The University of Western Ontario

Cortical Plasticity

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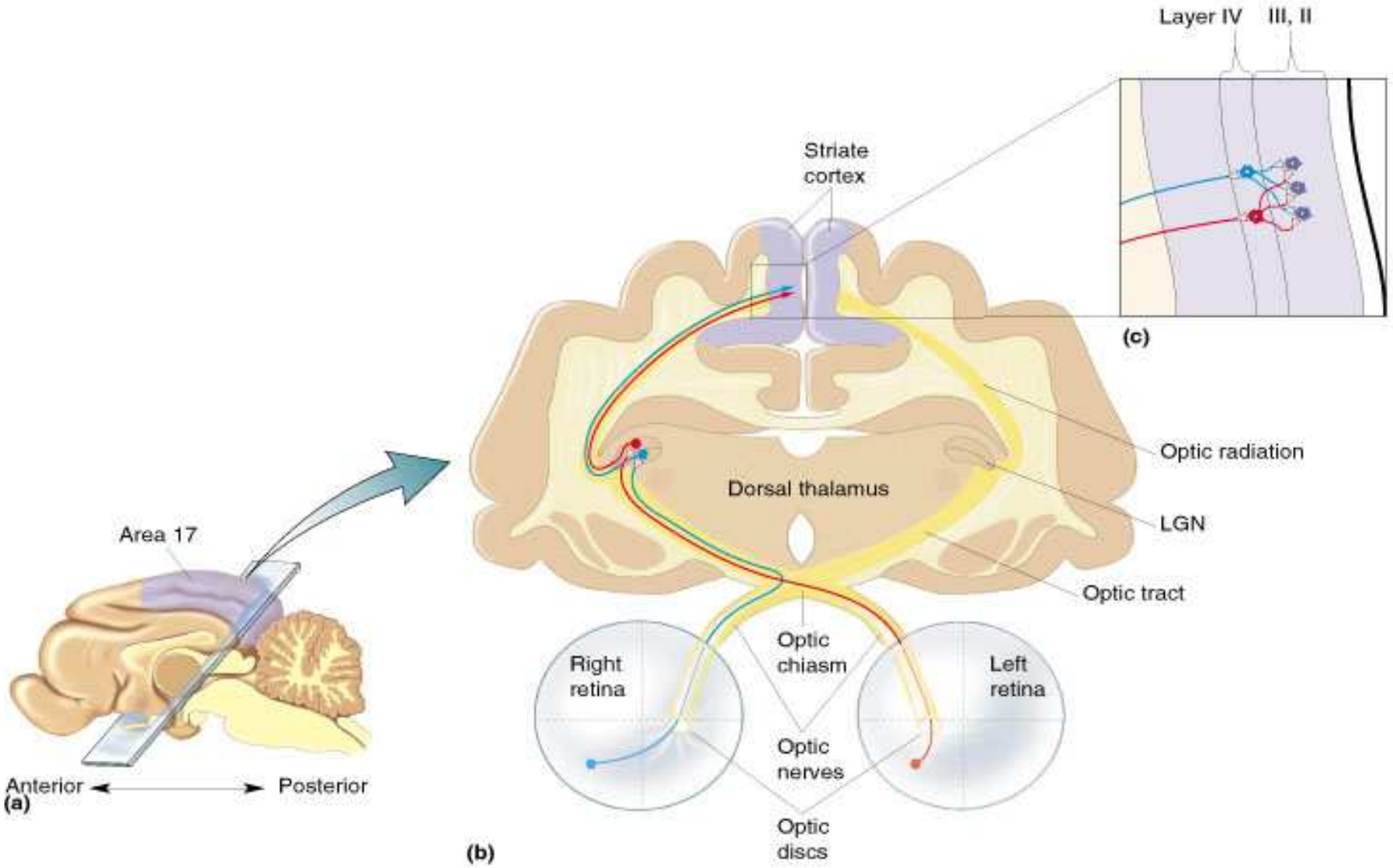


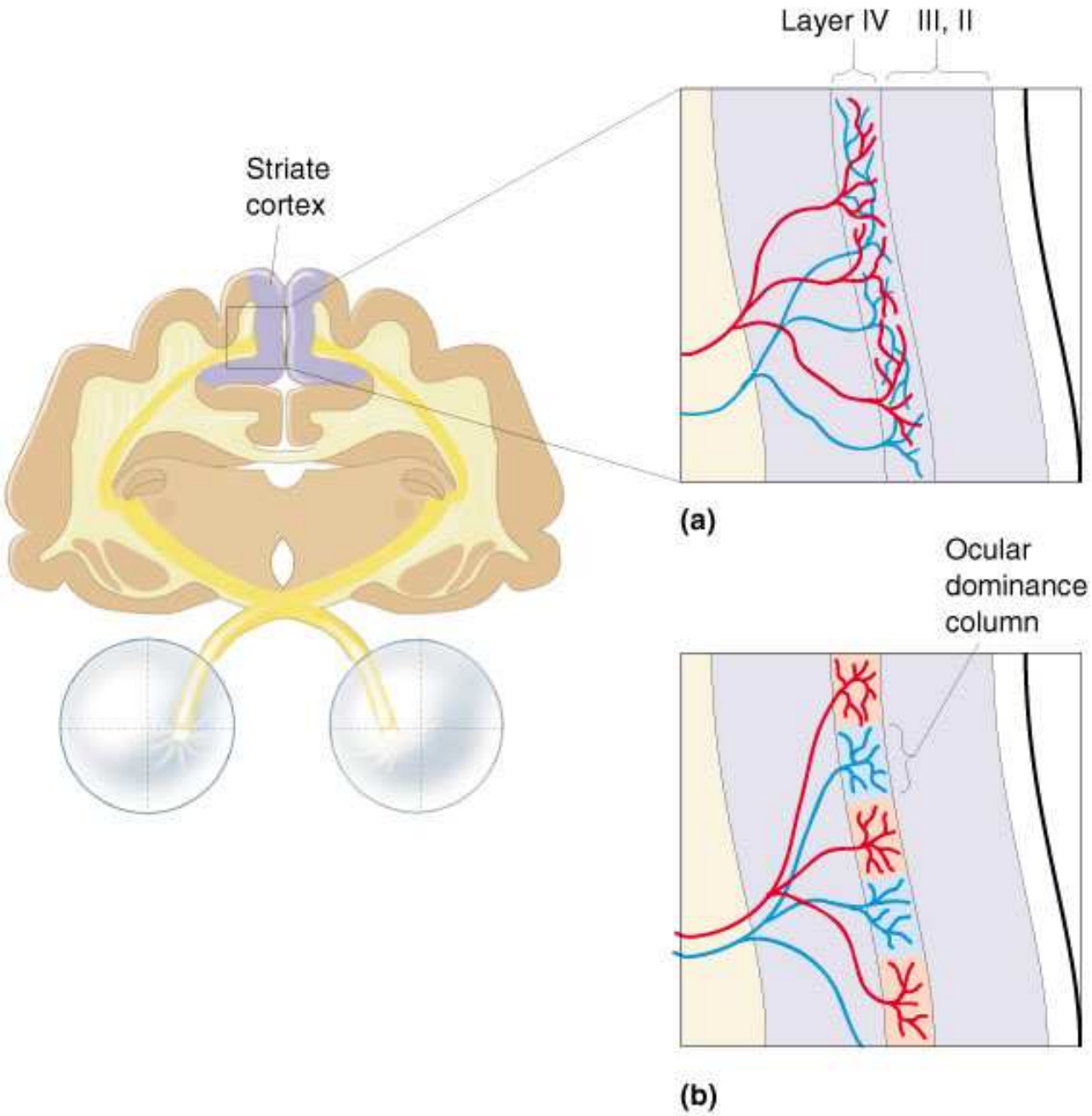
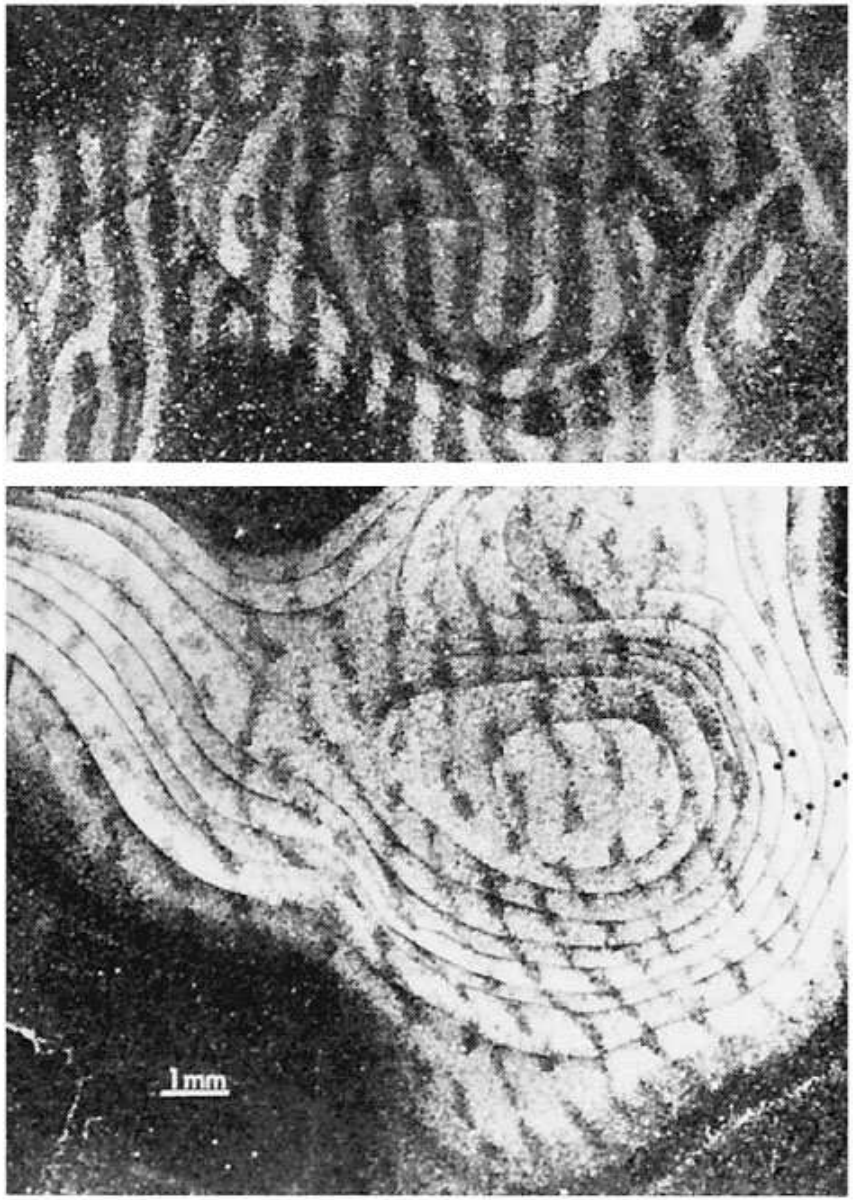
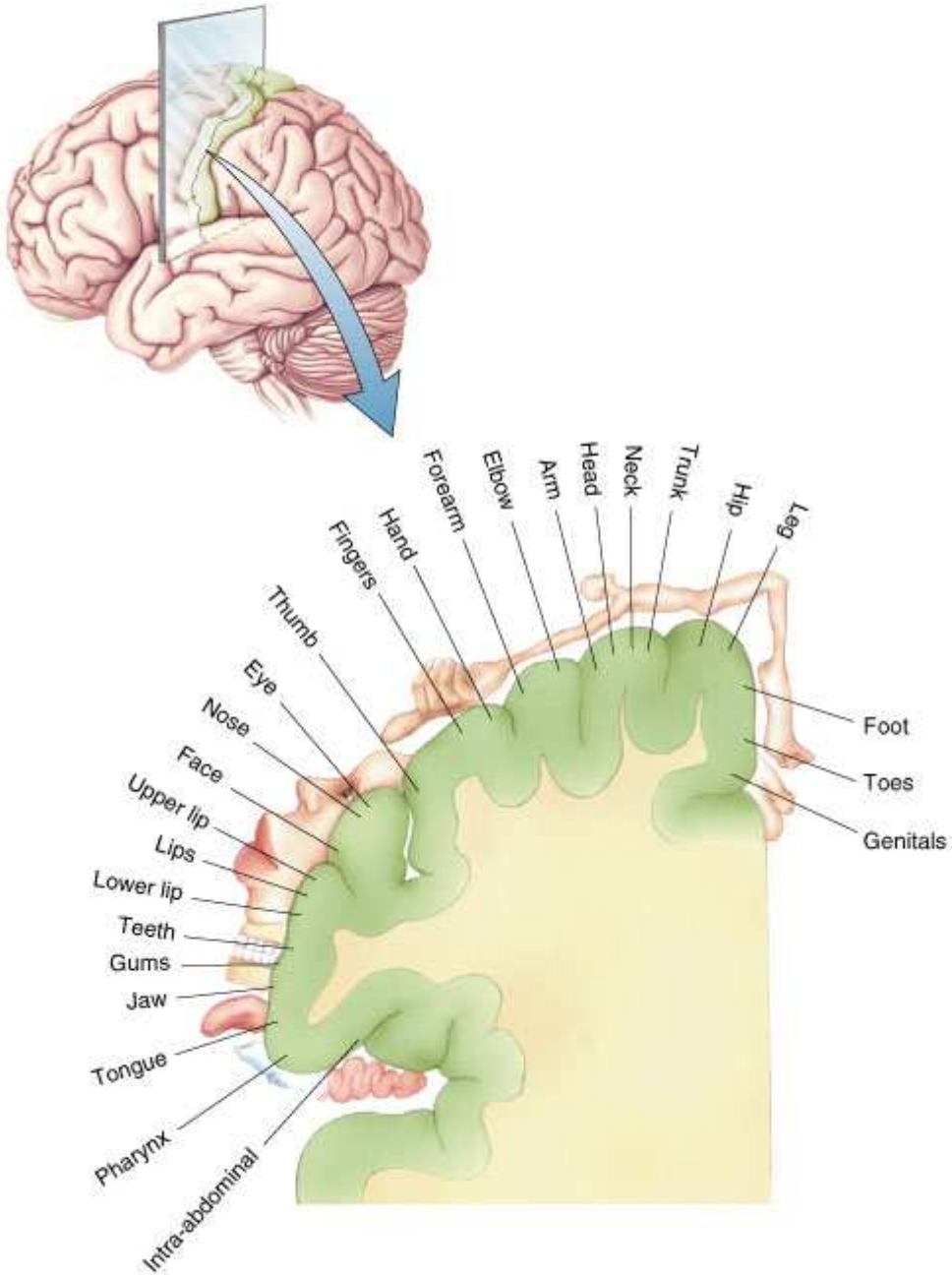
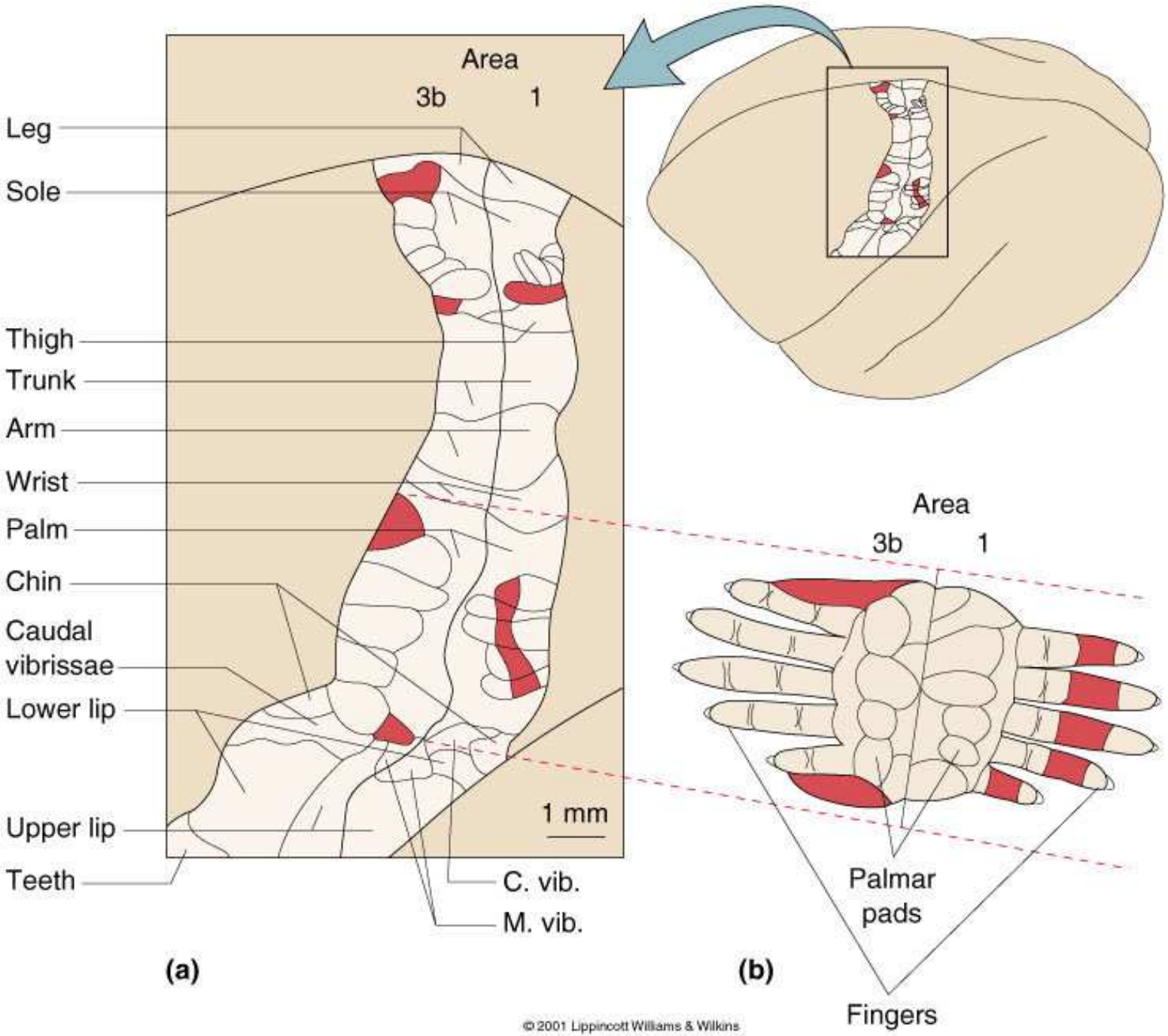


Figure 22.18
Modification of ocular dominance stripes after monocular deprivation. Tangential sections through layer IV of macaque monkey striate cortex illuminated to show the distribution of radioactive LGN terminals serving one eye. (a) A normal monkey. (b) A monkey that had been monocularly deprived for 22 months, starting at 2 weeks of age. The nondeprived eye had been injected, revealing expanded ocular dominance columns in layer IV. (Source: Wiesel, 1982, p. 585.)







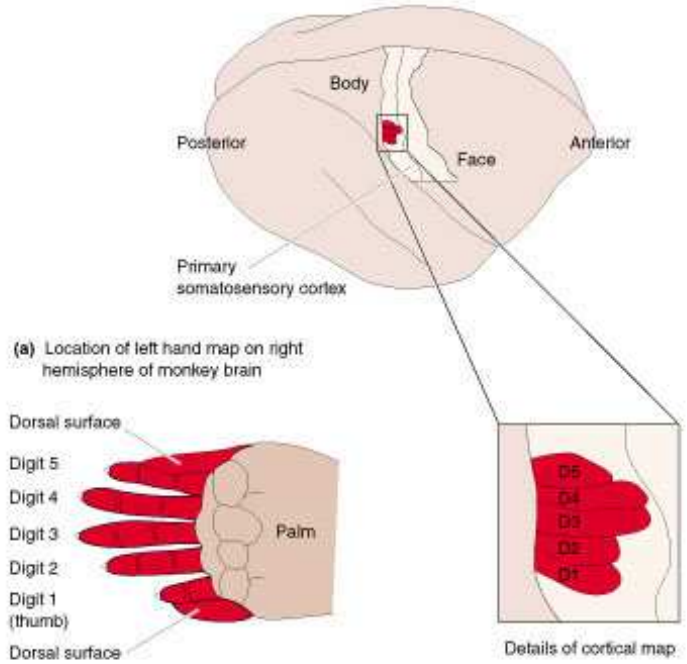
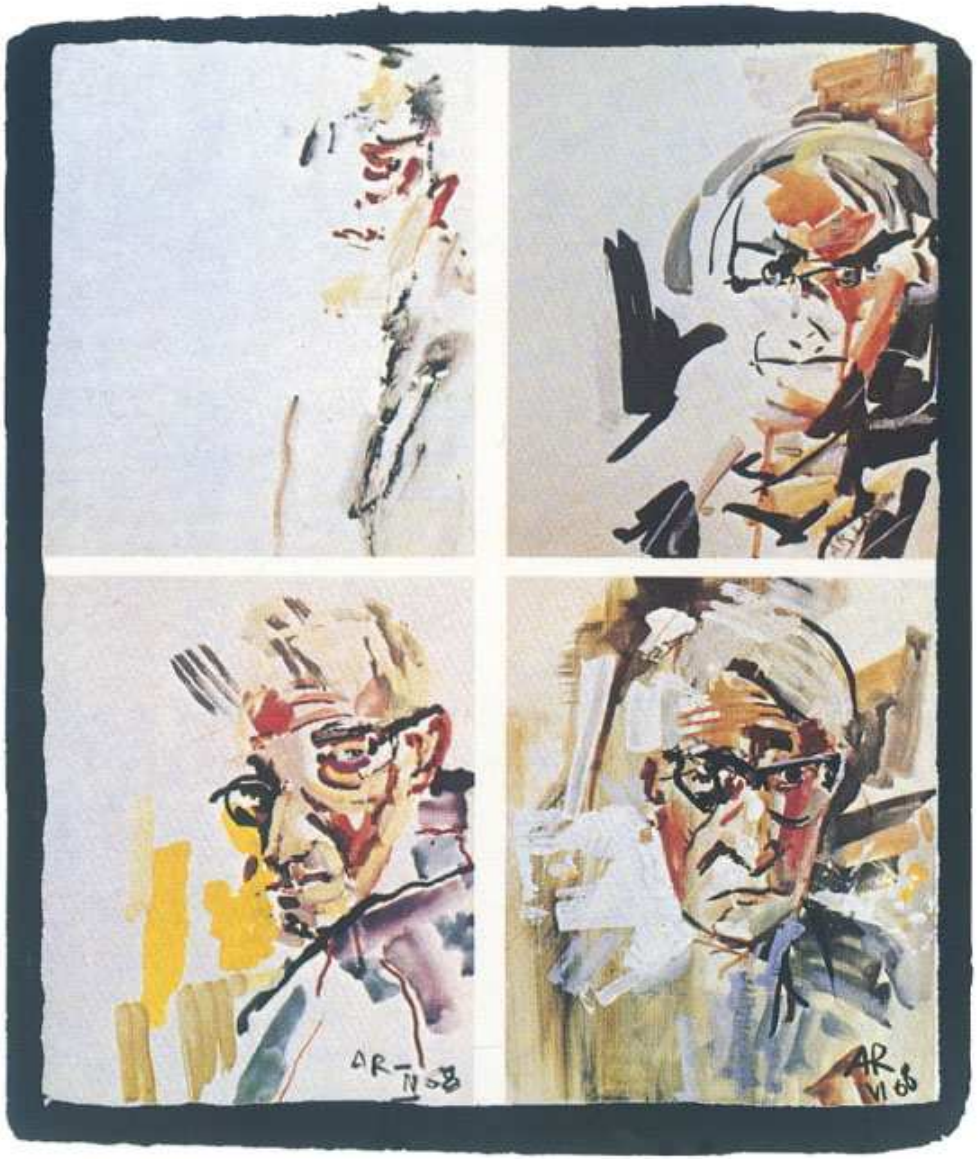
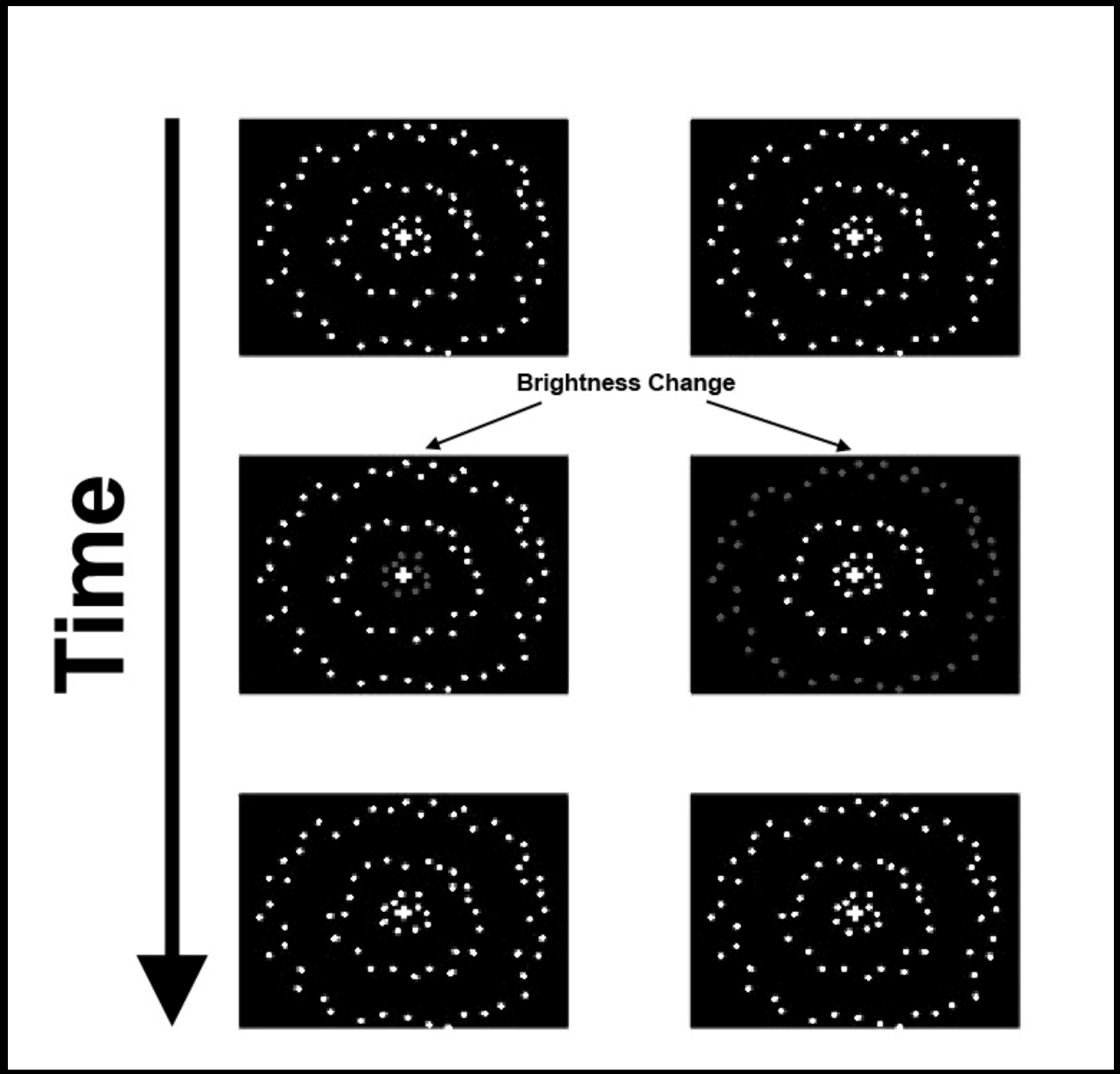


Figure 20.17
Self-portraits during recovery from a stroke that caused a neglect syndrome. Two months after suffering a stroke affecting parietal cortex on the right side, the artist made the upper left portrait. There is virtually no left side to the face in the painting. Three and a half months after the stroke (upper right), there is some detail on the left side but not nearly as much as on the right side. At 6 months (lower left) and 9 months (lower right) after the stroke, there is increasing treatment of the left side of the painting. (Source: Posner and Raichle, 1994, p. 152.)

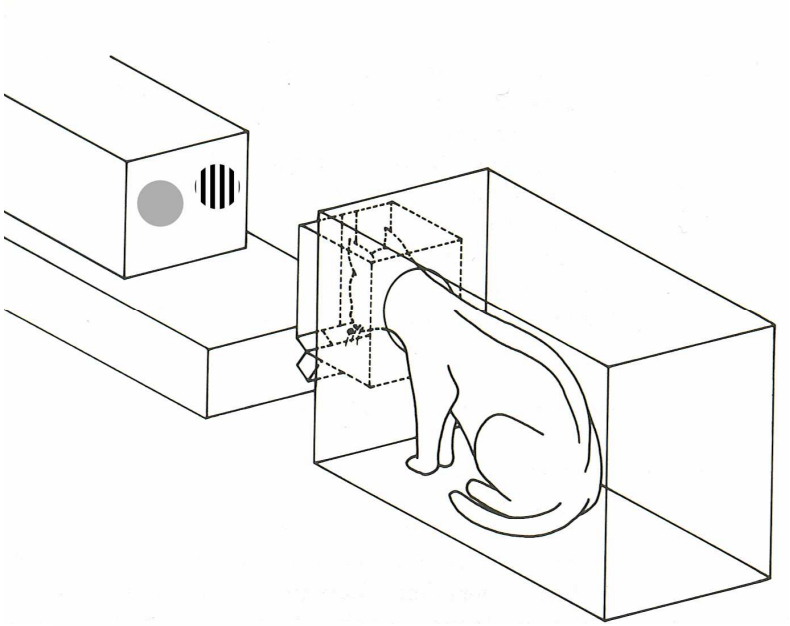


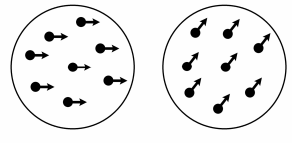
Do individuals with an impaired sense have superior abilities in other modalities?

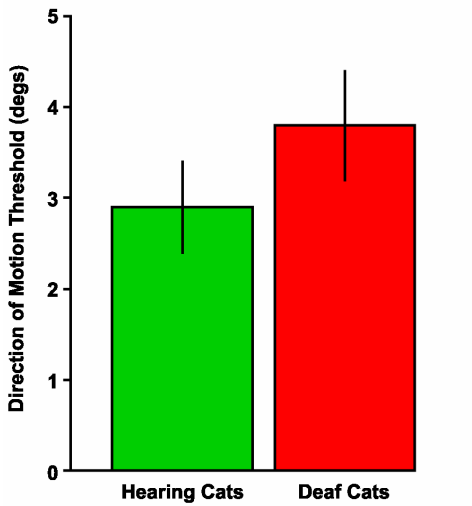
From *Scent of a Woman* (1992)

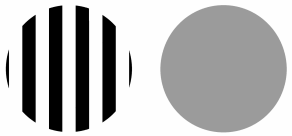


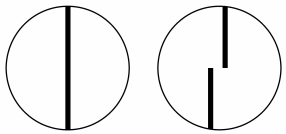
From Bavelier et al. (2000) J. Neurosci. 20: RC93

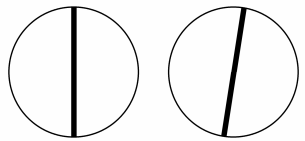


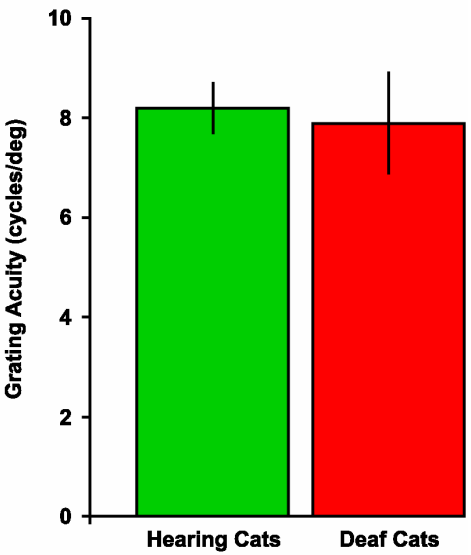


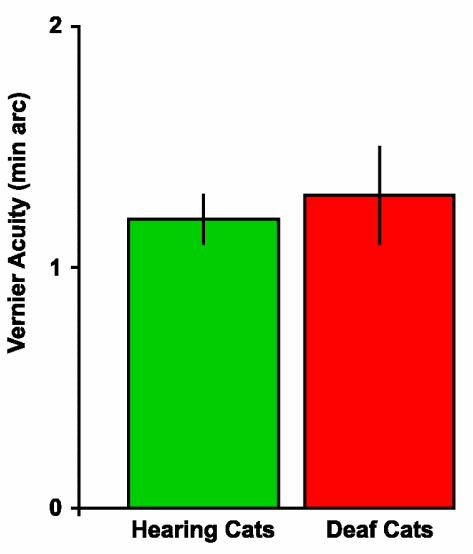

Direction of Motion Threshold (degs)
0
1
2
3
4
5
Hearing Cats
Deaf Cats

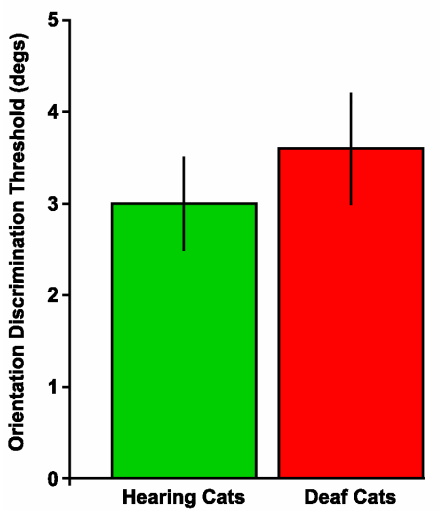


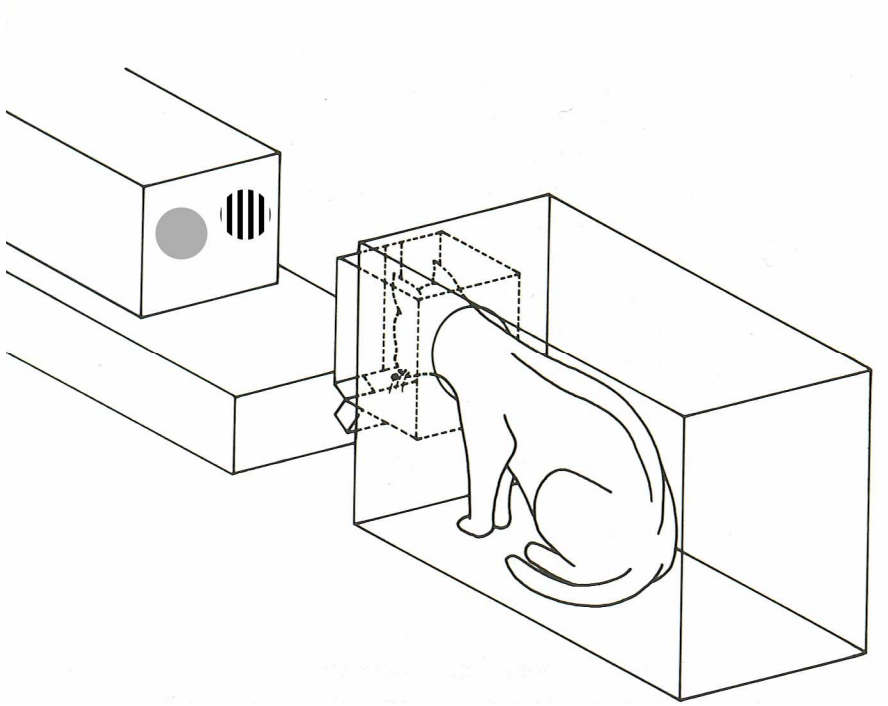


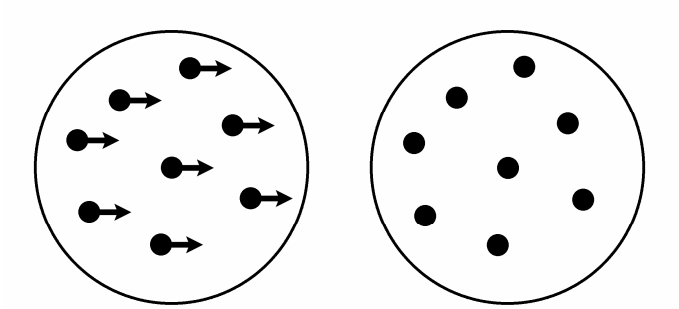


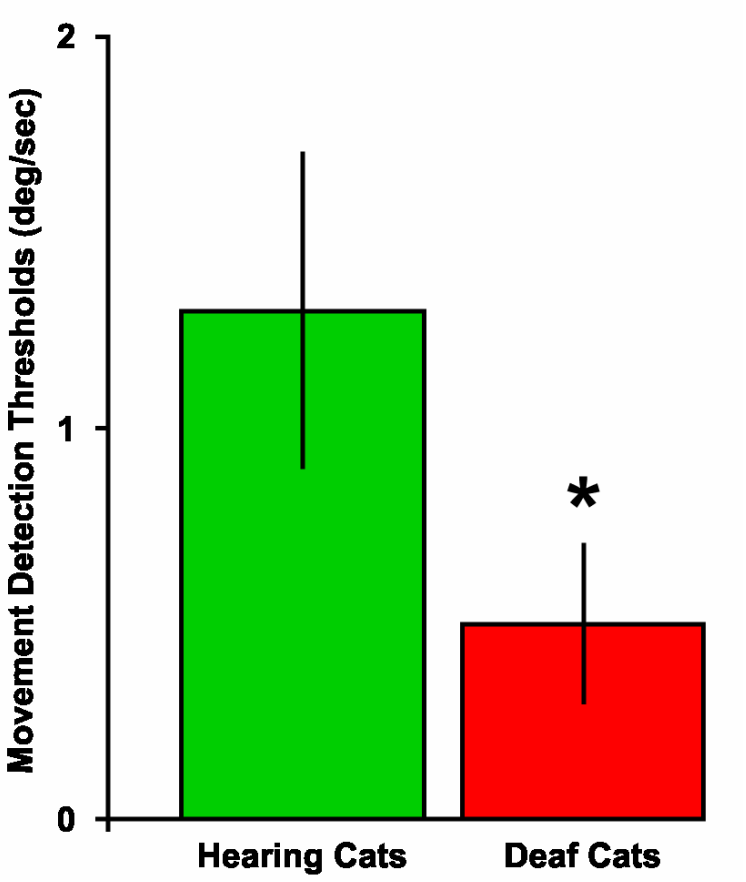

Grating Acuity (cycles/deg)
0
2
4
6
8
10
Hearing Cats
Deaf Cats

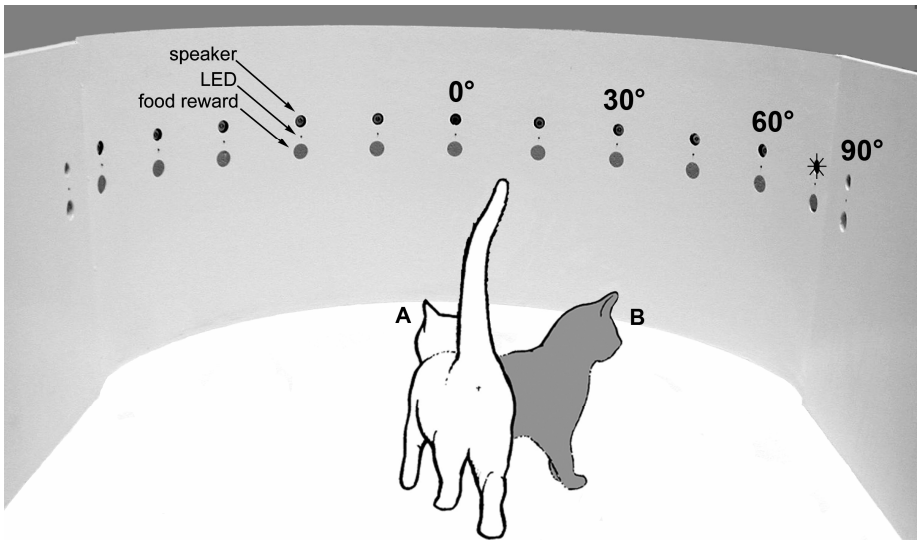

Vernier Acuity (min arc)
0
1
2
Hearing Cats
Deaf Cats

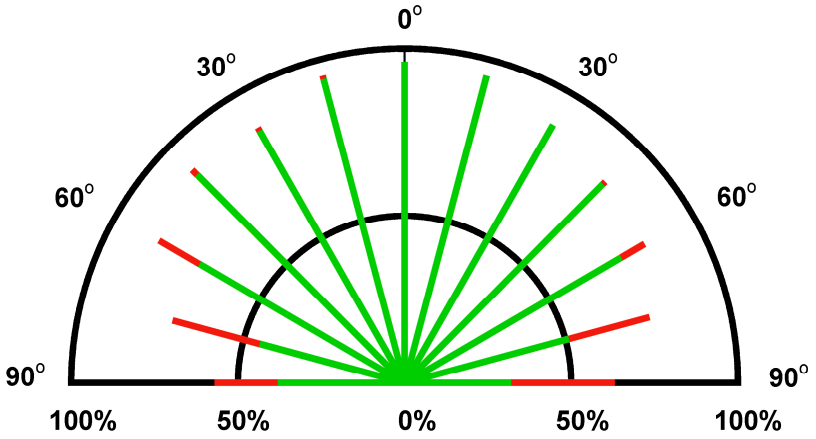

Orientation Discrimination Threshold (degs)
0
1
2
3
4
5
Hearing Cats
Deaf Cats

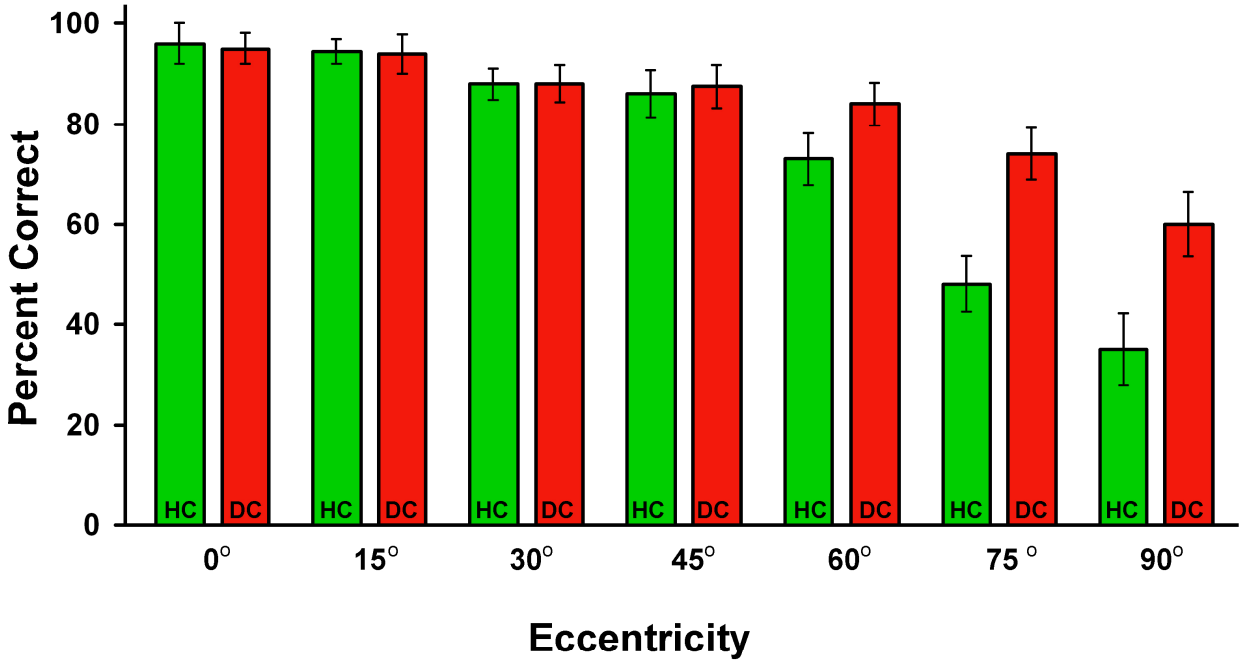





Movement Detection Thresholds (deg/sec)
2
1
0
*
Hearing Cats
Deaf Cats


speaker
LED
food reward
0°
30°
60°
90°
A
B


0°
30°
30°
60°
60°
90°
90°
100%
50%
0%
50%
100%


Percent Correct
100
80
60
40
20
0
HC
DC
0°
15°
30°
45°
60°
75 °
90°
Eccentricity

Summary

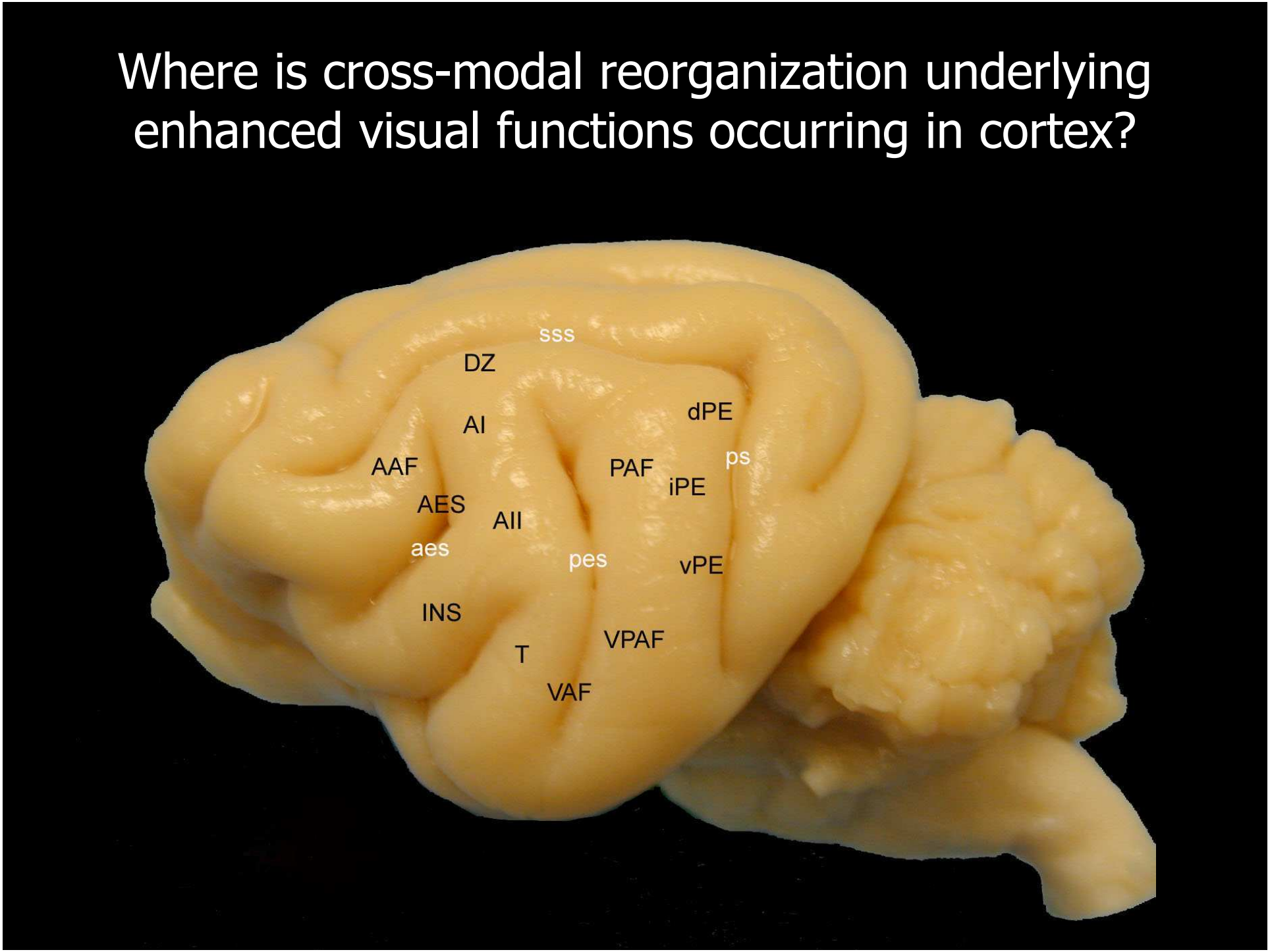
Congenitally Deaf Cats have visual abilities similar to Hearing Cats on the following tasks:

- Vernier Acuity
- Grating Acuity
- Orientation Discrimination
- Direction of Motion Discrimination

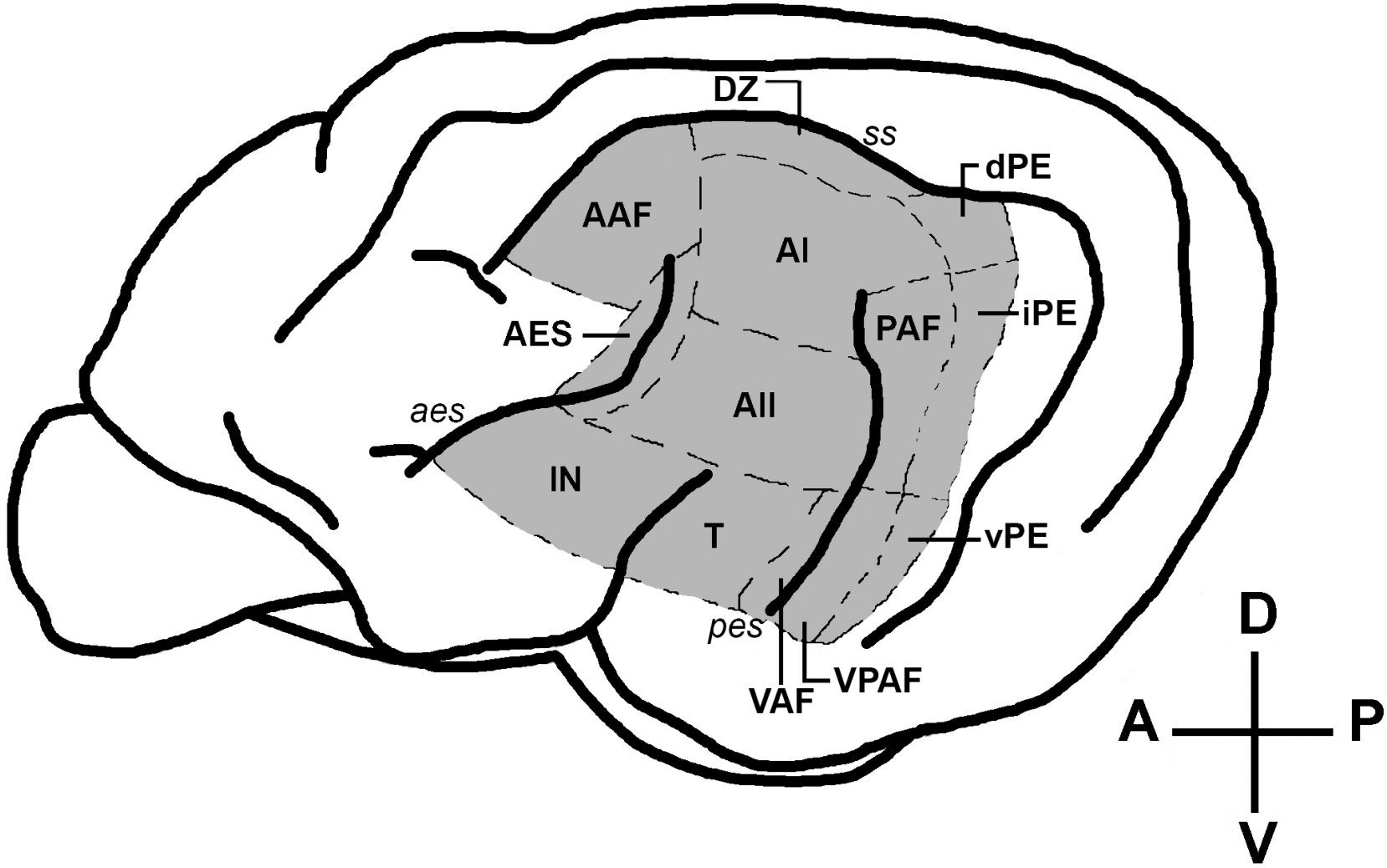
Congenitally Deaf Cats have visual abilities superior to Hearing Cats on the following tasks:

- Detection of Movement
- Visual Detection in the Peripheral Field

Where is cross-modal reorganization underlying enhanced visual functions occurring in cortex?



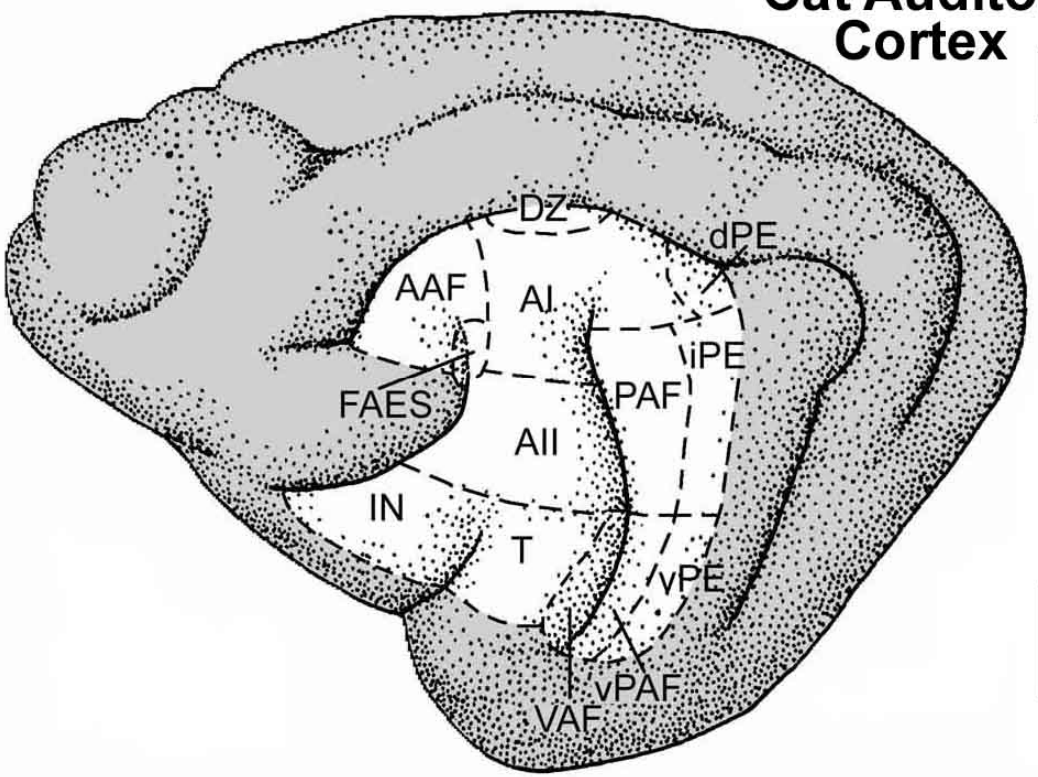
Cat Auditory Cortex

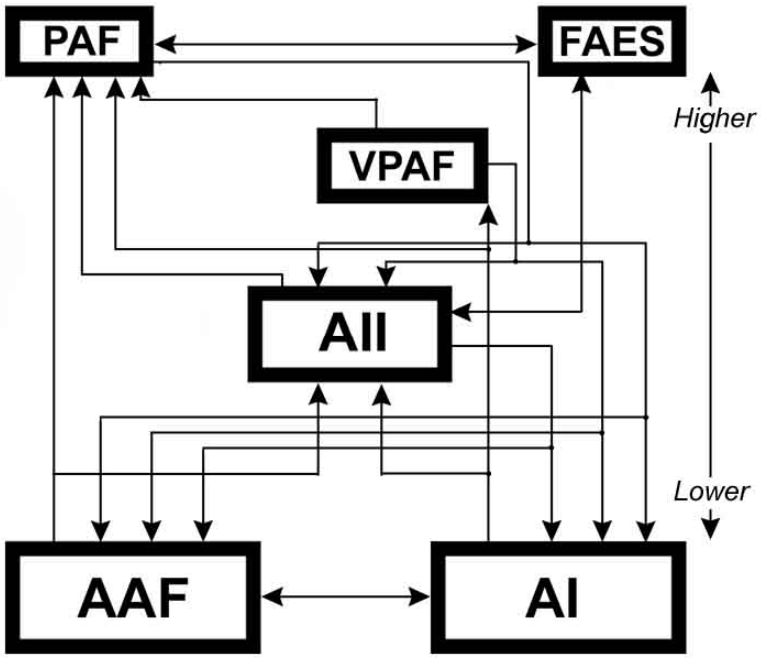


Hypothesis

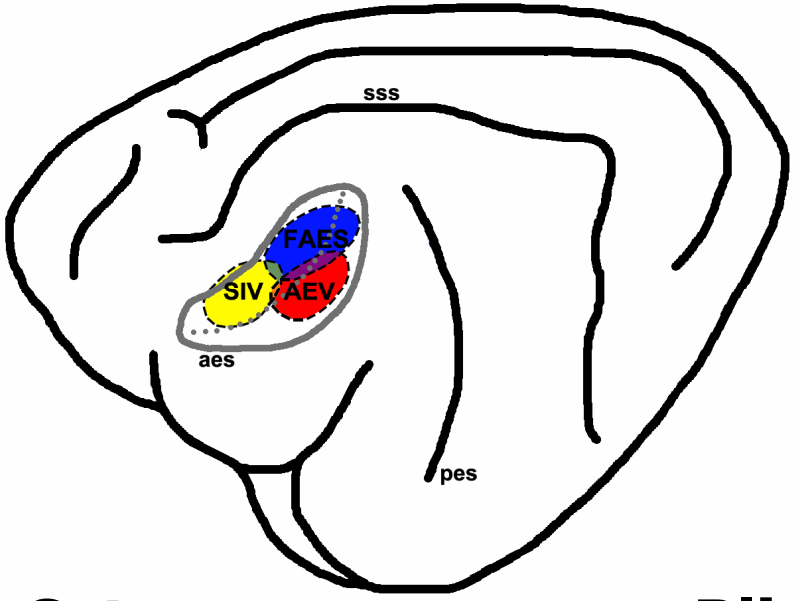
Congenital deafness induces a reverse hierarchical gradient in the level of cross-modal plasticity, whereby higher order auditory areas show more extensive cross modal reorganization than primary/core areas.

Cat Auditory Cortex

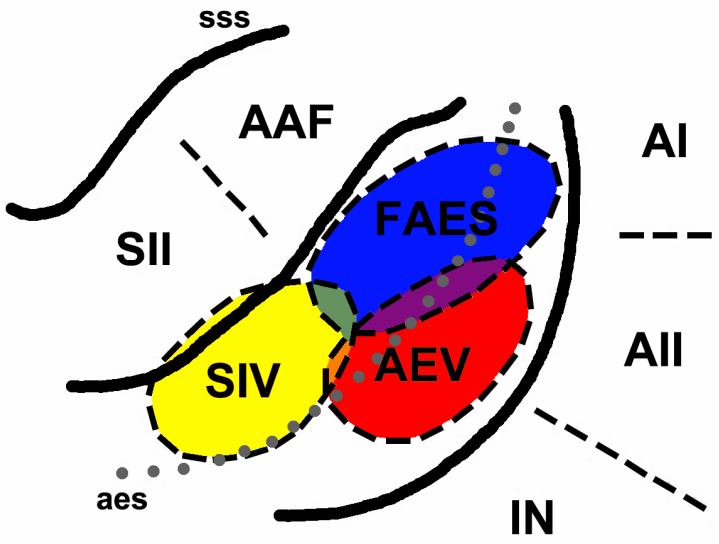




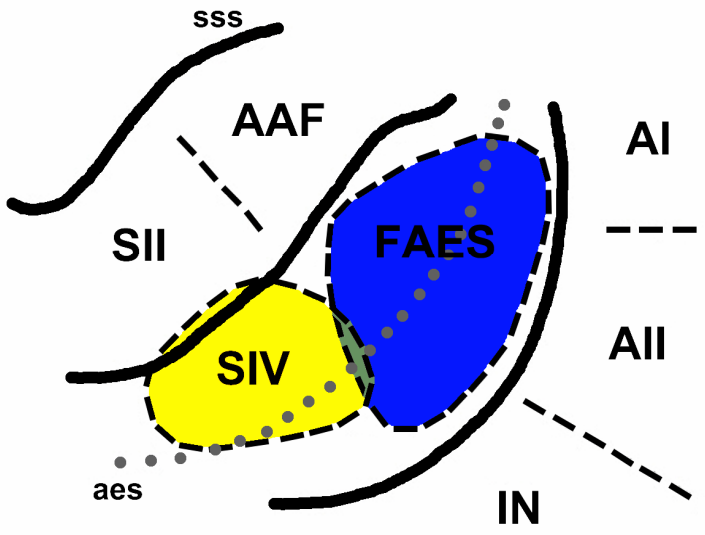
Modified from Roullier et al, 1991

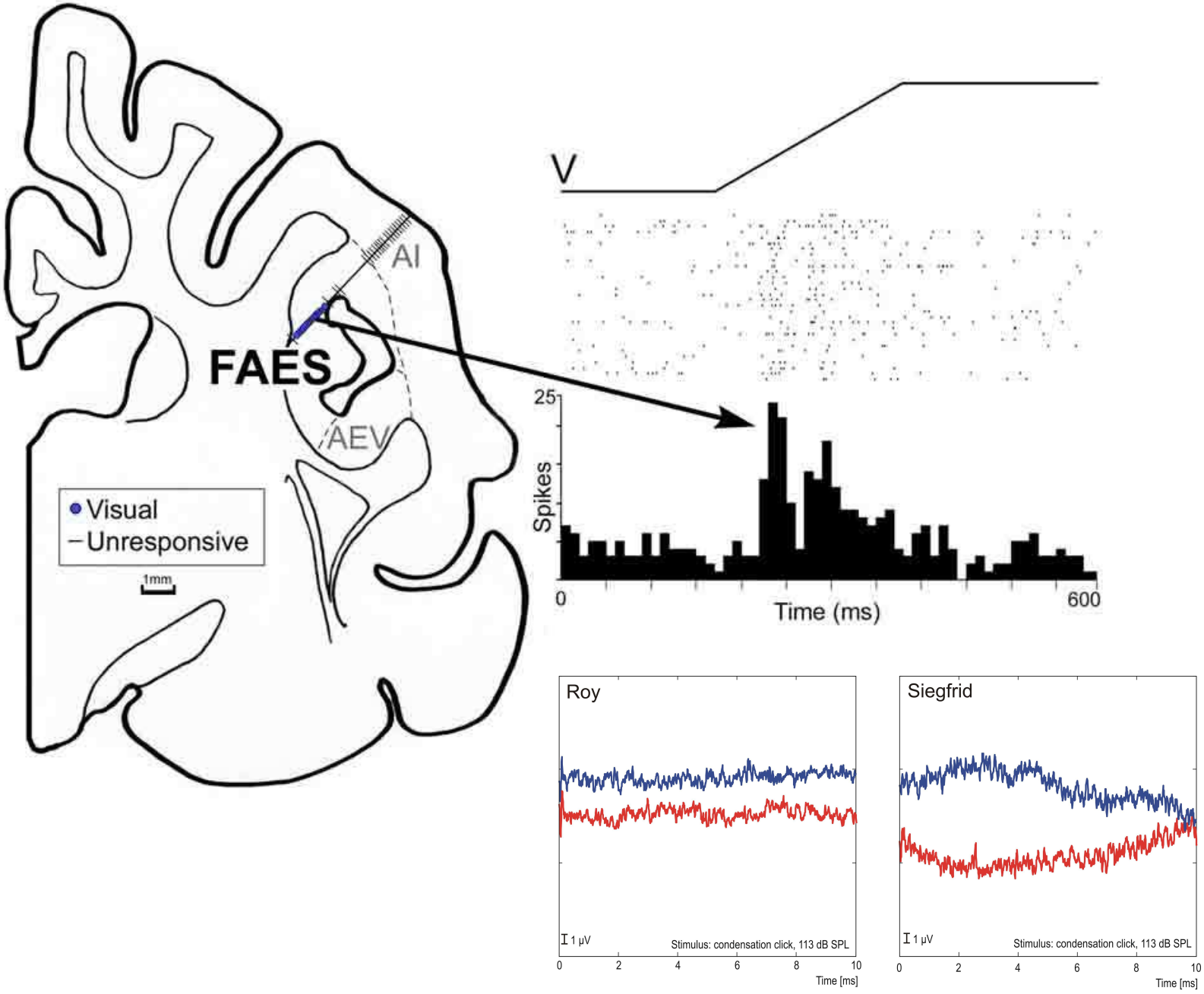


No Deficit Cat

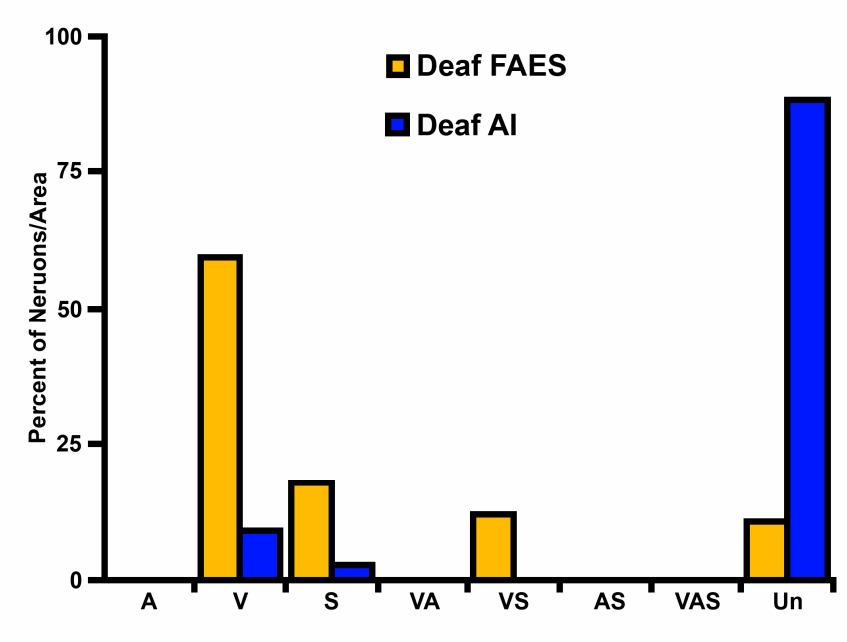


Blind Cat

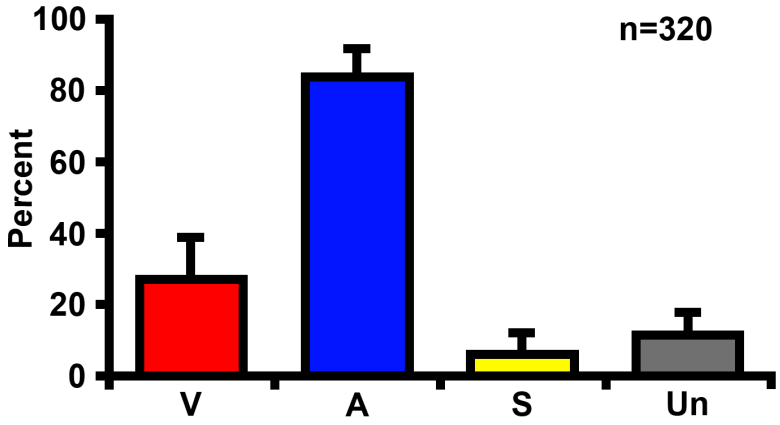



AI
FAES
AEV
Visual
Unresponsive
1mm
V
25
Spikes
0
600
Time (ms)
Roy
1 µV
Stimulus: condensation click, 113 dB SPL
0
2
4
6
8
10
Time [ms]
Siegfrid
1 µV
Stimulus: condensation click, 113 dB SPL
0
2
4
6
8
10
Time [ms]

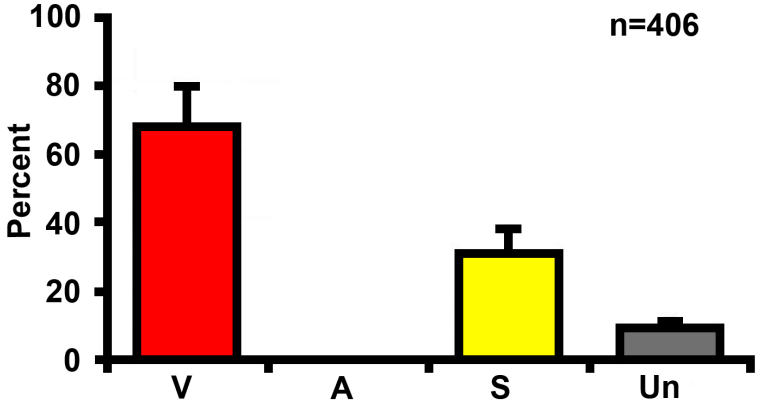
Deaf FAES vs. Deaf A1

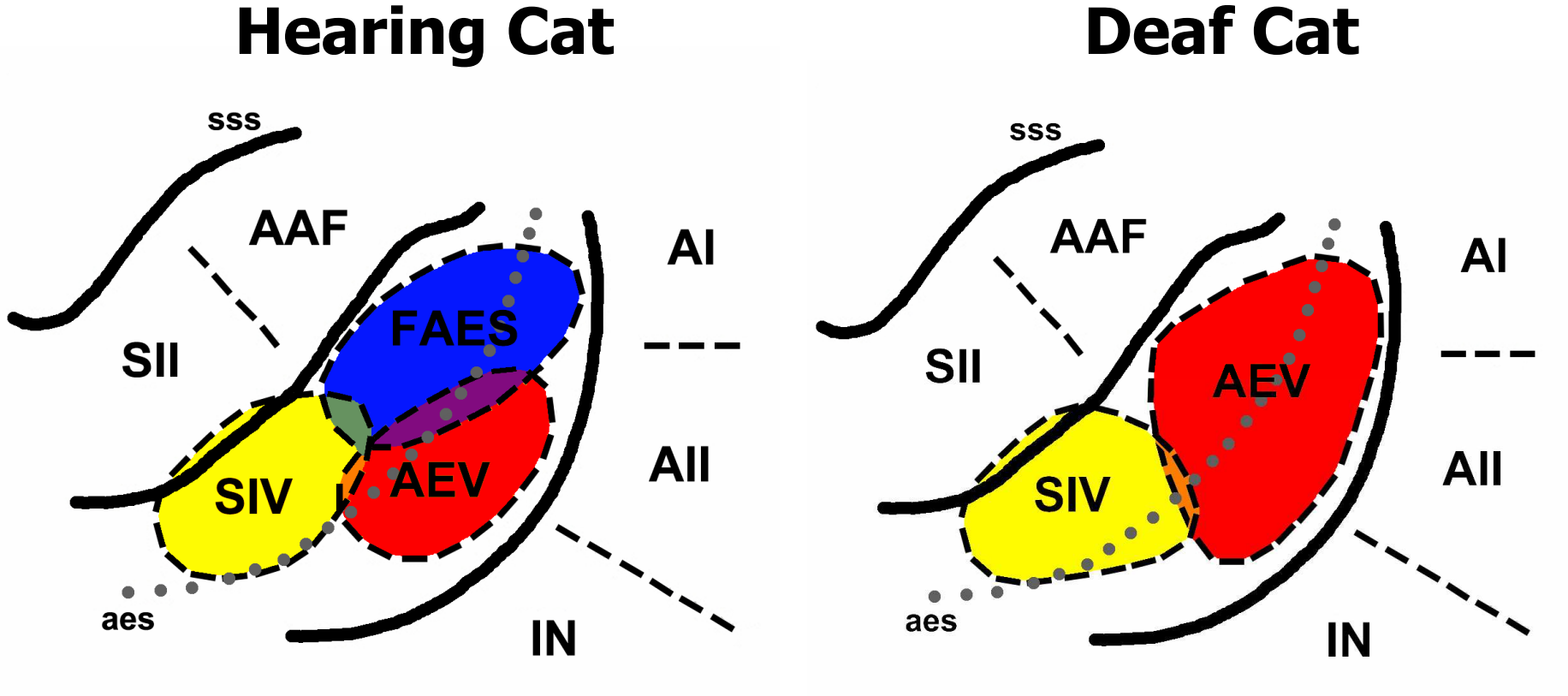


Responses in Hearing FAES

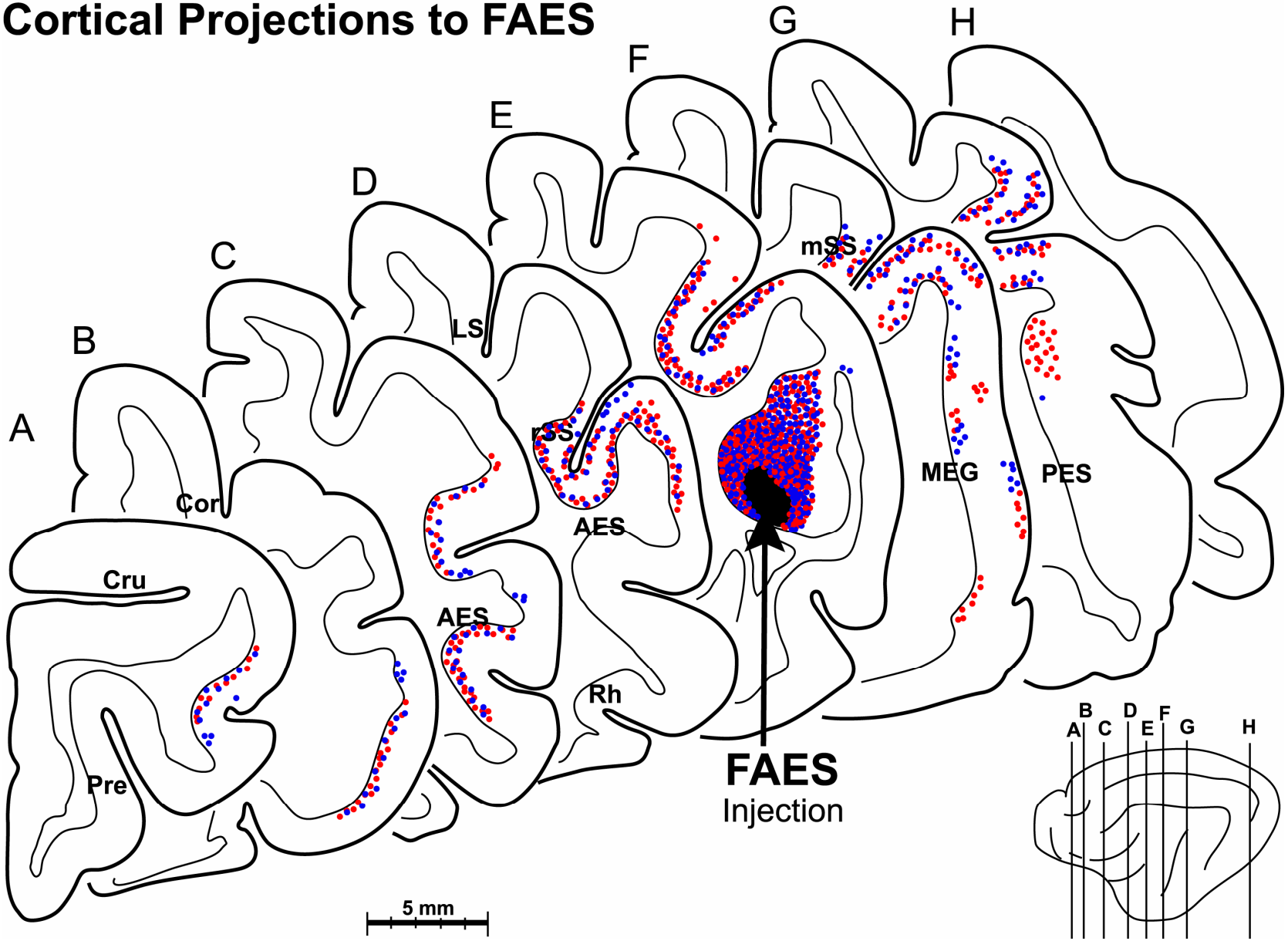


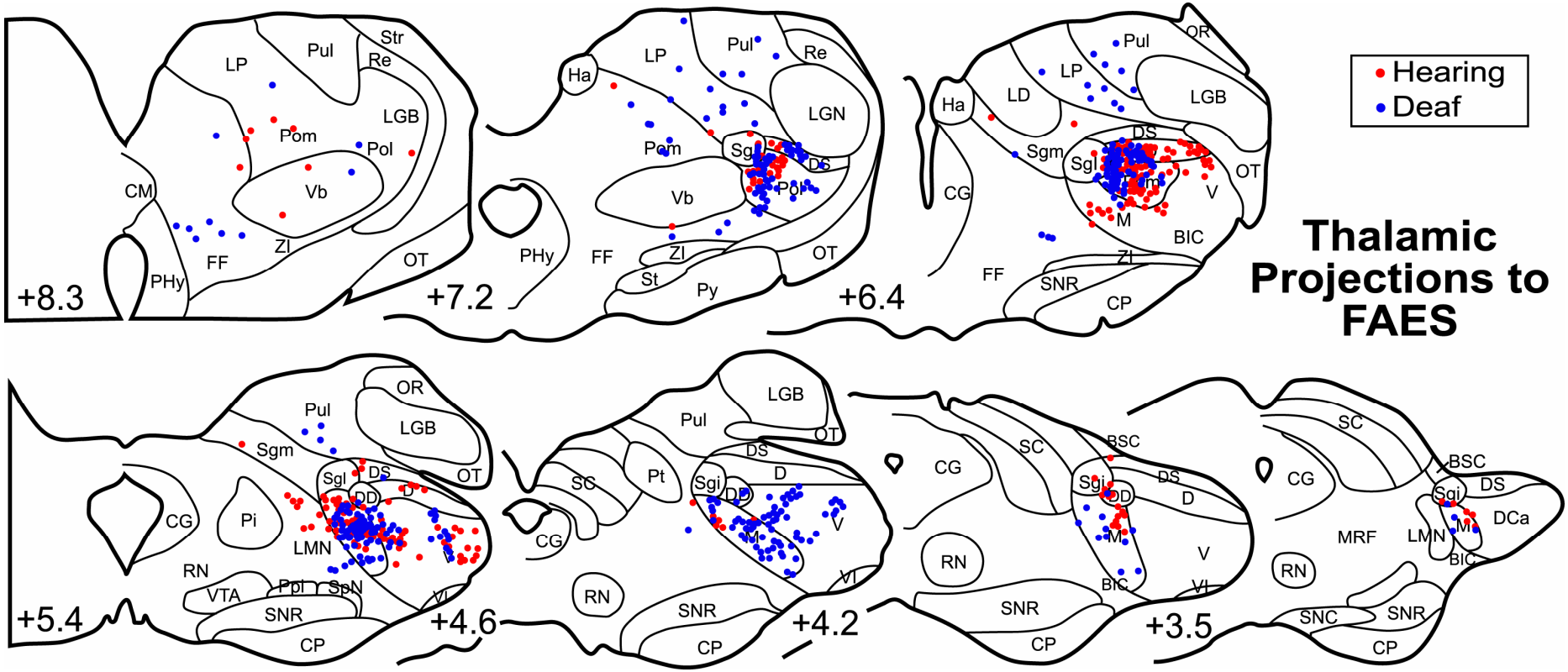
Responses in Deaf FAES



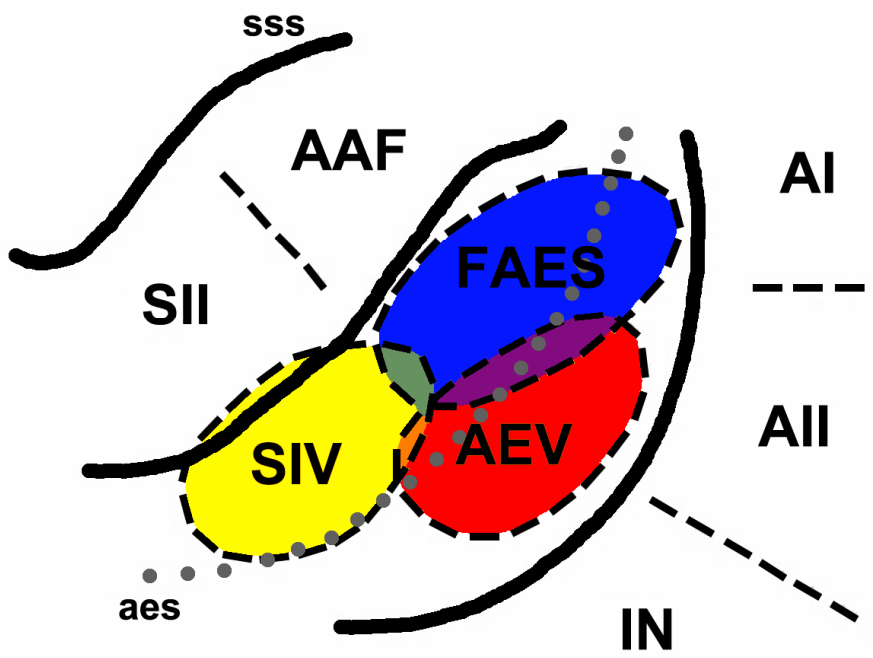

Hearing Cat
sss
AAF
AI
SII
FAES
AII
SIV
AEV
aes
IN
Deaf Cat
sss
AAF
AI
SII
AEV
AII
SIV
aes
IN

Cortical Projections to FAES

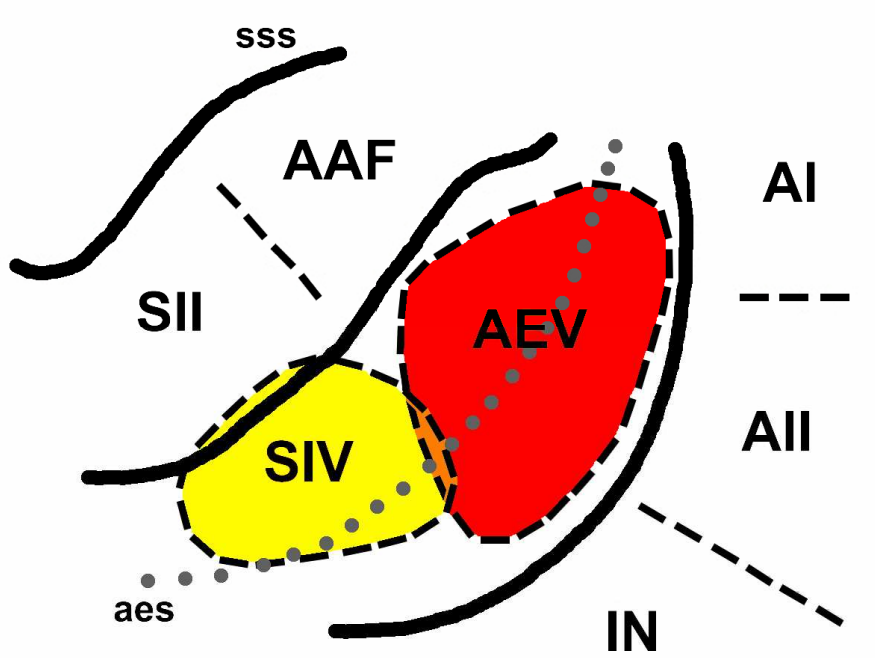



Hearing
Deaf
Thalamic Projections to FAES
+8.3
+7.2
+6.4
+5.4
+4.6
+4.2
+3.5
LP
Pul
Str
Re
LGB
Pom
Pol
Vb
CM
ZI
FF
OT
PHy
Ha
LGN
Sg
DS
St
Py
LD
OR
Sgm
Sgl
M
V
BIC
SNR
CP
CG
Pi
LMN
RN
VTA
Ppl
SpN
VL
SC
Pt
Sgi
DD
D
VM
BSC
MRF
DCa
SNC

Hearing Cat



Deaf Cat



What are the behavioural contributions of the reorganized cortex?

Types of Neural Deactivation

Permanent

- Physical ablation
- Chemical (neurotoxins)
- Electrolytic

Reversible

- Chemical (Lidocaine, Muscimol, GABA)
- Thermal – Cooling
  - (Thermoelectric-Peltier, Cryoloop)

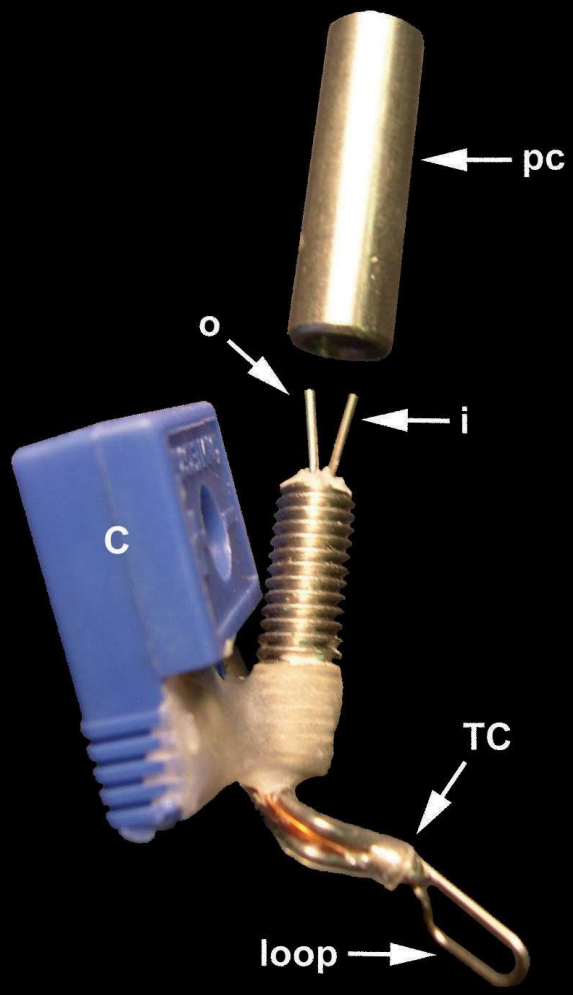
From Lomber (1999) J. Neurosci. Meth. 86: 109-117.

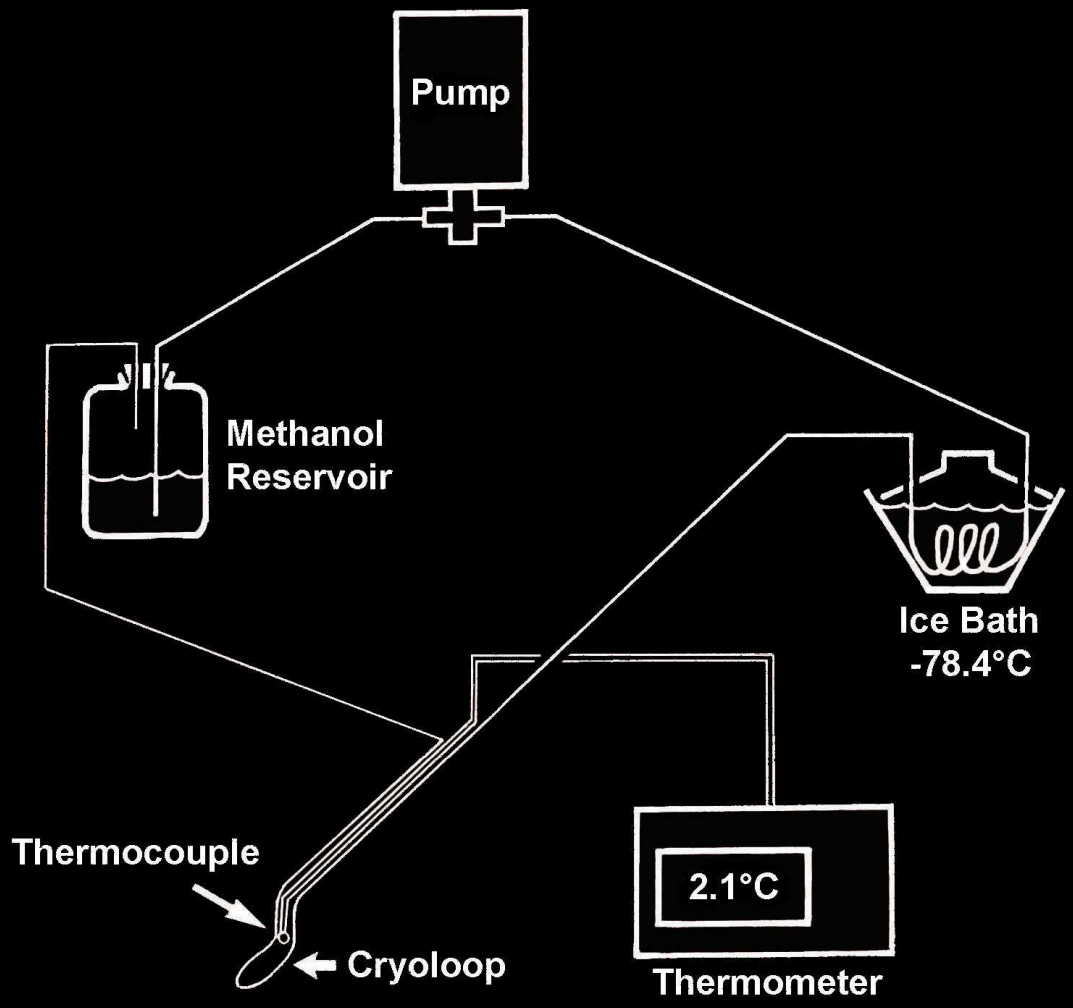
Advantages of Reversible Cooling Deactivation

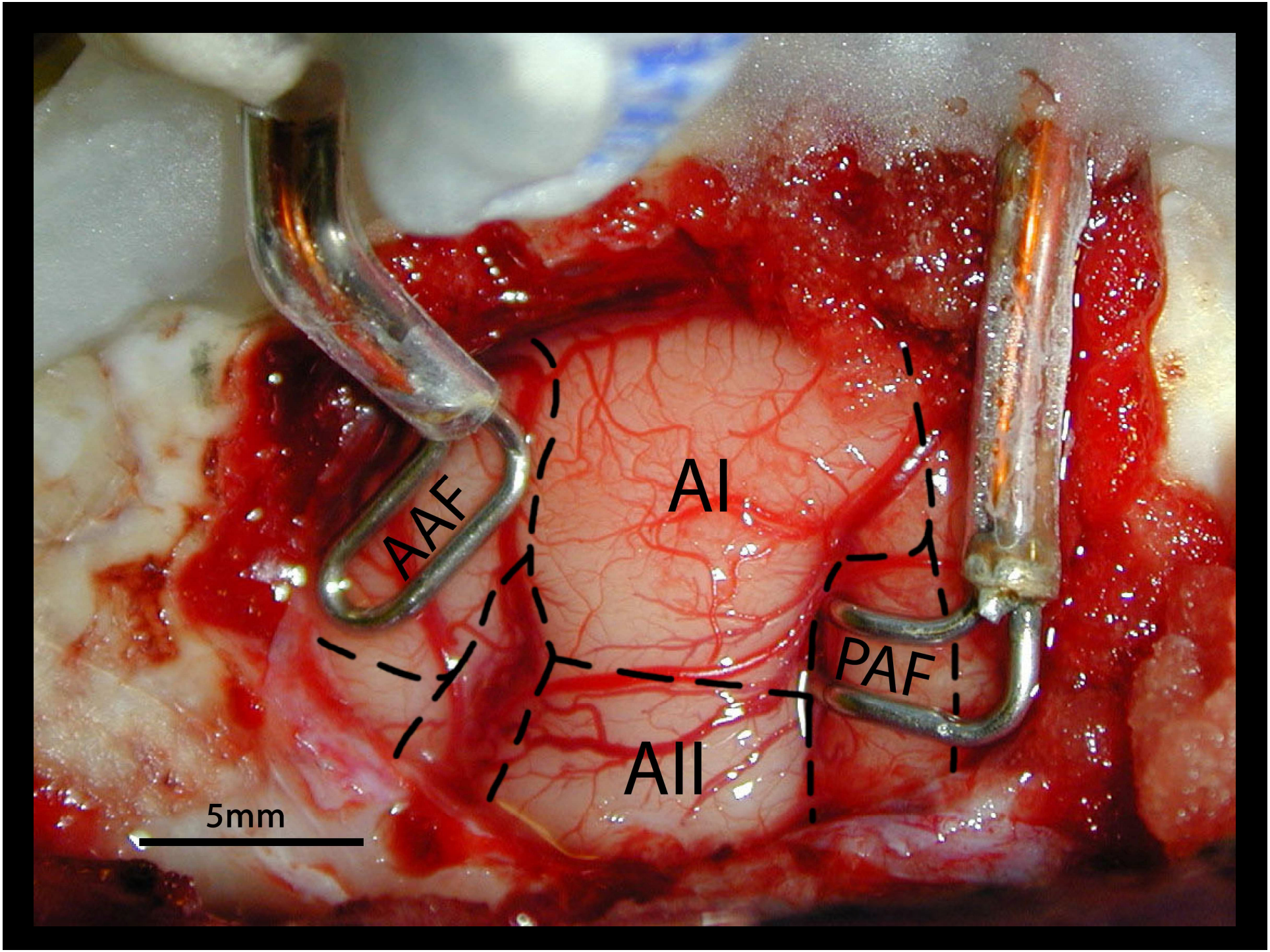
1. Each animal serves as its own control.
2. Double dissociations can be performed in the same animal.
3. Deactivations are highly localized and can be limited to superficial layers alone or induced through the full thickness of cortex.
4. Deactivations can be induced, held constant for long periods (>1hr), and reversed within minutes;
5. No deficit attenuation.
6. Deactivations alter neither the anatomical structure nor neuronal receptive field properties.
7. Animals can be trained on modified or new tasks as the investigations proceed and new data are accumulated because the brain is always intact.

From Lomber (1999) J. Neurosci. Meth. 86: 109-117.

The Cryoloop Technique






AAF
AI
PAF
AII
5mm

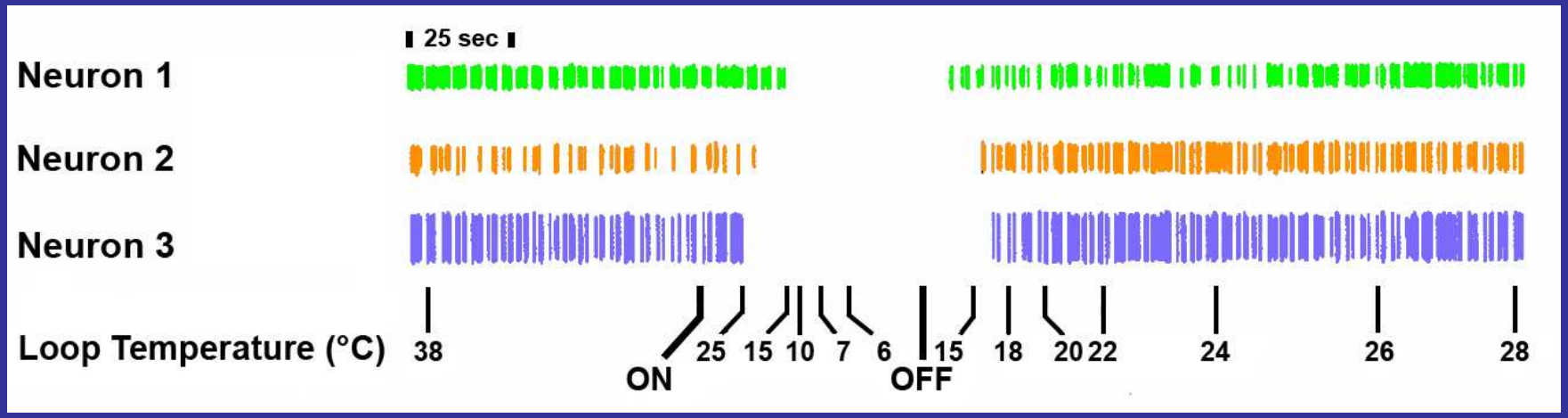
Demonstrating Reversible Deactivation

Two Questions:

1. How do you know what you deactivated?
2. Can you demonstrate a lack of damage?

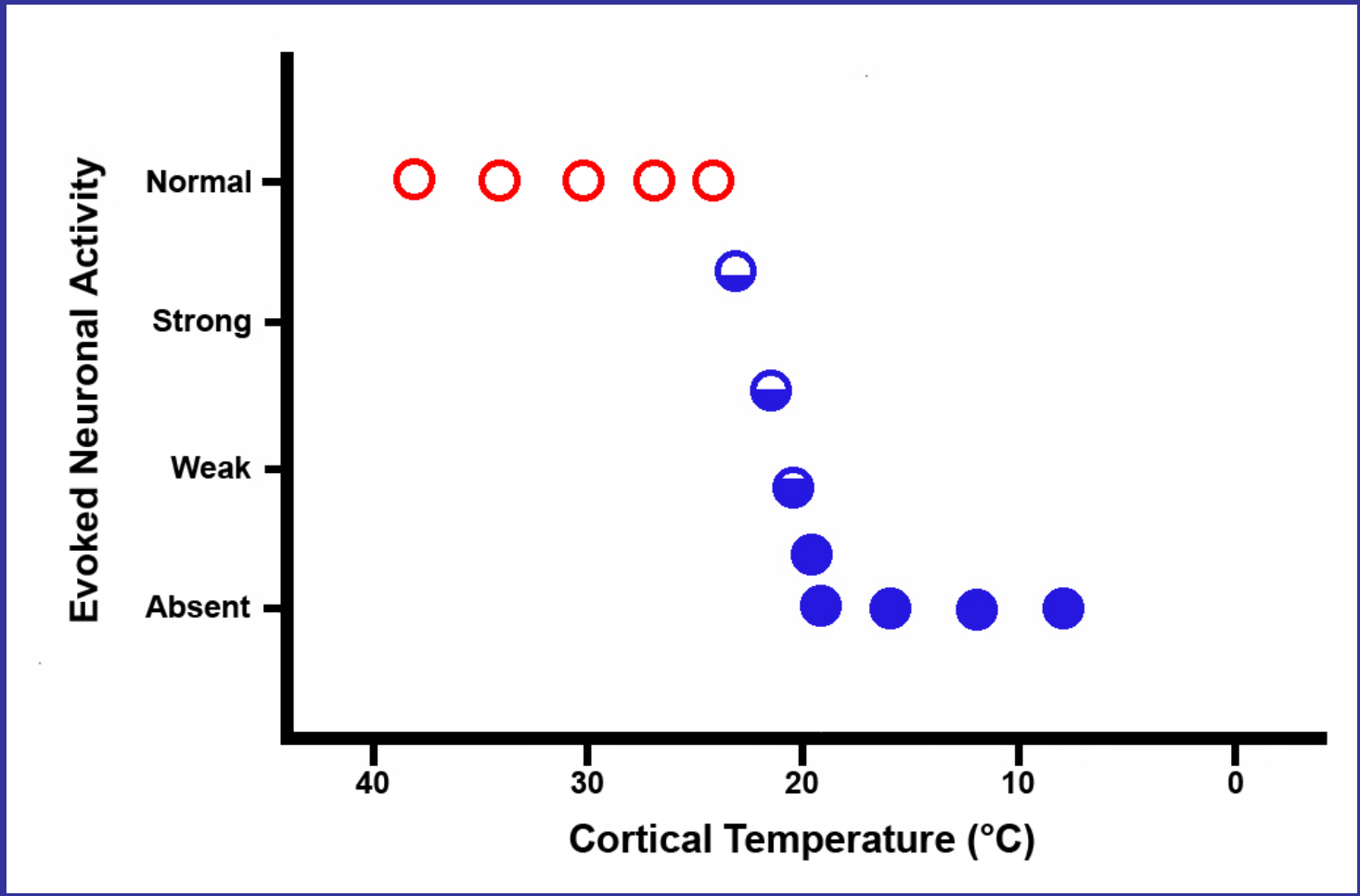
- Electrophysiologically
- Thermodynamically
- Metabolically
- Anatomically

Electrophysiologically



from Lomber et al. (1994) Proc. Natl. Acad. Sci. (USA) 91: 2999-3003.

Thermodynamically



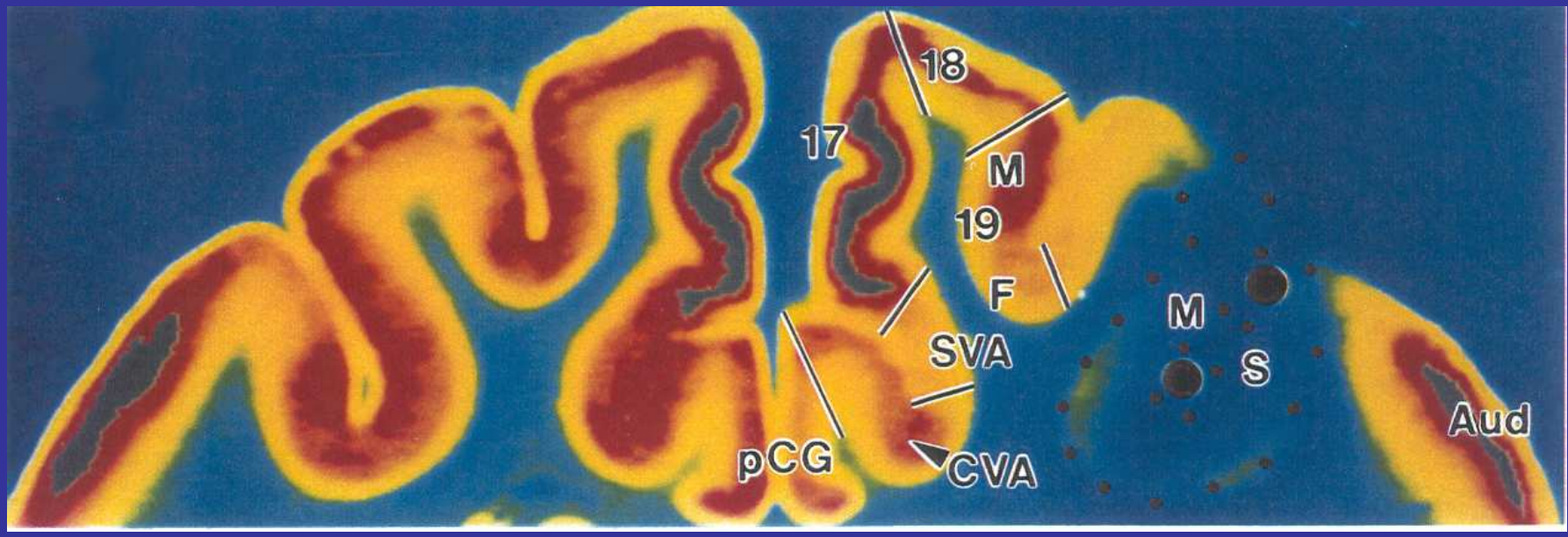
from Lomber et al. (1999) J. Neurosci. Meth. 86: 179-194.

Metabolically:

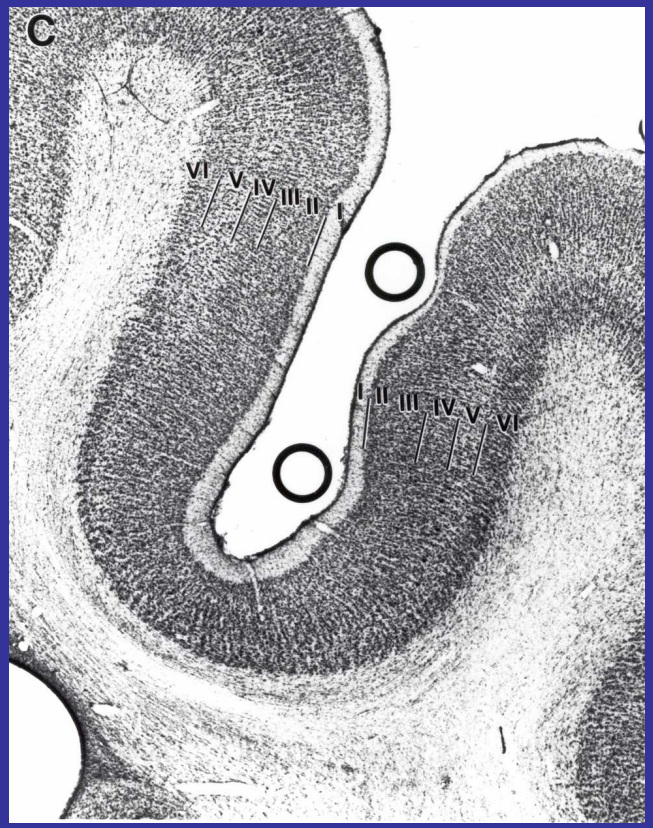
Radiolabelled 2-deoxyglucose

- Administer 2DG in the awake animal, just prior to sacrifice, while one or more loops are being cooled.
- Process tissue for autoradiography

2DG Uptake During Cooling of Right MS Sulcus



Anatomically



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Neurobiology of Disease 23 (2006) 637 – 643

Cooling produces minimal neuropathology in neocortex and hippocampus

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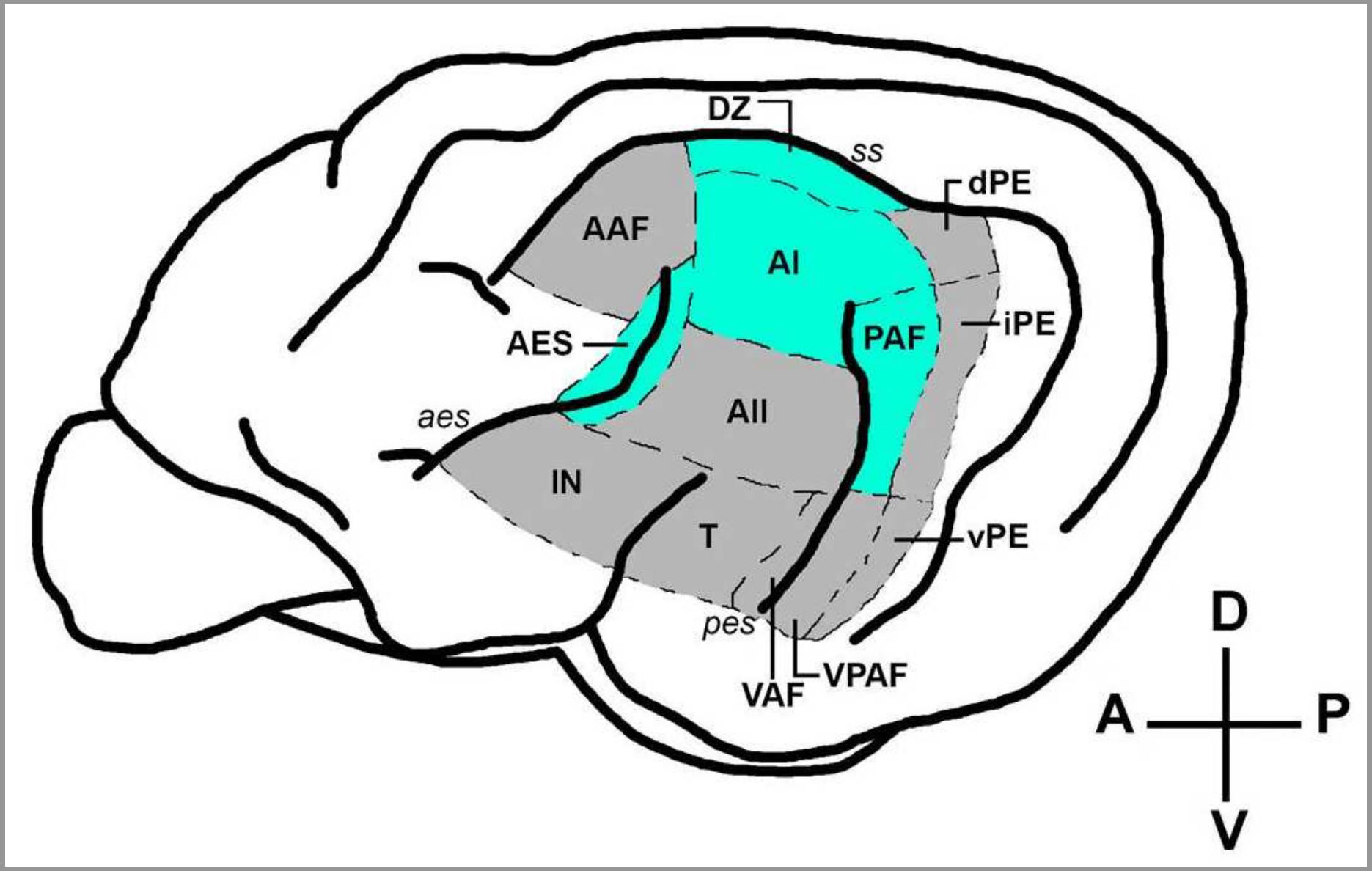
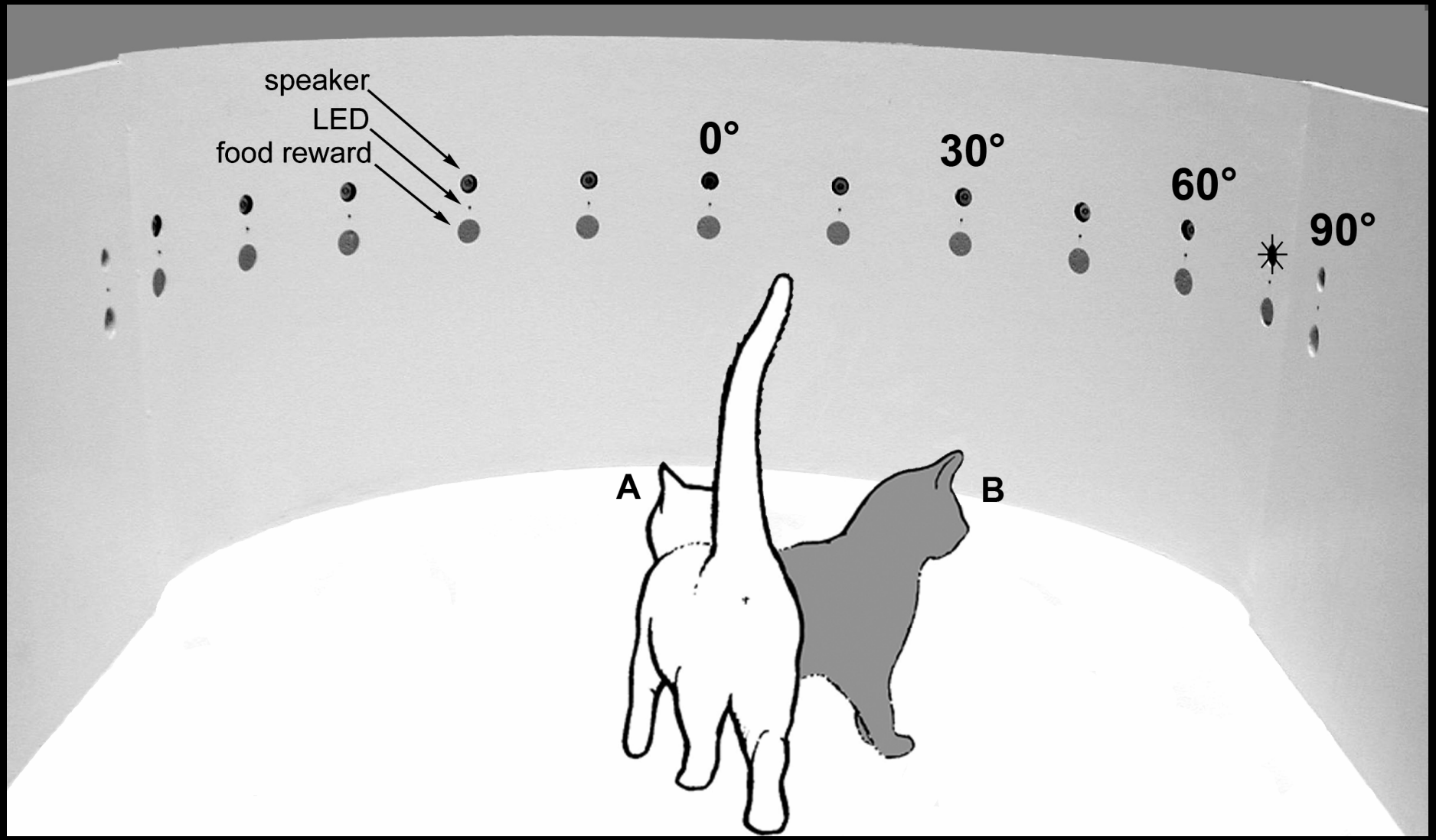
Sound Localization



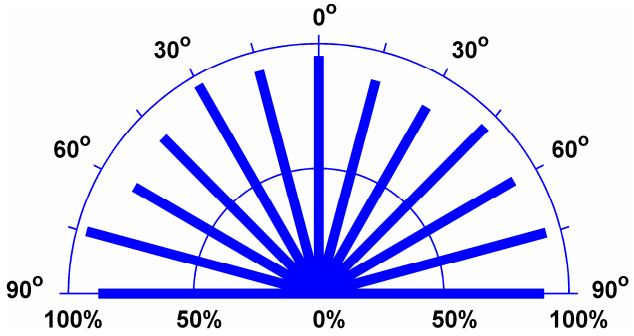
Hypothesis

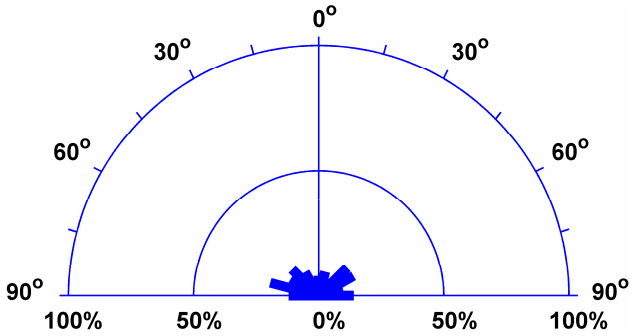
Cortical areas that have been physiologically reorganized in response to deafness will be involved in behaviors that are similar to those of hearing animals, but are mediated by the replacement modality (vision).

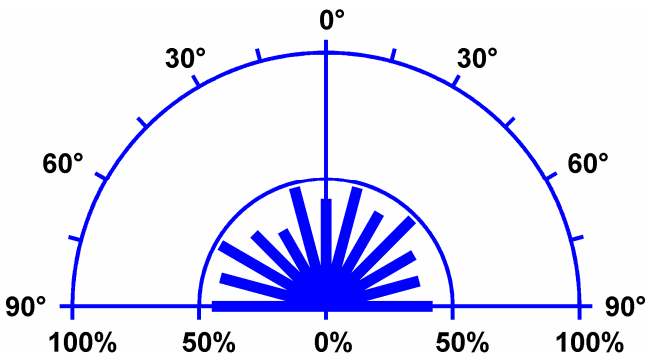

speaker
LED
food reward
0°
30°
60°
90°
A
B

Hearing Cat

Acoustic Stimulus





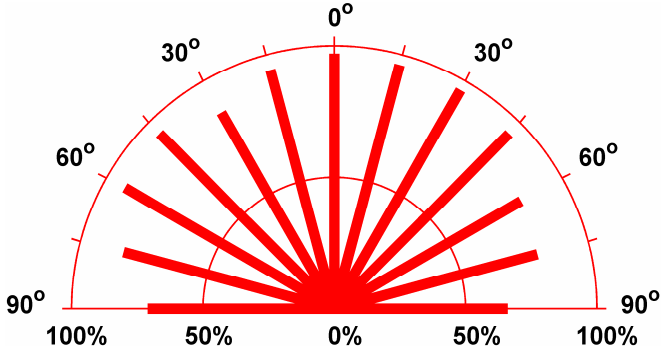


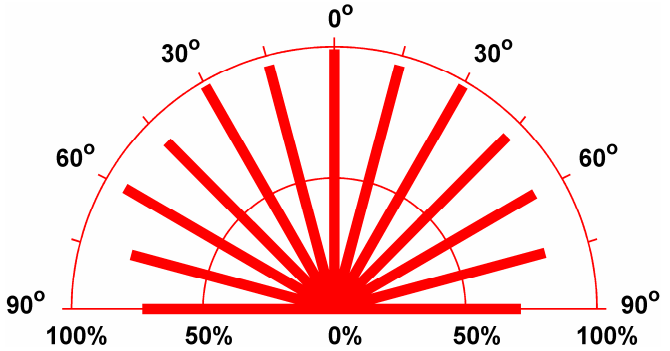
Control

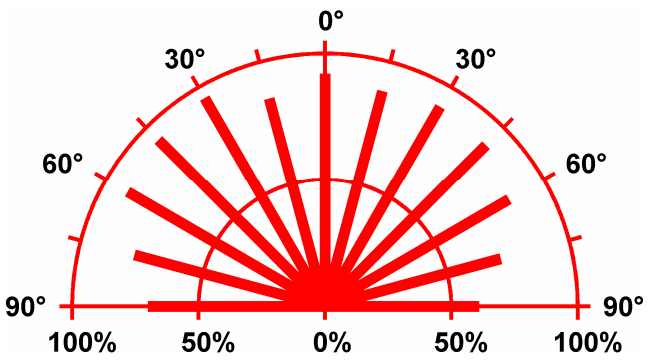
FAES Deactivated

A1 Deactivated

Visual Stimulus





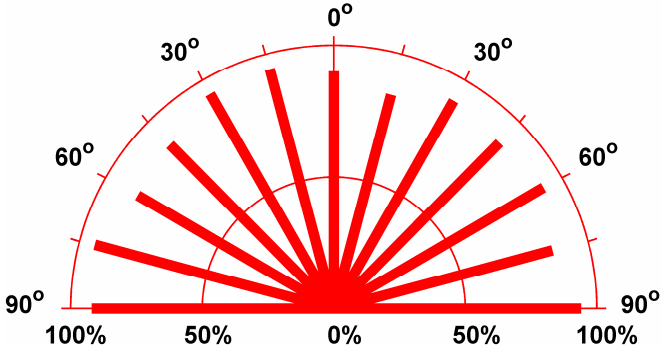


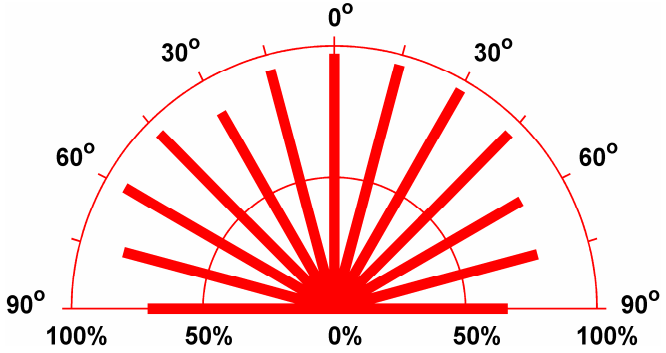
Visual Stimulus

Deaf Cat

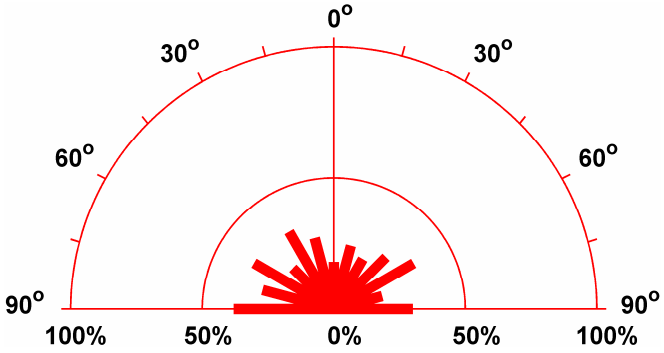
Hearing Cat

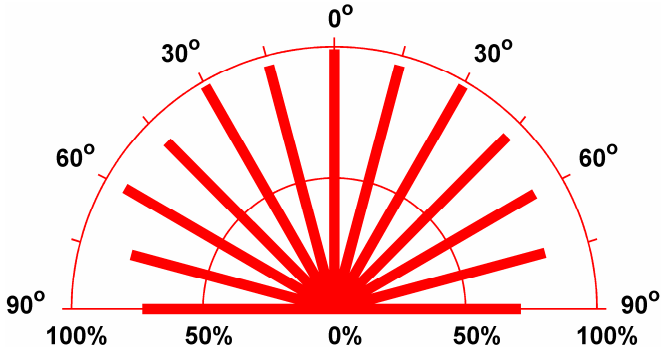
Control



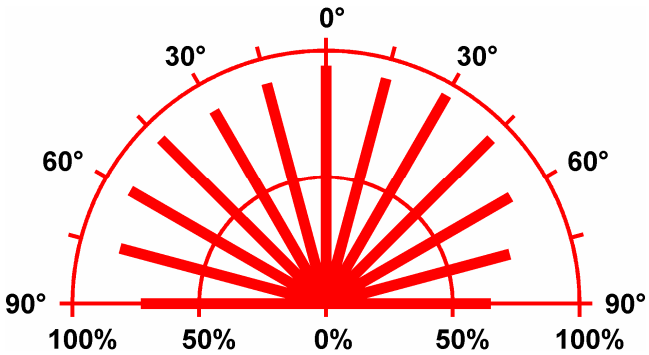


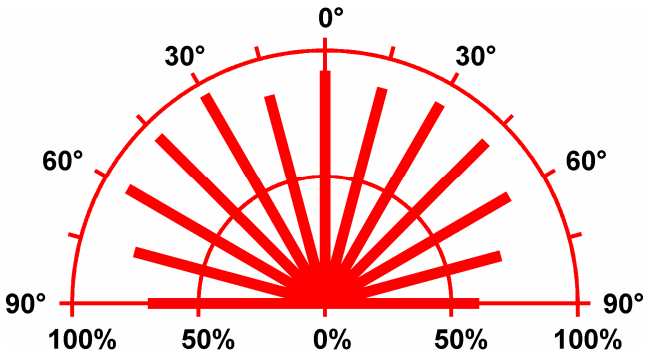
FAES Deactivated

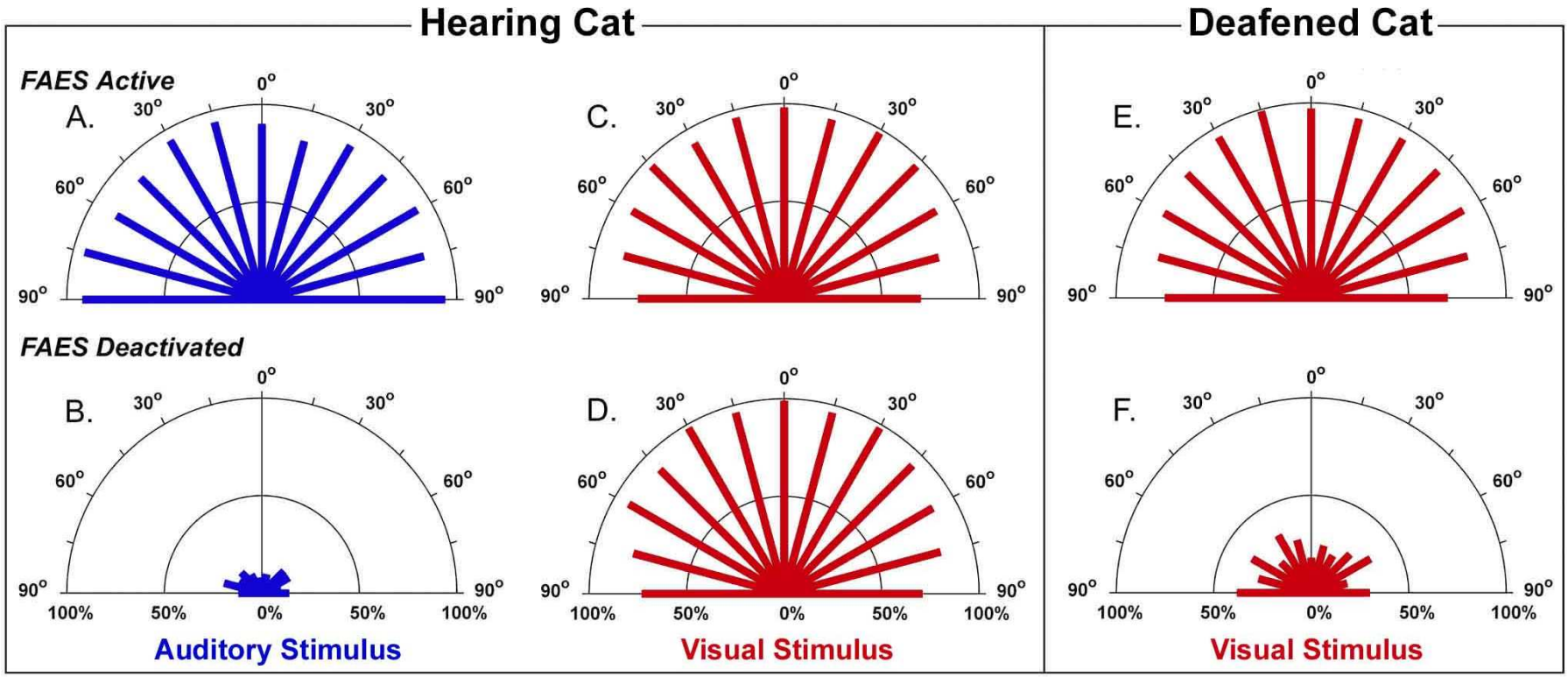




A1 Deactivated







Next: What happens to FAES in deaf cats following introduction of a cochlear prosthetic?

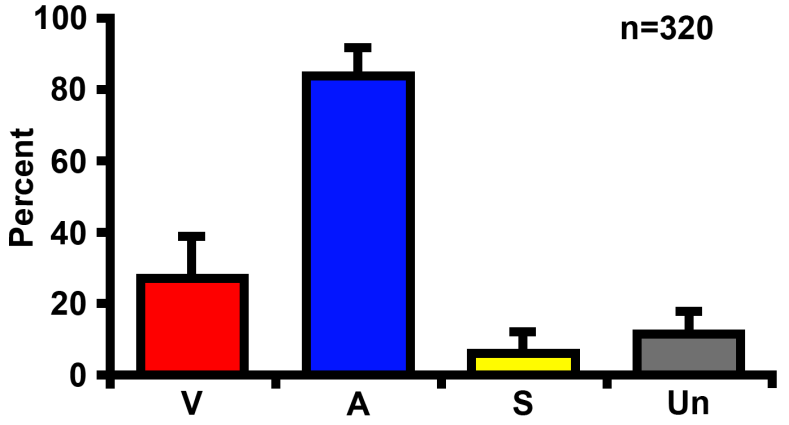
Hypothesis

When other modalities "invade" auditory cortex following deafness, the "invasion" can be reversed (both physiologically and behaviourally) following cochlear implant.

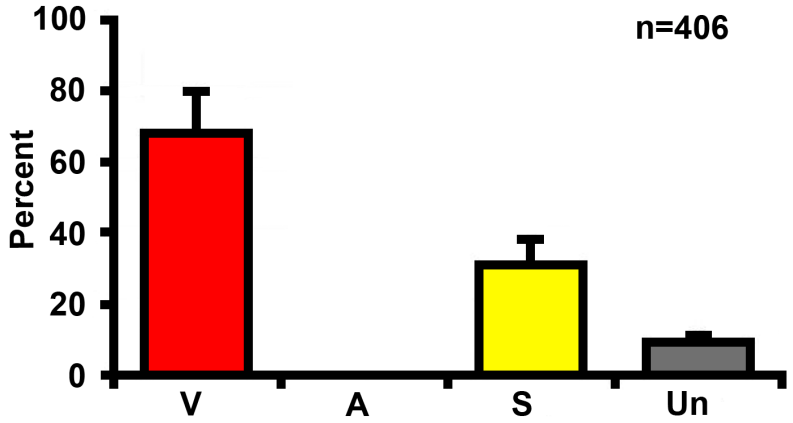
Experimental Approach

- White cats born
- Deafness confirmed with ABR's at 1M
- Testing of visual functions
- Receive bilateral cochlear implants at (4M)
- Trained on a battery of acoustic tasks
- Receive cooling loops at ~ 1.5 years
- Daily testing on the learned tasks during deactivation of individual cortical areas
- Acute cortical recordings/ tracer injections

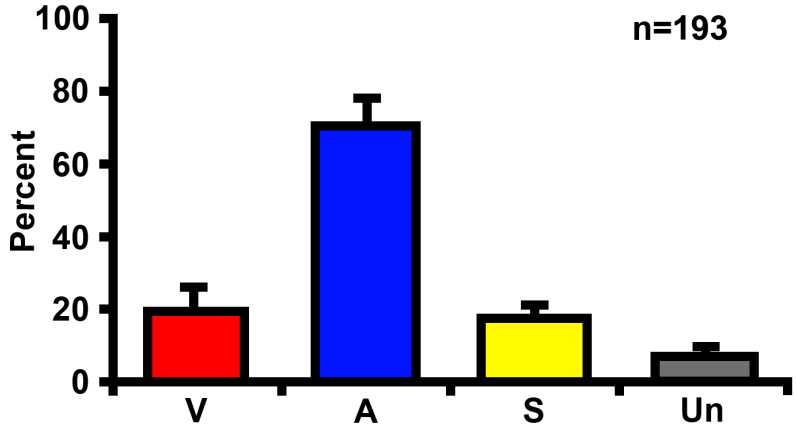
Hearing Cat



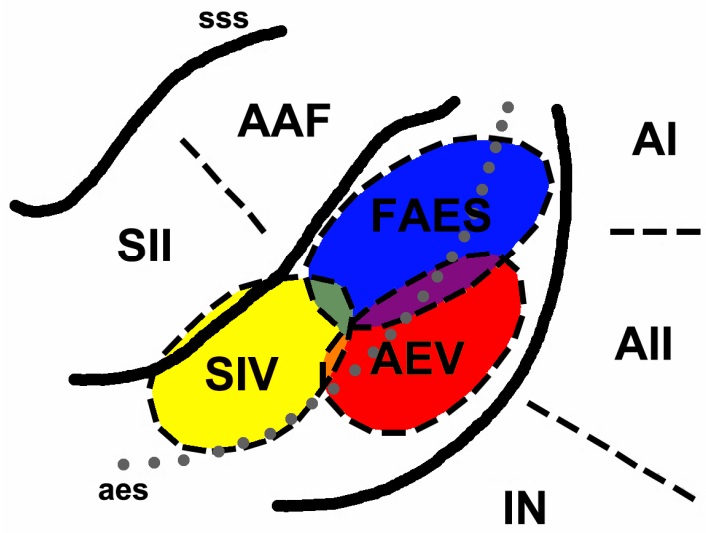
Deaf Cat



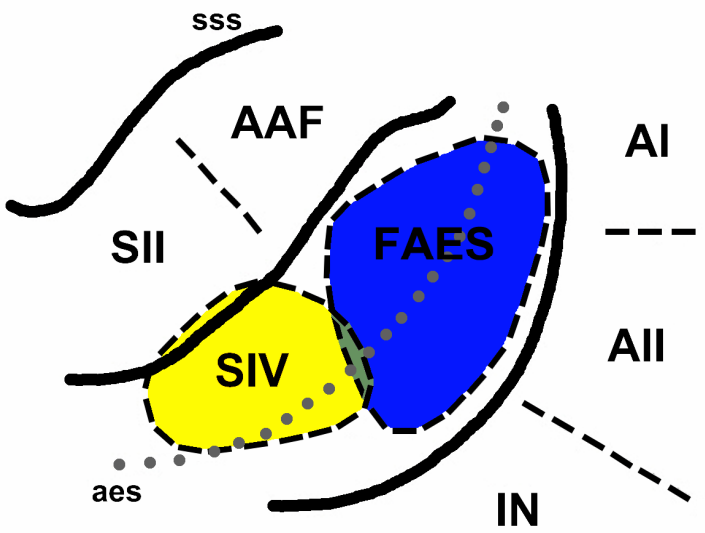
Deaf Cat w/CI



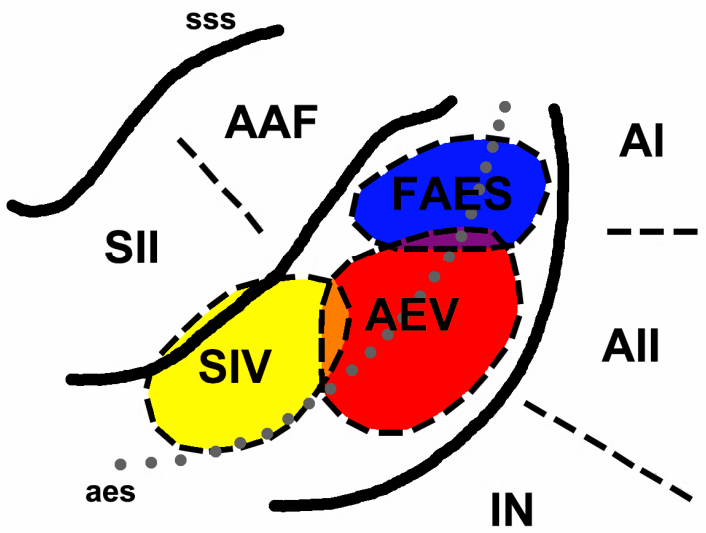
Hearing Cat



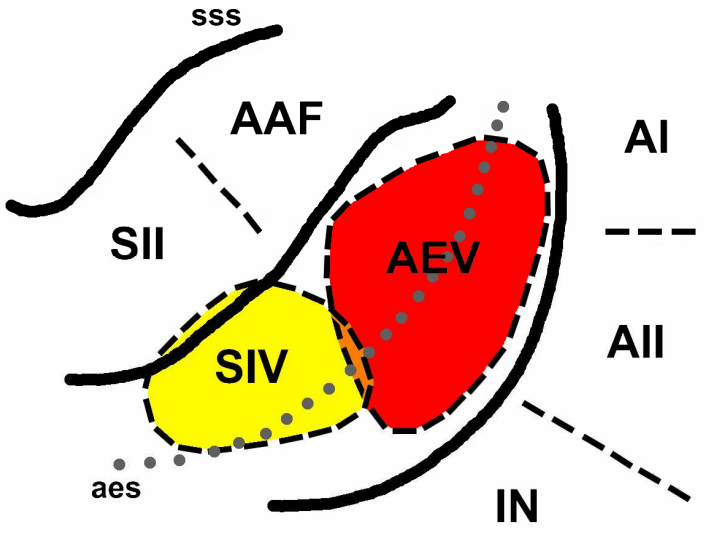
Blind Cat

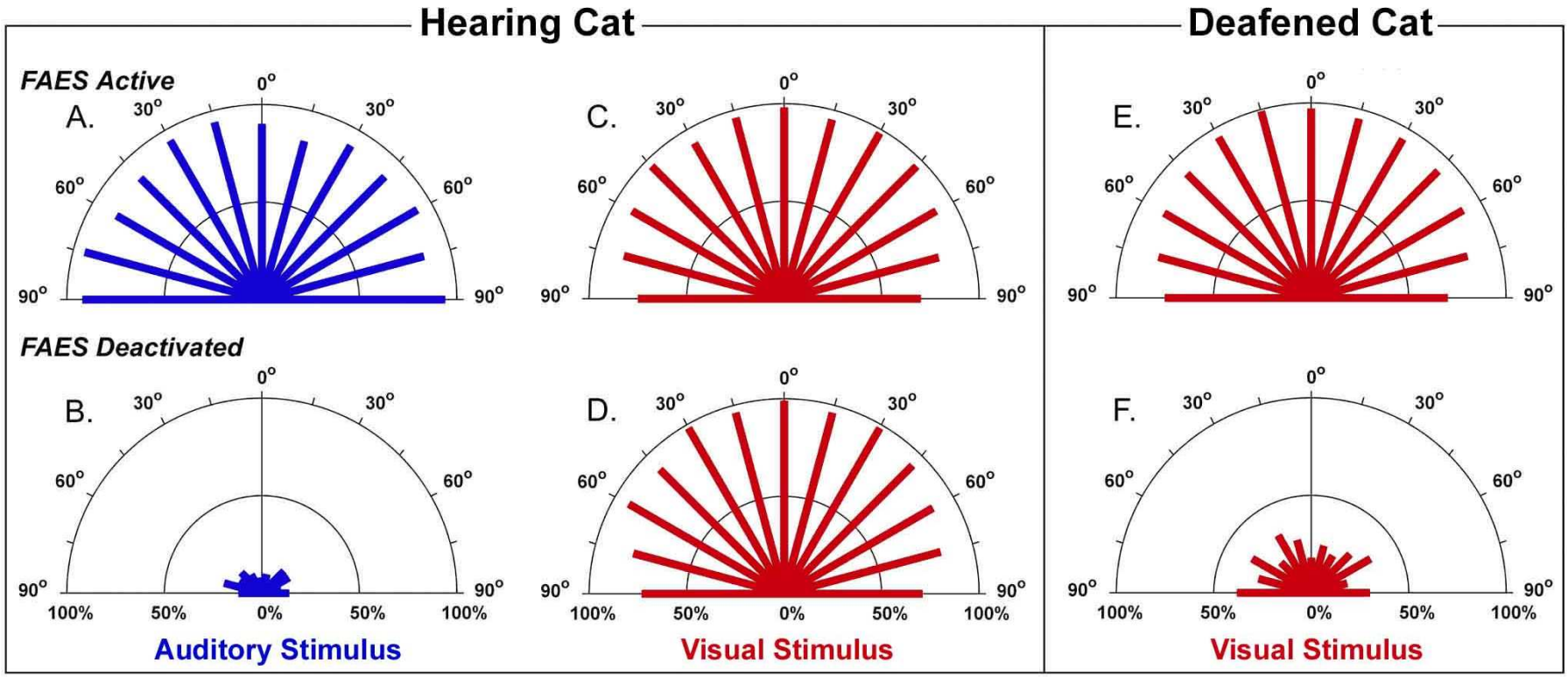


Deaf Cat w/CI



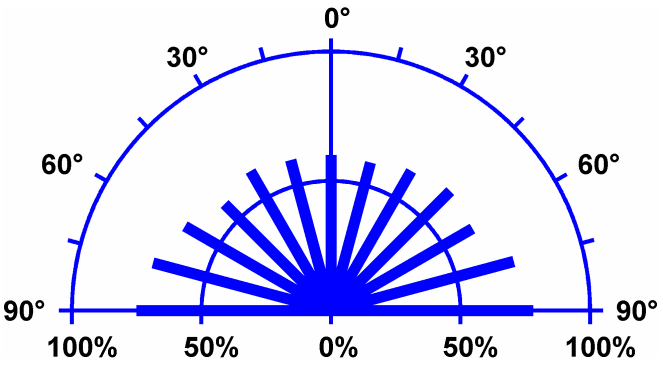
Deaf Cat

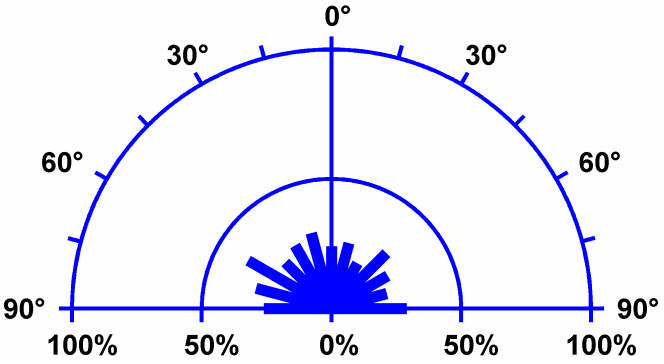


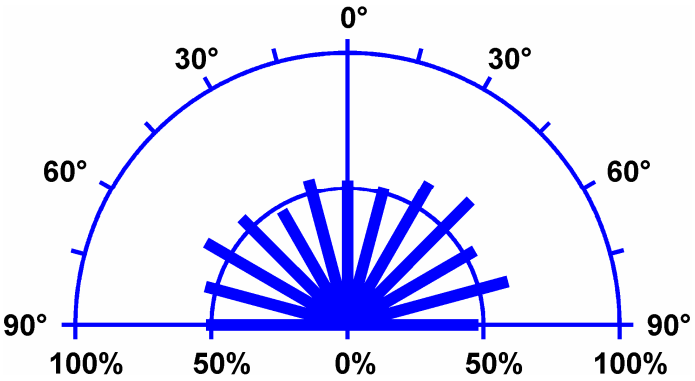

Hearing Cat
Deafened Cat
FAES Active
FAES Deactivated
A.
B.
C.
D.
E.
F.
0°
30°
60°
90°
100%
50%
0%
Auditory Stimulus
Visual Stimulus
Visual Stimulus

Deaf Cat w/CIs

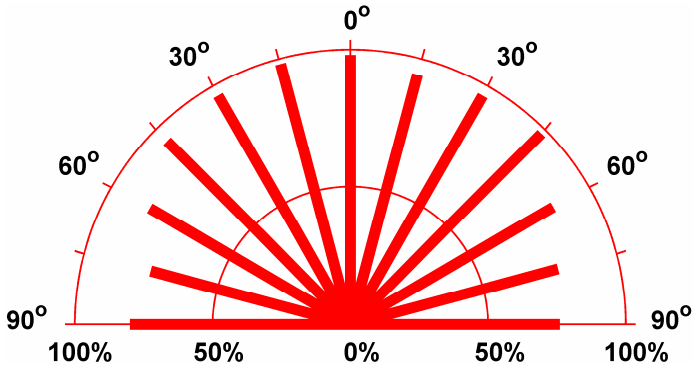
Acoustic Stimulus

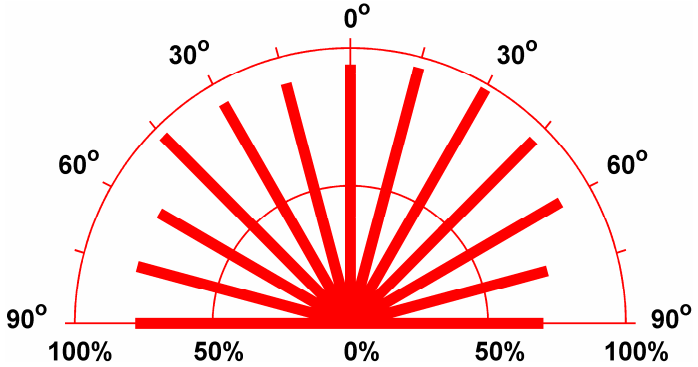


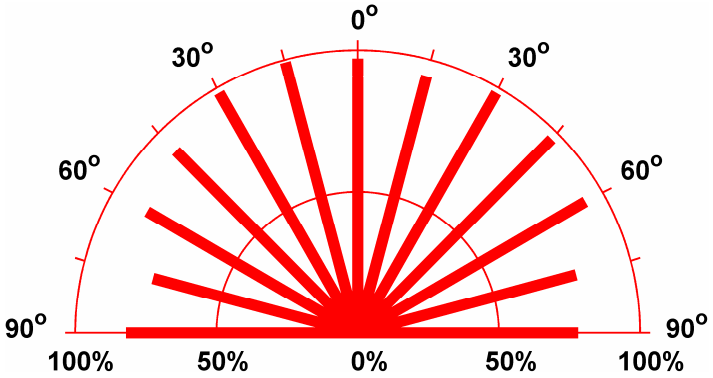




Visual Stimulus







Control

FAES Deactivated

A1 Deactivated

Summary of Visual and Acoustic Orienting Deficits

	Hearing Cat	Deaf Cat	Deaf Cat w/CI
Deactivate FAES	Acoustic Deficit	Visual Deficit	Acoustic Deficit*
Deactivate A1	Acoustic Deficit	No Orienting Deficits	Acoustic Deficit*

Conclusions

1) Congenital deafness induces a reverse hierarchical gradient in the level of cross-modal plasticity, whereby higher order auditory areas show more extensive cross modal reorganization than primary/core areas.

2) Cortical areas that have been physiologically reorganized in response to deafness are involved in behaviors that are similar to those of hearing animals, but are mediated by the replacement modality (vision).

3) When other modalities "invade" auditory cortex following deafness, the "invasion" can be stopped and reversed (both physiologically and behaviourally) following cochlear implant.

Future Questions to Consider

- How does degree of deafness effect cross-modal cortical plasticity?
- How does age at implant effect the ability of cochlear prosthetics to establish acoustic processing in auditory cortex?
- How rapidly do these cortical changes occur following the activation of a cochlear prosthetic?
- If use of a cochlear prosthetic is discontinued, does visual processing re-establish itself?

The brain has a remarkable ability to adapt in the event of damage - in many cases shifting responsibility for specific cognitive functions to other non-damaged brain regions. This 'plasticity' can be crucial in aiding recovery from stroke, trauma, and peripheral damage such as eye or ear damage. Over the past thirty years our view of cortical plasticity has evolved greatly . Early studies suggested that changes to cortical function due to peripheral lesions could only occur during development and that these plastic changes were specific to a particular temporal window or "critical period". Over time, it has been demonstrated that cortical modifications as a consequence of either peripheral or central lesions can induce adaptive, or beneficial, changes in cortical function in an effort to preserve or enhance function. More recently, studies have identified that many of these adaptive changes, once thought only possible in the developing brain, are also possible in the mature or developed brain. At present, many laboratories are defining the beneficial capabilities of cerebral cortex plasticity, upon which many proactive and therapeutic strategies may be developed in order to maximize the "reprogramming" capabilities of the cerebrum.

Reprogramming the Cerebral Cortex describes these exciting studies and examines adaptive cortical plasticity in a variety of systems (visual, auditory, somatomotor, cross-modal, language and cognition). The book leads the reader through the complexities and promise of neuroplasticity, and presents insights into current and future research and clinical practice. It is unique in looking at the beneficial capabilities of cerebral cortex plasticity, upon which many proactive and therapeutic strategies may be developed.

The book will be a valuable resource for behavioral, systems, computational and cognitive neuroscientists, as well as clinicians and neuropsychologists.

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plasticity following central and peripheral lesions

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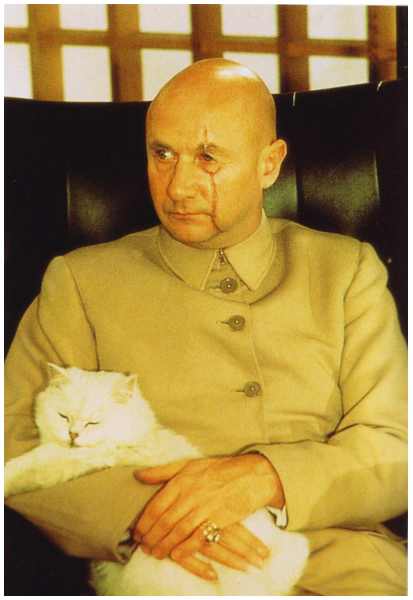
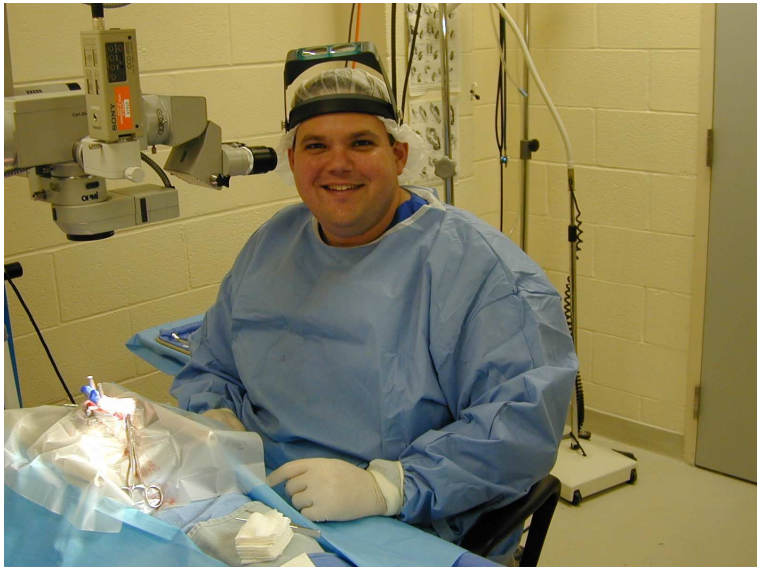
STEPHEN LOMBER
JOS EGGERMONT

For additional information:





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