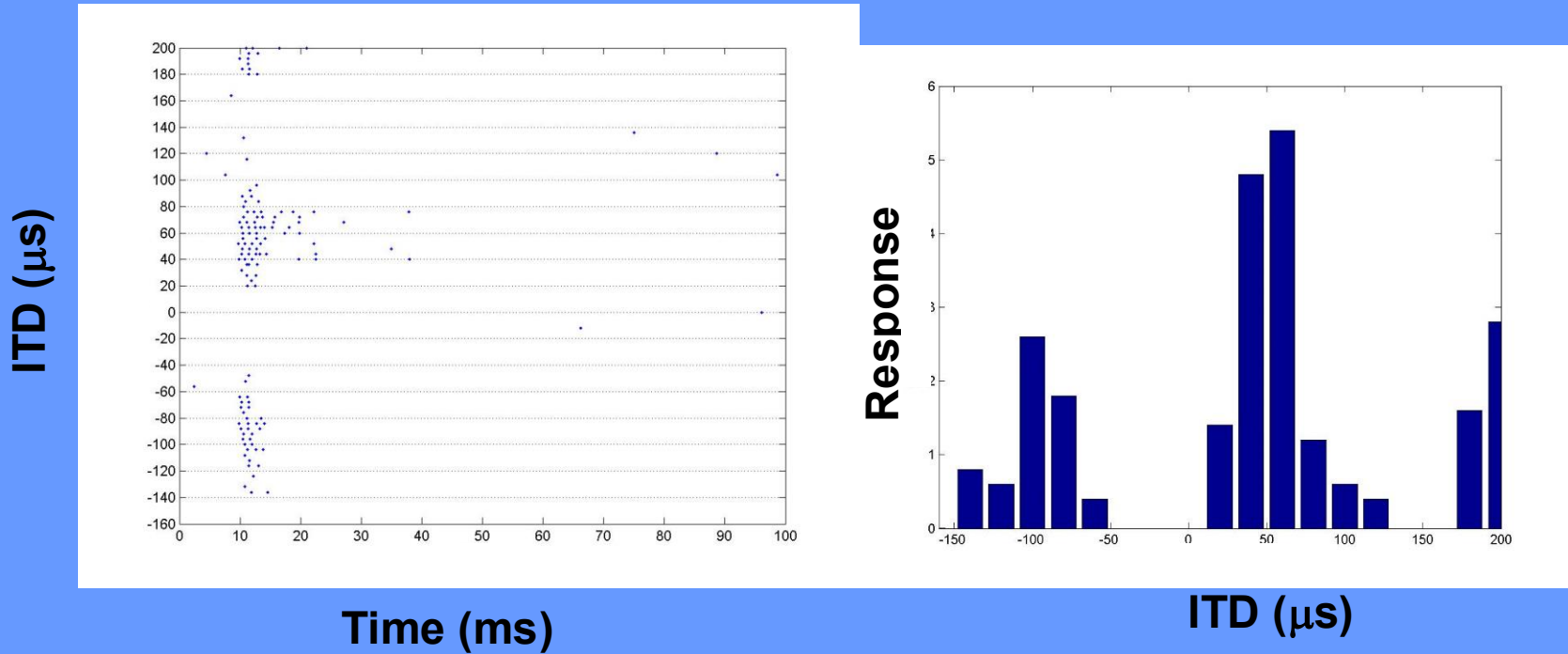
Does the brain compute ITDs as
Jefferees suggested?

Nucleus Laminaris / Medial Superior Olive -
sites of binaural convergence

Anatomical evidence for Jeffress model



ITD curves in Nucleus Laminaris



SOUND LOCALIZATION

GAZE CONTROL

Forebrain

Sensory/Association
Areas

Archistriatum
(FEF)

Thalamus

Ovoidalis
(MGN)

Rotundus
(Pulvinar)

Midbrain

Inferior
Colliculus
central n.

Inferior
Colliculus
external n.

Optic Tectum
(SC)

VLVp
(LSO/DNLL)

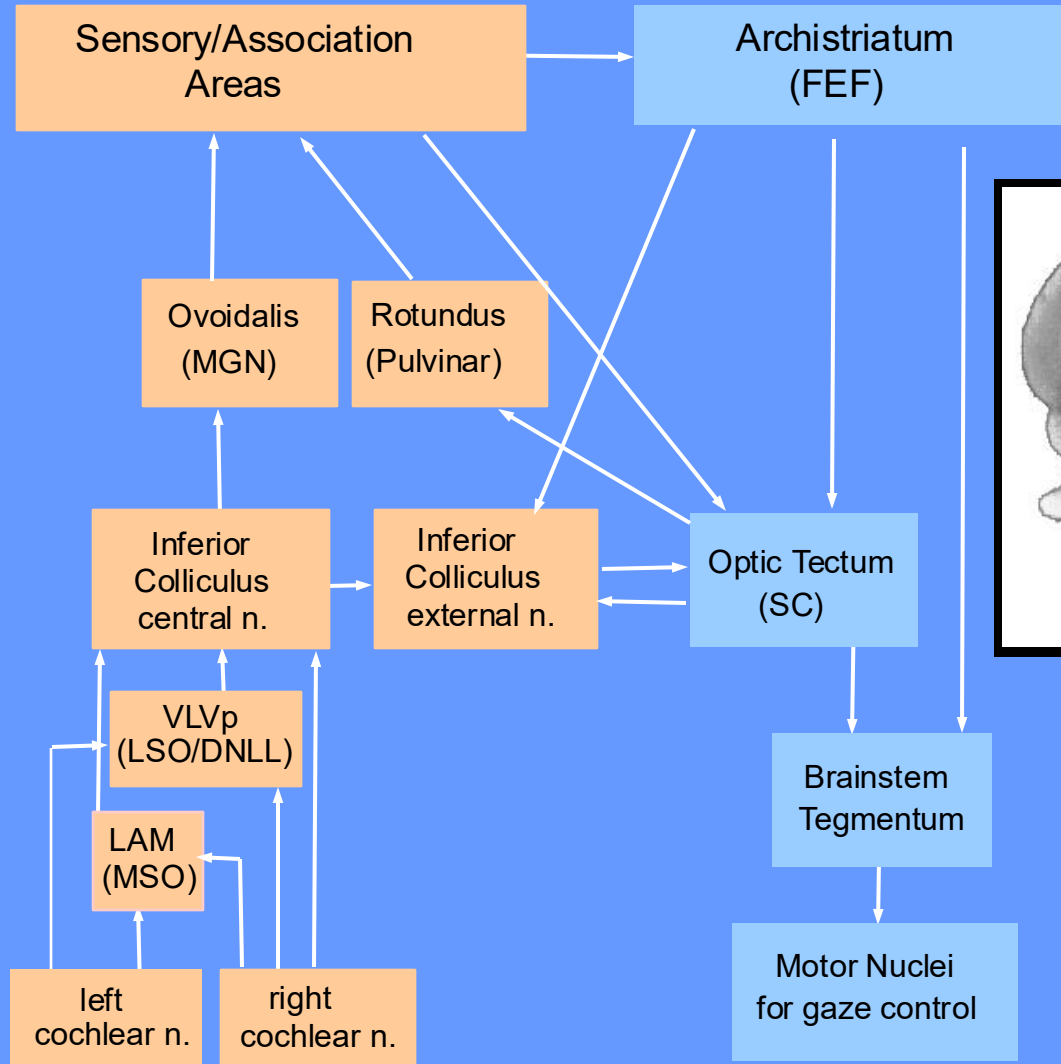
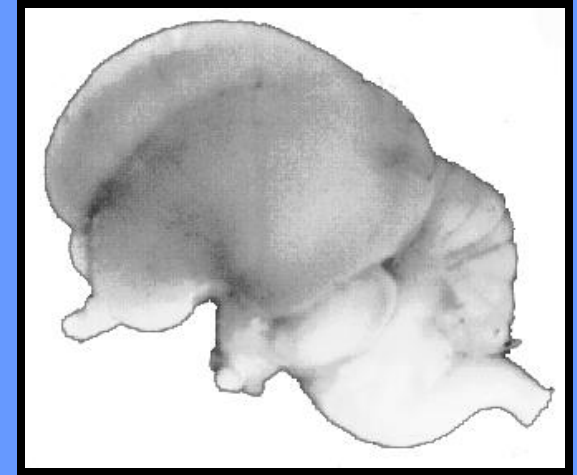
LAM
(MSO)

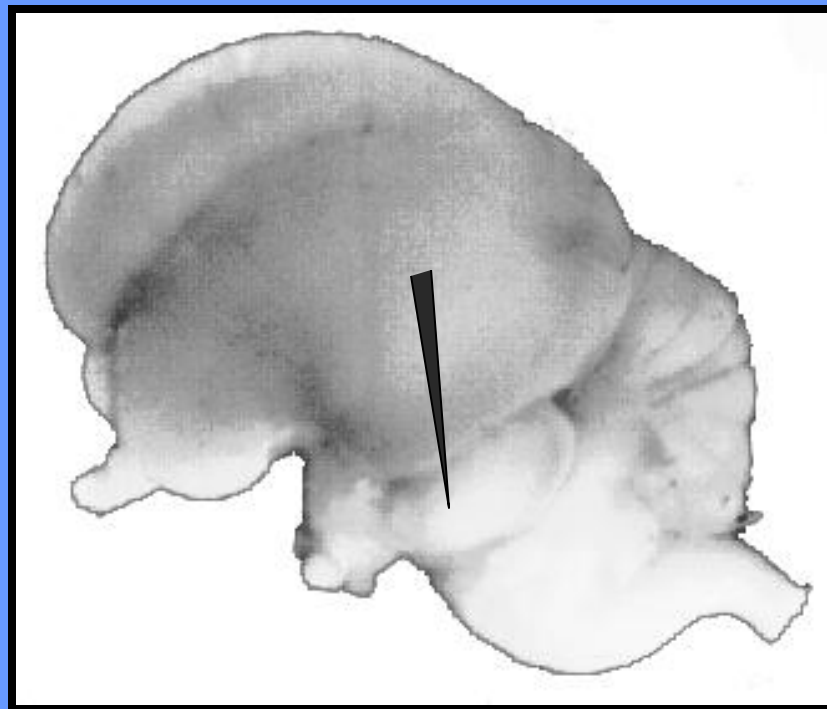
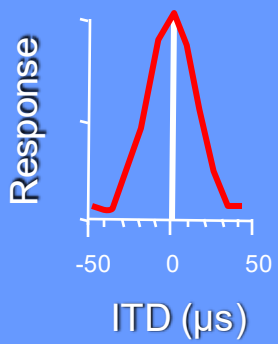
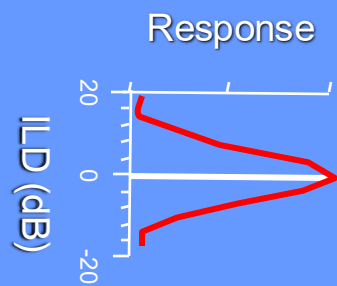
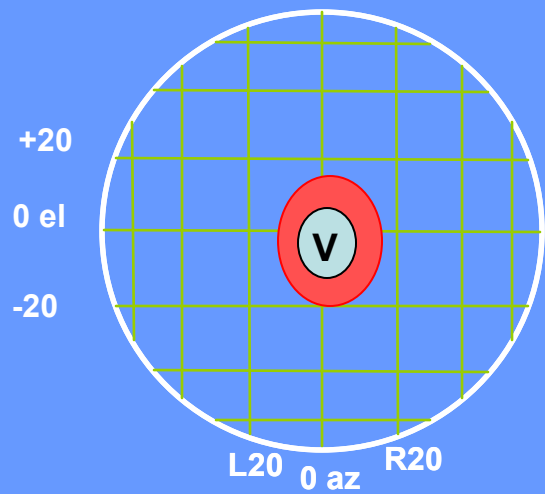
left
cochlear n.

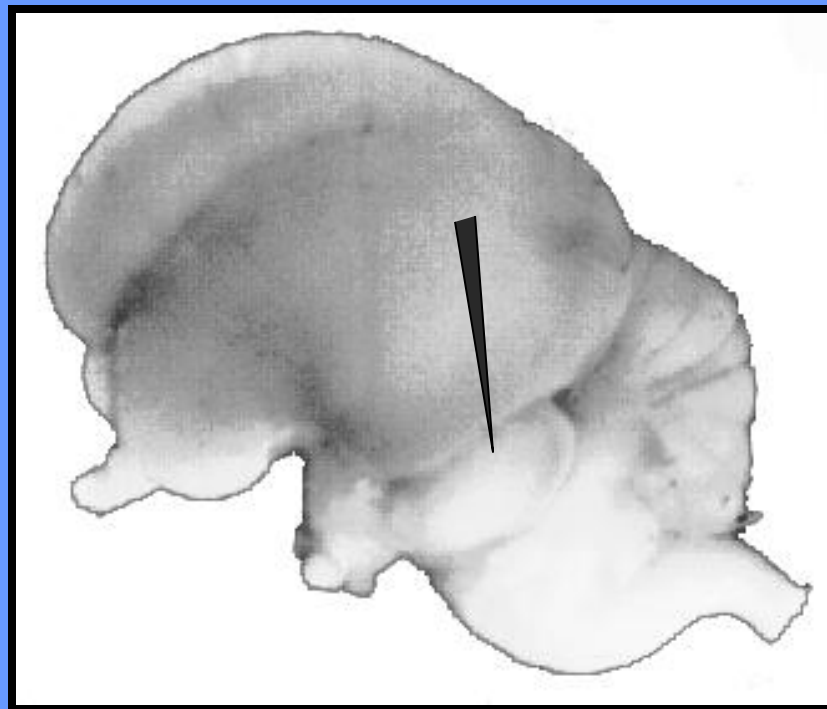
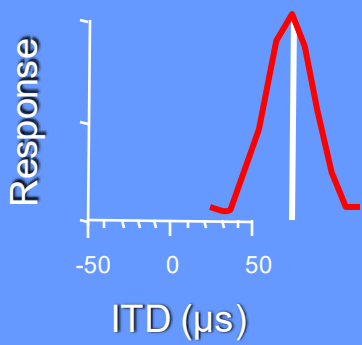
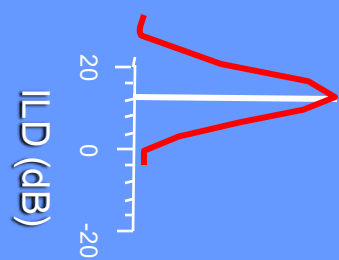
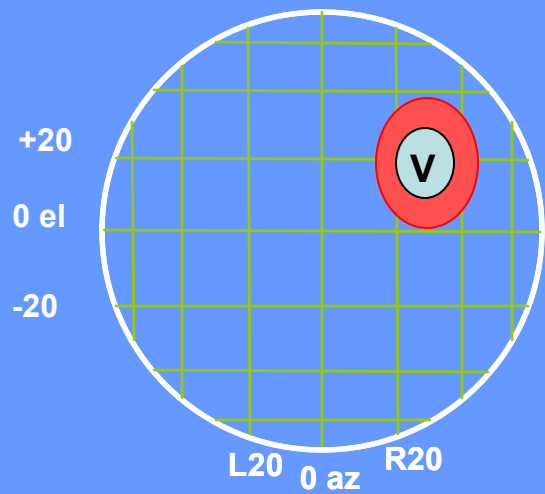
right
cochlear n.

Brainstem
Tegmentum

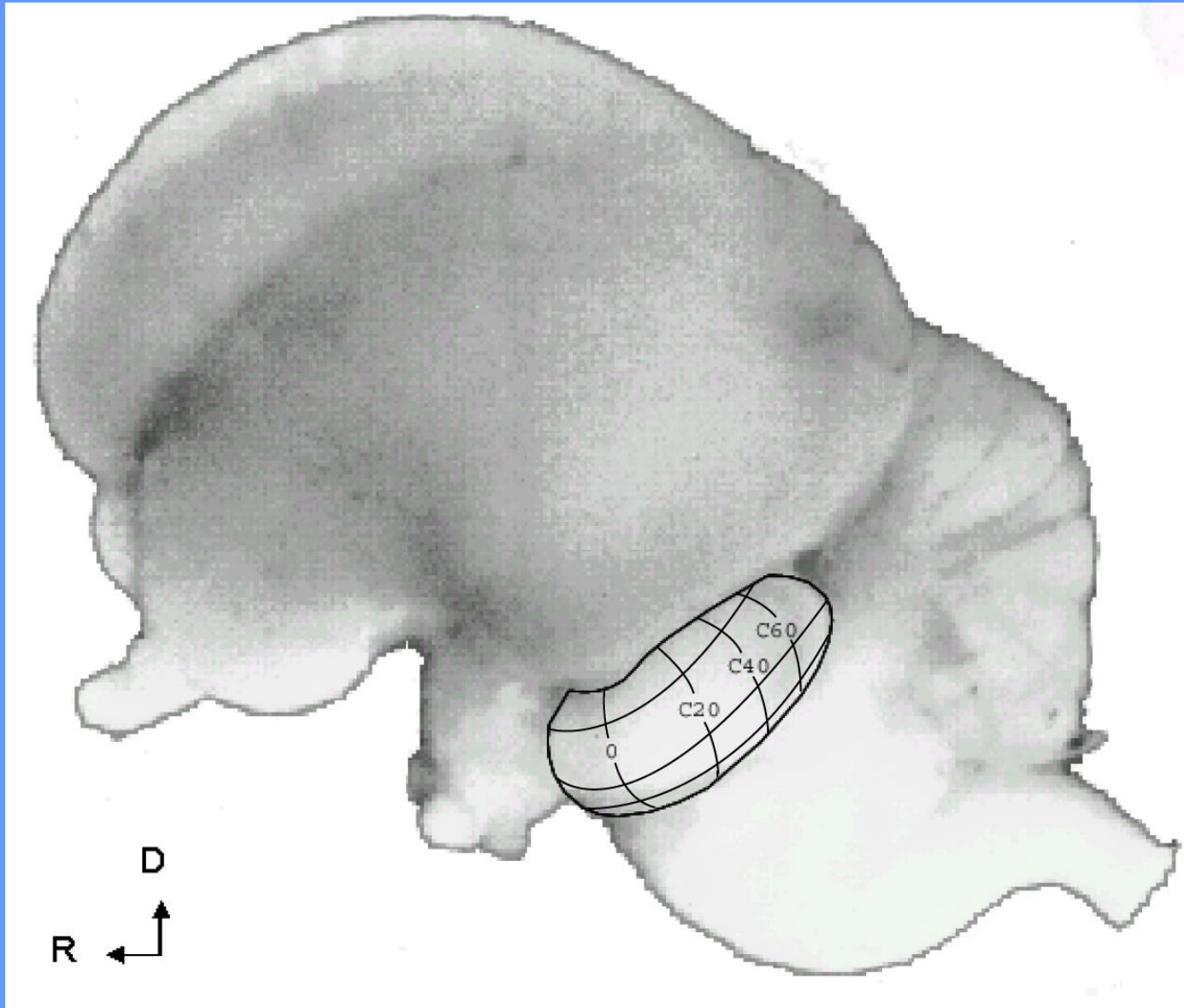
Motor Nuclei
for gaze control



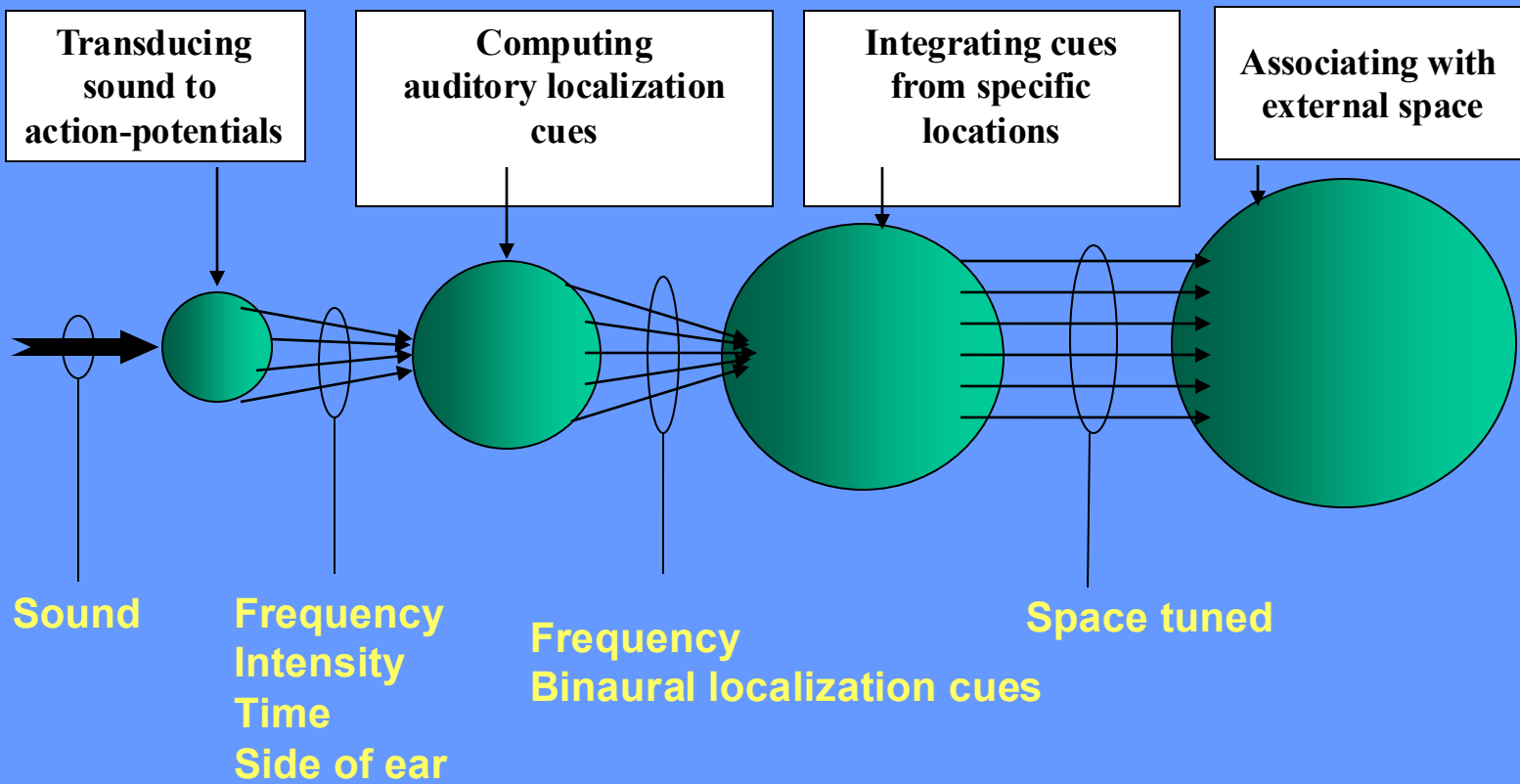




Visual and auditory maps in the OT



Computational map

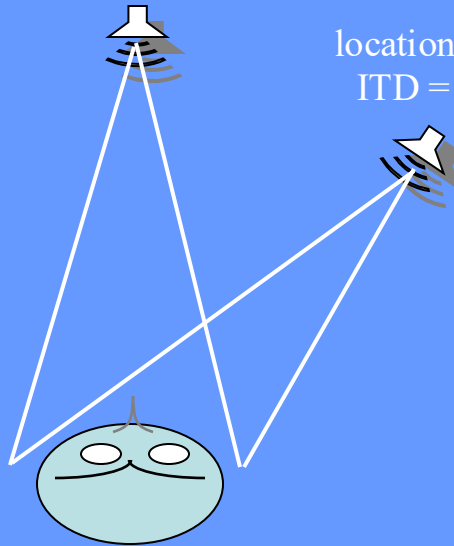


Computational maps

The matching problem

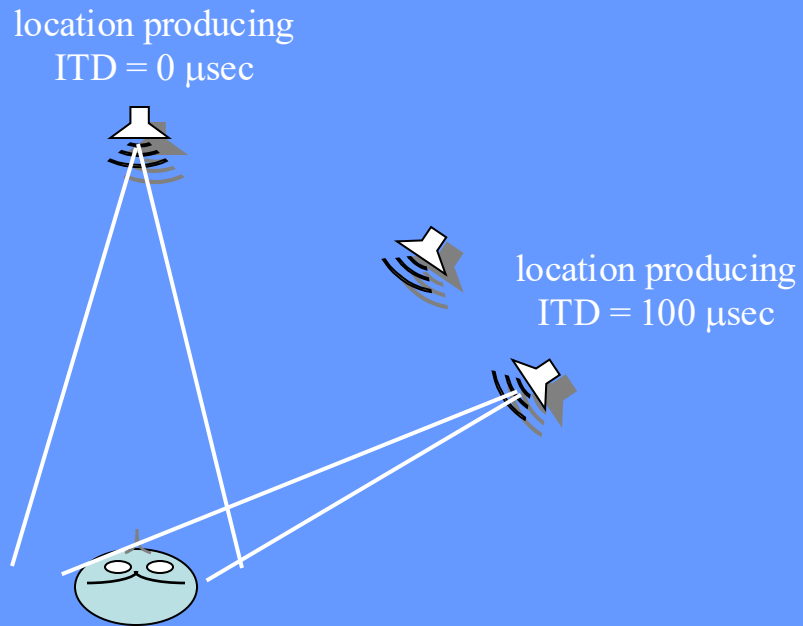
location producing
ITD = 0 μ sec

location producing
ITD = 100 μ sec

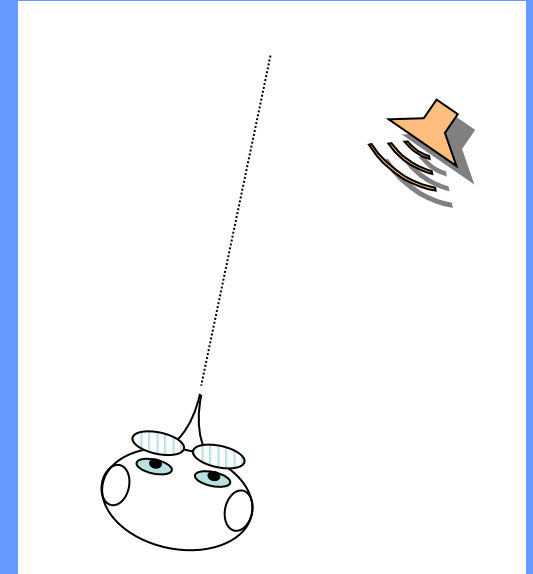
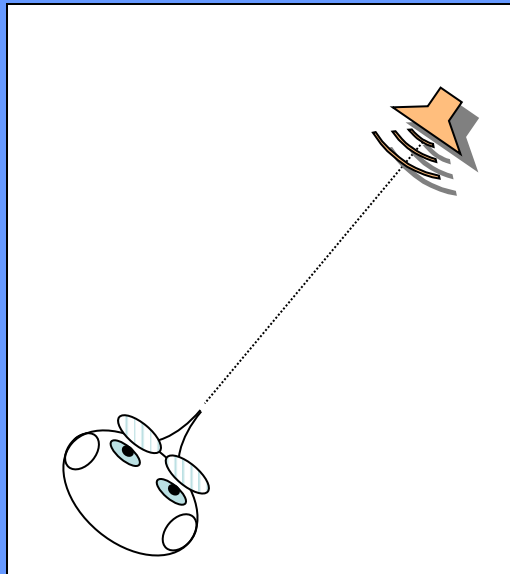
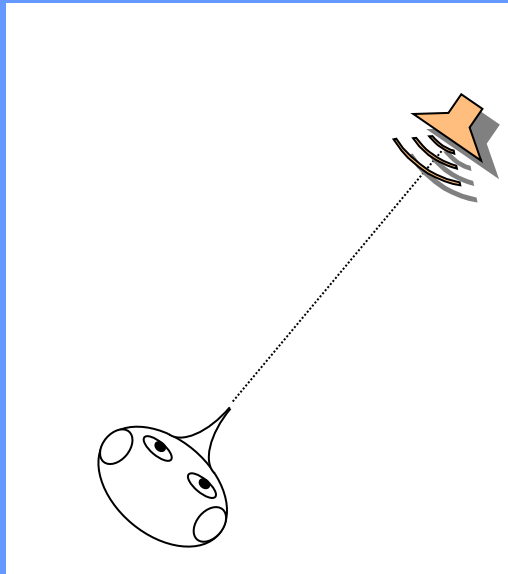
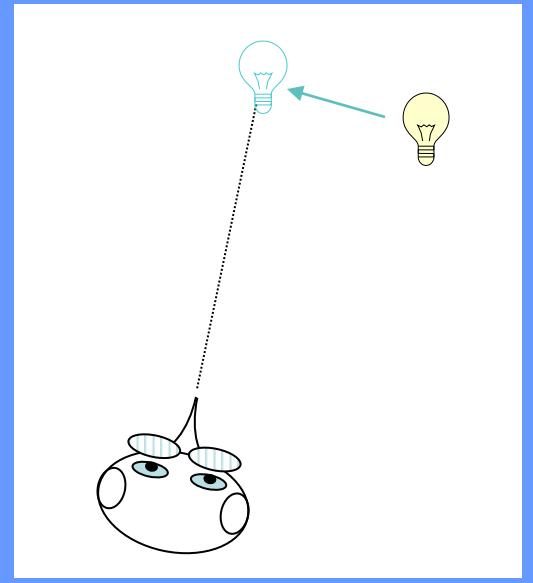
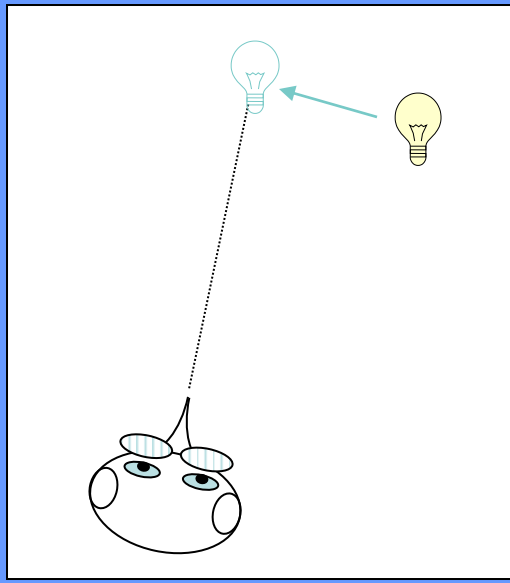
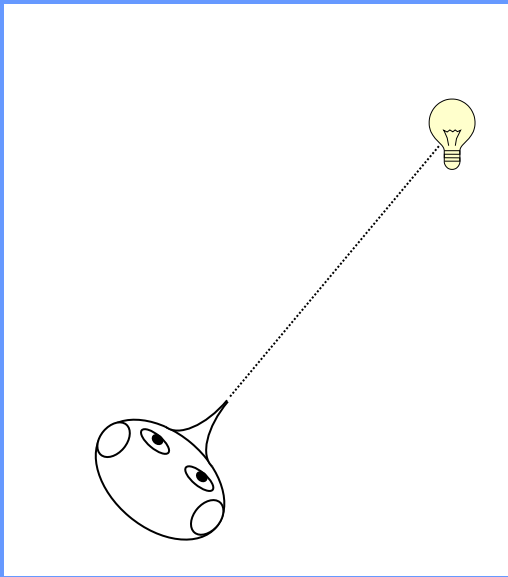


Computational maps

The matching problem







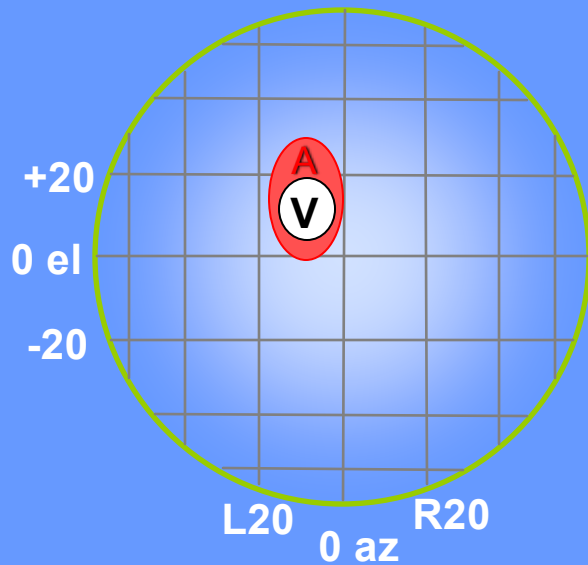
Normal

**Immediate Effect
of Prisms**

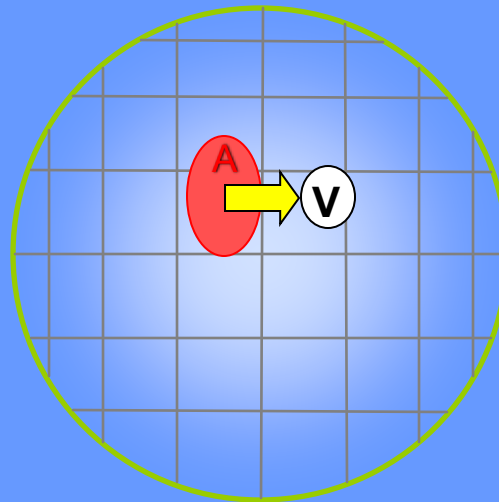
Prism-adapted

Effect of prism experience on auditory tuning

Normal

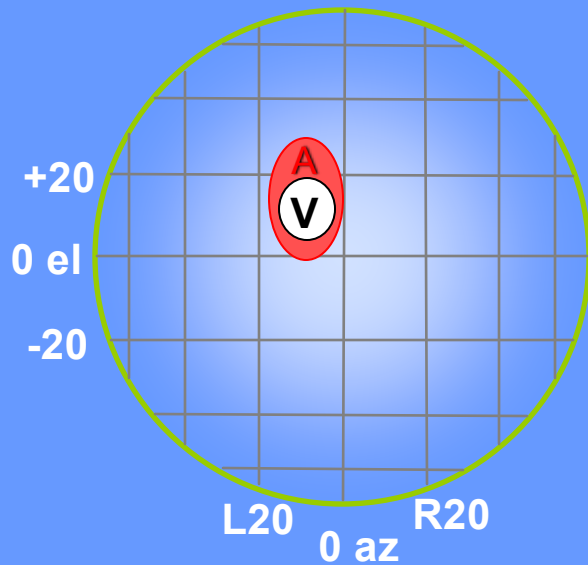


Immediate effect of prisms

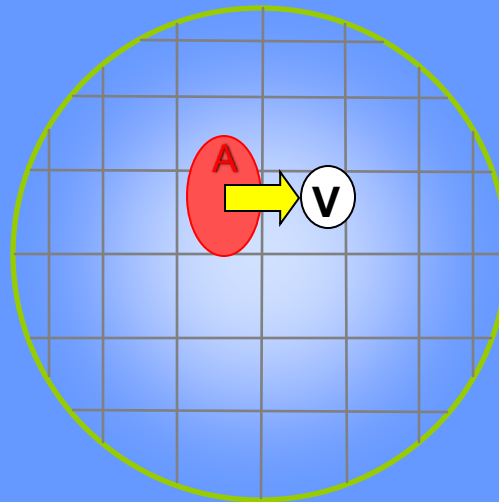


Effect of prism experience on auditory tuning

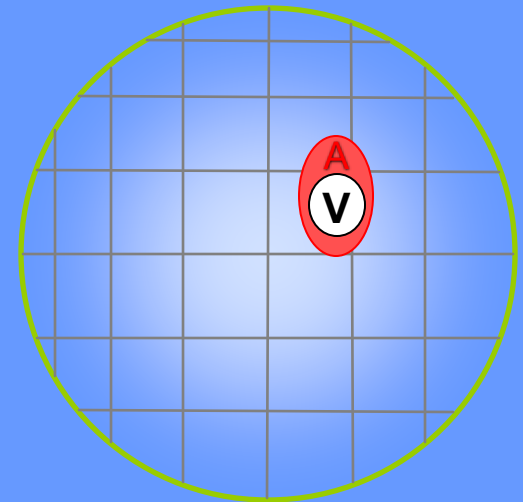
Normal



Immediate effect of prisms

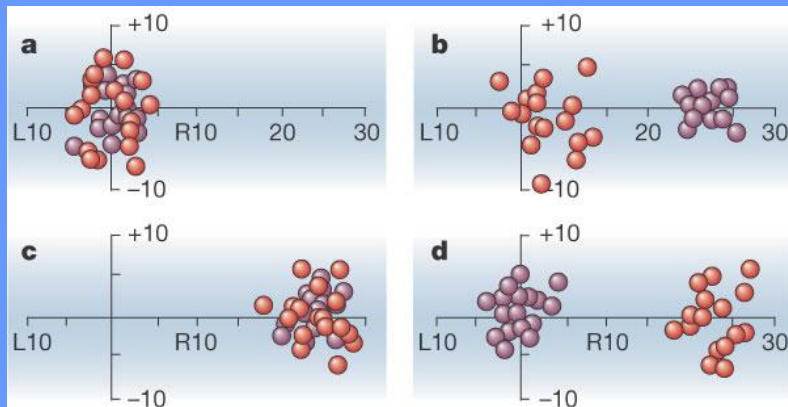


After 8 weeks of prism experience

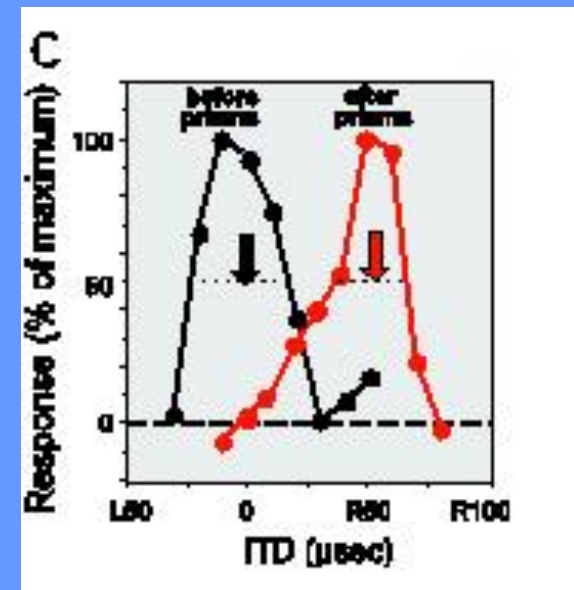


Quantification of learning

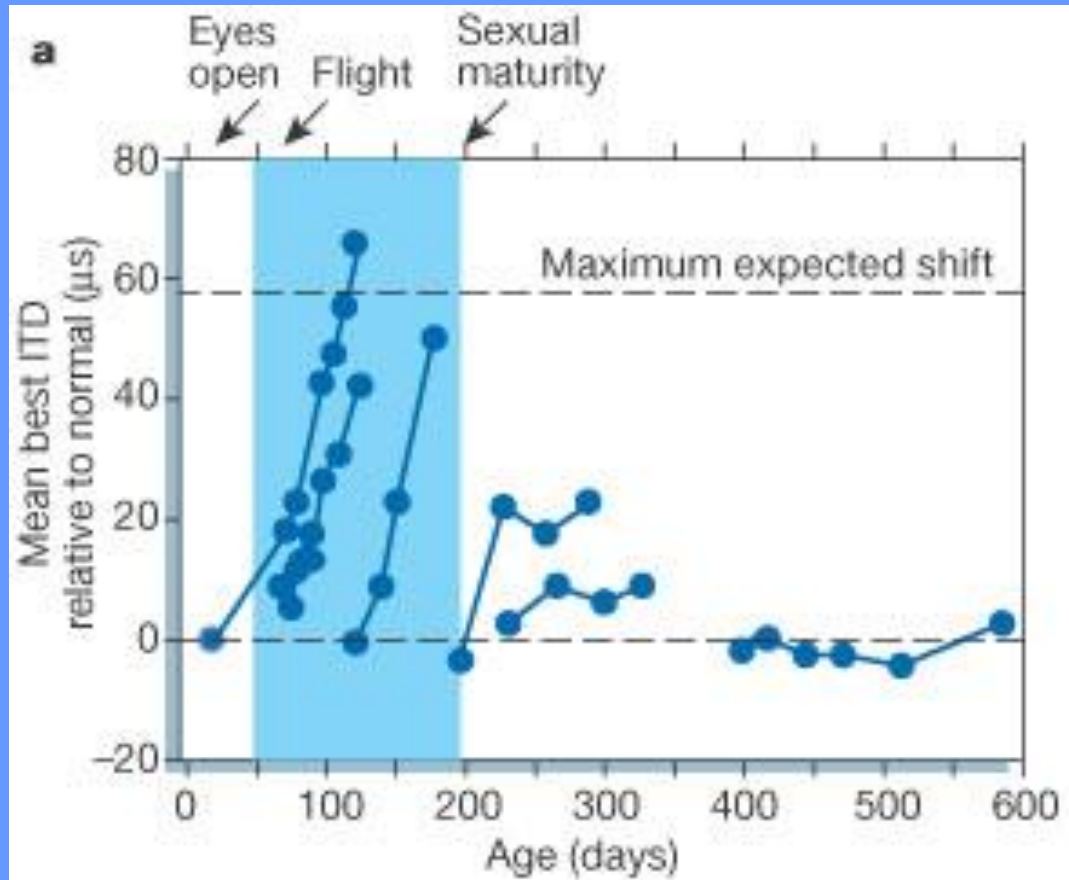
1. Behavioral test



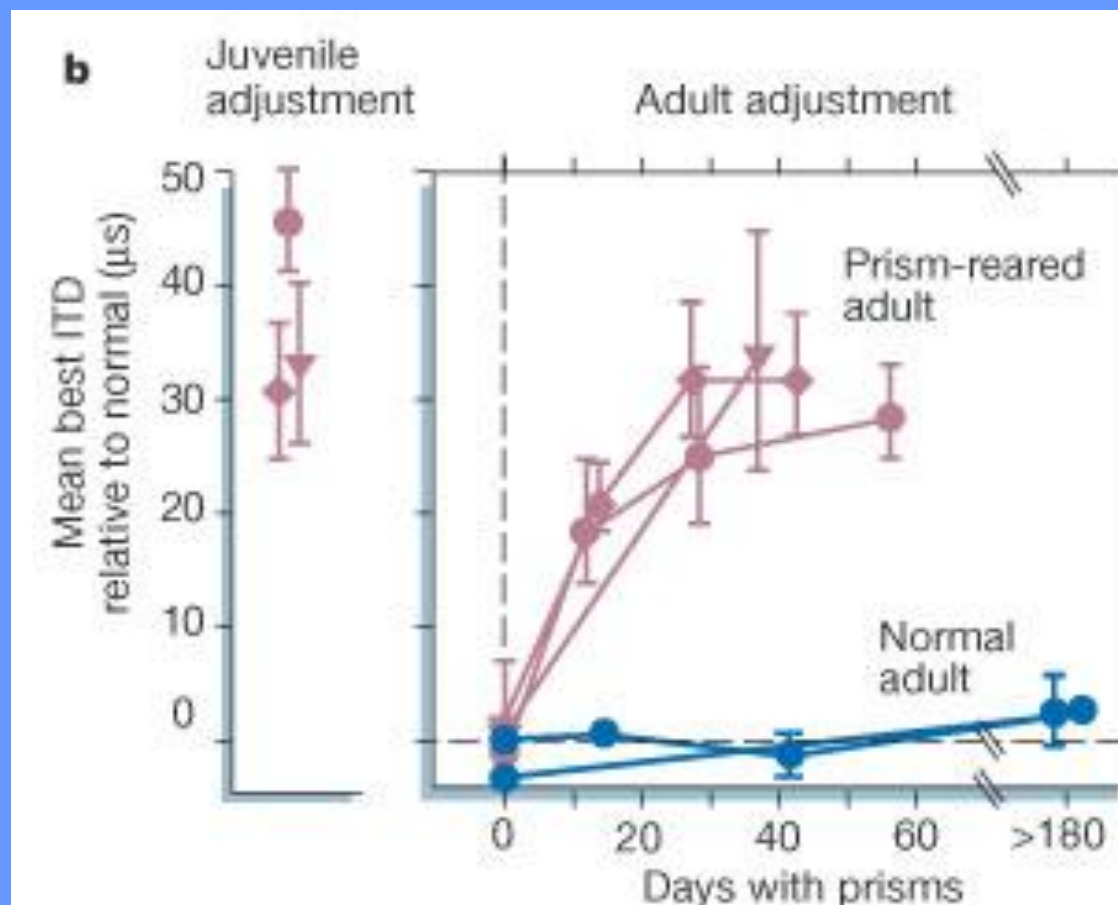
2. Physiological test



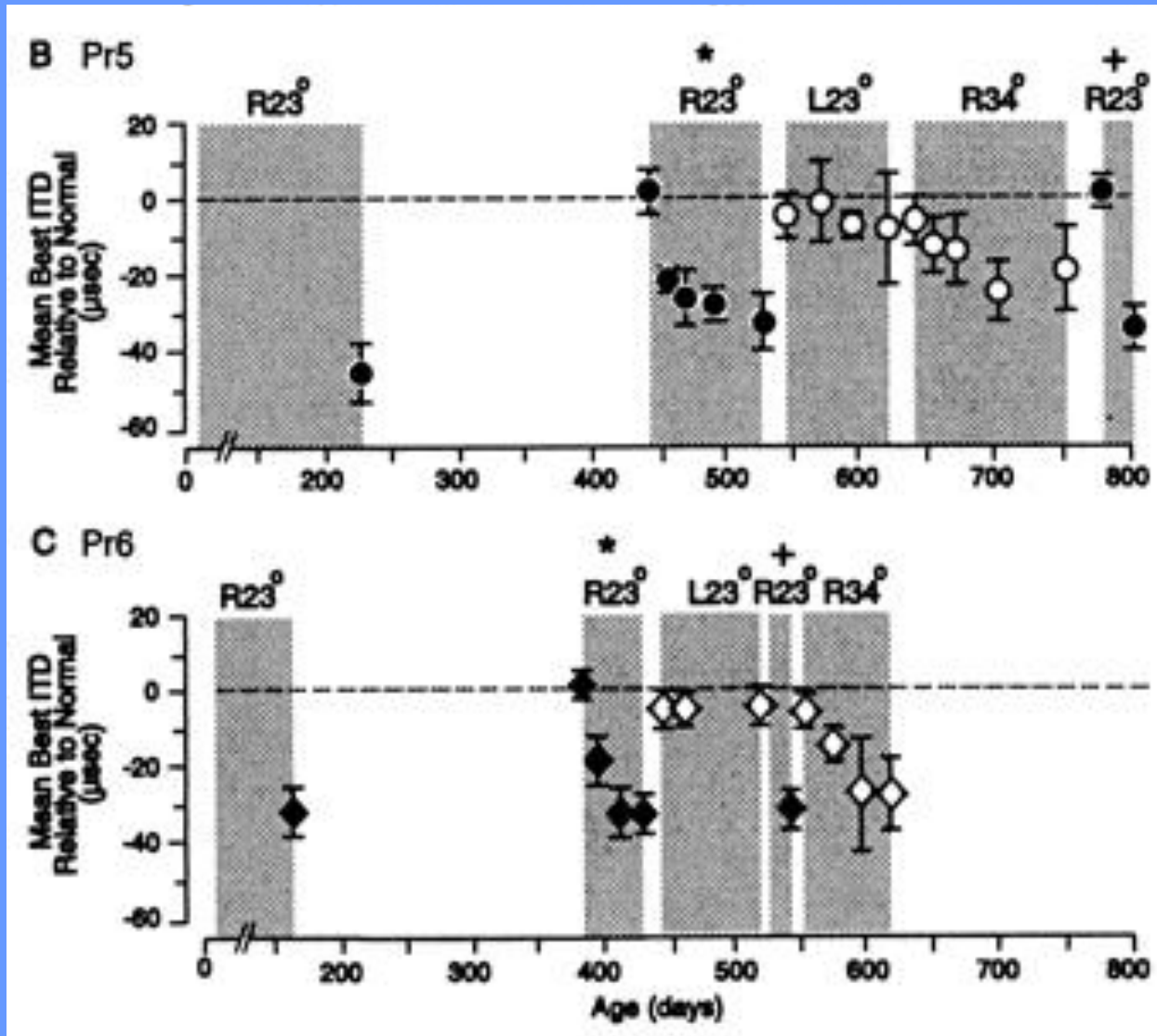
Decline in learning with age



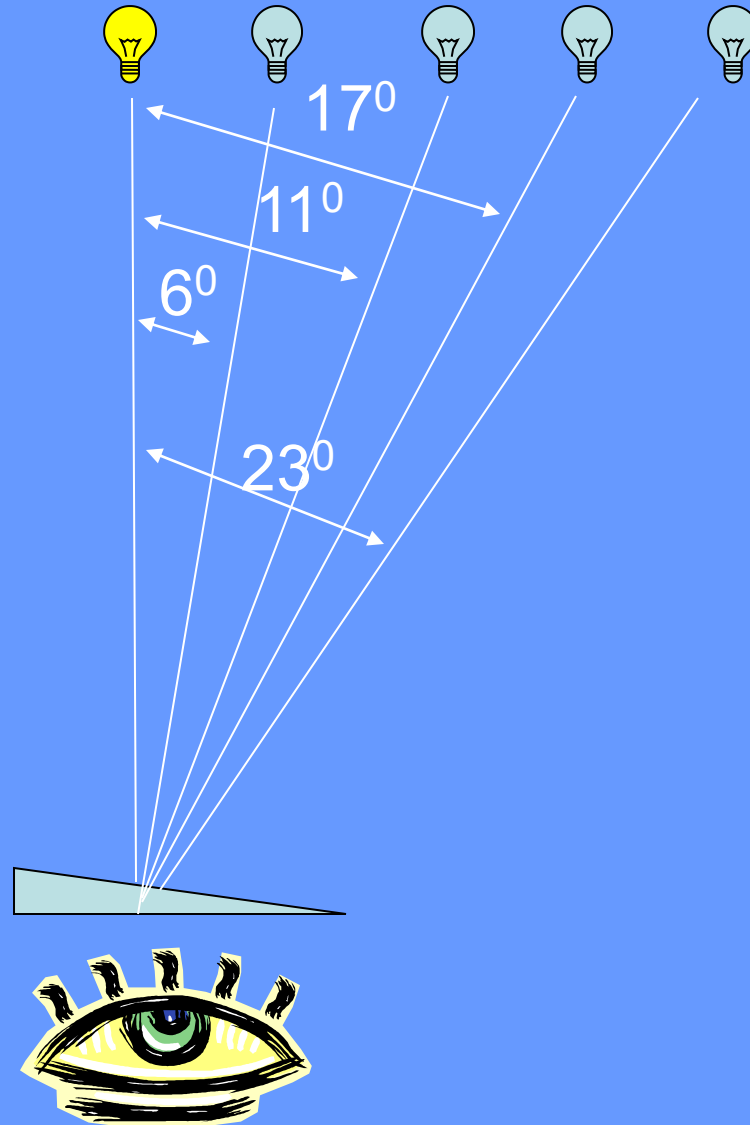
Increased capacity for learning in adults that have had appropriate experience as juveniles



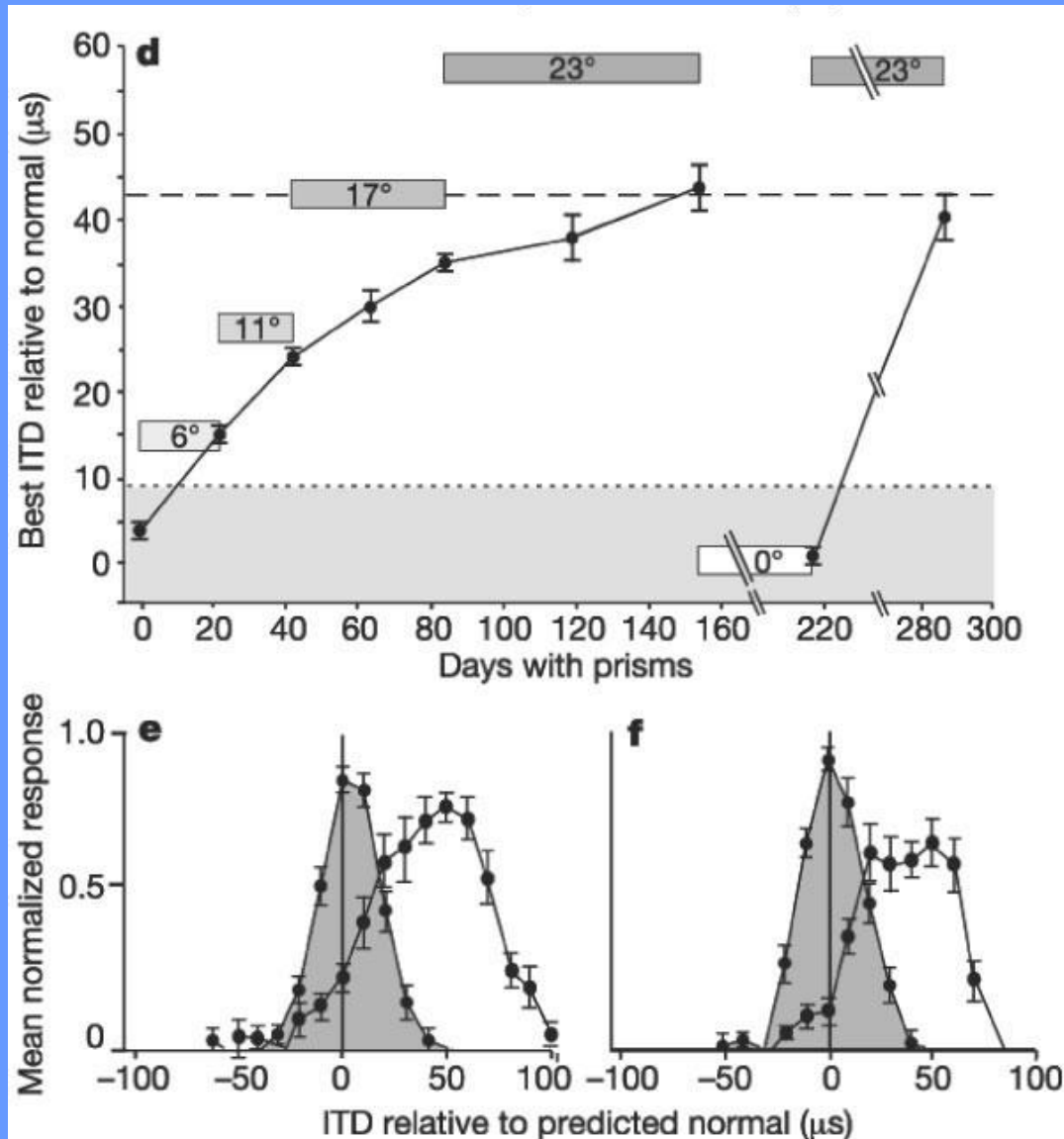
Effects of juvenile experience on adult learning



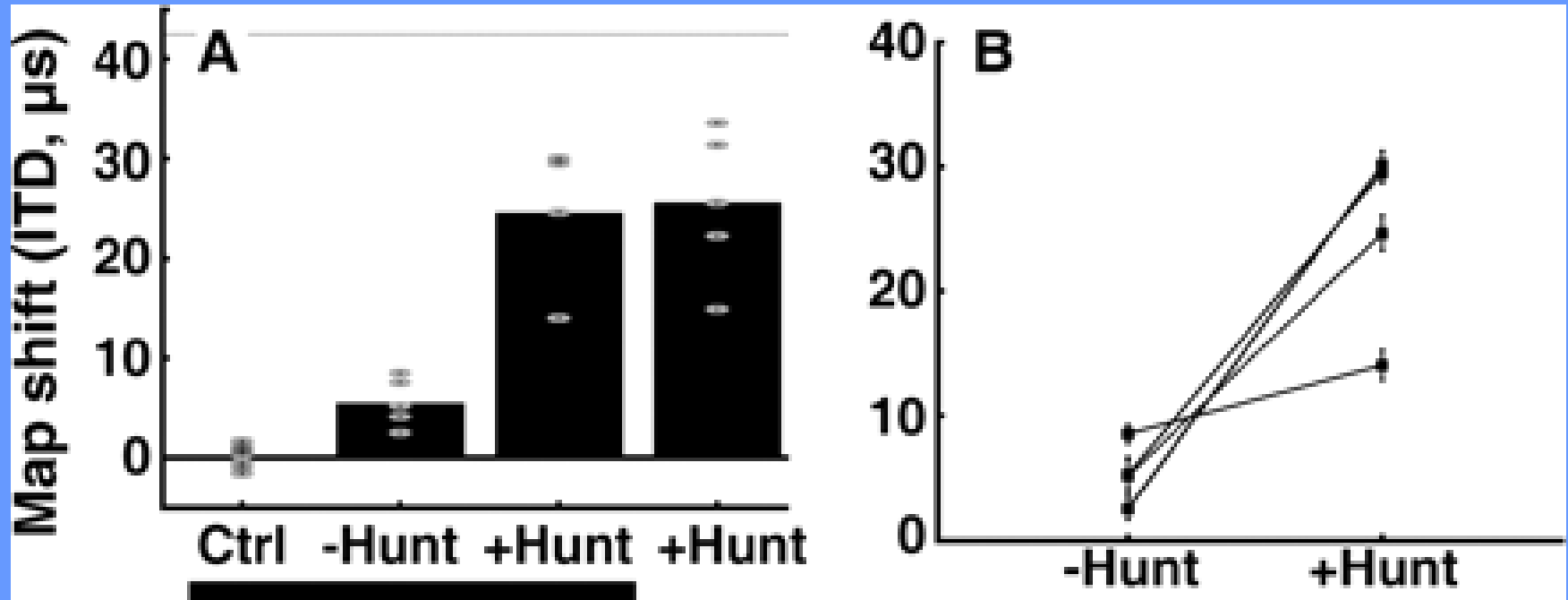
Incremental learning



Incremental learning



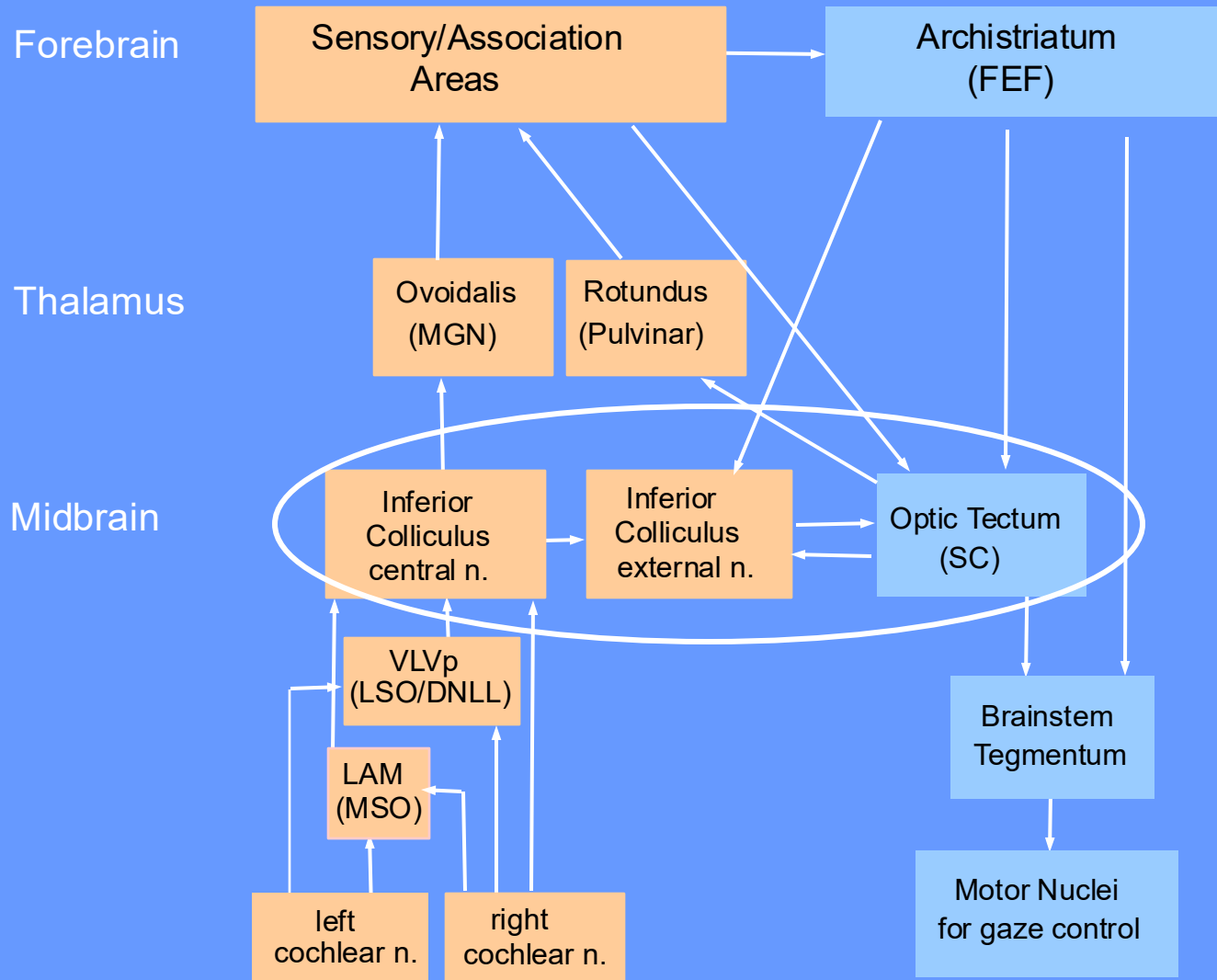
Rich and lively experiences increase learning capacity in adults



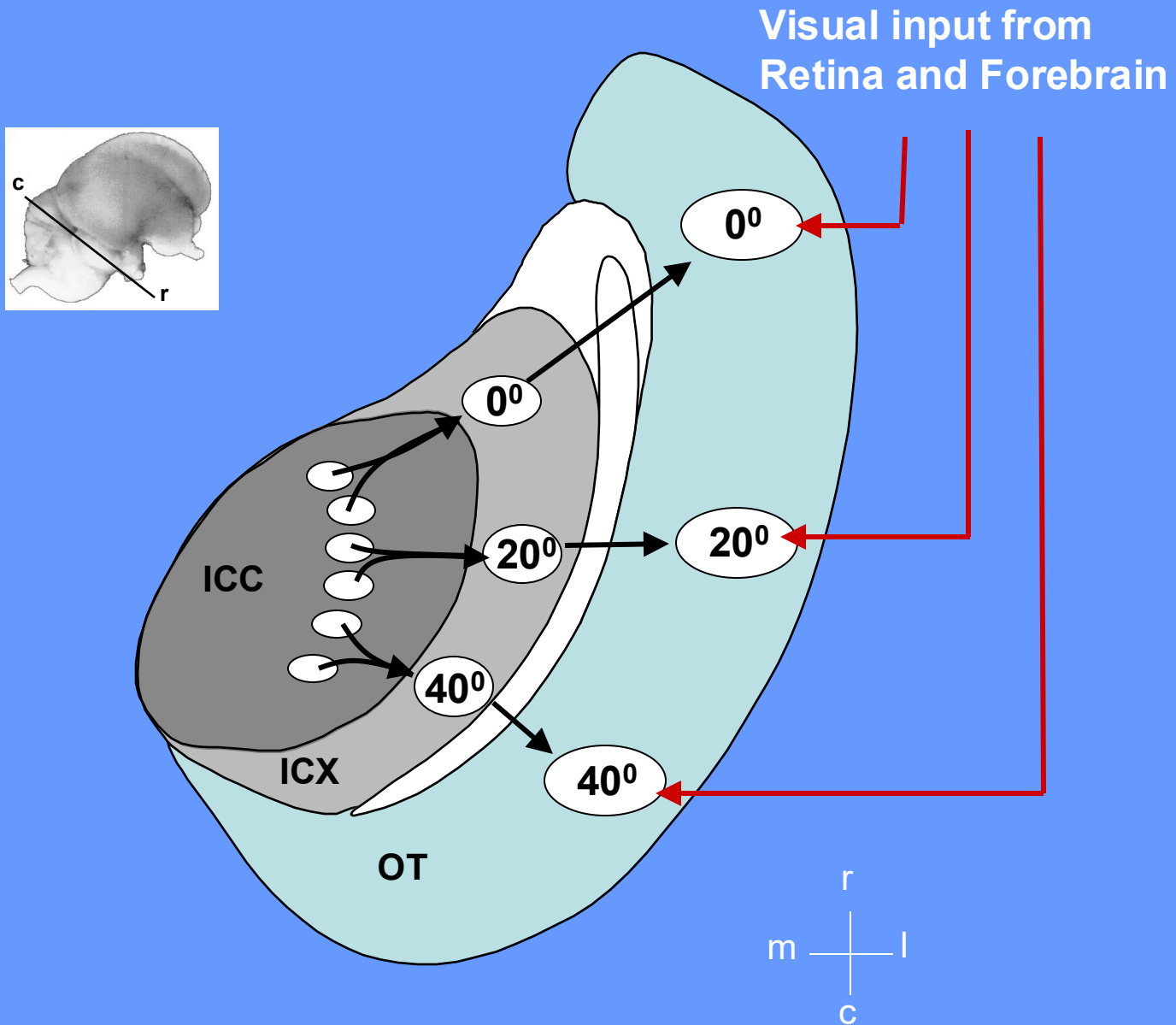
Summary

- Decline in learning with age
- Increased capacity for learning in adults that have had appropriate experience as juveniles
- Incremental training improves learning
- Rich and lively experiences increase learning capacity in adults

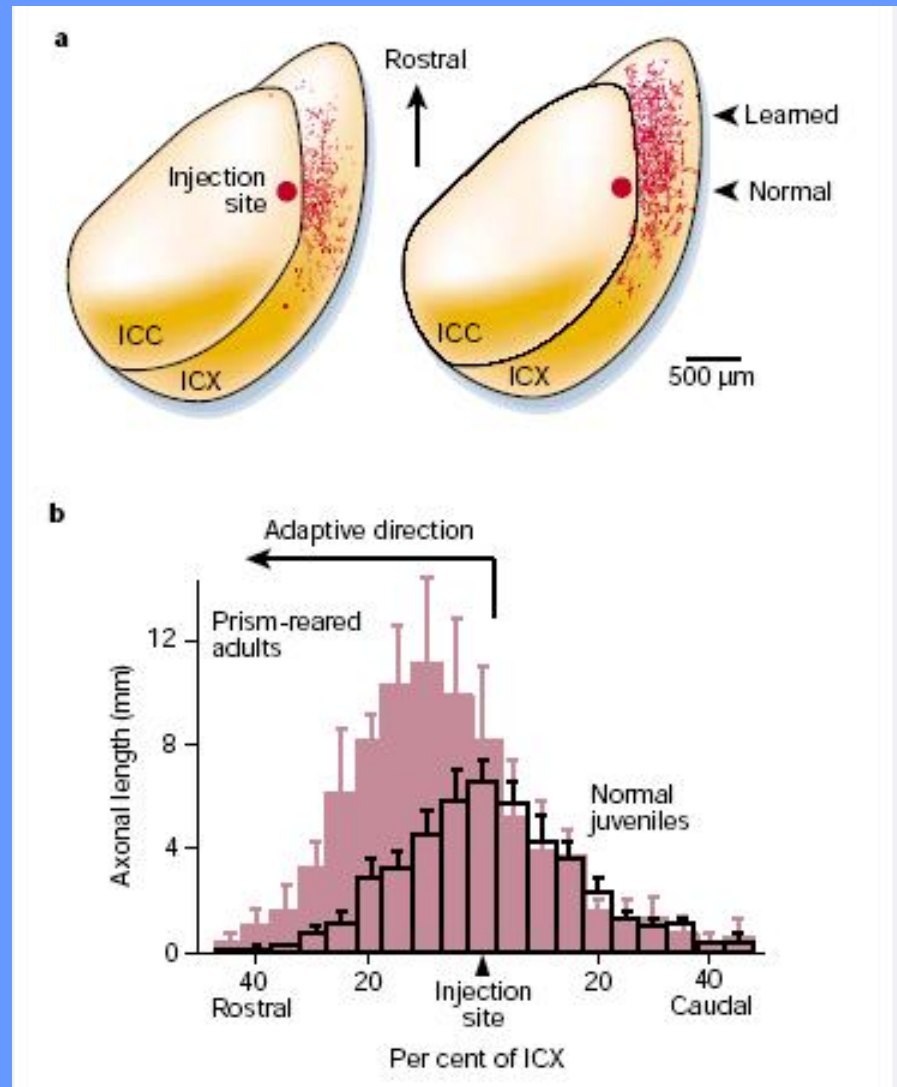
Where is the site of plasticity?



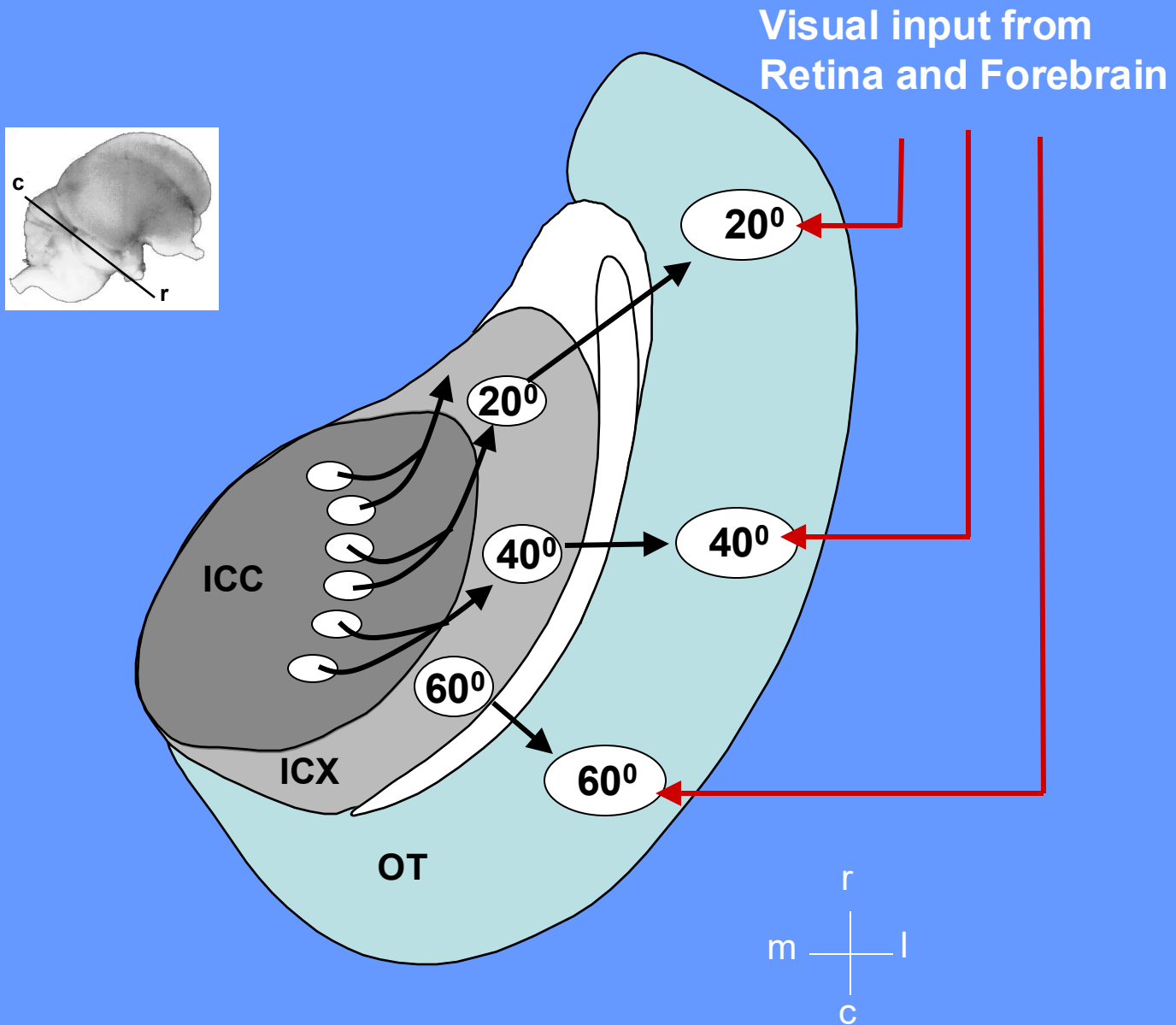
Horizontal section through the tectal lobe



Site of plasticity in the ICX



After prism learning

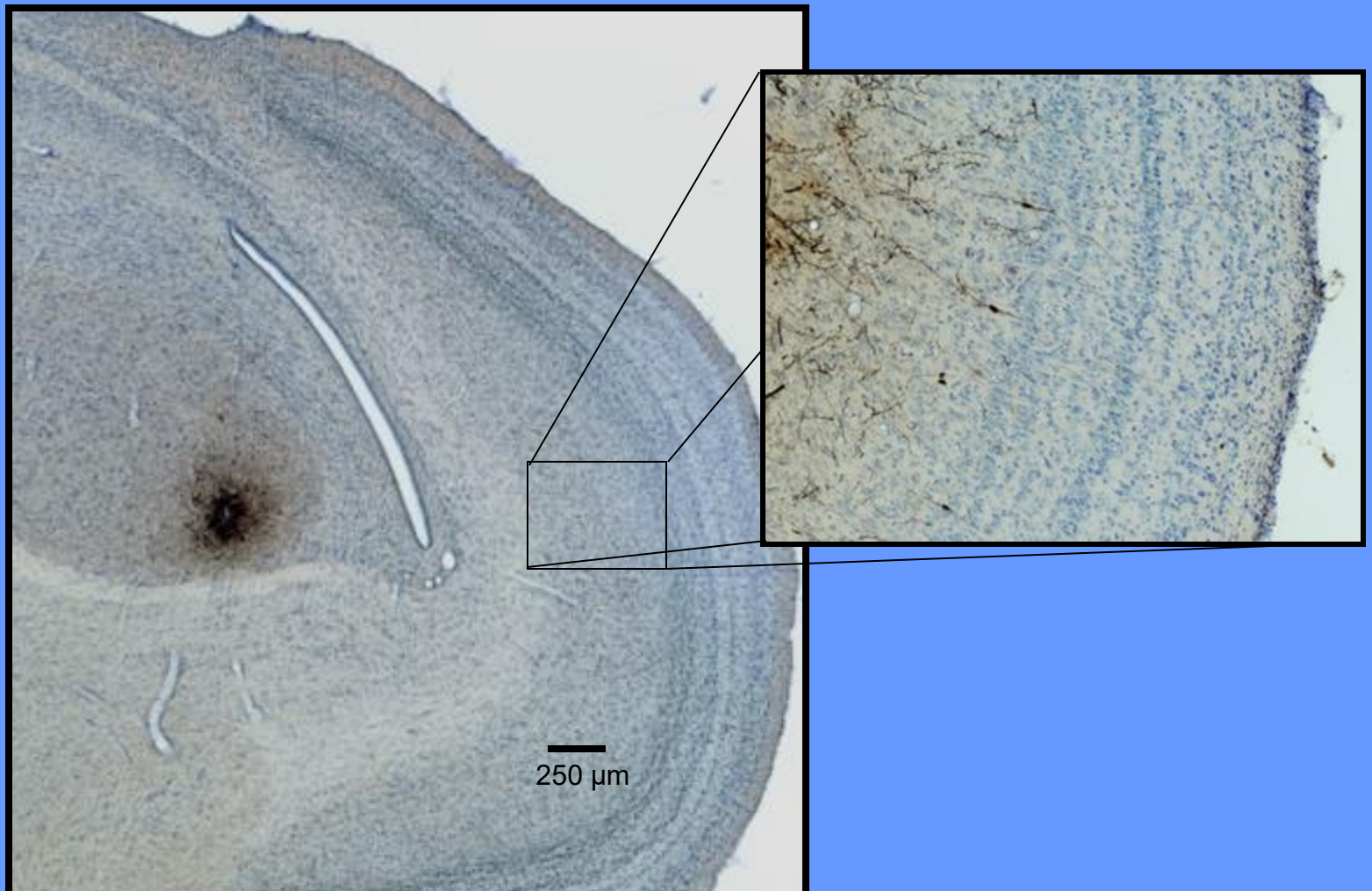


The instructive signal

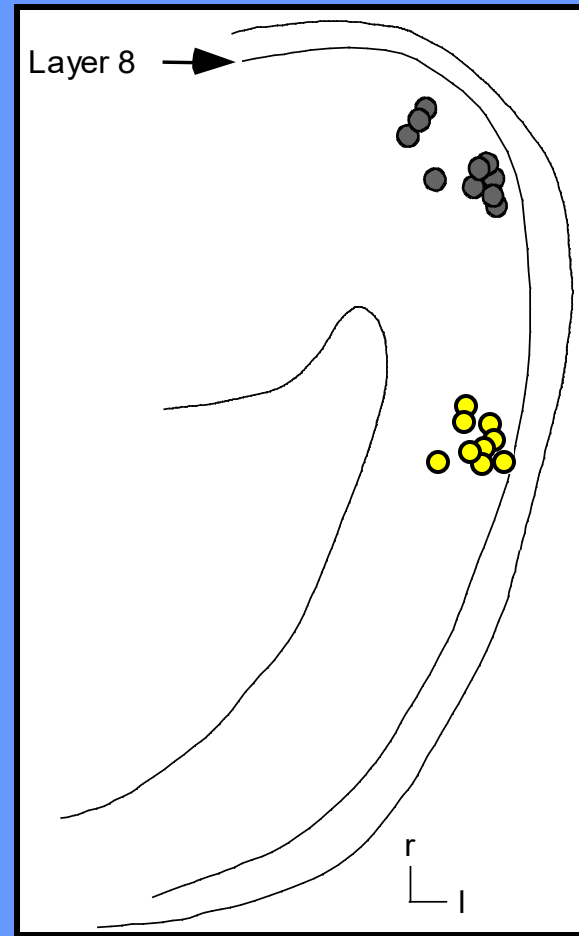
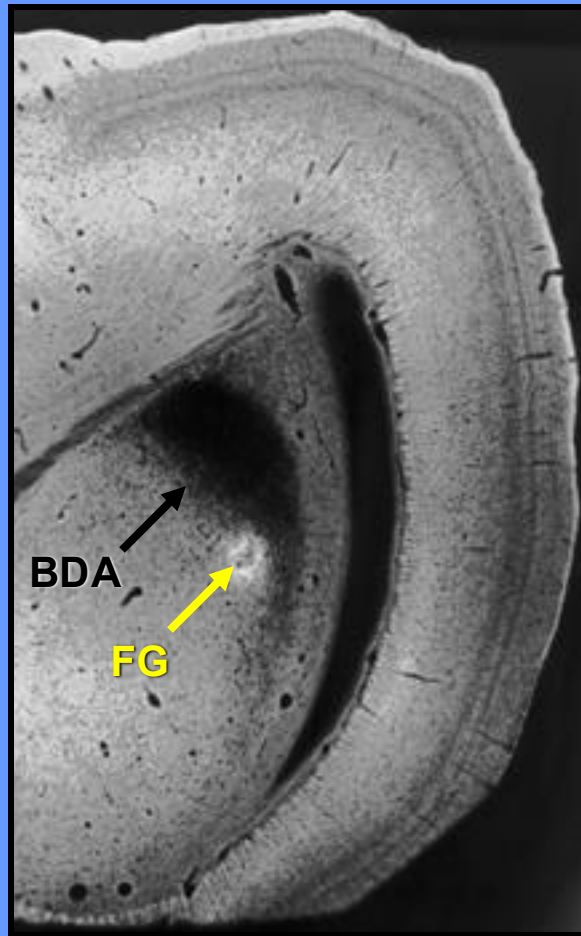
- Operates in the ICX
- Visually based

**Where is the instructive signal
coming from?**

BDA injection site in ICX



Topography of the OT-ICX projection

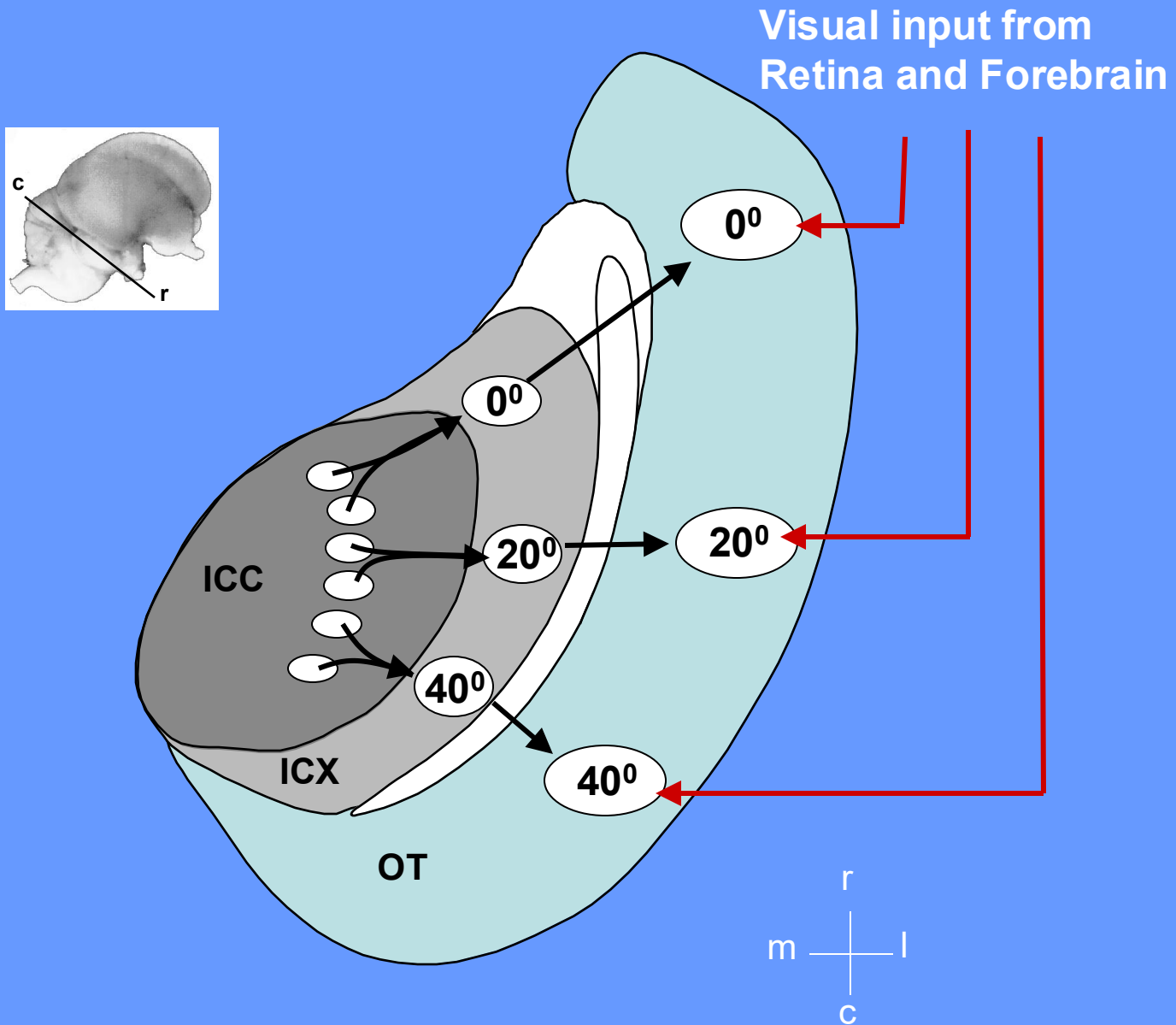


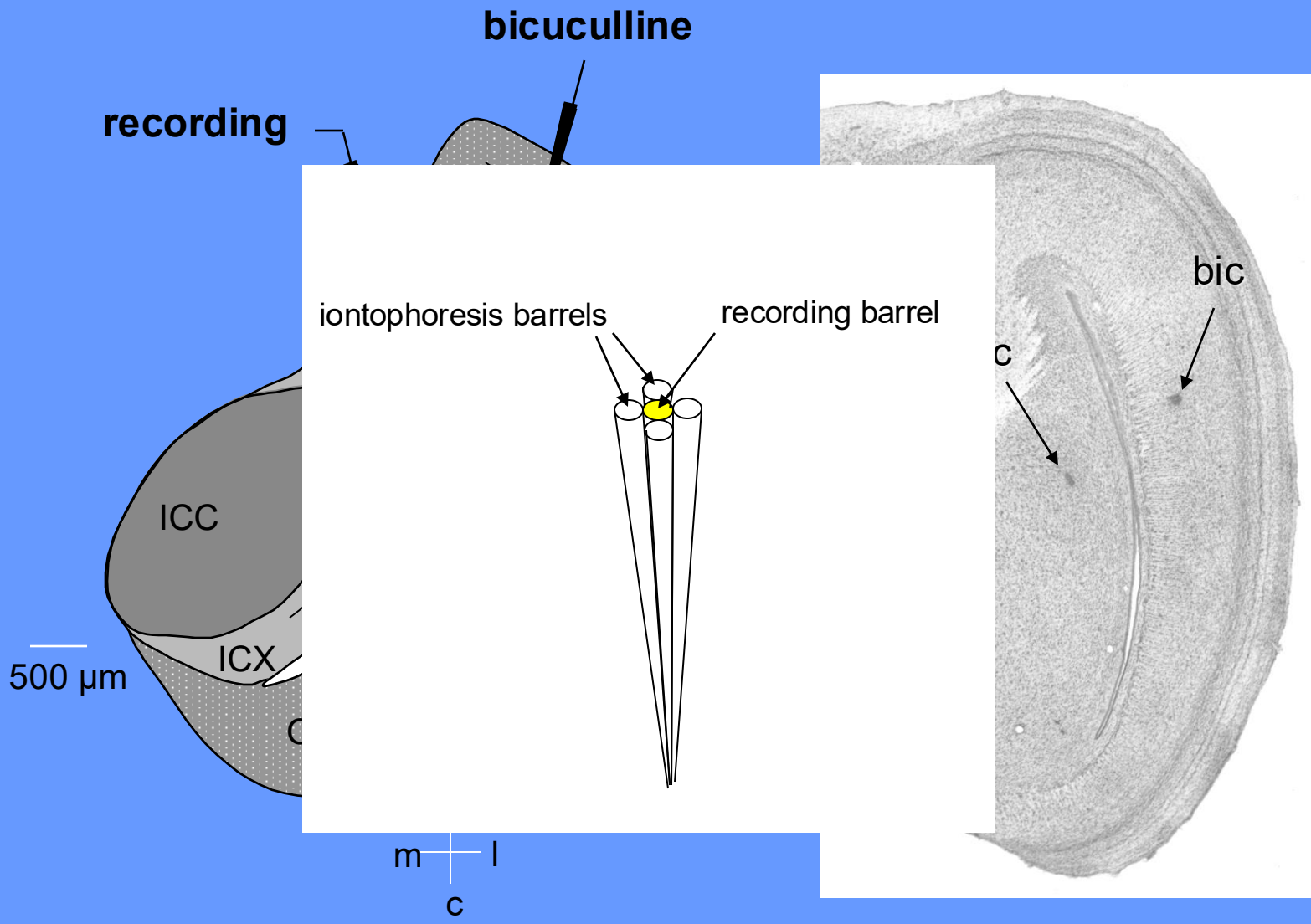
Restricted lesion of the optic tectum



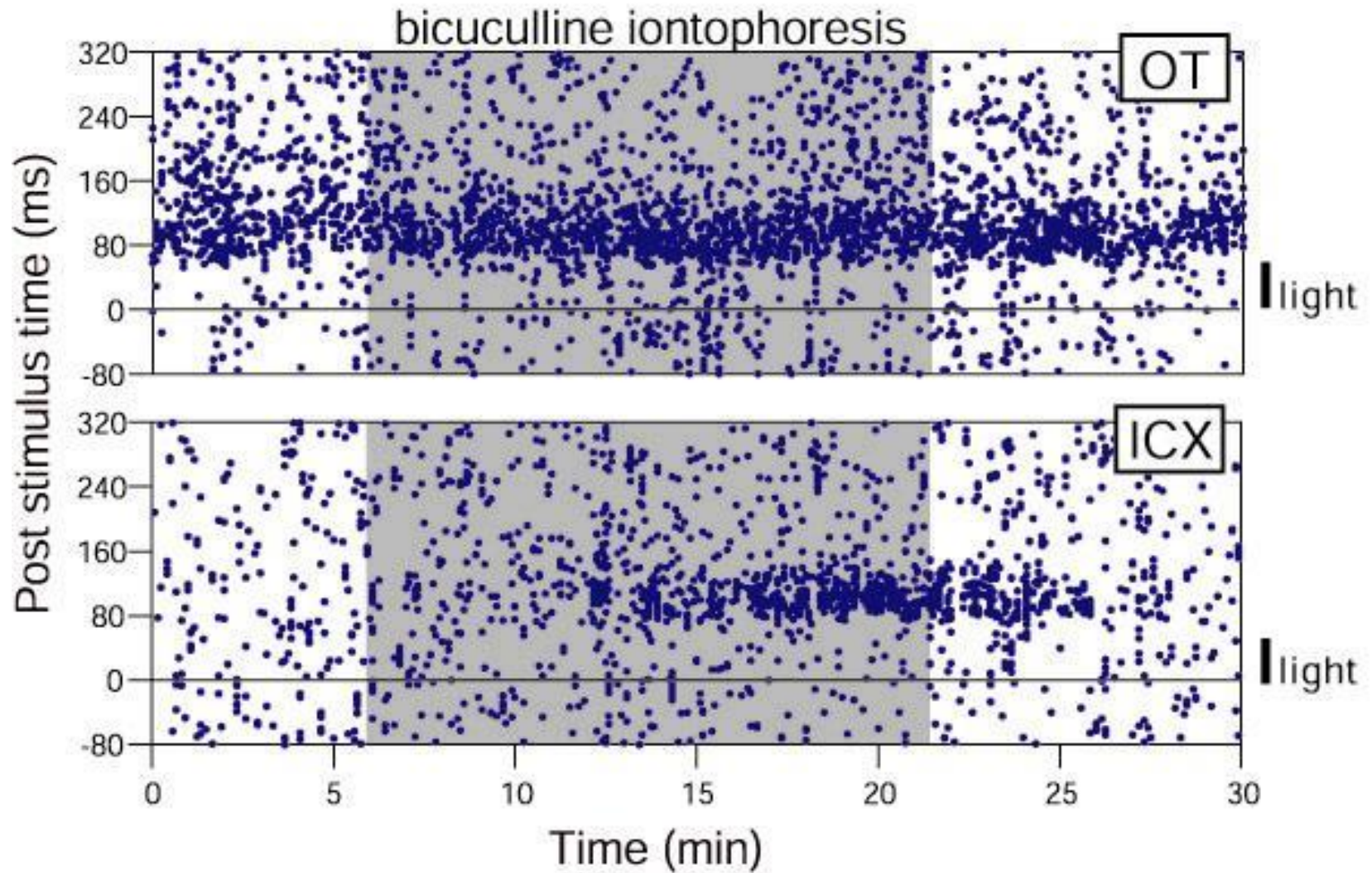
**How can a visually based
instructive signal act in
an auditory structure?**

Horizontal section through the tectal lobe

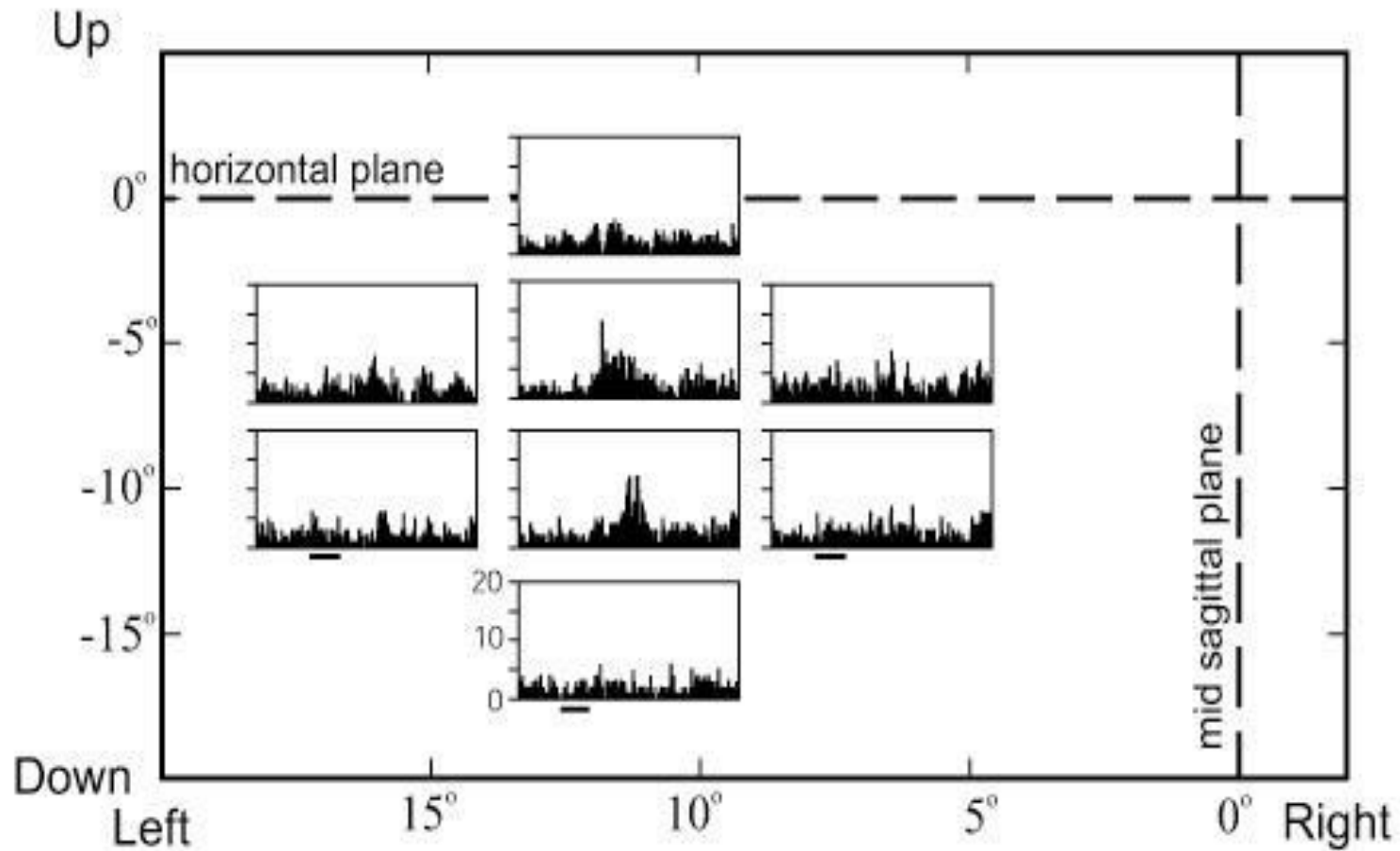


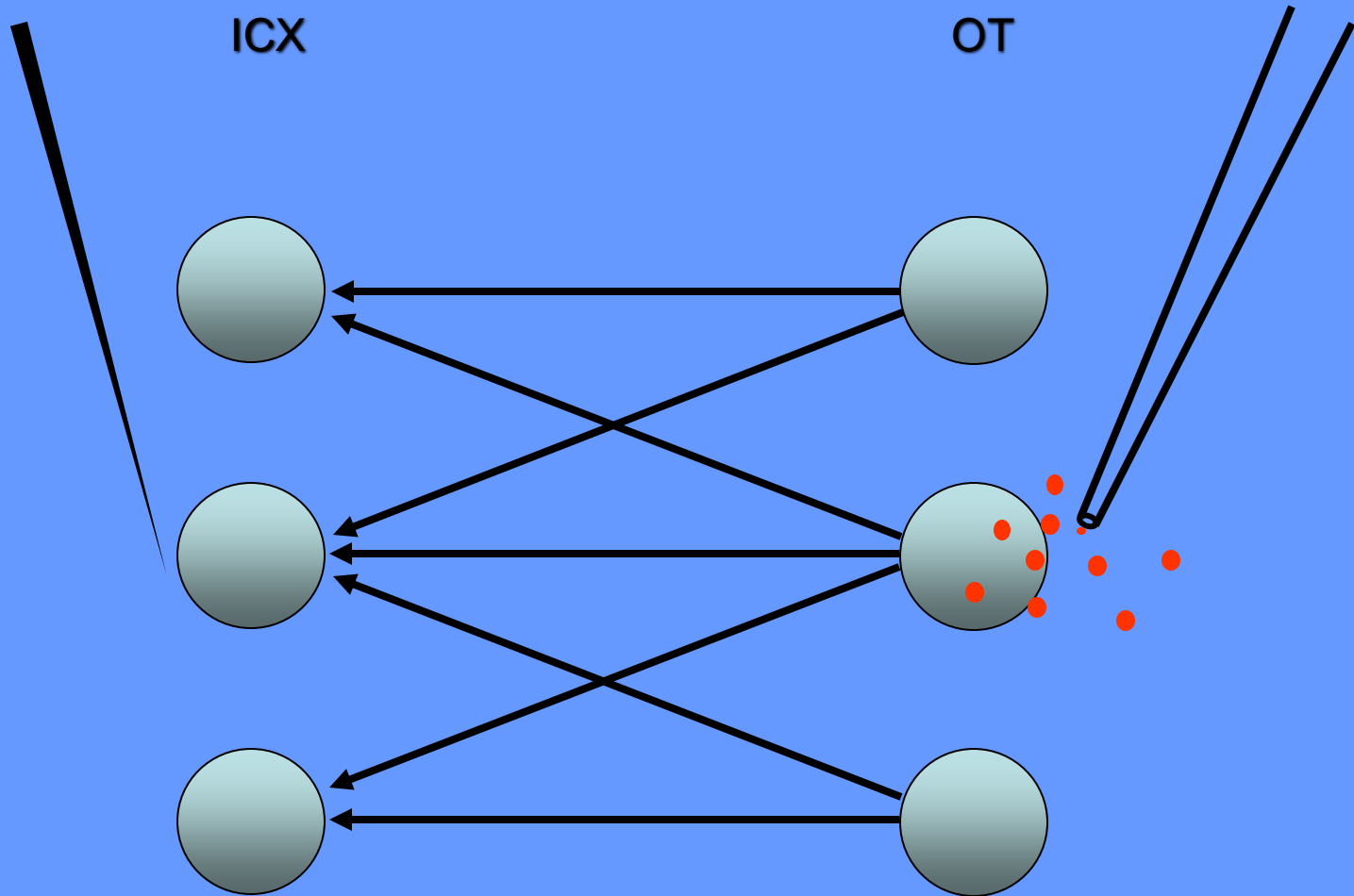


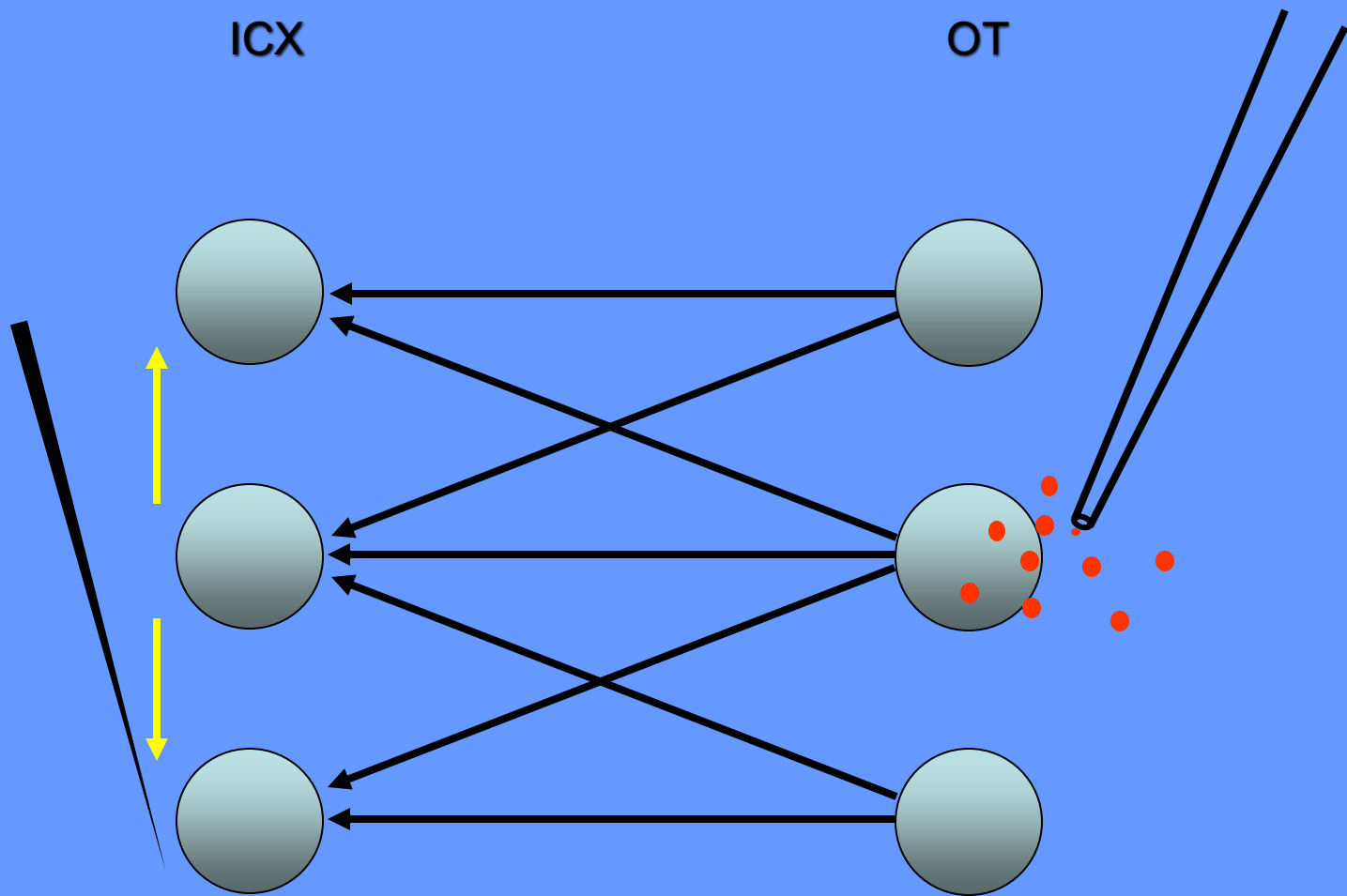
Light responses in the ICX

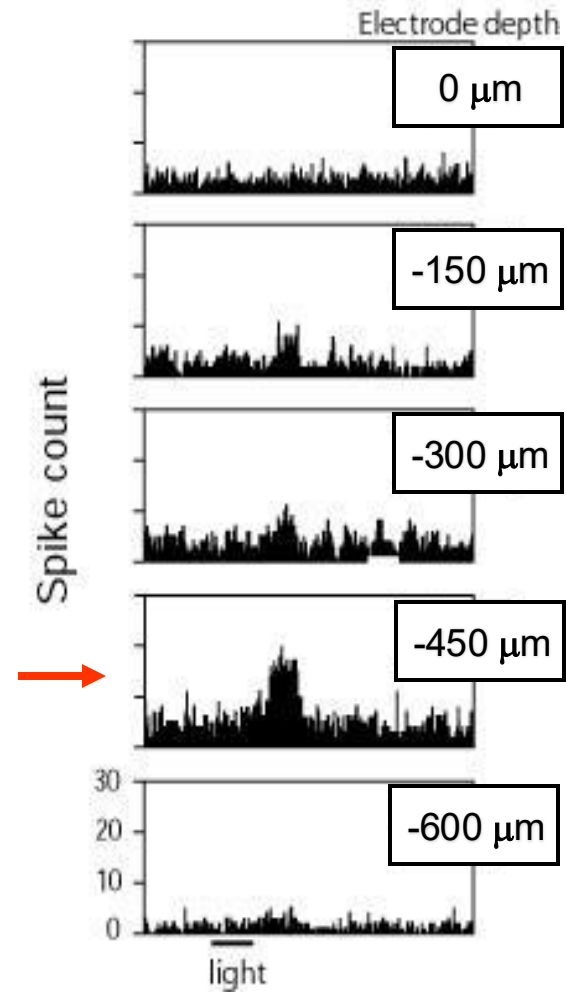
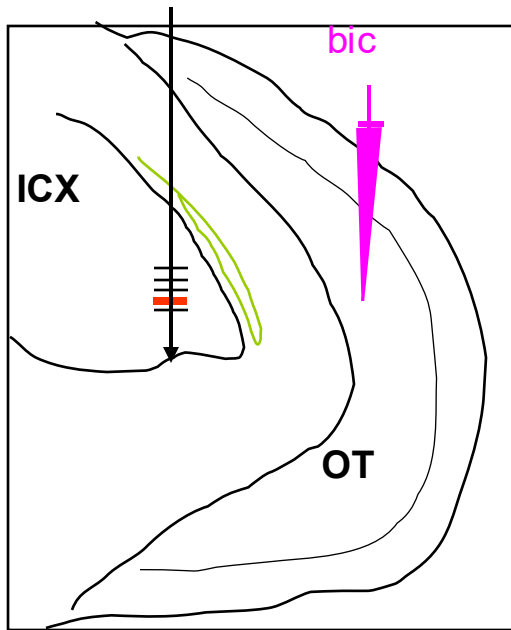


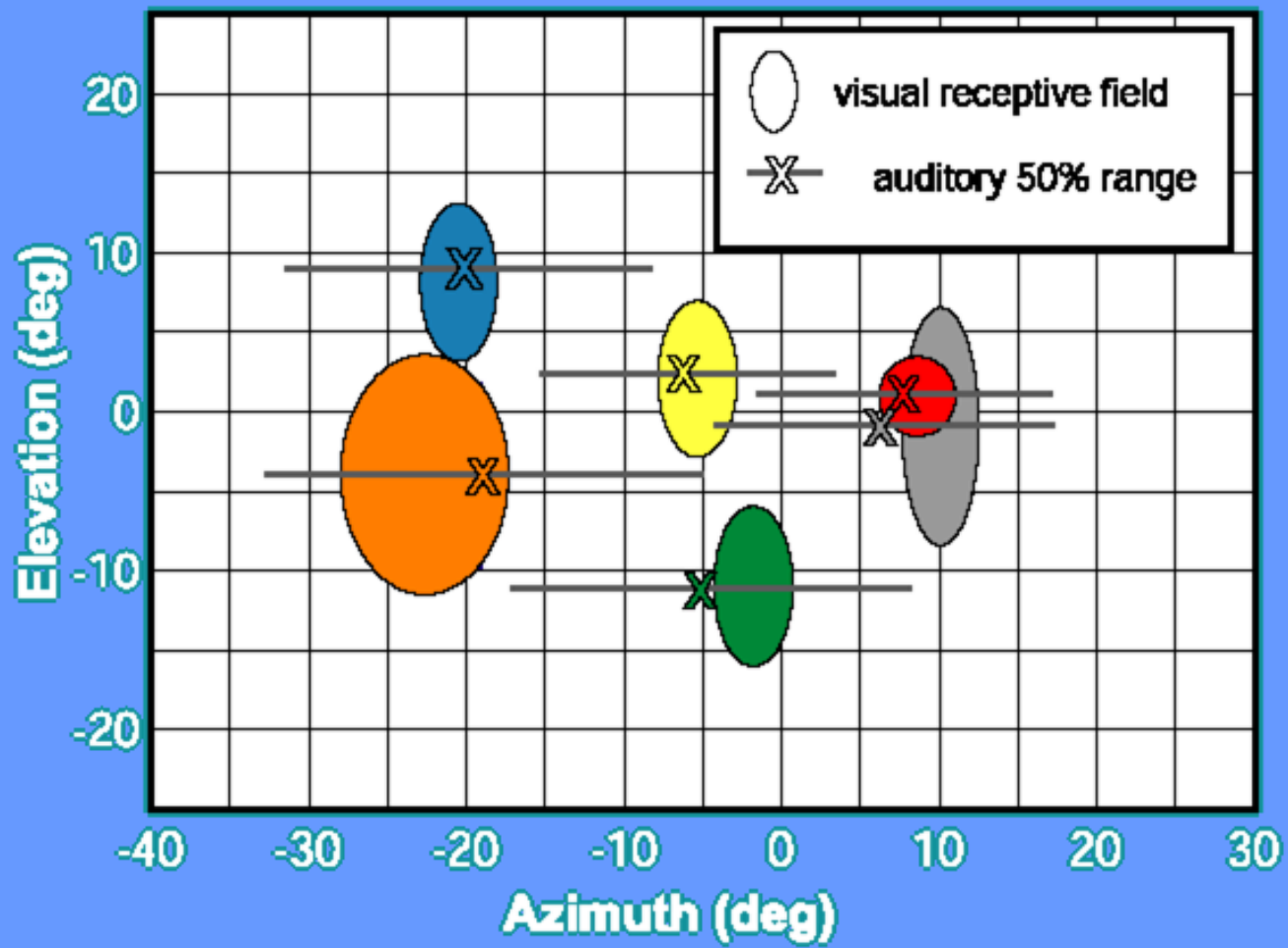
Visual Receptive Fields in the ICX





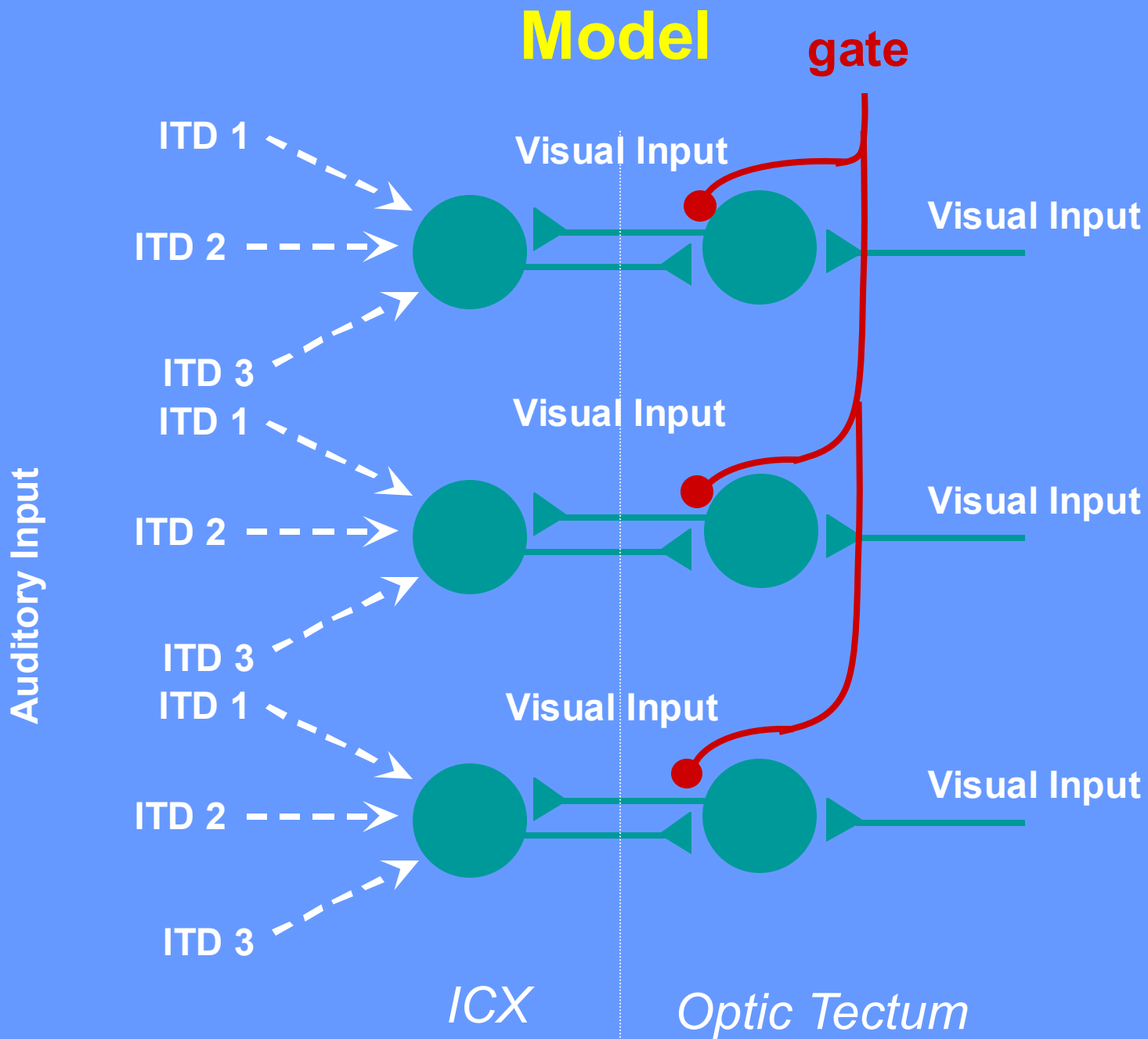




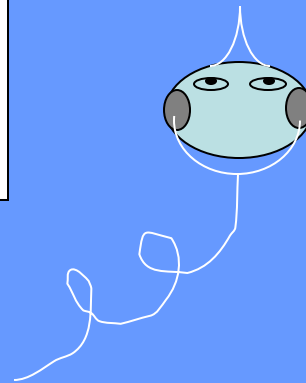
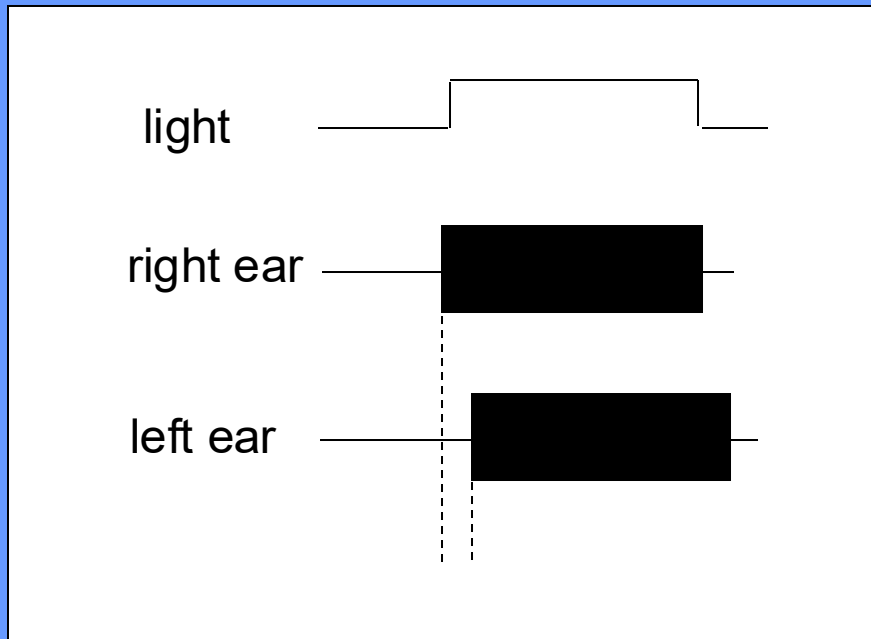


Properties of visual responses in ICX

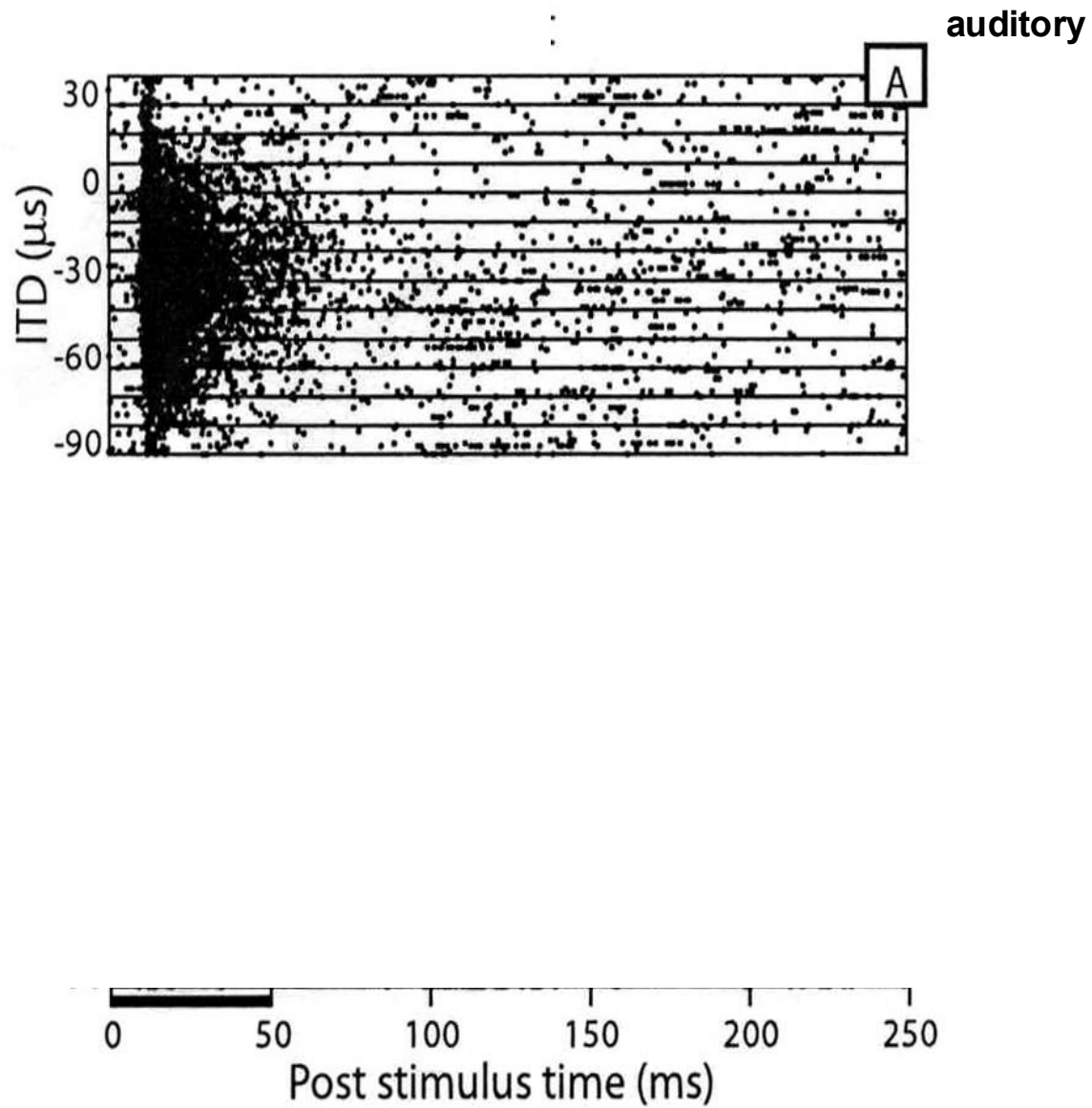
- Arrive from the OT
- Display spatially restricted visual receptive fields
- Form a map of space
- Align with auditory spatial representation



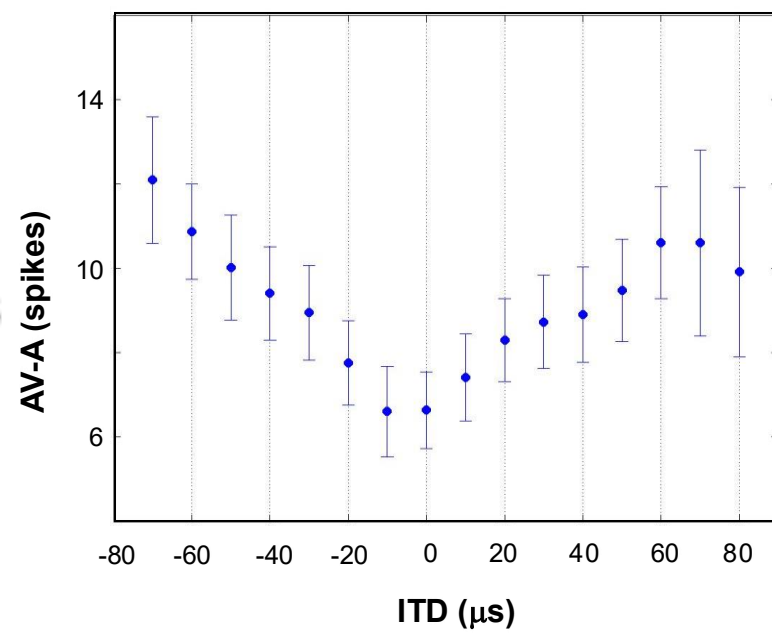
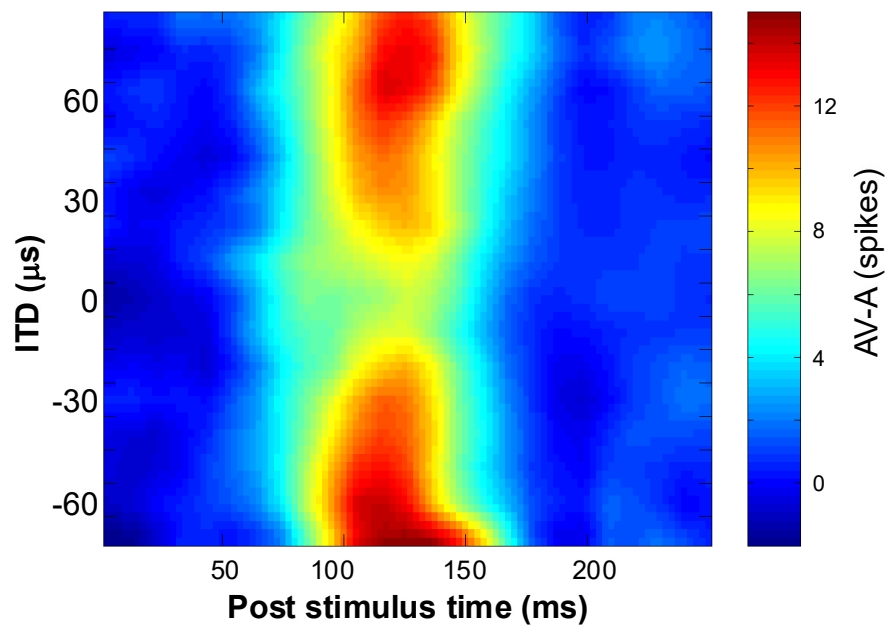
Bimodal Stimulus



Visual and auditory interactions in the ICX

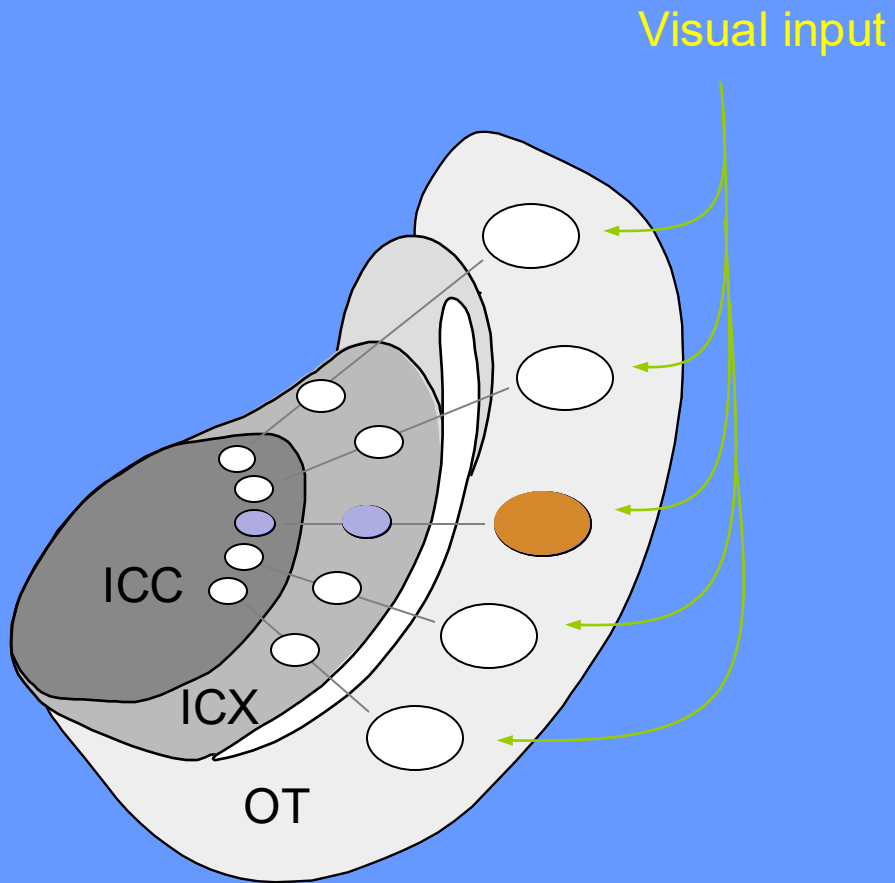


Average



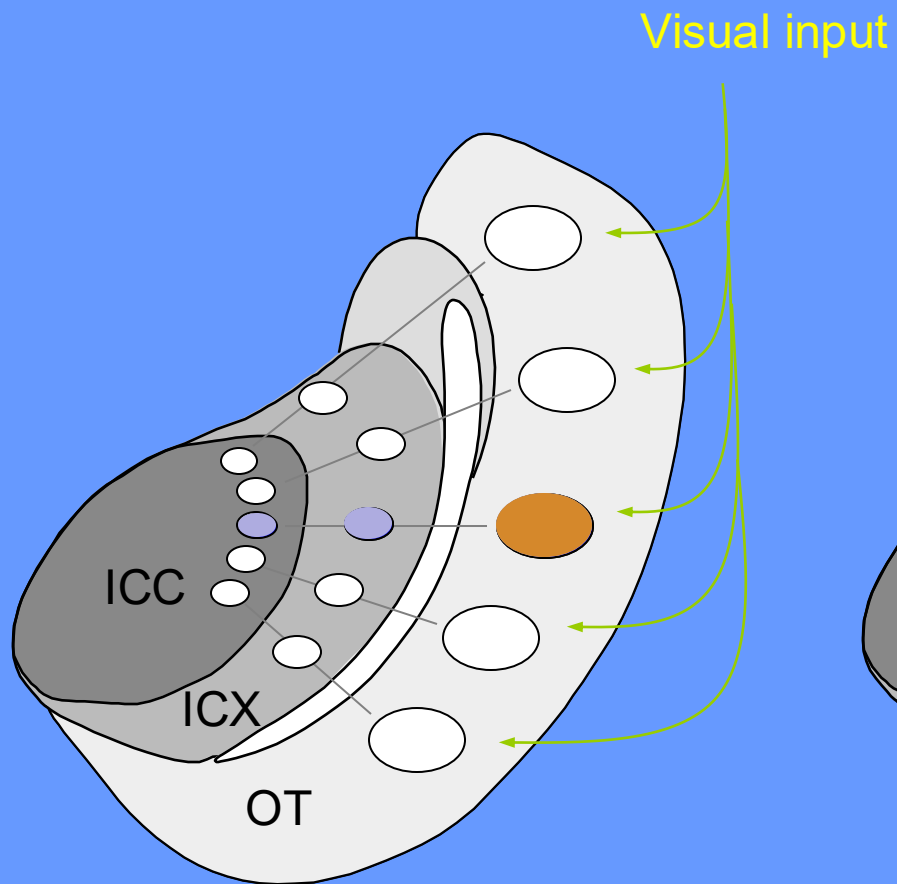
Bimodal stimulus

Normal

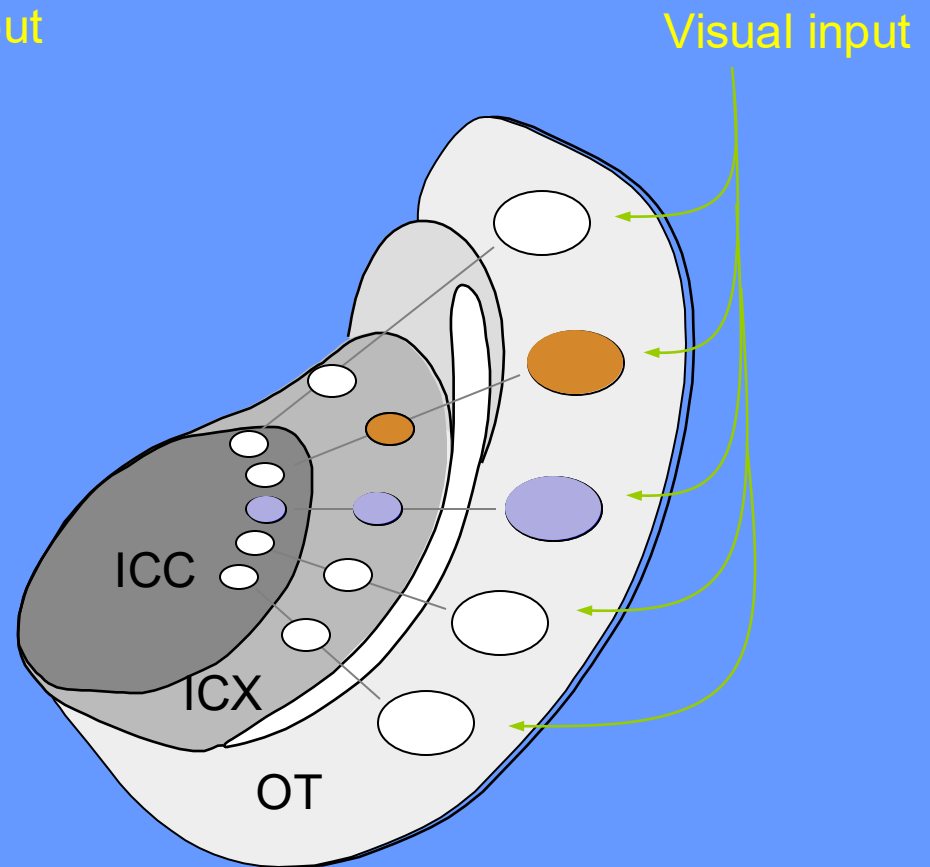


Bimodal stimulus

Normal

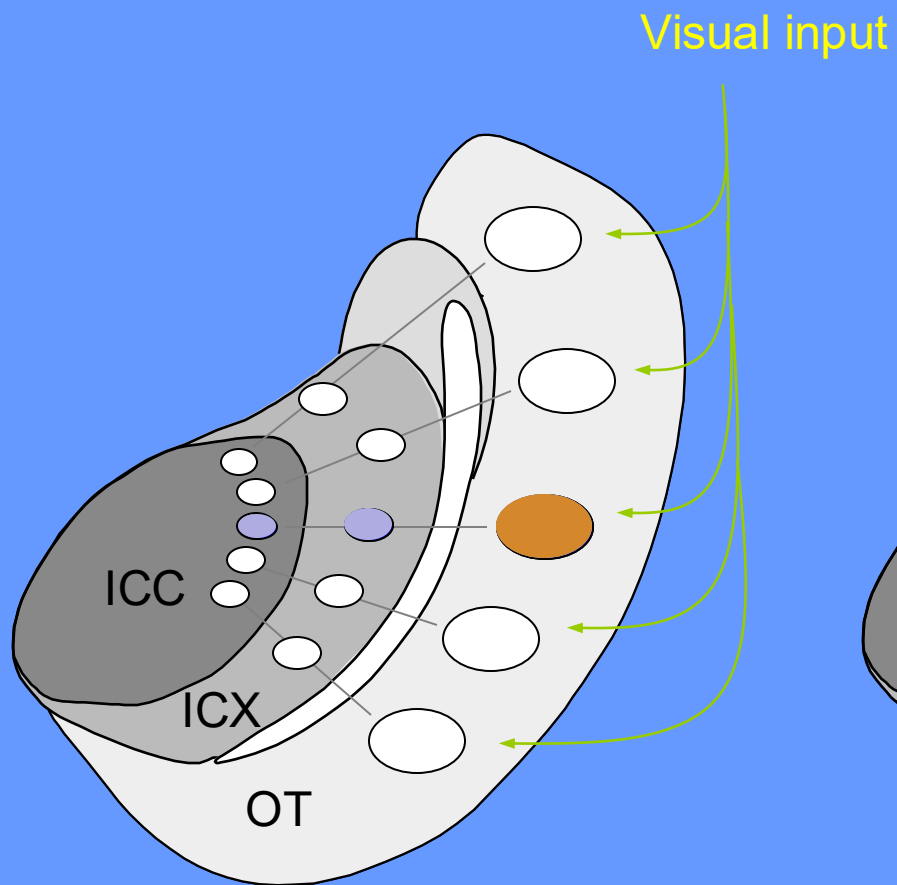


With prisms

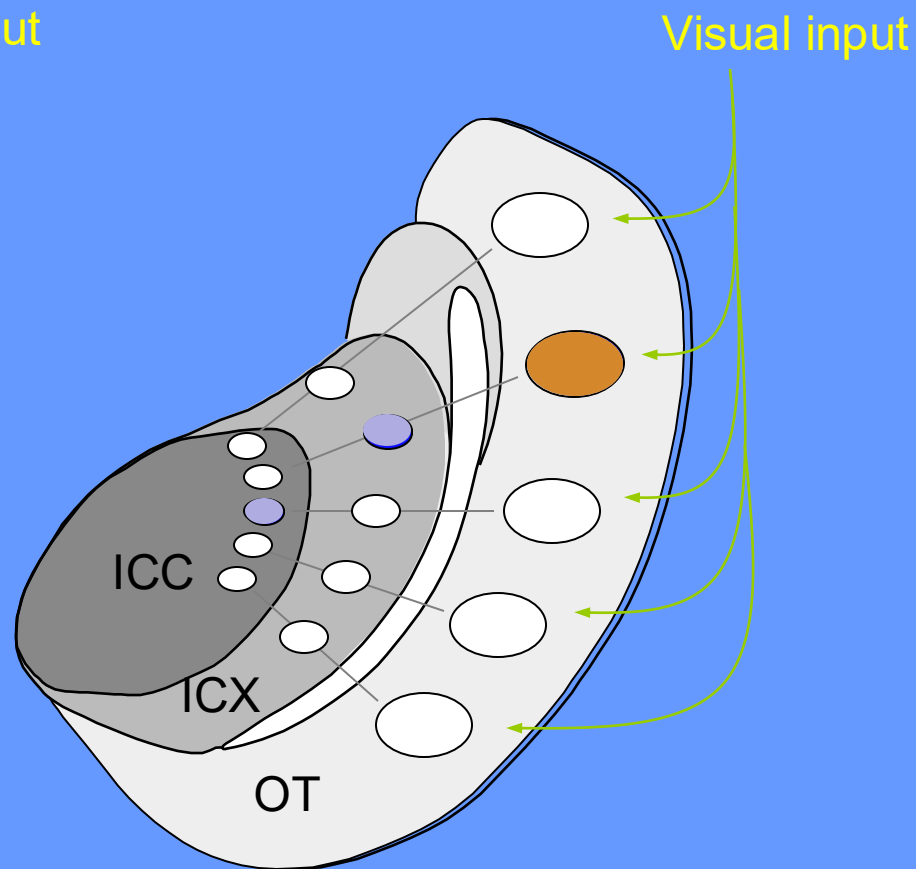


Bimodal stimulus

Normal



With prisms



Summary

- An inhibitory gate controls the flow of visual information into the auditory system

Summary

- An inhibitory gate controls the flow of visual information into the auditory system
- The visual signals are appropriate to serve as the instructive signal for auditory plasticity

- Eric Knudsen
Daniel Feldman
Michael Brainard
Will DeBello
Peter Hyde
Brie Linkenhoker
Joe Bergan

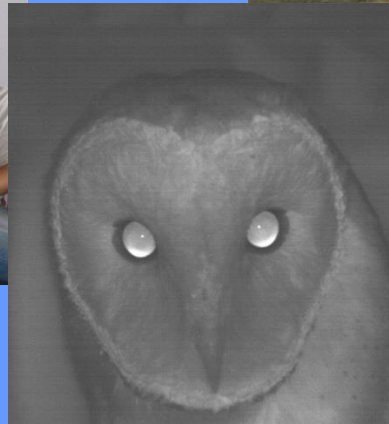


Stanford University

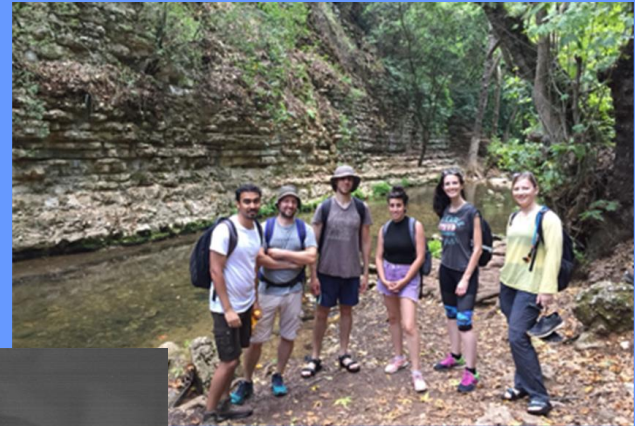
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