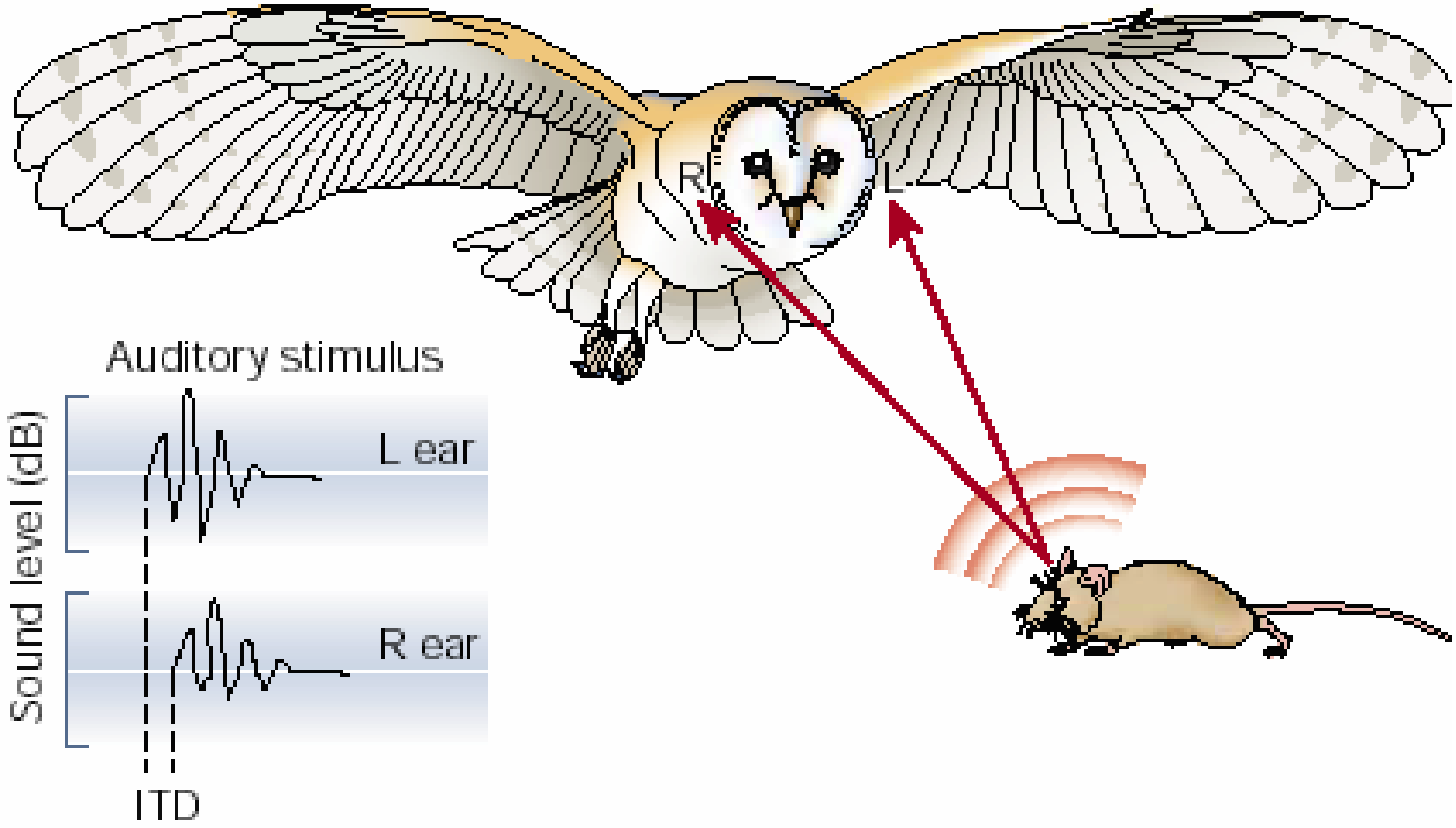
LECTURE 5:
PLASTICITY OF MULTIMODAL MAPS IN THE BRAIN

MCP 9.018/7.68 ‘04

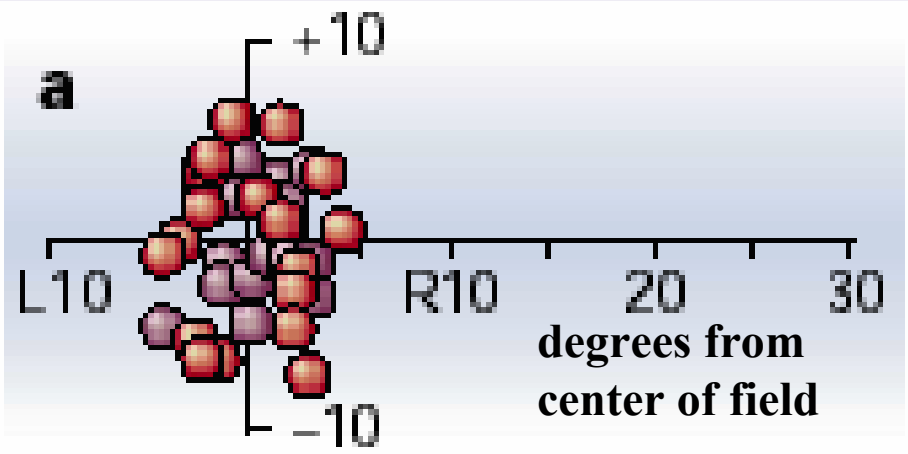
Owls Localize Prey Along the Horizontal Axis (azimuth) Using Interaural Time Difference Cues and, If it is Light, They also Use Visual Cues

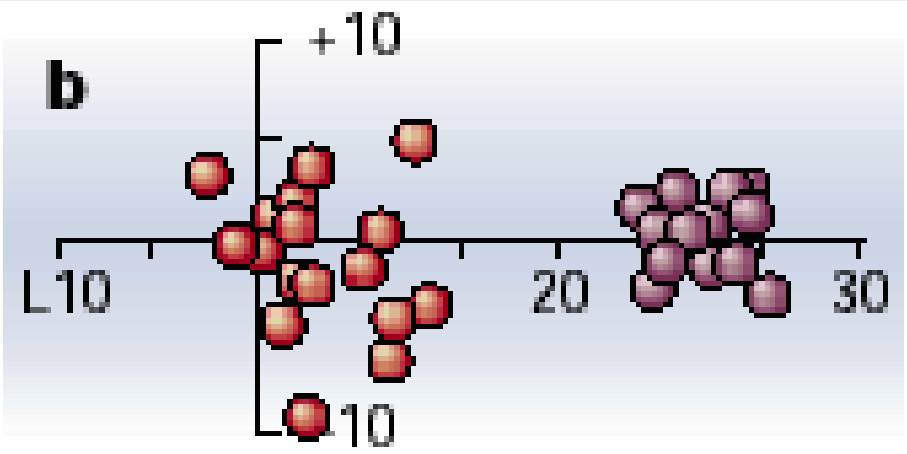


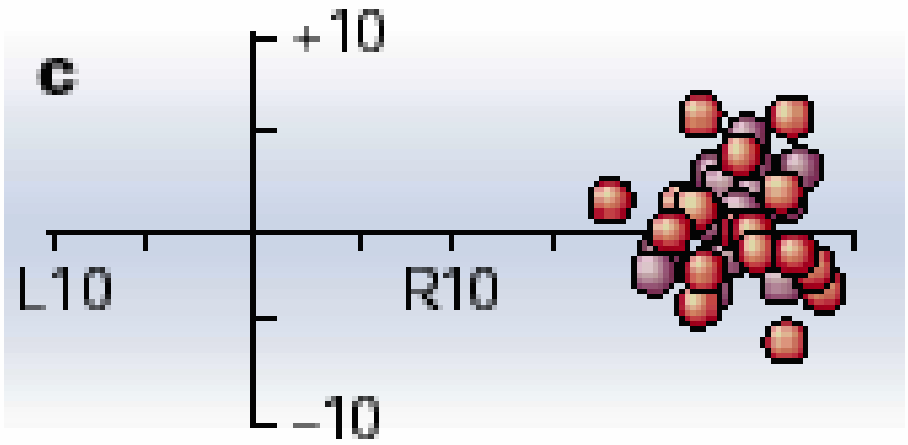
Head Orientation In the Dark Using Auditory Cues (red) Or Visual Cues (purple)

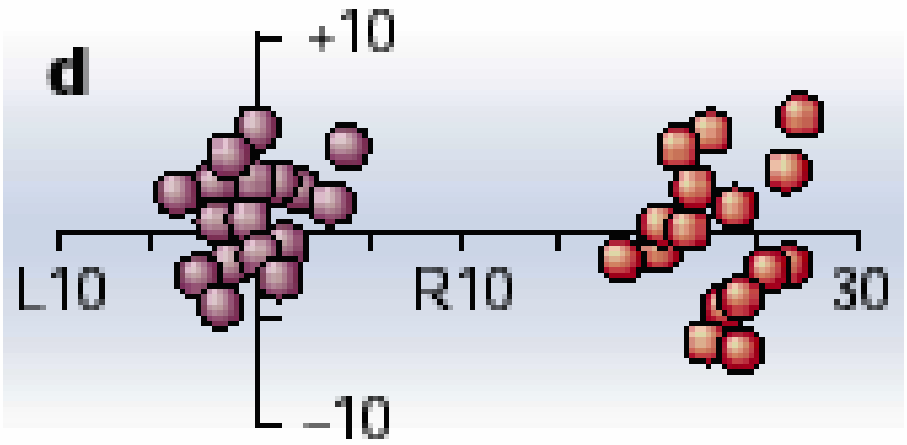
before prisms

1 day after visual field displacement to the right with prisms





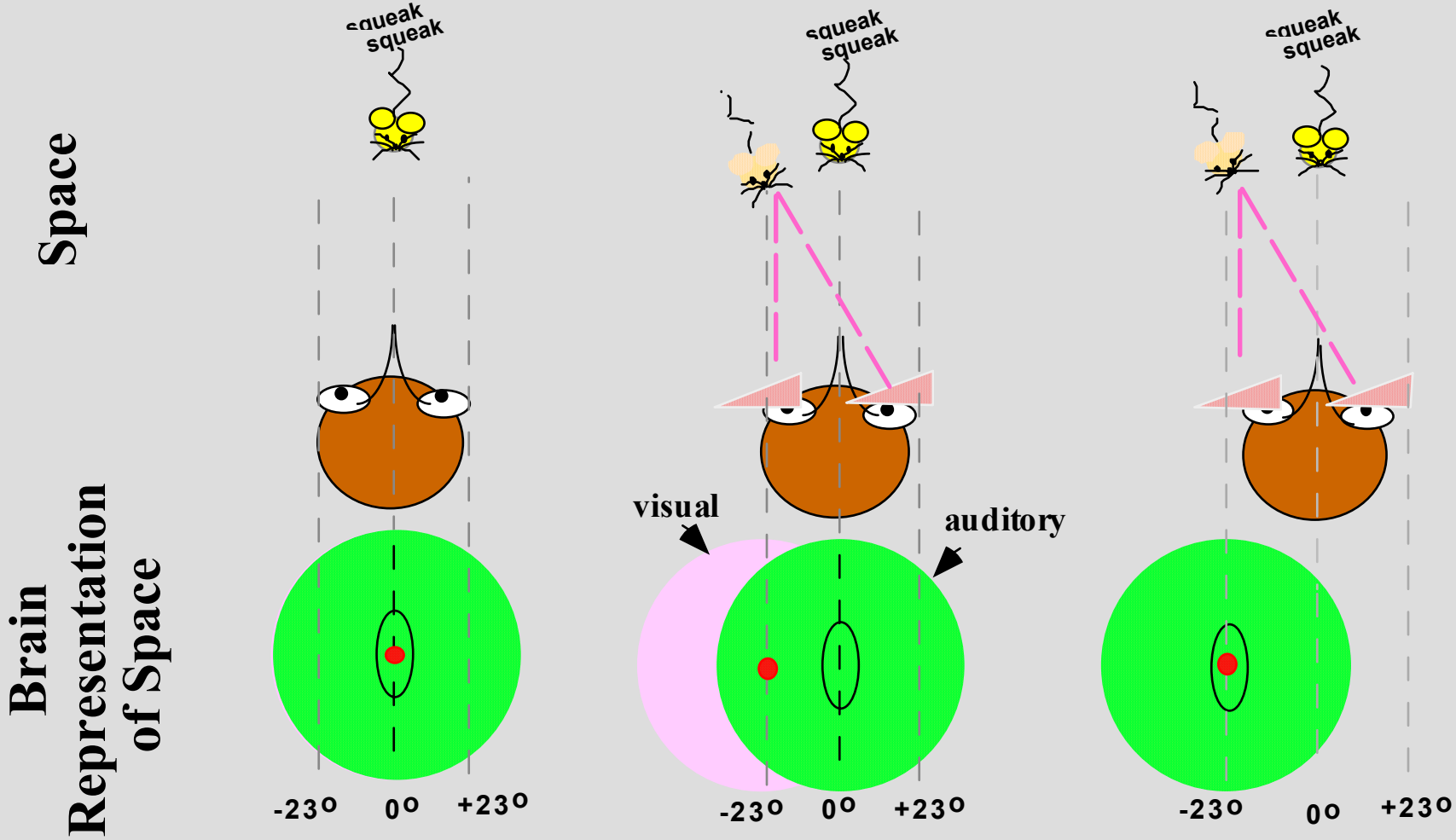




day 42 with 23degree prisms

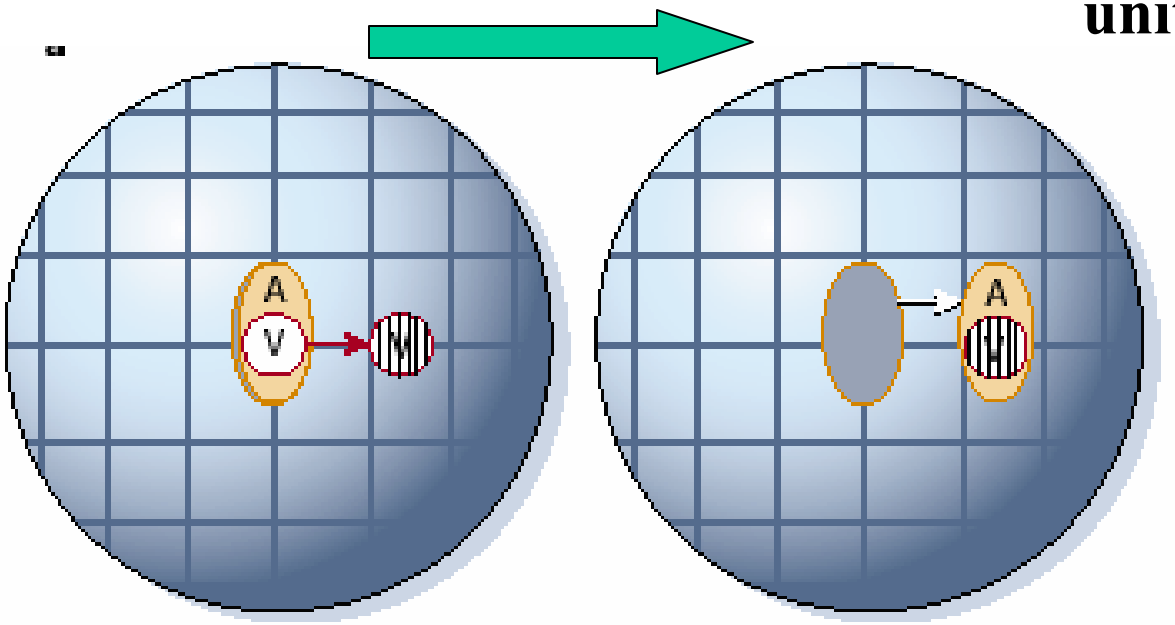
shortly after prisms are removed

The Brain Uses Correlations In Activity to Bring Auditory and Visual Space Maps Into Register

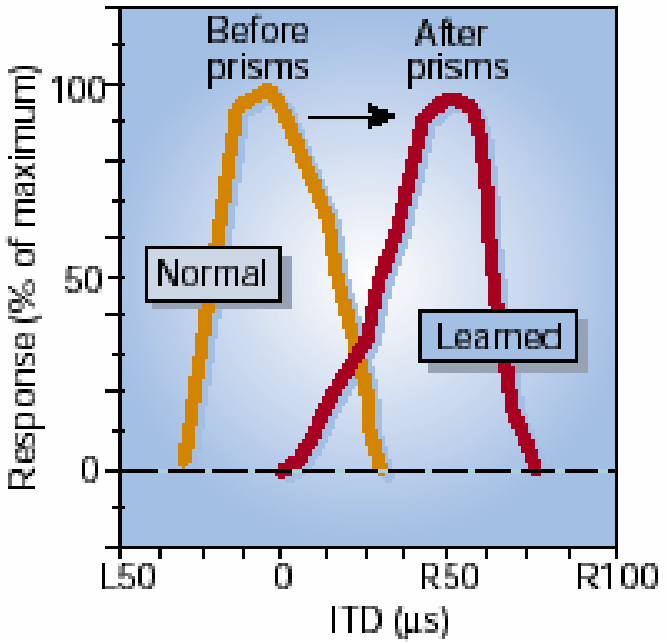


Shift In Behavior Corressponds to a Shift in ITD Tuning When Single Neurons are Recorded Extracellularly in the Optic Tectum after Prism Learning but with the Prisms Off

Behavioral Shift



Corresponding interaural time difference (ITD) sensitivity of a multimodal unit in the optic tectum



WHAT IS GOING ON IN THE BRAIN ?

1. Where is the locus of the change?

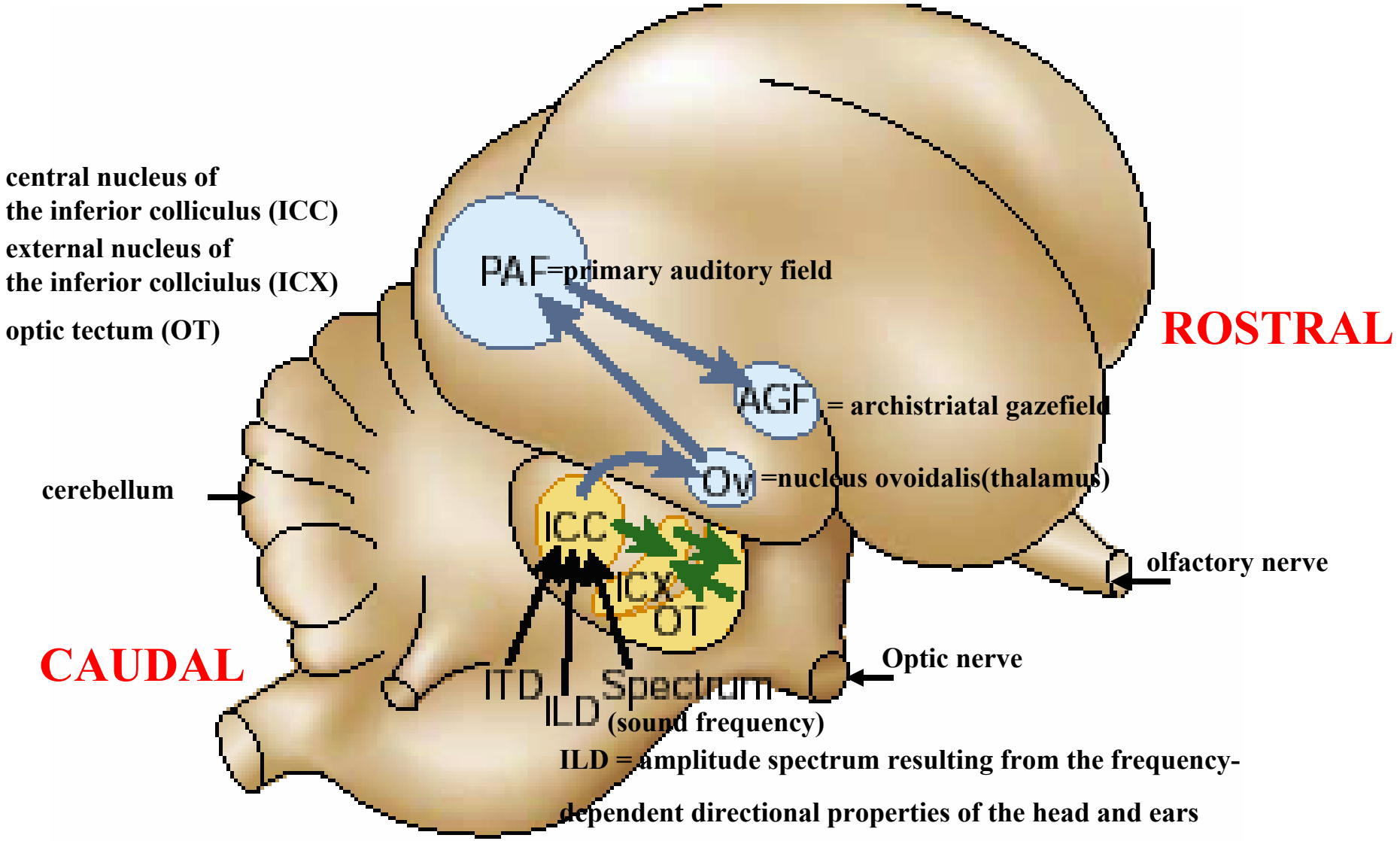
2. Is correlation detection involved?

3. Does correlation detection involve NMDA receptors?

4. Is the change anatomical or a shift in weight of synapses or both?

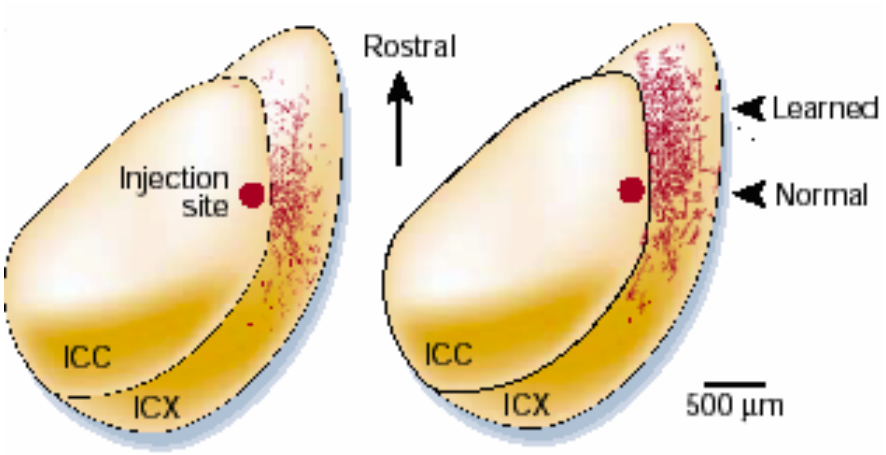
5. How are responses to original ITD map positions suppressed?

Midbrain (yellow) and Forebrain (blue) Pathways that Mediate Auditory Orienting Responses

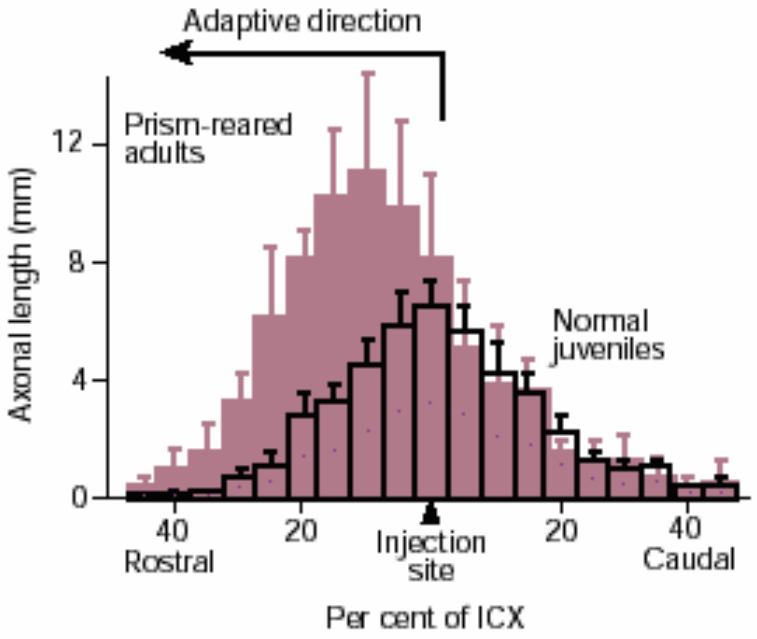


Axons from a single site in ICC arborize in a a restricted site in the ICX ITD map.

Normal **Prisim Reared**



Shifted electro-physiological and behavioral responses have an anatomical counterpart.

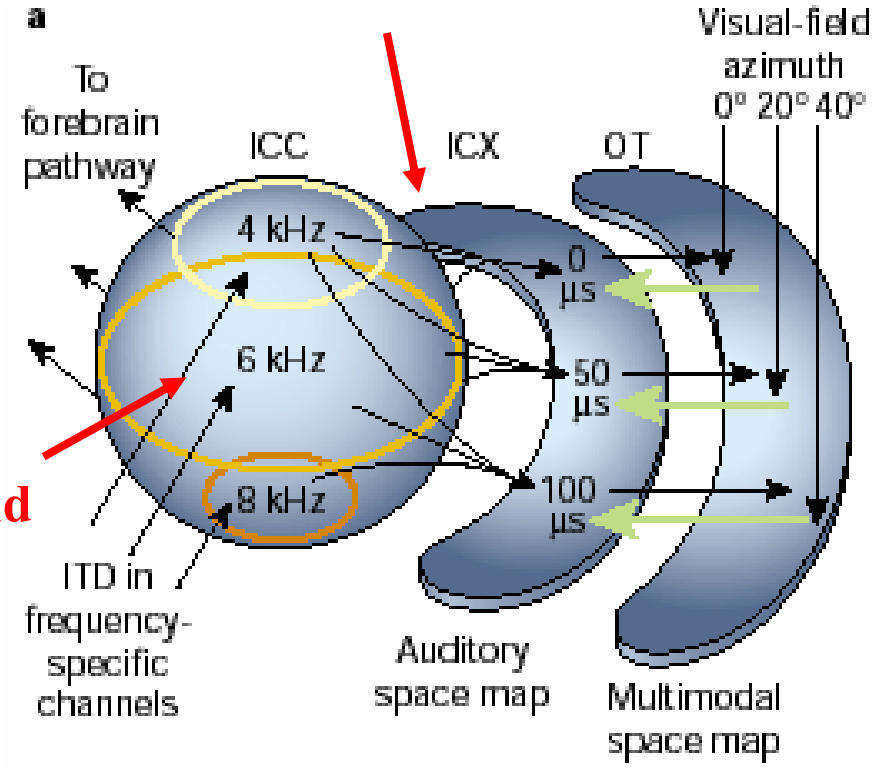


Axons from a similar site in ICC arborize over a much larger region in the ICX. The new arbori-zation occurs toward the position of the shifted auditory receptive field

Experience dependent Changes in Connectivity Occur Within the Owls' Midbrains

NORMAL CONNECTIVITY

Neurons in ICX are tuned sharply for interaural time differences (ITDs).

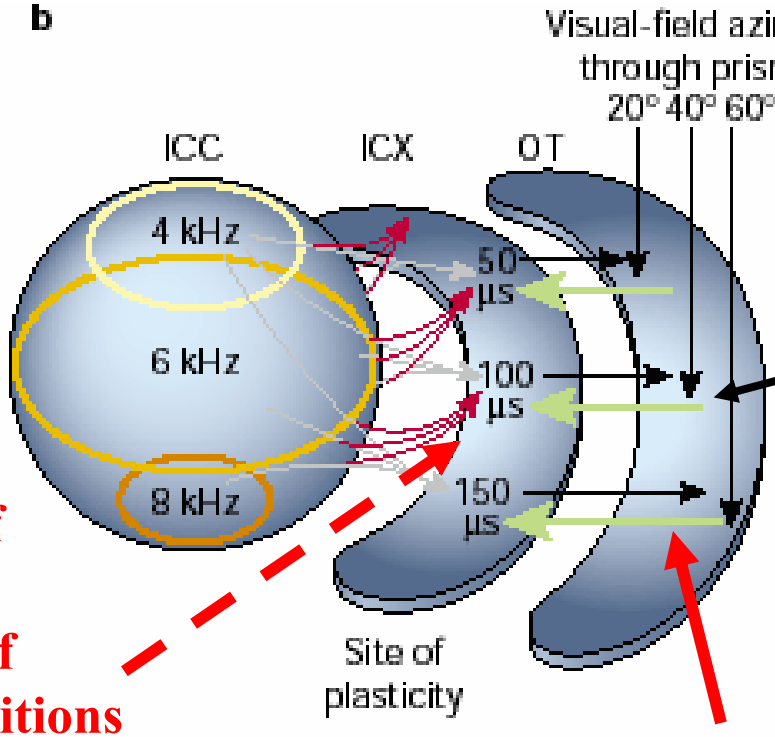


There is a one dimensional frequency map in the ICC. Within each frequency band the range of ITDS is represented.

The optic tectum receives direct visual input from the retina

ALTERED CONNECTIVITY AFTER LEARNING WITH PRISMS

The ICC has a tonotopic map (frequency is mapped).



Grey arrows represent the"instructive" pathway from the optic tectum

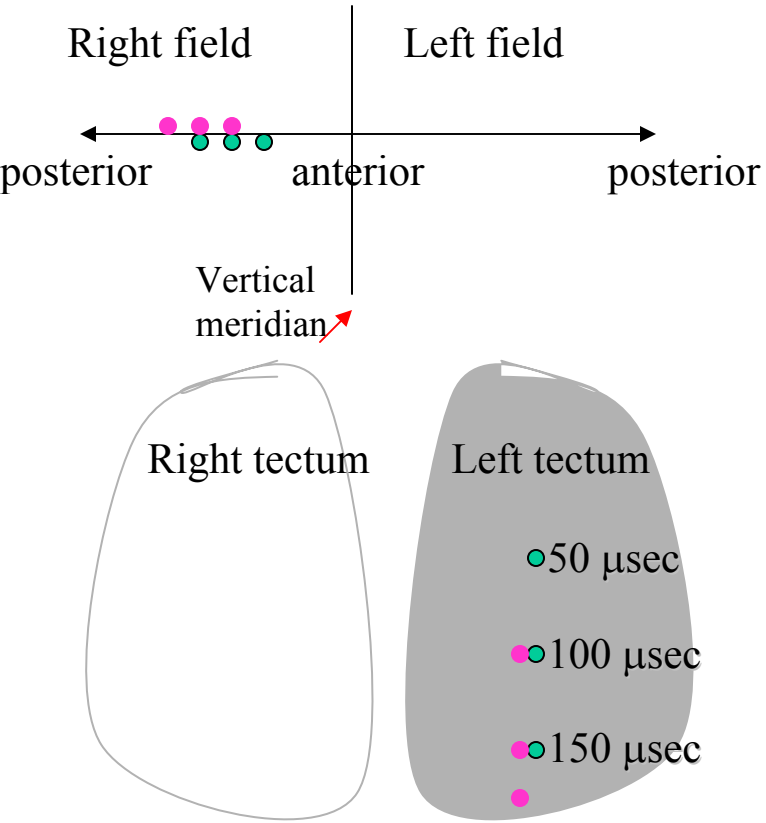
The connections between ICC & ICX from each of the multiple representations of ITD's shift to positions where coincident activity from the prism shifted visual map is delivered to ICX.

Connections between ICX and OT do not change.

Extracellular multiunit recordings in the optic tectum can follow the transition from one mapped auditory position to another

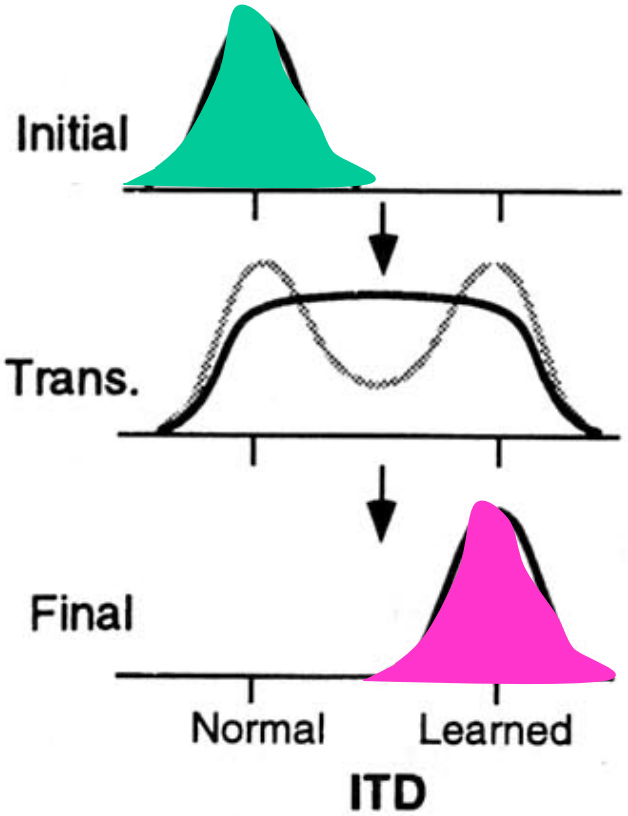
In the optic tectum, extracellular recordings show a peak in spike frequency at the anterior-posterior (rostral-caudal) position corresponding to ITD position in the auditory space map.

Visual and auditory space



In the transition period spike frequency is increased between the initial and final and final positions using point source auditory stimuli

Tectal Recordings



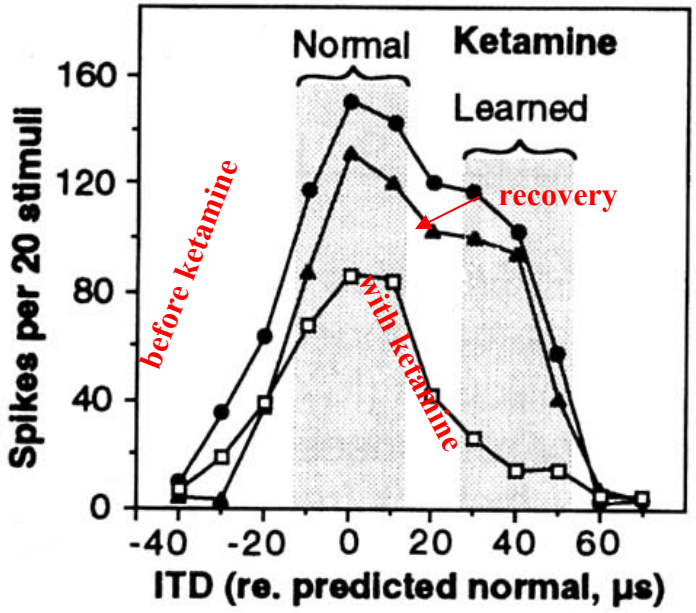
(Position along rostral-caudal tectal axis)

From: Feldman et al., 1996

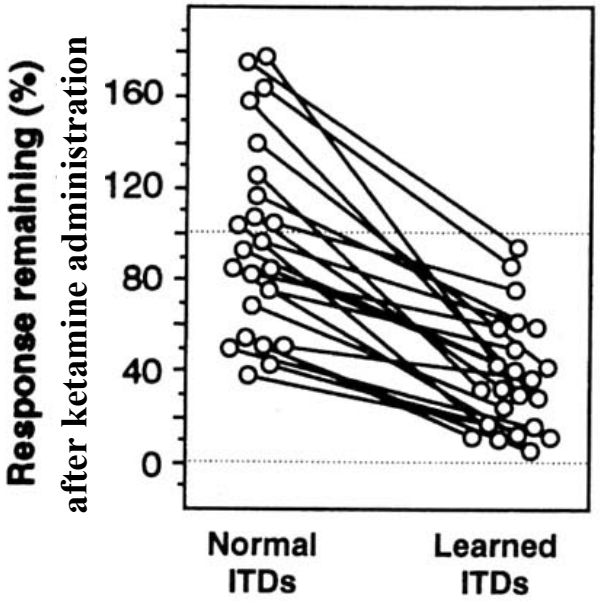
Evidence that NMDA Receptor (NMDAR) Mediated plasticity Is Involved in this Learning

In the optic tectum, during the transition period when the auditory ITD map is shifting, the NMDA receptor contribution to responses at the original ITD position decreases and the contribution of the NMDAR at the new ITD position increases.

Experiments during the transition period.



NMDAR antagonism with ketamine has a larger effect at the learned site



The shoulder in the tuning curve due to development of functional connections at the learned site virtually disappears with systemic ketamine which antagonizes NMDA receptors.

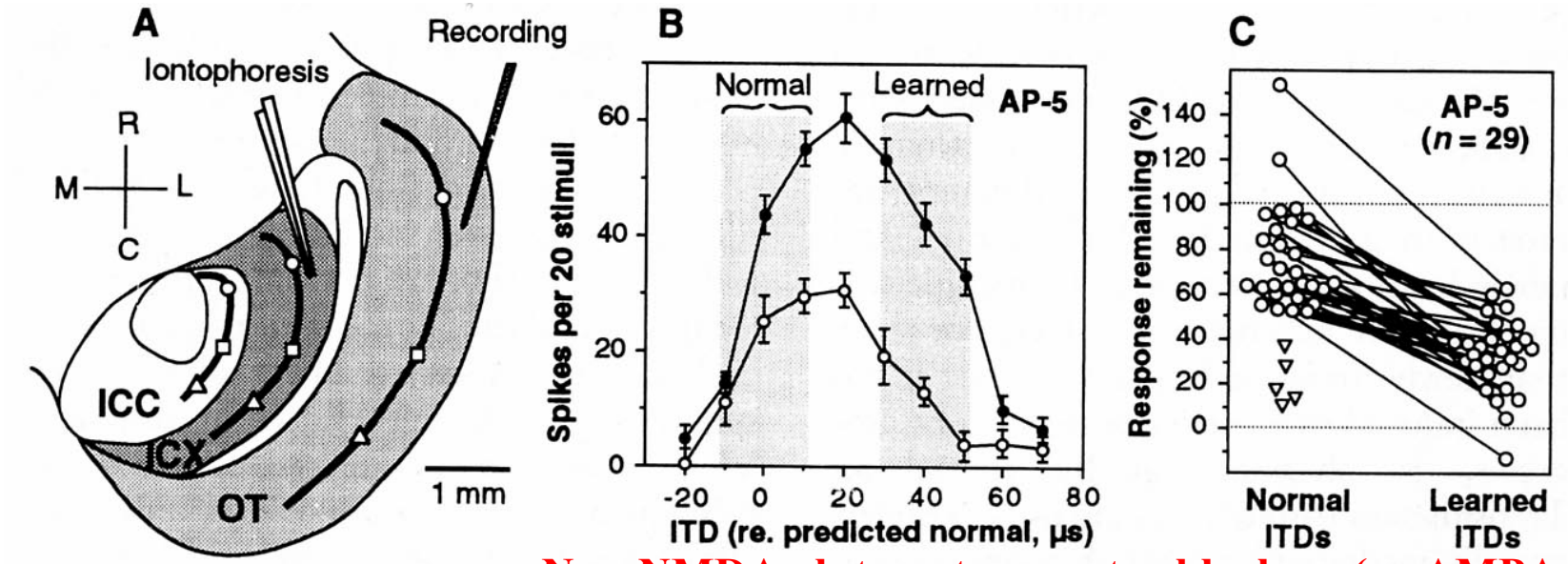
Where in the pathway does the ITD map change originate?

The NMDAR antagonist AP5 is iontophoresed into ICX while the ITD tuning curve is recorded at the corresponding normal ITD map position in the optic tectum.

Recording in a horizontal midbrain slice.

○ = tuned to 0µsec ITD
□ = tuned to 100 µsec ITD
△ = tuned to 50 µsec ITD

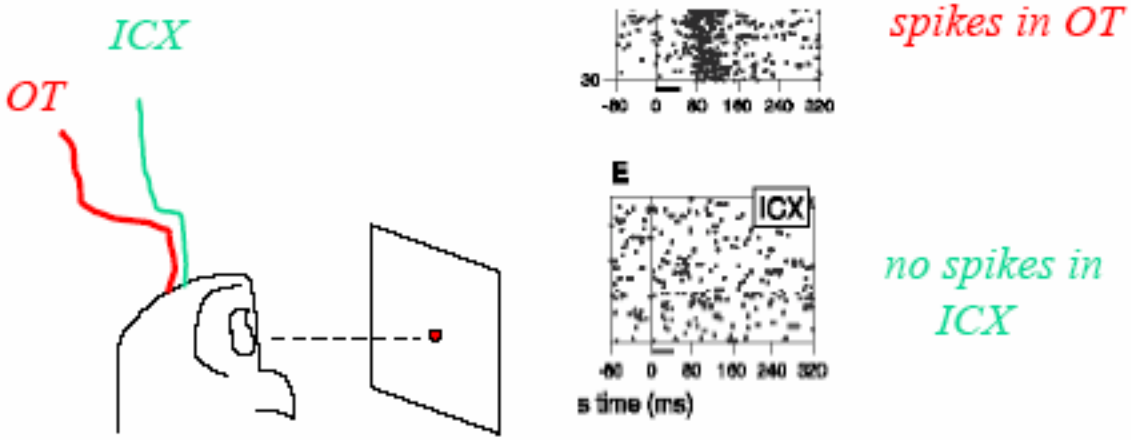
AP5 in the ICX greatly reduces the responses produced by the learned ITD at the normal ITD tectal site.



What is an important control for this experiment?

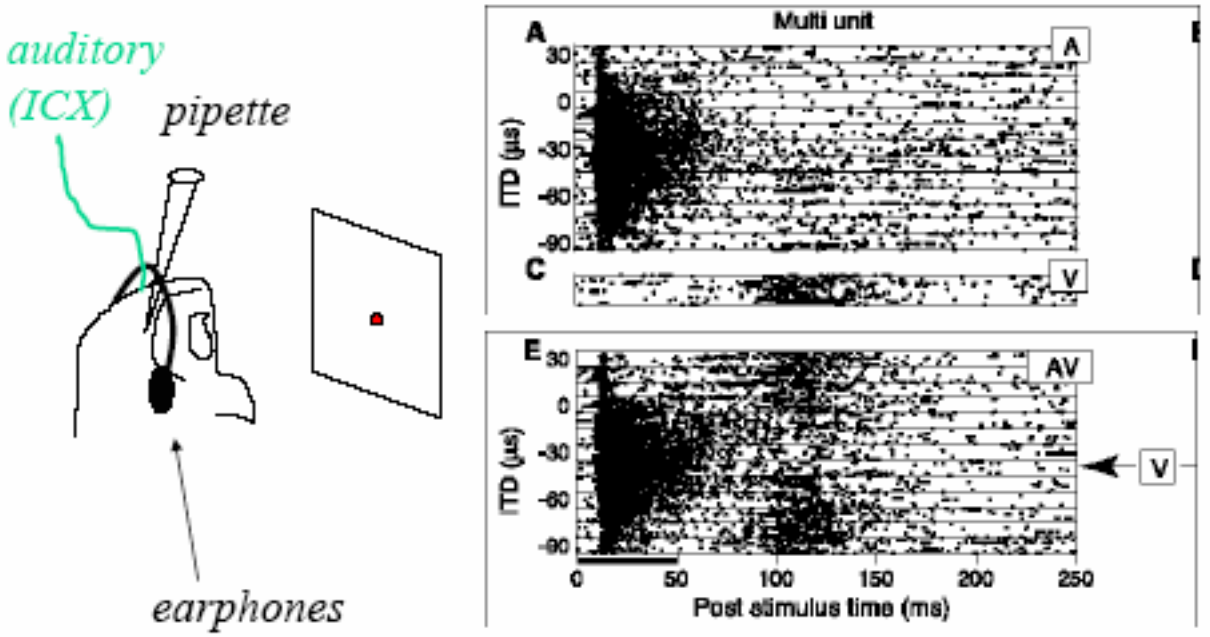
Non-NMDA glutamate receptor blockers (eg AMPA, Kainate receptor blockers decreased both normal and learned responses.

But no Activity is Detected in Auditory System



Gutfreund, Y et al. (2002) Gated visual input to the central auditory system. Science 297:1556-1558.

The Influence of Auditory Stimulus on Visual Responses in ICX



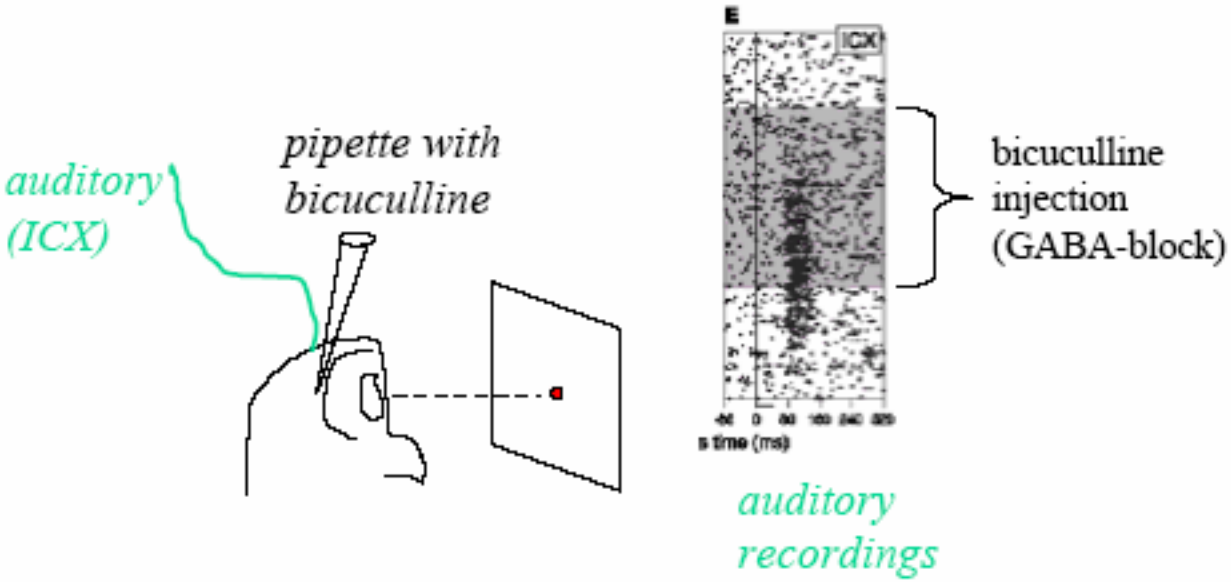
Visual signal is extinguished if auditory signal is coincident

Gutfreund, Y et al. (2002) Gated visual input to the central auditory system. Science 297:1556-1558.

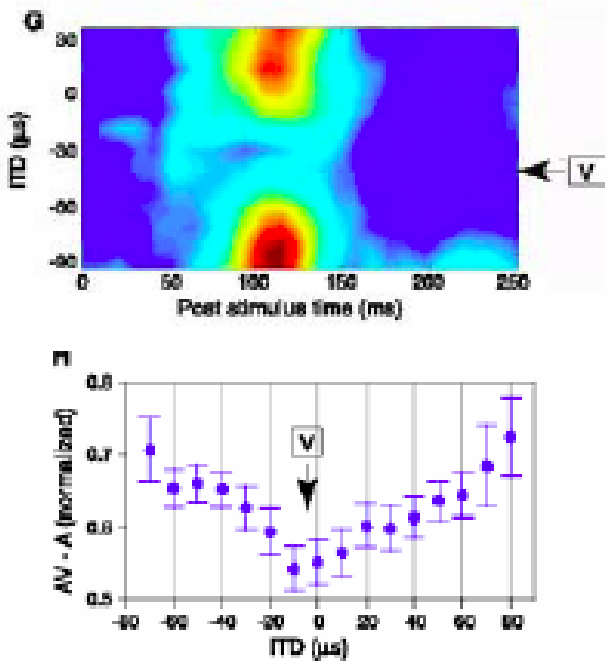
Hypothesis: Input is Gated

- Inhibitory neurons stop visual activity from reaching the ICX?

Visual Stimulus now Elicits Response in ICX



AV – A response



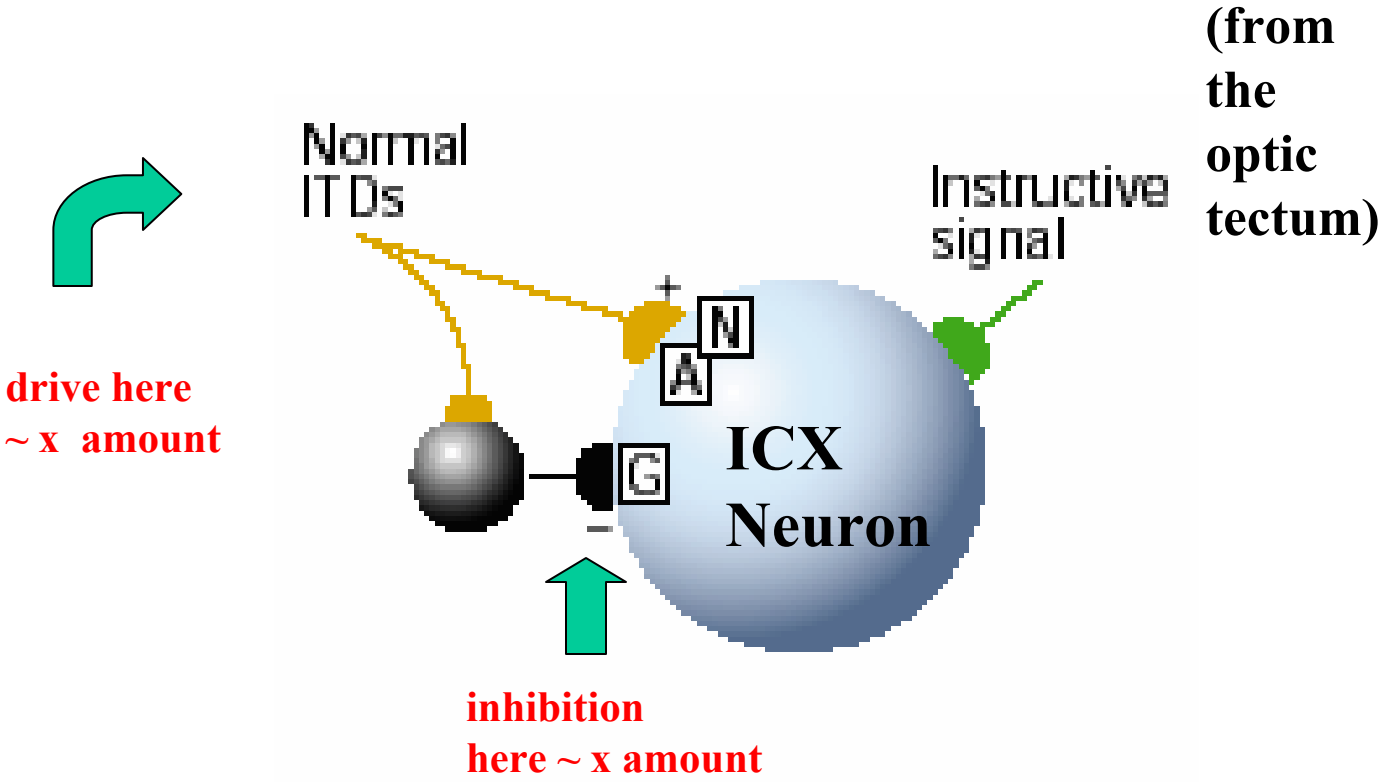
Low visual signal with coincident auditory and visual signals, high if they are contradictory

Gutfreund, Y et al. (2002) Gated visual input to the central auditory system. Science 297:1556-1558.

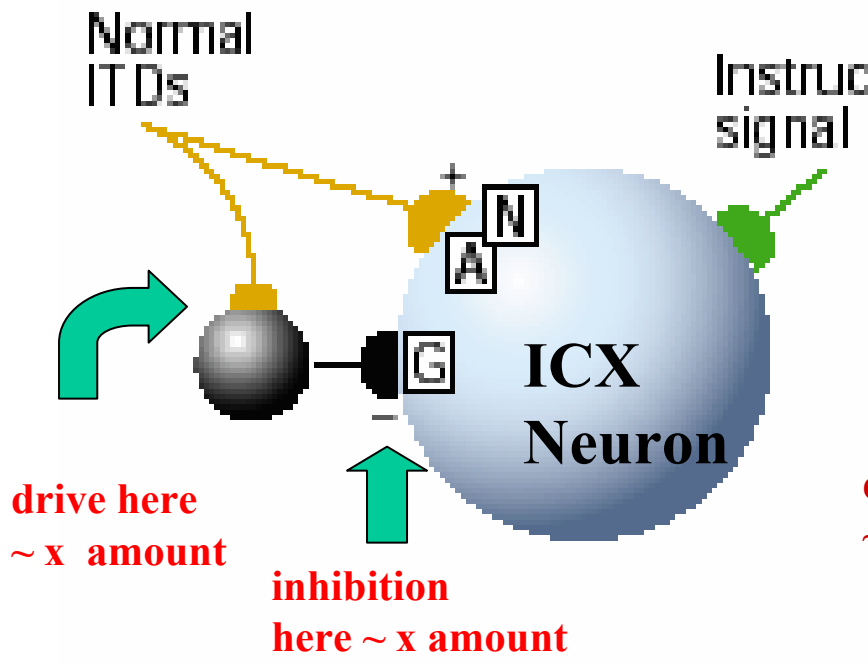
Plasticity Occurs in the ICX Involving Changes Both In Excitatory Inputs to ICX Excitatory Neurons and to ICX Inhibitory Neurons

A= AMPA receptors
N= NMDA receptors
G=GABAA receptors

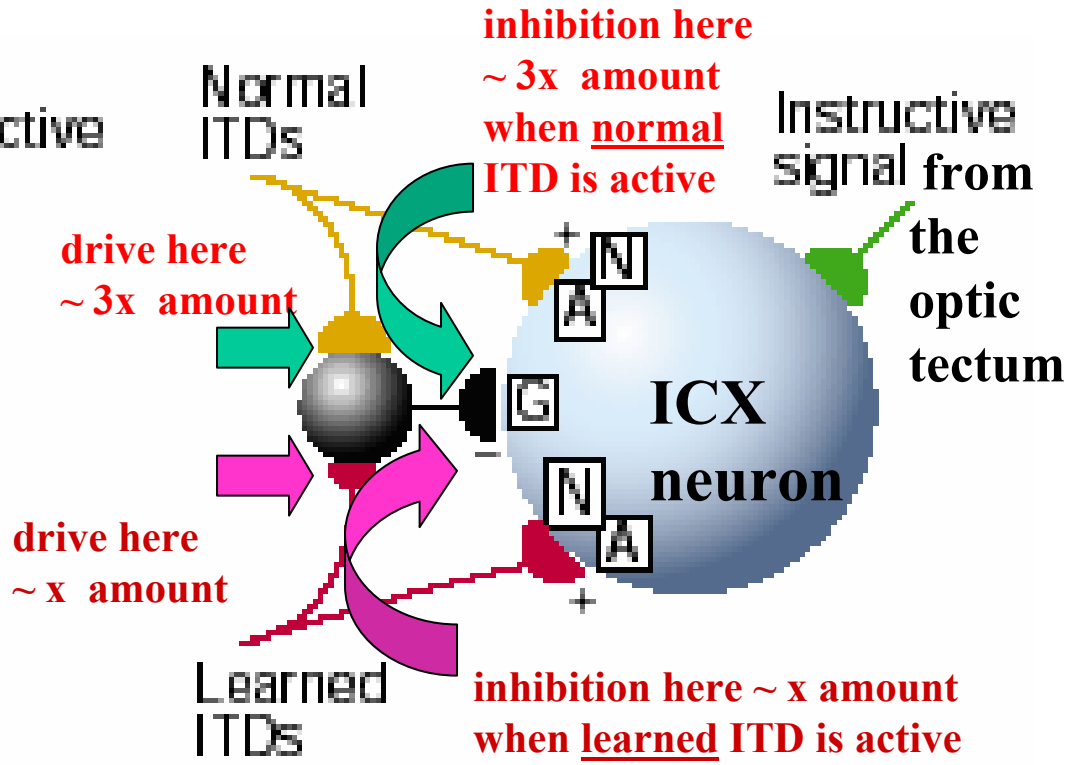
Young bird before prisms



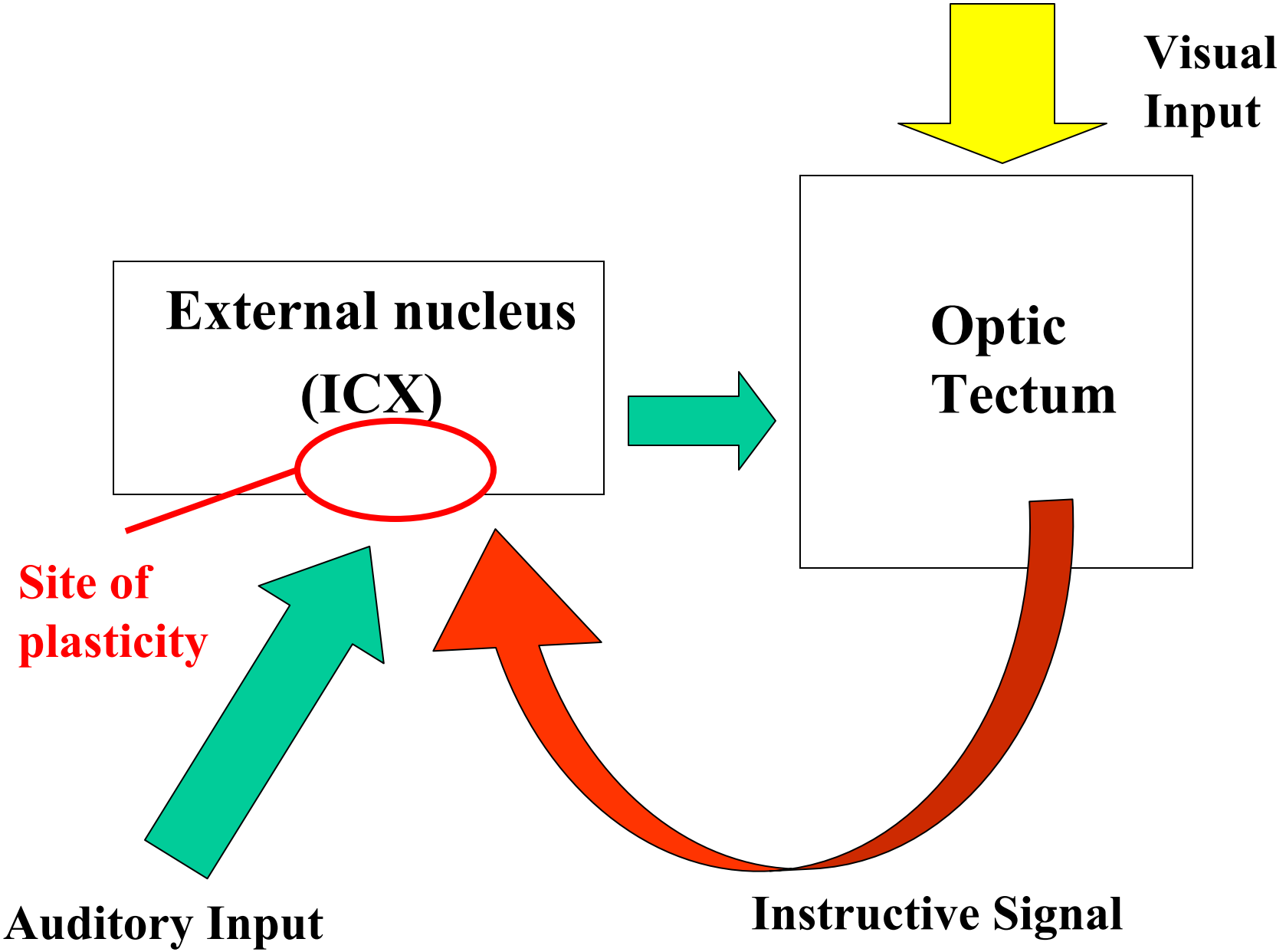
Inhibition selectively increases when instructive signal from the visual pathway is not synchronized with the normal input from ICX



Young bird before prisms

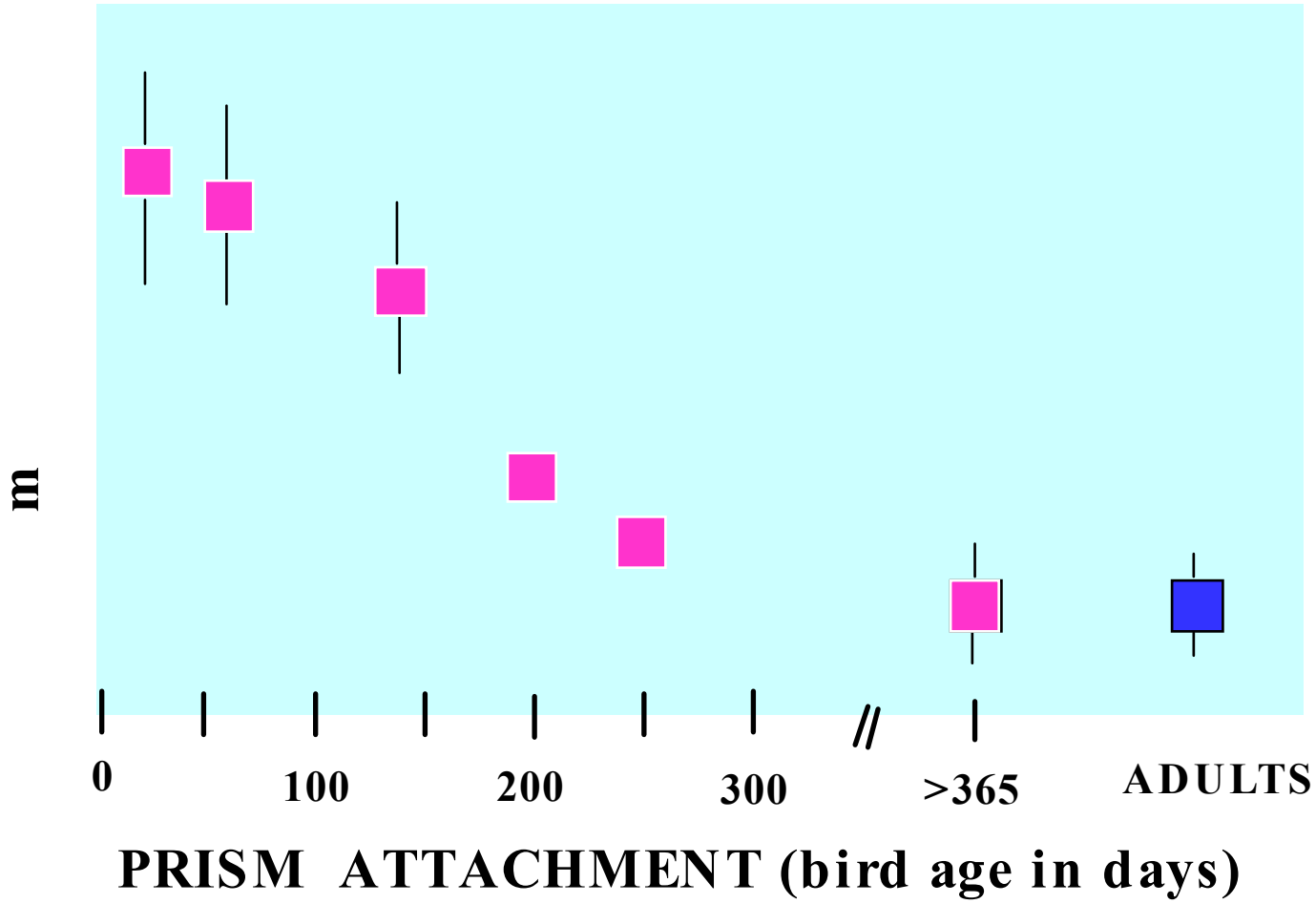


After learning to navigate w/ prisms



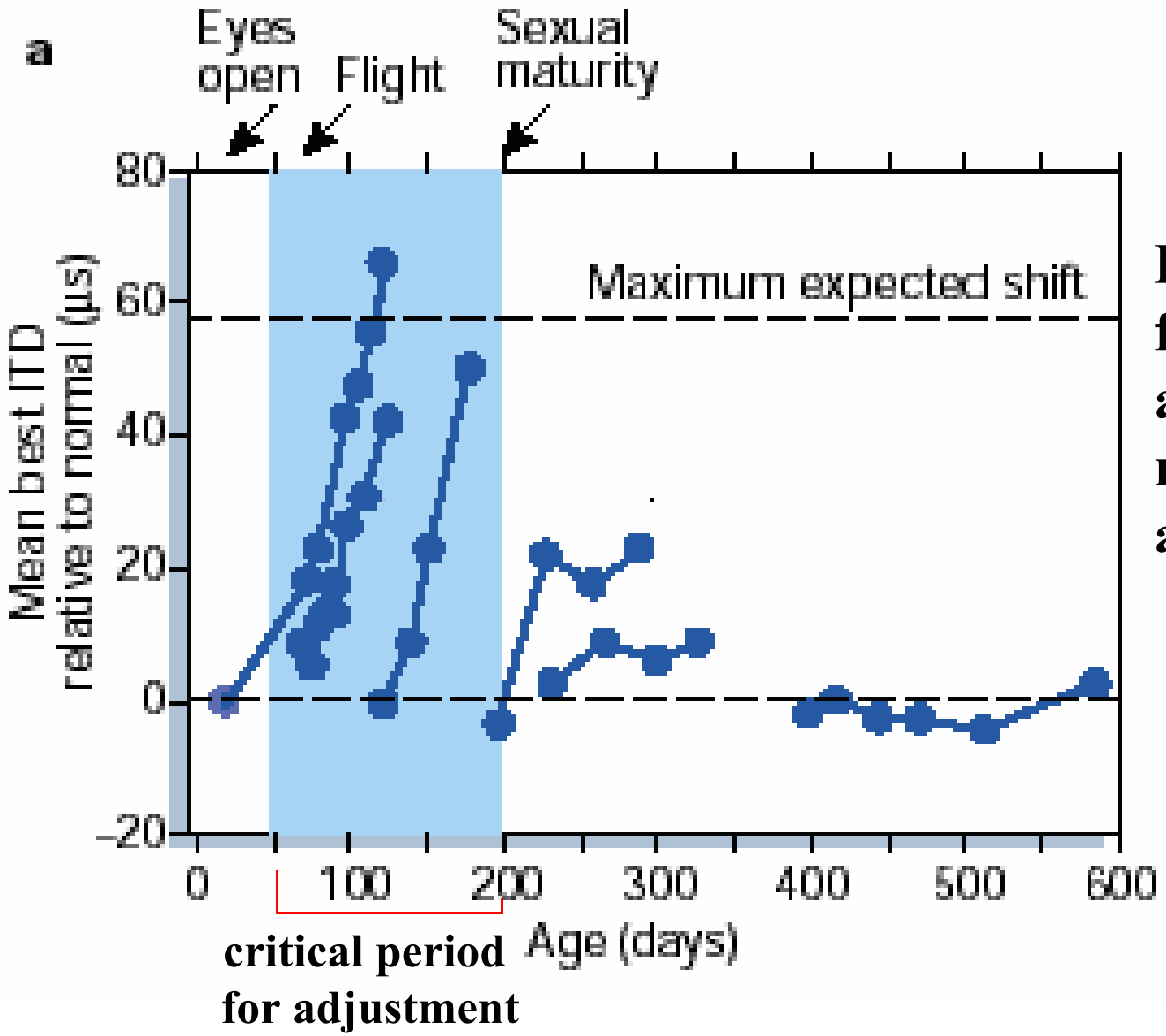
(Beau will present the details on this experiment.)

Plasticity Decreases With Age



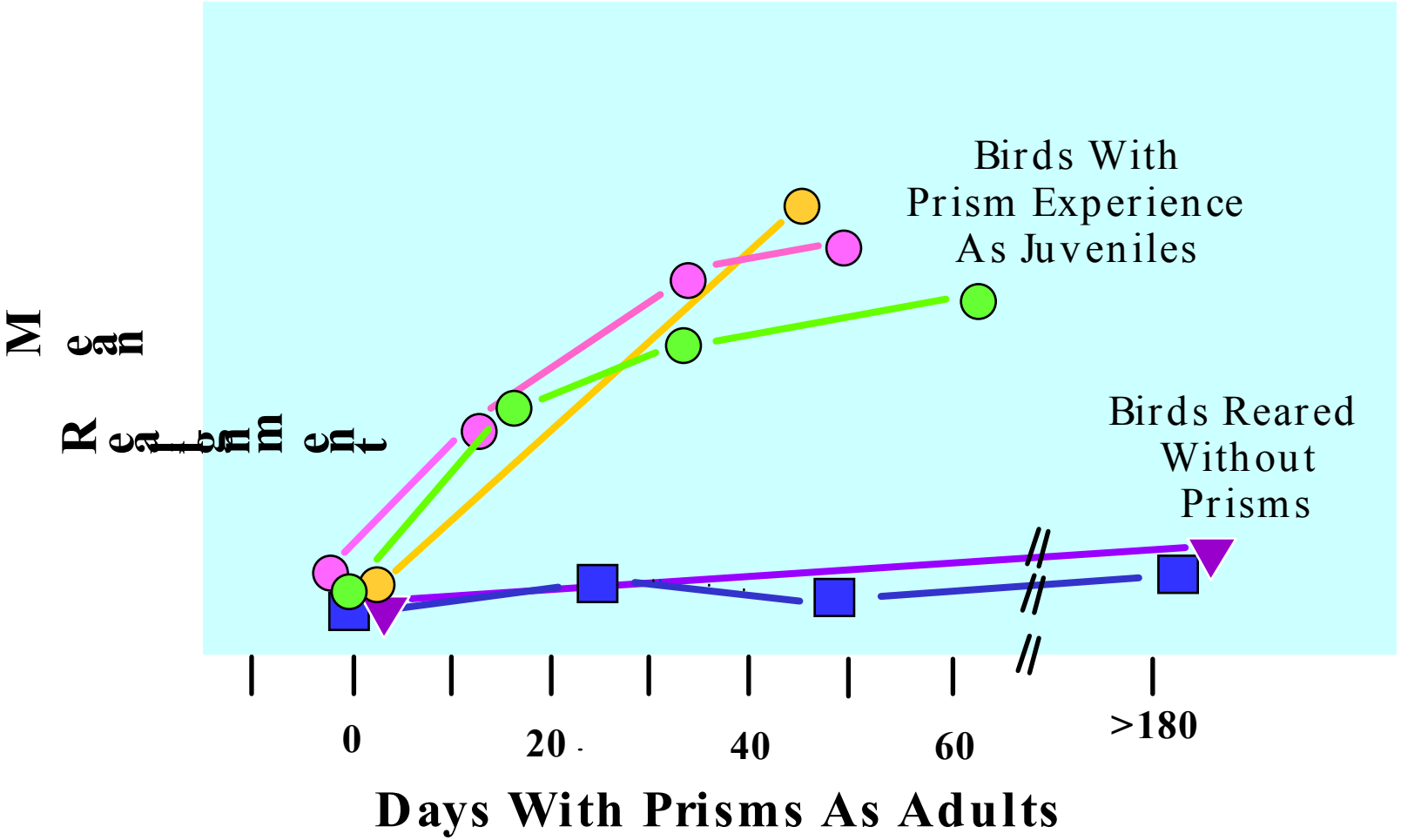
from Brainard & Knudsen, 1998

Older Owls Have A Decreased Ability to Shift Their Auditory ITD To the Shifted Visual Field Positions



Data from 6 owls fitted with prisms and tested at multiple ages afterward.

Early Experience Increases Adult Plasticity

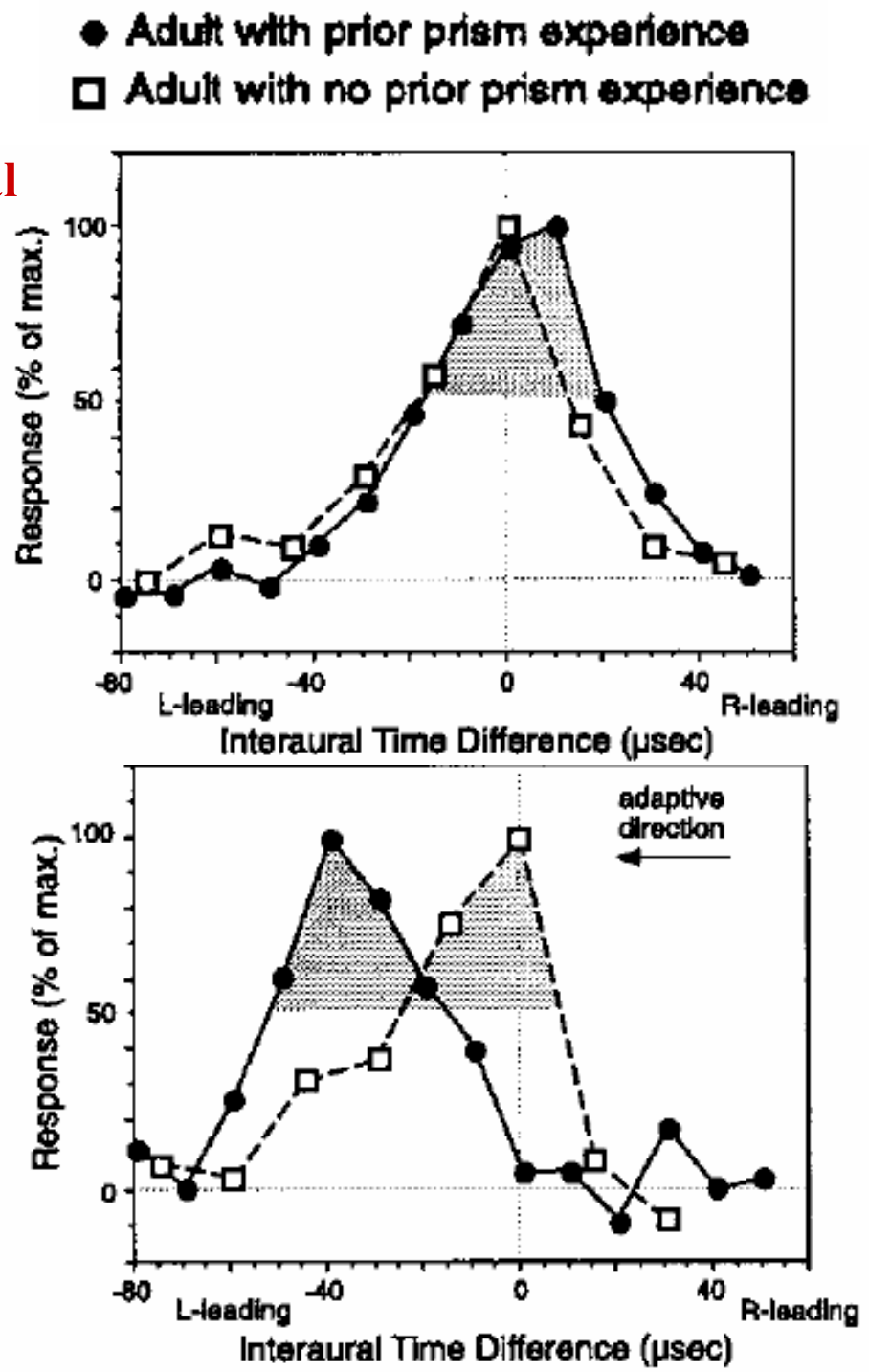


from Knudsen, 1998

Adult Owls With Prism Experience As Juveniles then Allowed to Have Normal Experience Re-Attain Normal Registration Between Auditory and Visual Field Maps

However, these young owls can readjust to large visual field displacement as adults when normally reared owls cannot.

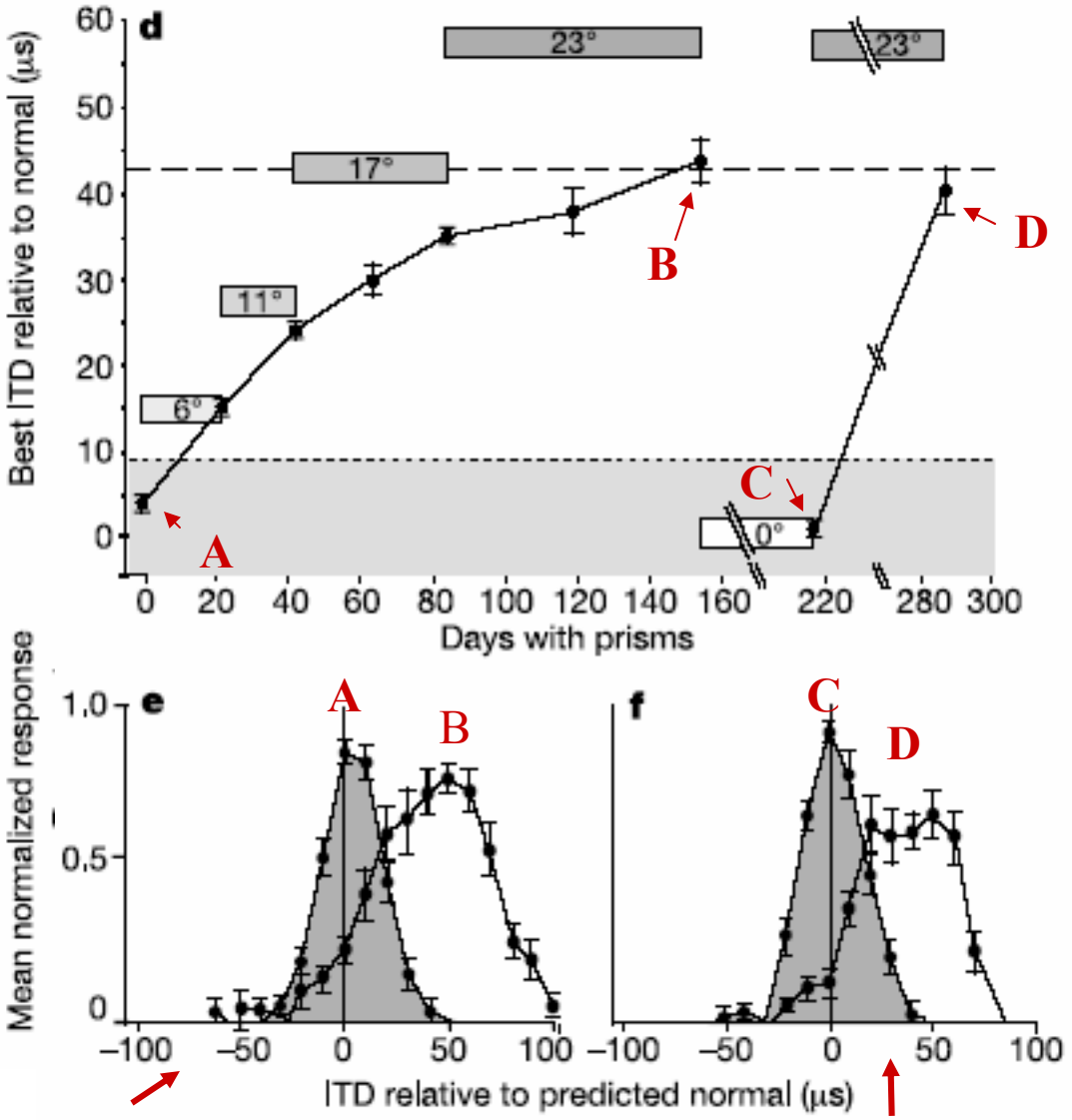
A visual field shift of 23° in an adult owl experienced with prisms as a juvenile will cause an ITD tuning shift of ~ 43µsec after a few months. An inexperienced adult owl can wear the same prisms more than 2 x as long and switch only ~ 4 µsec.



Knudsen, EI, (1998) Science 279:1531-1533.

All data is from 0wl A15

Adult owls can learn to shift their auditory receptive fields if they are given incremental training with prisms that shift the position of the object in the visual receptive field in small steps



Tuning curves measured in optic tectum before (**A**) and after (**B**) incremental training as an adult.

Tuning curves measured after 60 days with prisms removed (**C**) and after a single jump to the large increment prism (**D**).

Linkenhoker, BA and Knudsen,EI (2002) Nature 419:293-296

Practice Questions: 4/28/03

1. When examining plasticity of synaptic connections why is it important to try to do an analysis of miniature EPSC's or EPSPs?

2. Name two assumptions involved in performing a quantal (mini)analysis.

3. Name at least two molecular mechanisms known to decrease the probability of transmitter release.

4. What would happen to mixed NMDA,AMPA post-synaptic current amplitudes if one poisoned glutamate transporters?

5. You are stimulating a single input to a post-synaptic cell you are recording extracellulary, you antagonize all AMPA/Kainate currents in the slice. However you find that you are still able to record an NMDAR mediated post-synaptic potential in normal Mg++. Name an event that could be happening on and within the post-synaptic cell to allow this result. How could you test this hypothesis?

6. Does the "circuit level" explanation for auditory map plasticity in slide 13 require Retrograde signals between the ICX neuron and its ICC inputs? Explain your answer.