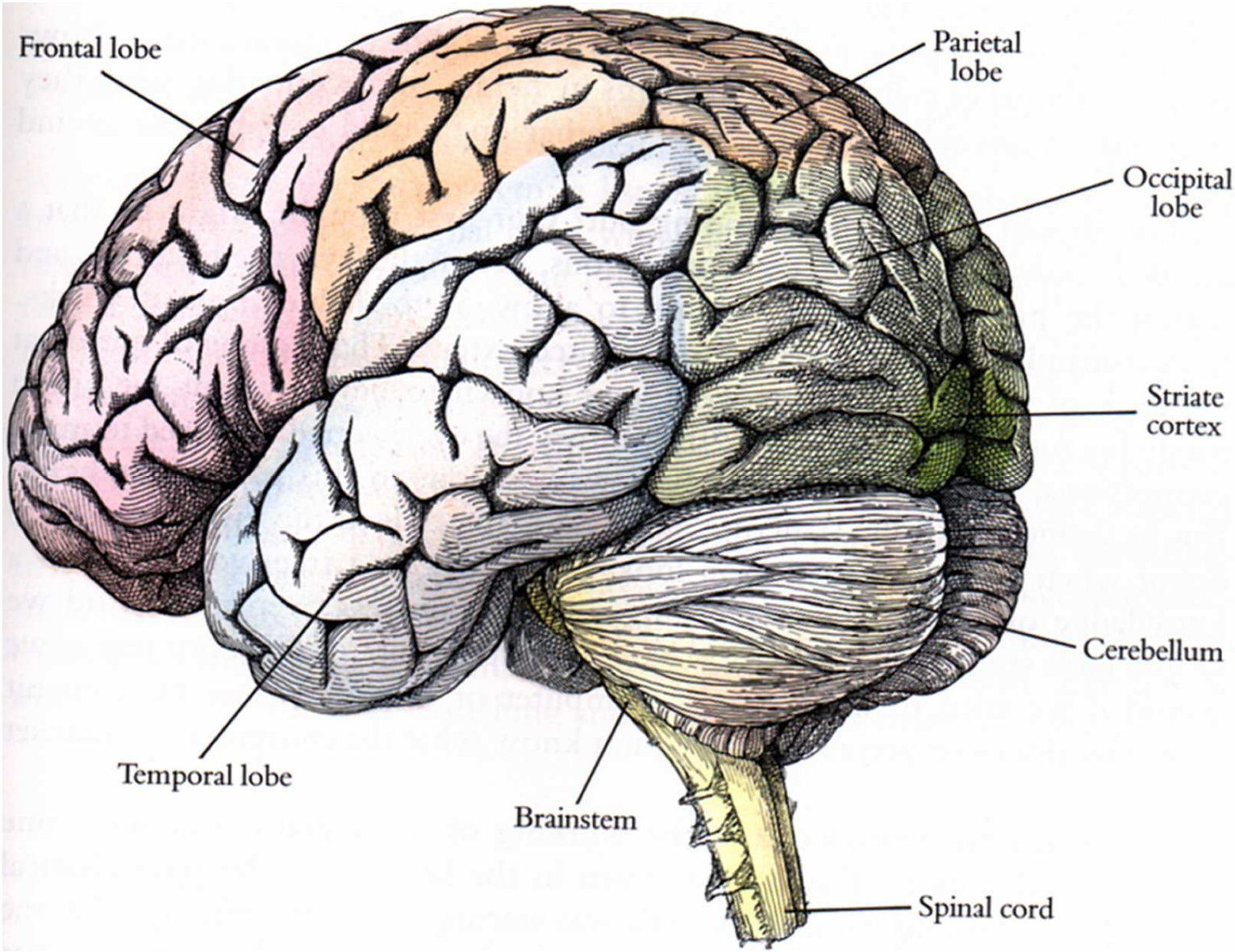
The effects of sensory deprivation on sensory processing

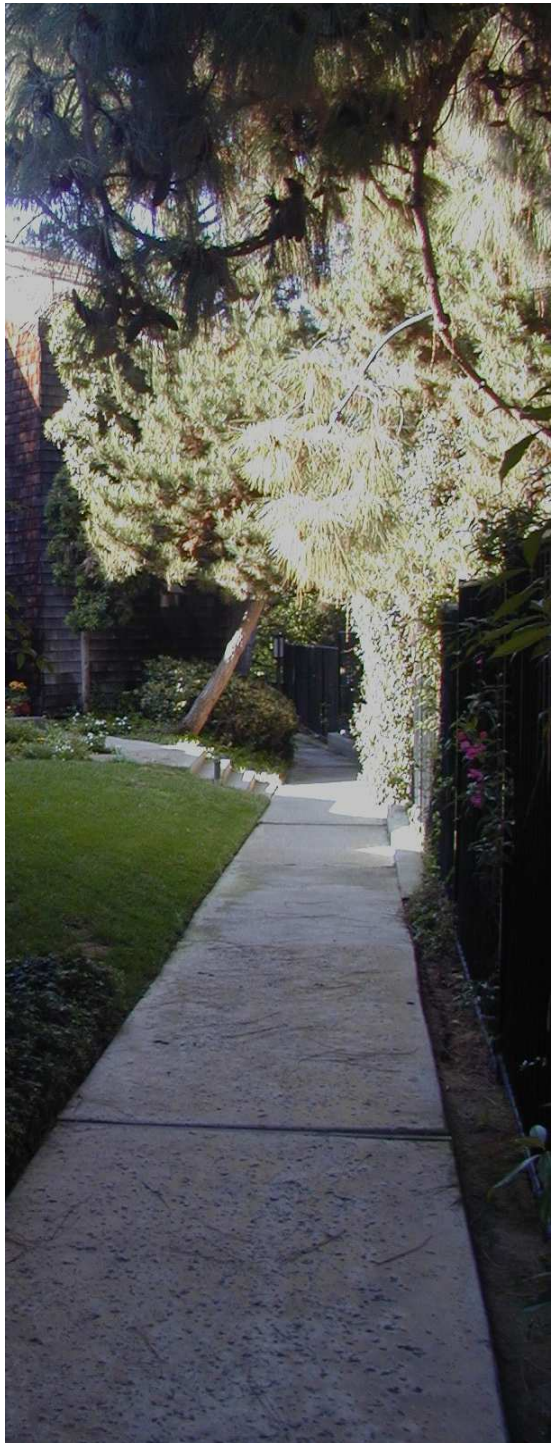
Ione Fine, University of Washington


Frontal lobe
Parietal lobe
Occipital lobe
Striate cortex
Cerebellum
Temporal lobe
Brainstem
Spinal cord

Molyneux's question

"Suppose a man born blind, and now adult, and taught by his touch to distinguish between a cube and a sphere … Suppose then … the blind man made to see … Query: whether by his sight, before he touched them, he could distinguish and tell which is the globe, which is the cube?"

John Locke (1690)
Essay Concerning Human Understanding

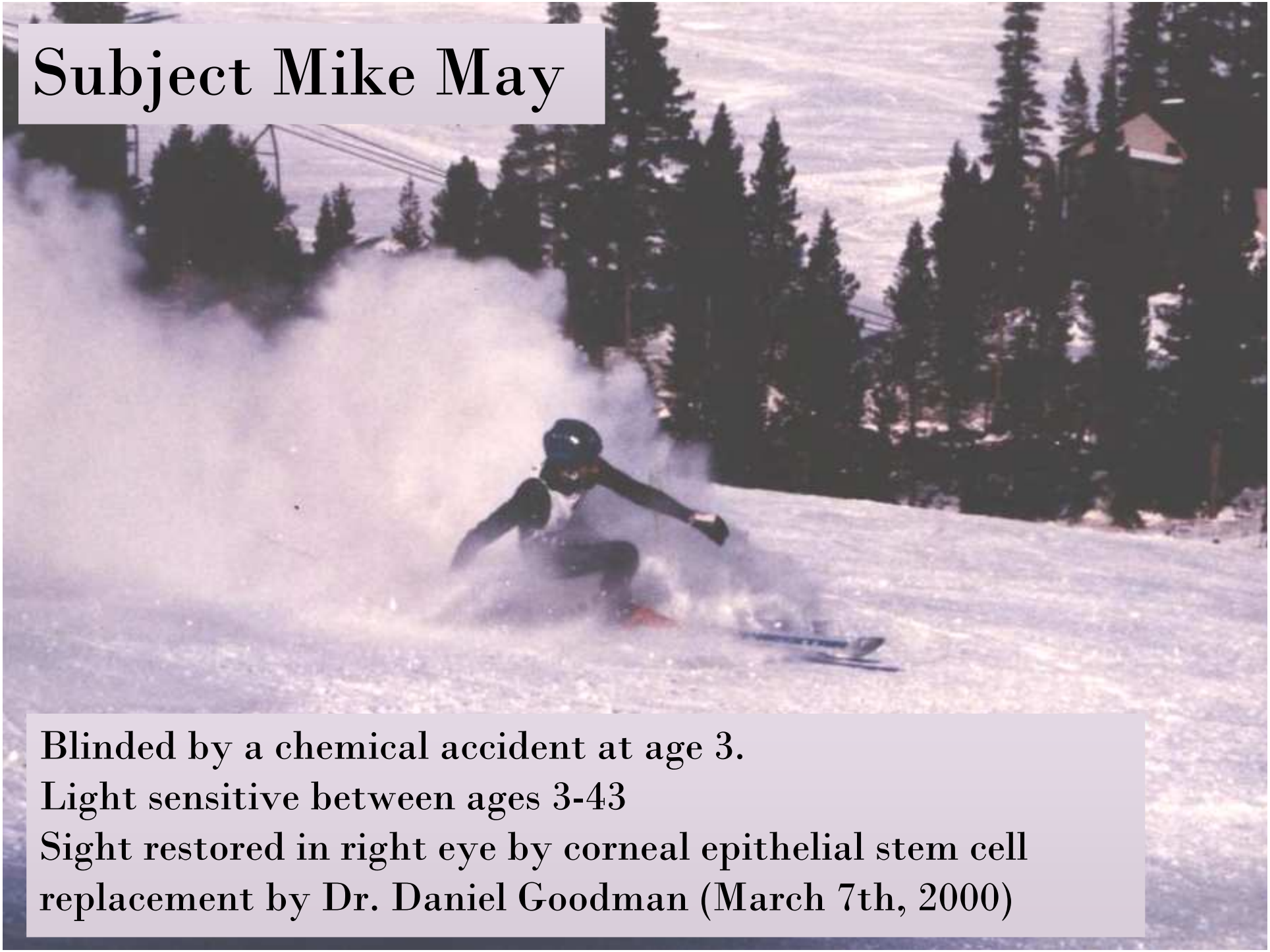


To what extent does visual processing rely on visual experience?

SB (Gregory & Wallace, 1963)

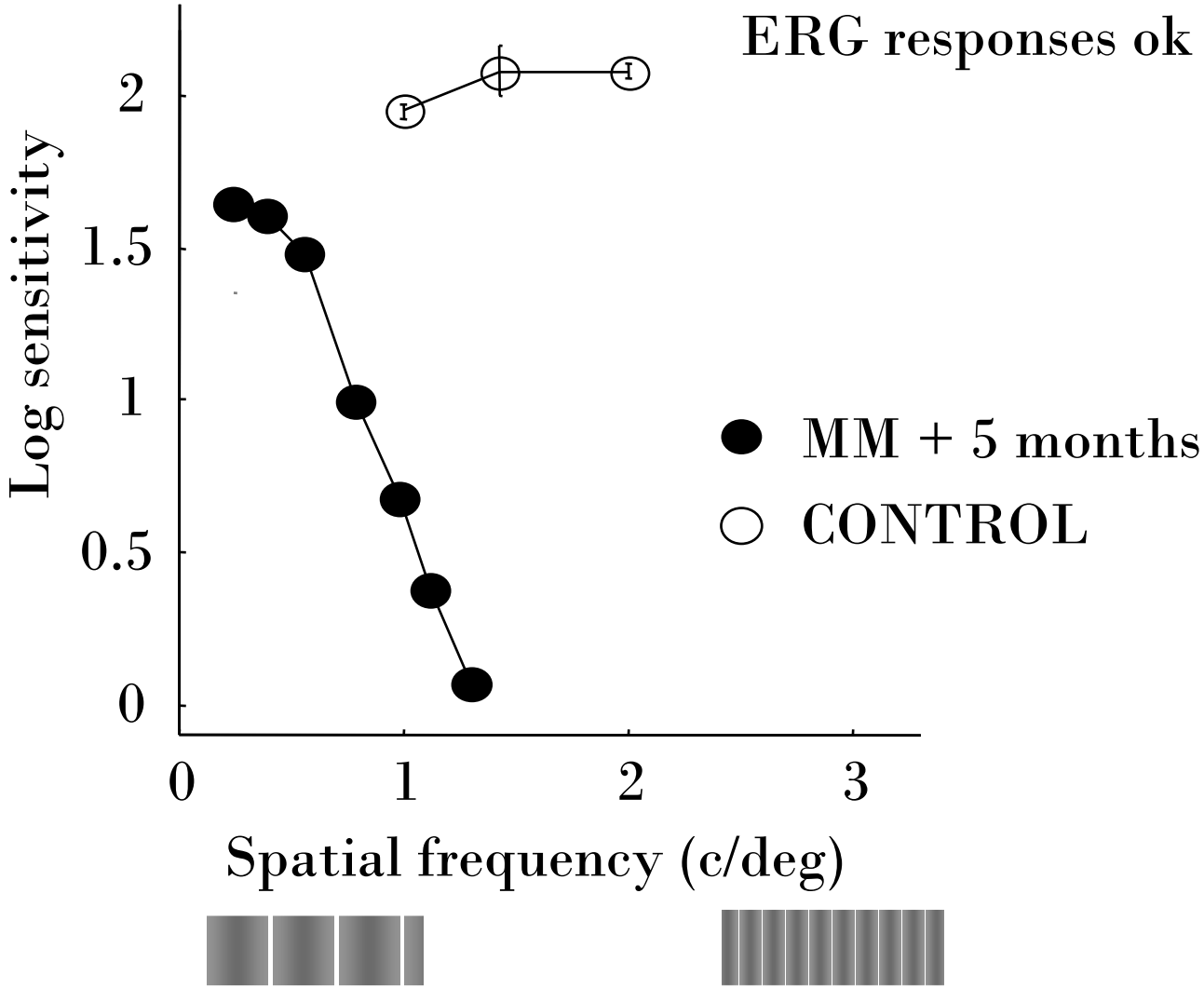
Sacks, 1991
Hyvarinen et al., 1978, 1981
Ackroyd, et al. 1974
Valvo, 1971
Gregory & Wallace, 1963
Cheselden, 1768

Subject Mike May

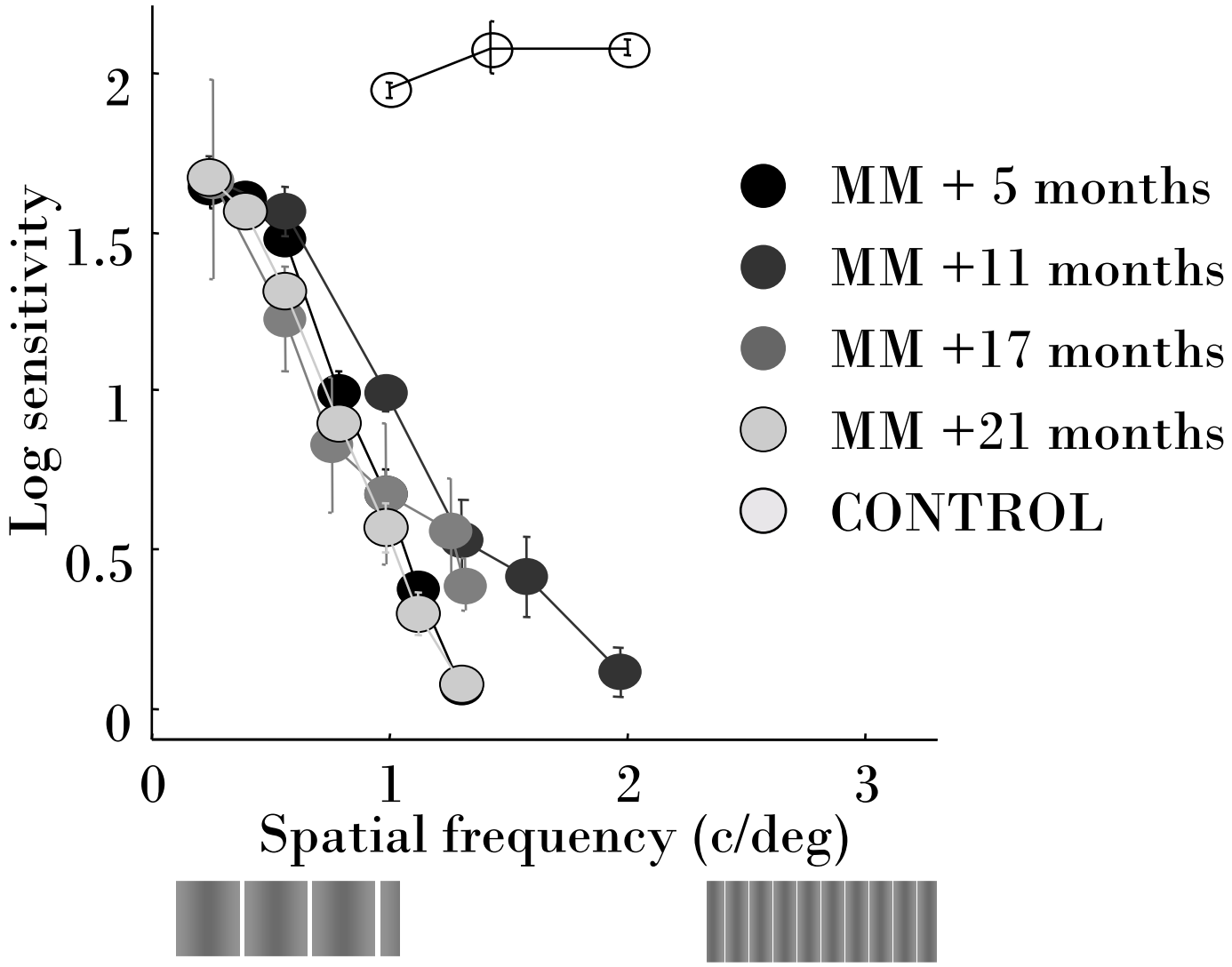


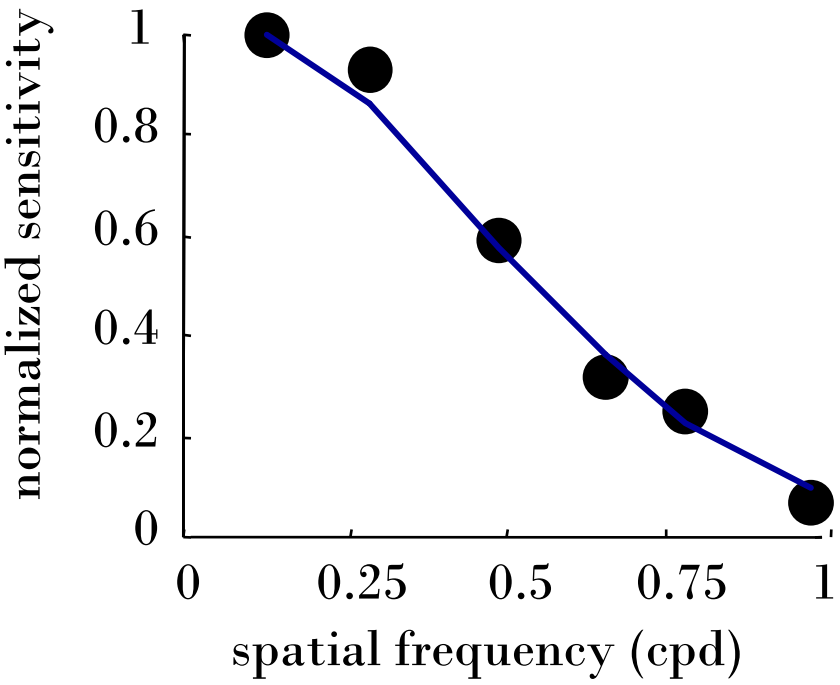
Blinded by a chemical accident at age 3.
Light sensitive between ages 3-43
Sight restored in right eye by corneal epithelial stem cell replacement by Dr. Daniel Goodman (March 7th, 2000)

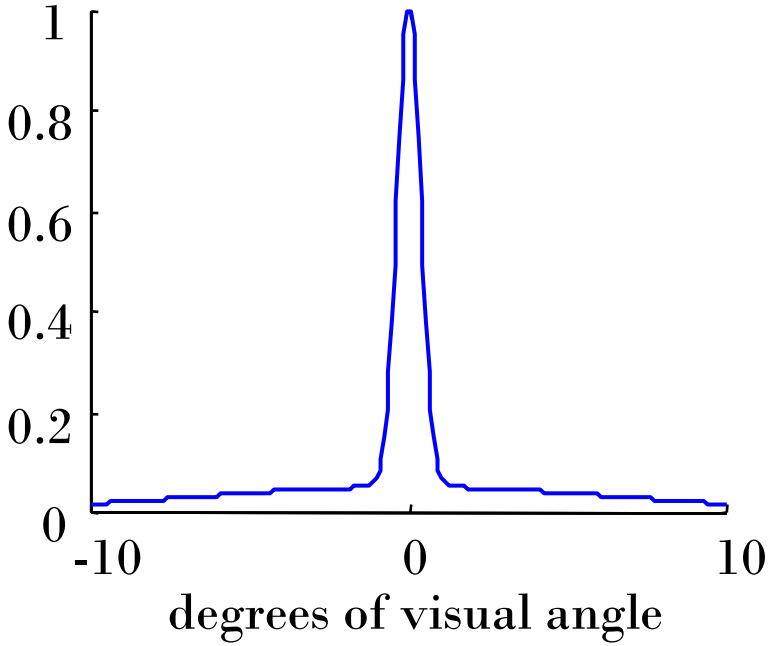
Poor spatial acuity



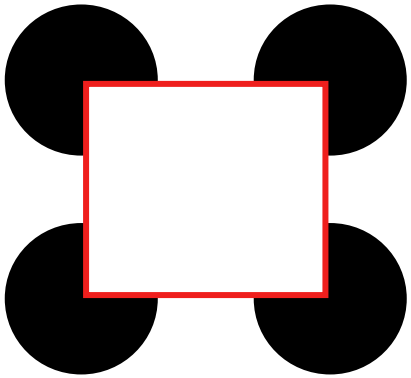
No recovery over time




normalized sensitivity
1
0.8
0.6
0.4
0.2
0
0
0.25
0.5
0.75
1
spatial frequency (cpd)


1
0.8
0.6
0.4
0.2
0
-10
0
10
degrees of visual angle

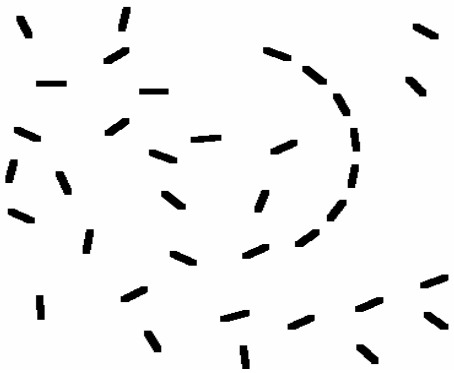
Simple form ok



MM=100%

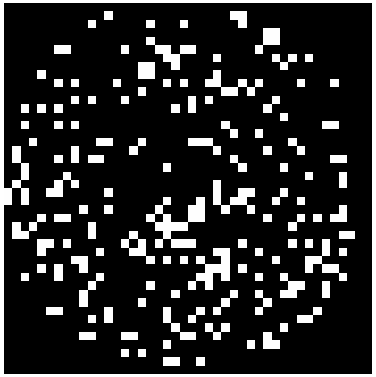
C=100%, 100%, 100%

Global form weak



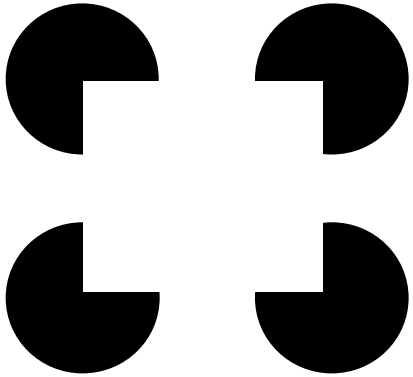
MM=80%

C=100%, 90%, 95%



MM=73%

C=80%, 85%, 100%



MM=0%

C=100%, 100%, 100%

Depth

***Virgil* (Sacks)**

"surfaces of objects would seem to loom … when they were still quite a distance away; sometimes he would get confused by his own shadow… [Steps] posed a particular hazard.

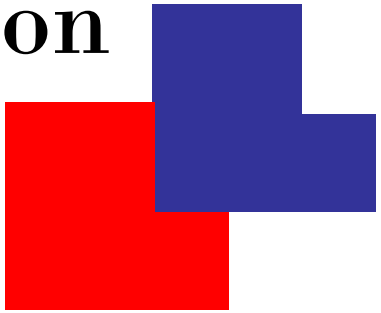
All he could see was a confusion, a flat surface of parallel and crisscrossing lines"

HS (Valvo)

"I had no appreciation of depth or distance; street lights were luminous stains stuck to window panes, and the corridors of the hospital were black holes"

Depth

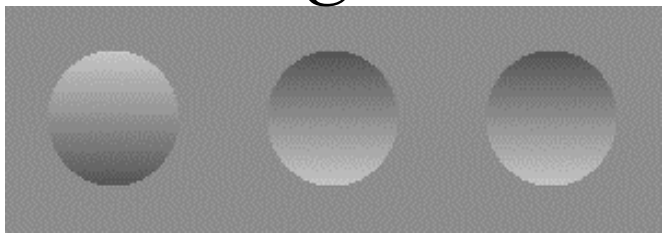
occlusion ok



MM=100%

C=100%, 100%, 100%

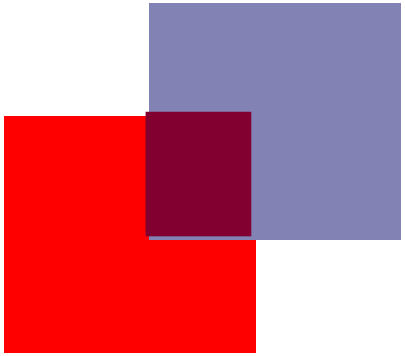
shading weak



MM=96% BUT long RTs

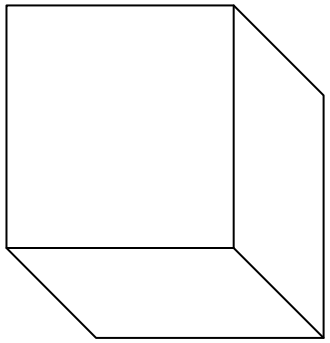
C=100%, 100%, 100%

transparency & perspective poor



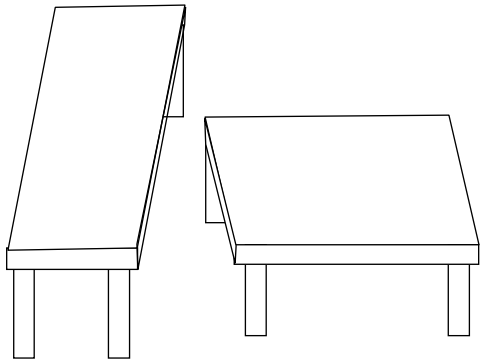
MM=0%

C=100%, 100%, 100%



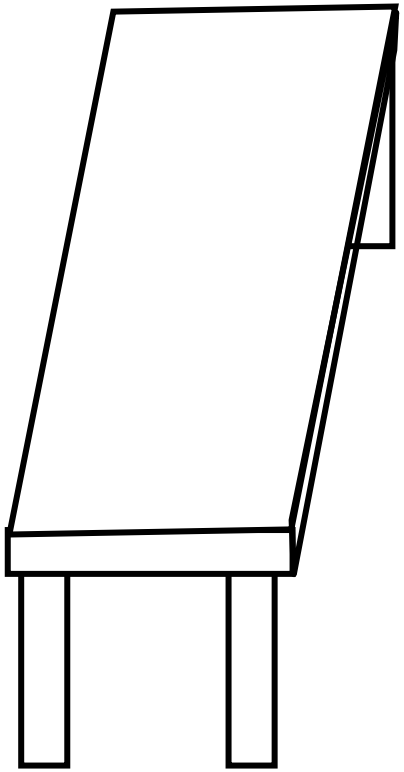
MM=NR

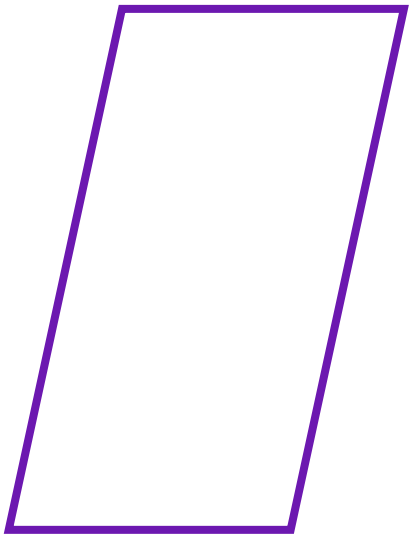
C=100%, 100%, 100%

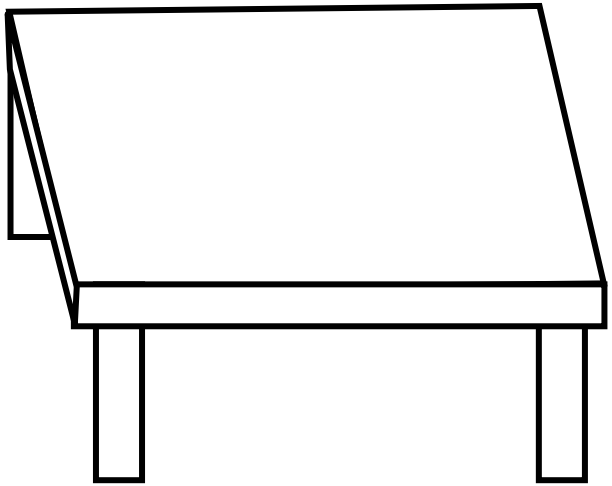


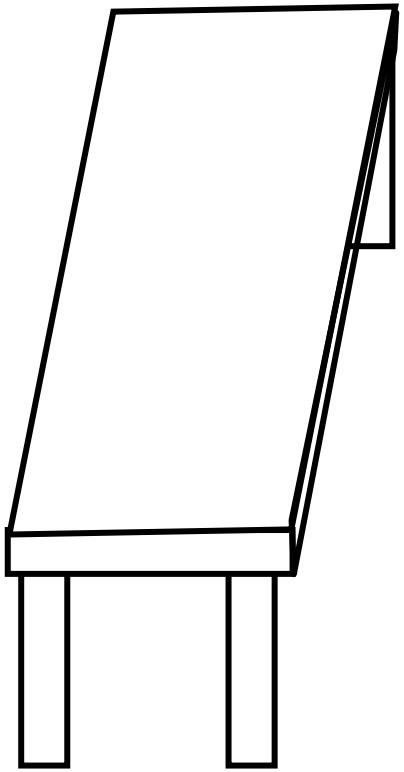
MM=0 bias

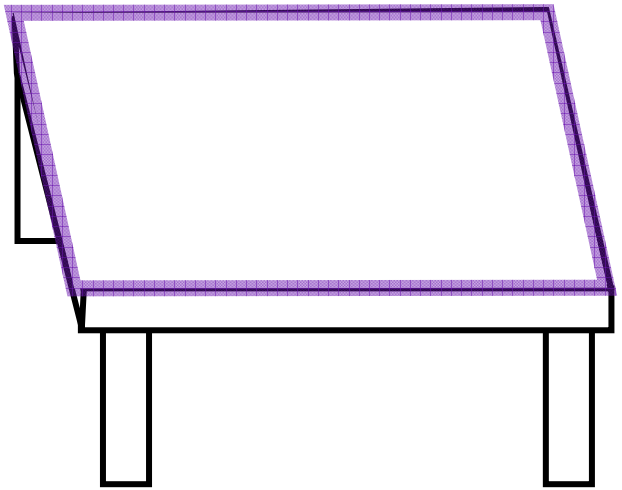
C=+26%, +31%, +29%











Objects & Faces

(Cheselden, 1720)

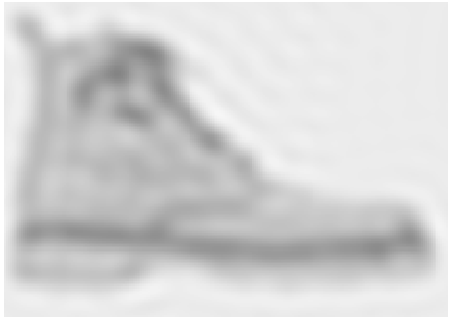
"Having often forgot which was the cat and which the dog, he was ashamed to ask, but catching the cat which he knew from feeling, he was observed to look at her steadfastly and then … have said, So puss, I shall know you another time"

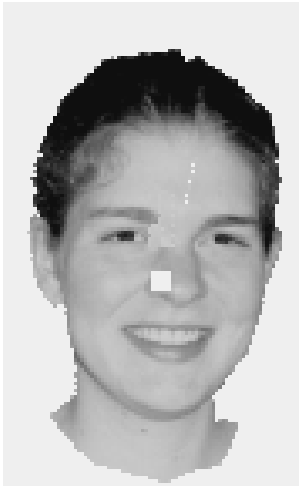
Virgil (Sacks)

"He did not really look at our faces, though he smiled and laughed and listened intently … He reminded me of … the man who mistook his wife for a hat"

Poor object & face identification

MM 25% correct
control 100%





Gender
MM 70% correct
control 100%

Expression (happy/sad/neutral)
MM 61% correct
control 100%

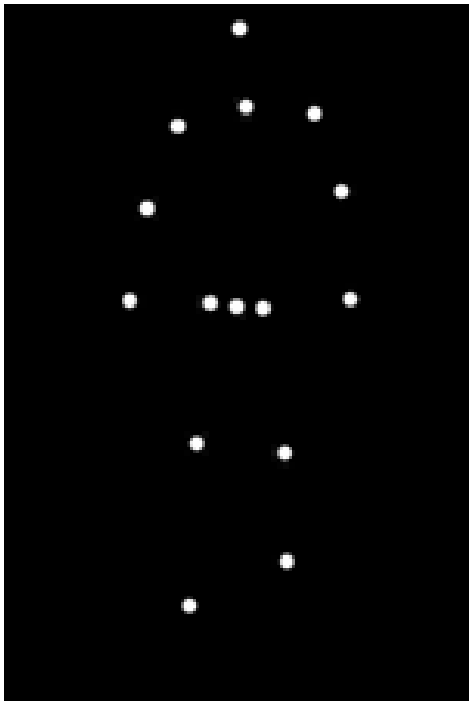
Motion

SB (Ackroyd et al)

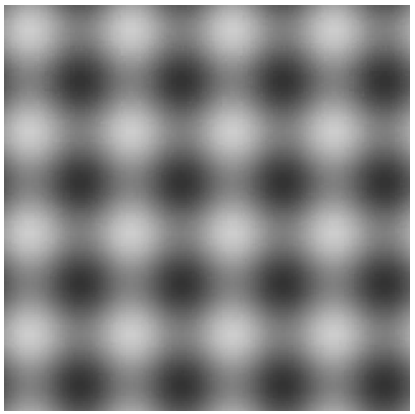
"His only signs of appreciation were to moving objects, particularly the pigeons in Trafalgar square… He clearly enjoyed … watching … the movement of other cars on the road …He spotted a speeder coming up very fast behind us"

Virgil (Sacks)

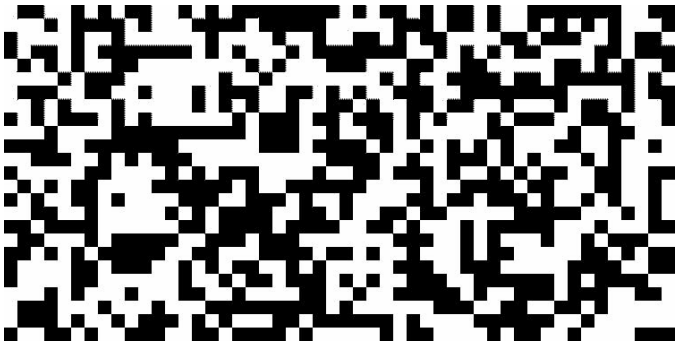
"when [the gorilla] finally came into the open he thought that, though it moved differently, it looked just like a large man"



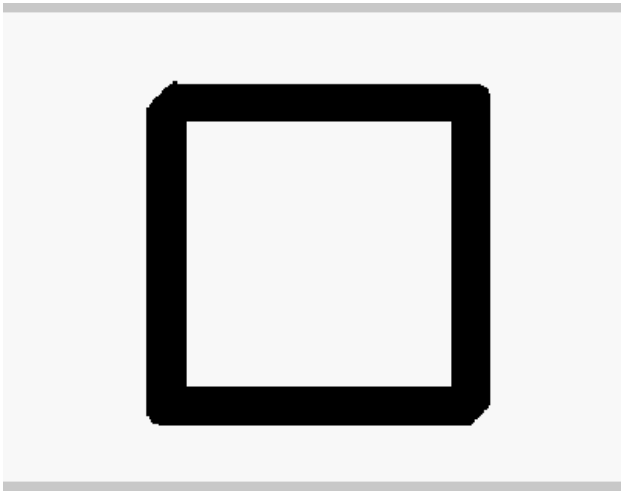
Motion fine!



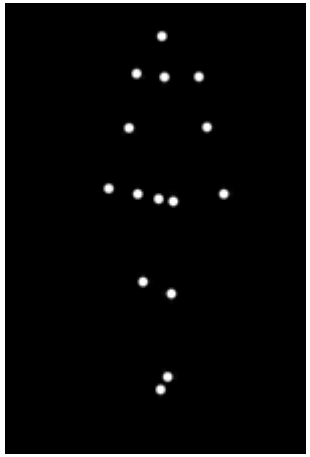
MM =100%
C=100%, 100%, 100%



MM=100%
C=100%, 100%, 100%



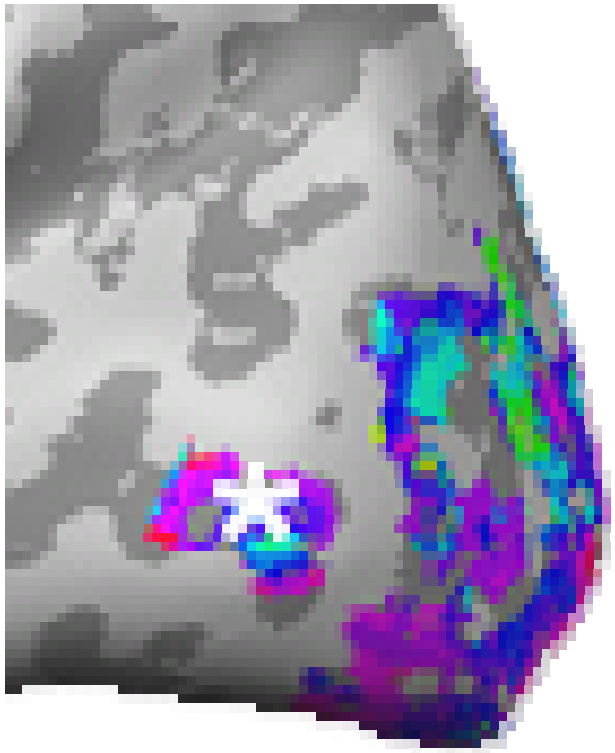
MM = 100%
C=100%, 100%, 100%

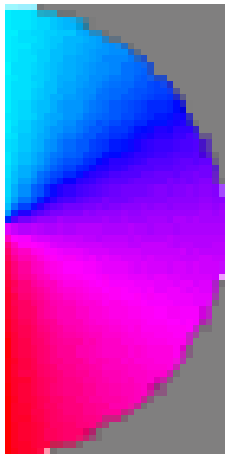


MM = 100%

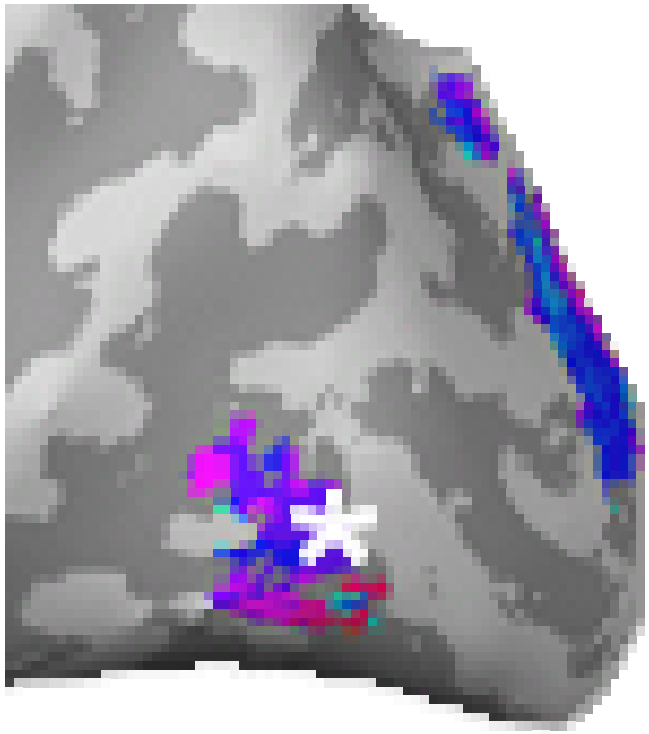
Control

LEFT HEMI



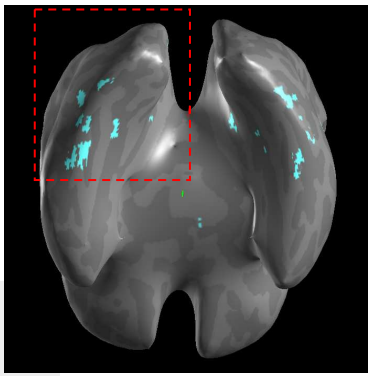


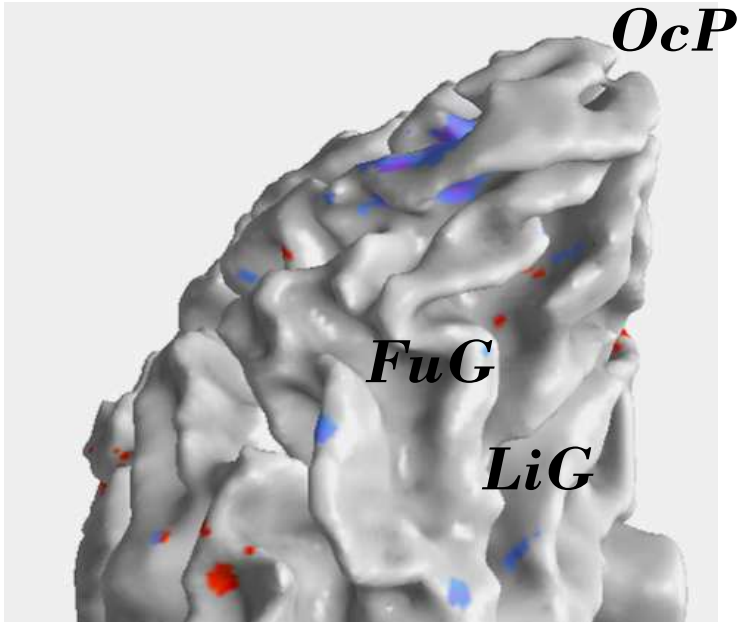
MM

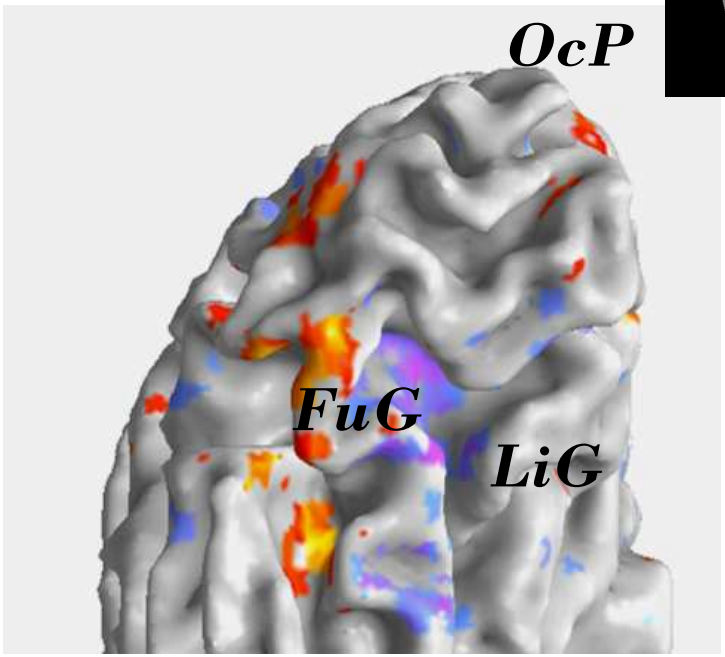


MM

Control







Posterior

Medial

1 0.4 0 0.4 1

Cross-modal Plasticity

When an area that normally processes a missing sense begins to respond to other senses

E.g. visual cortex responding to sound in people who are blind

Auditory cortex responding to vision in people who are deaf

Compensatory hypertrophy

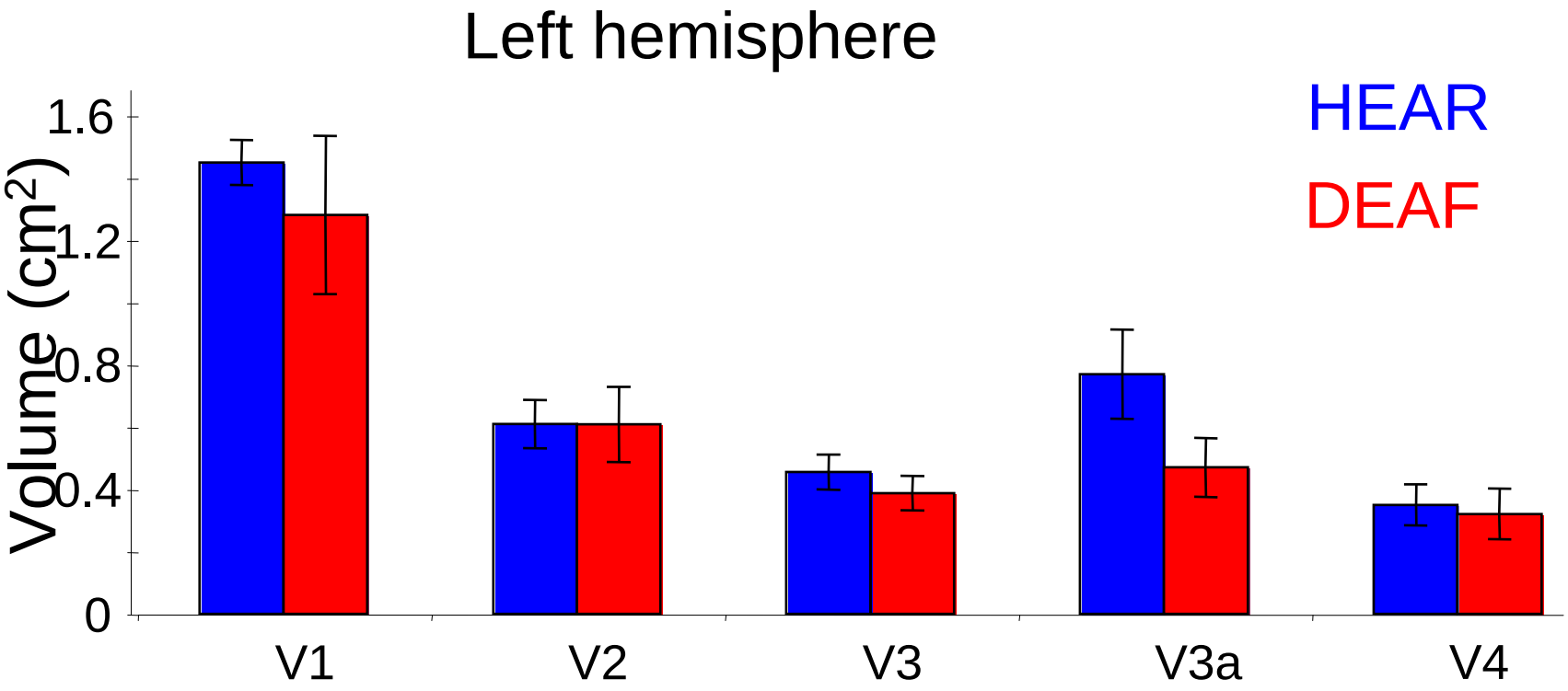
When processing in an sensory area changes to compensate for a different missing sense.

E.g. Different processing within visual cortex in people who are deaf

Different auditory or tactile regions in people who are blind

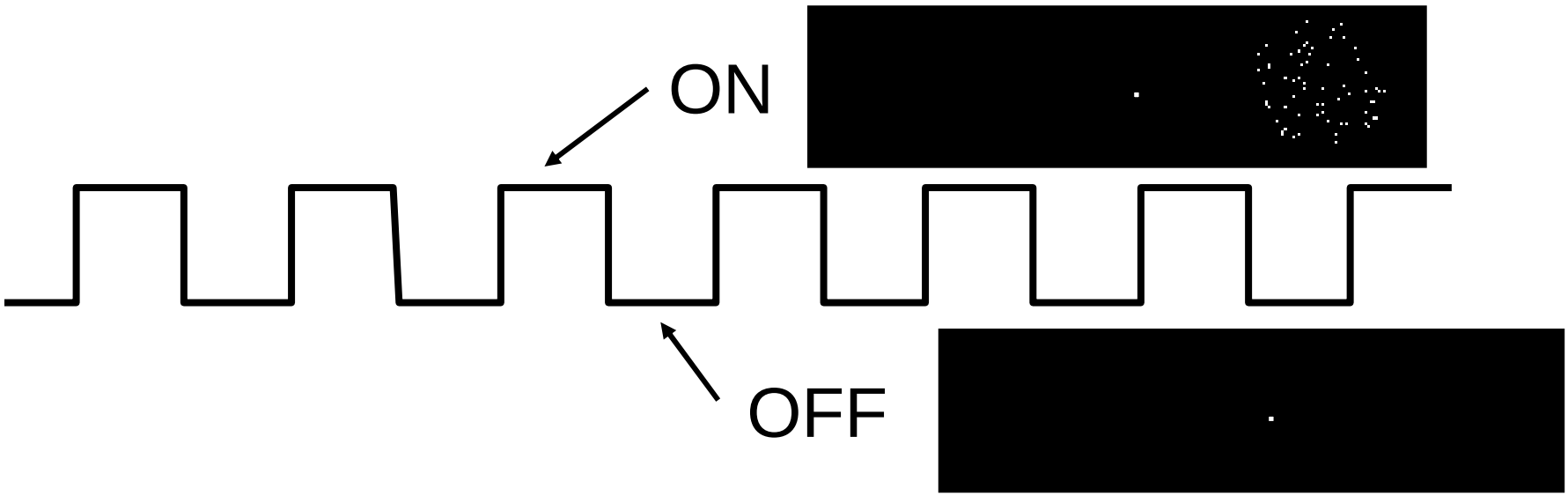
Does compensatory hypertropy occur in deaf subjects?

Is visual processing within visual cortex different in deaf observers?

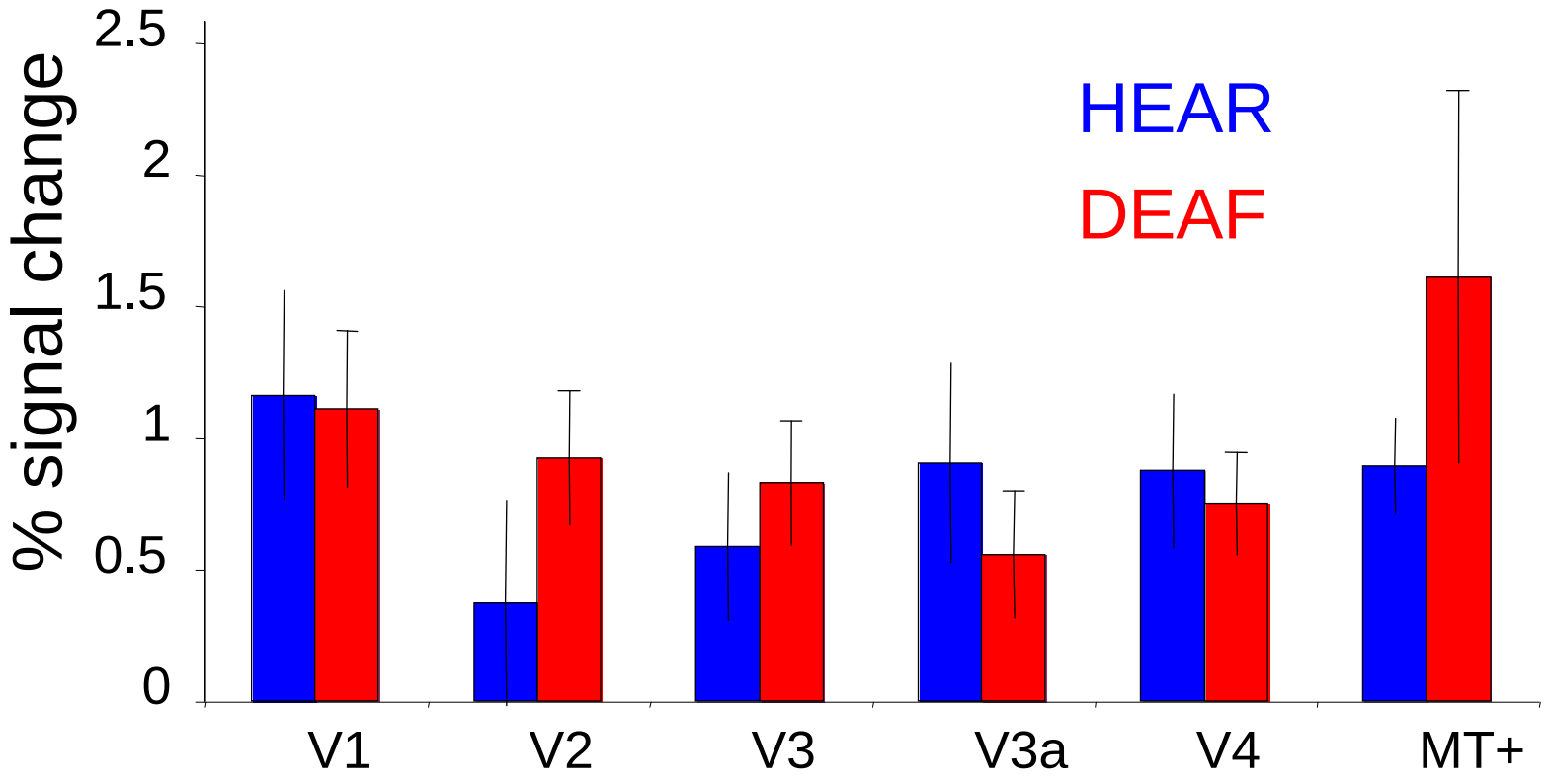


Deaf - better performance in right visual field …

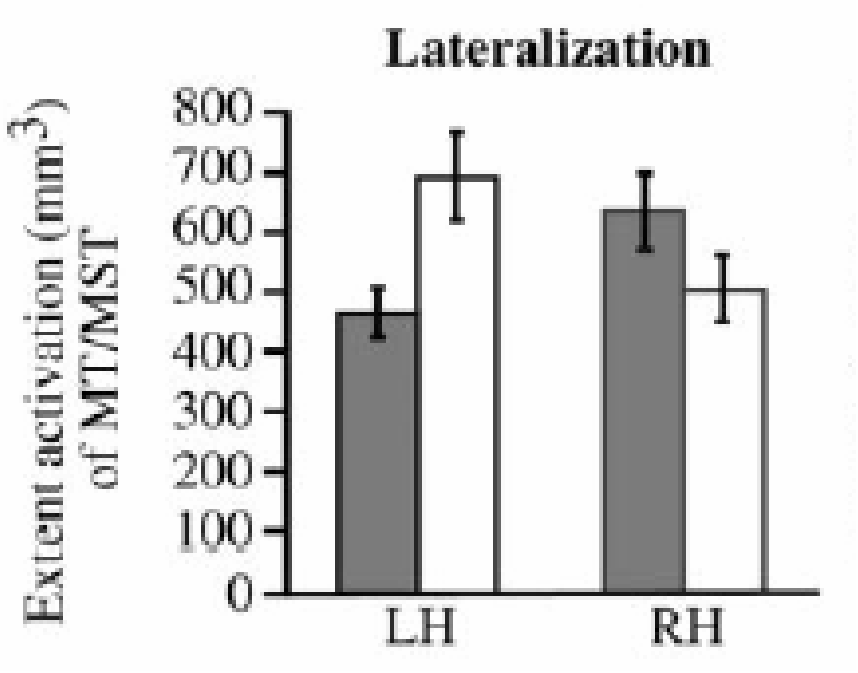
But no differences in cortical area

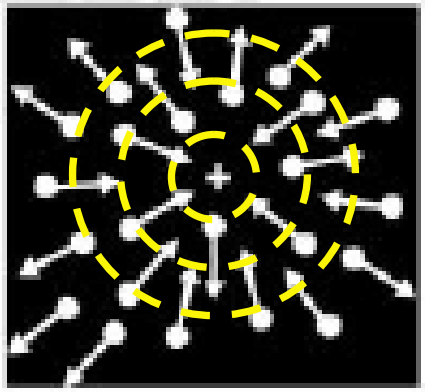

ON
OFF

Left hemisphere activation for attend-motion (RVF)



Others do find changes in early visual areas
But not particularly whopping.





Bavelier et al.
J Neuroscience, 2001

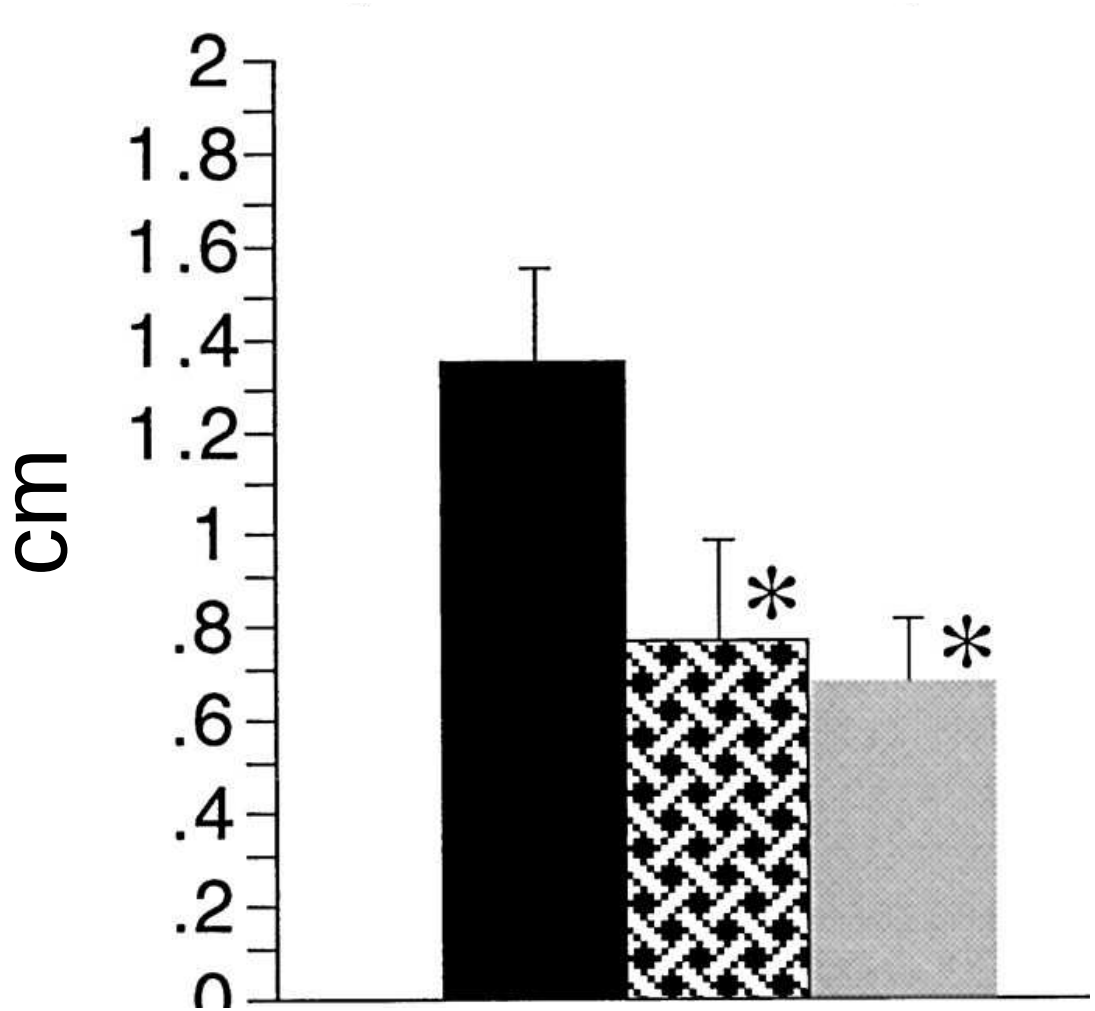
Why the discrepancy?

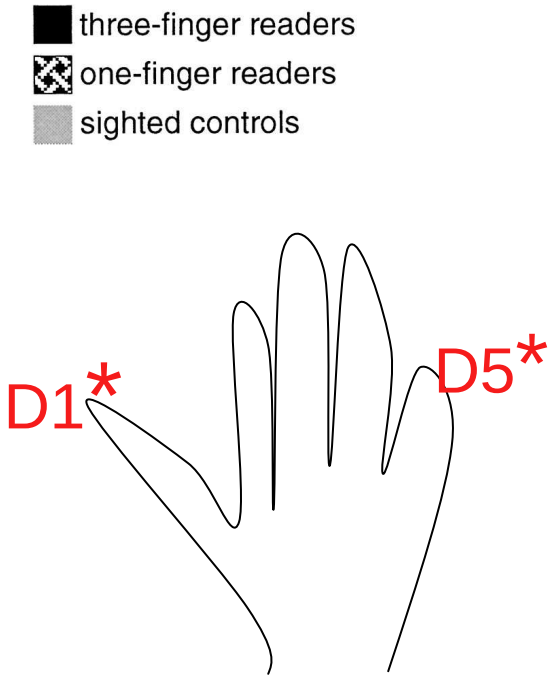
a) Full field stimulus
b) More subjects
c) Velocity discrimination
d) Task localized to center, near periphery and far periphery

An example of compensatory hypertropy in blind subjects

Tactile processing is different in 3 finger Braille readers

Blind 3 finger readers have larger finger representations





Sterr et al. J Neuroscience, 1998

Cross-modal Plasticity

When an area that normally processes a missing sense begins to respond to other senses

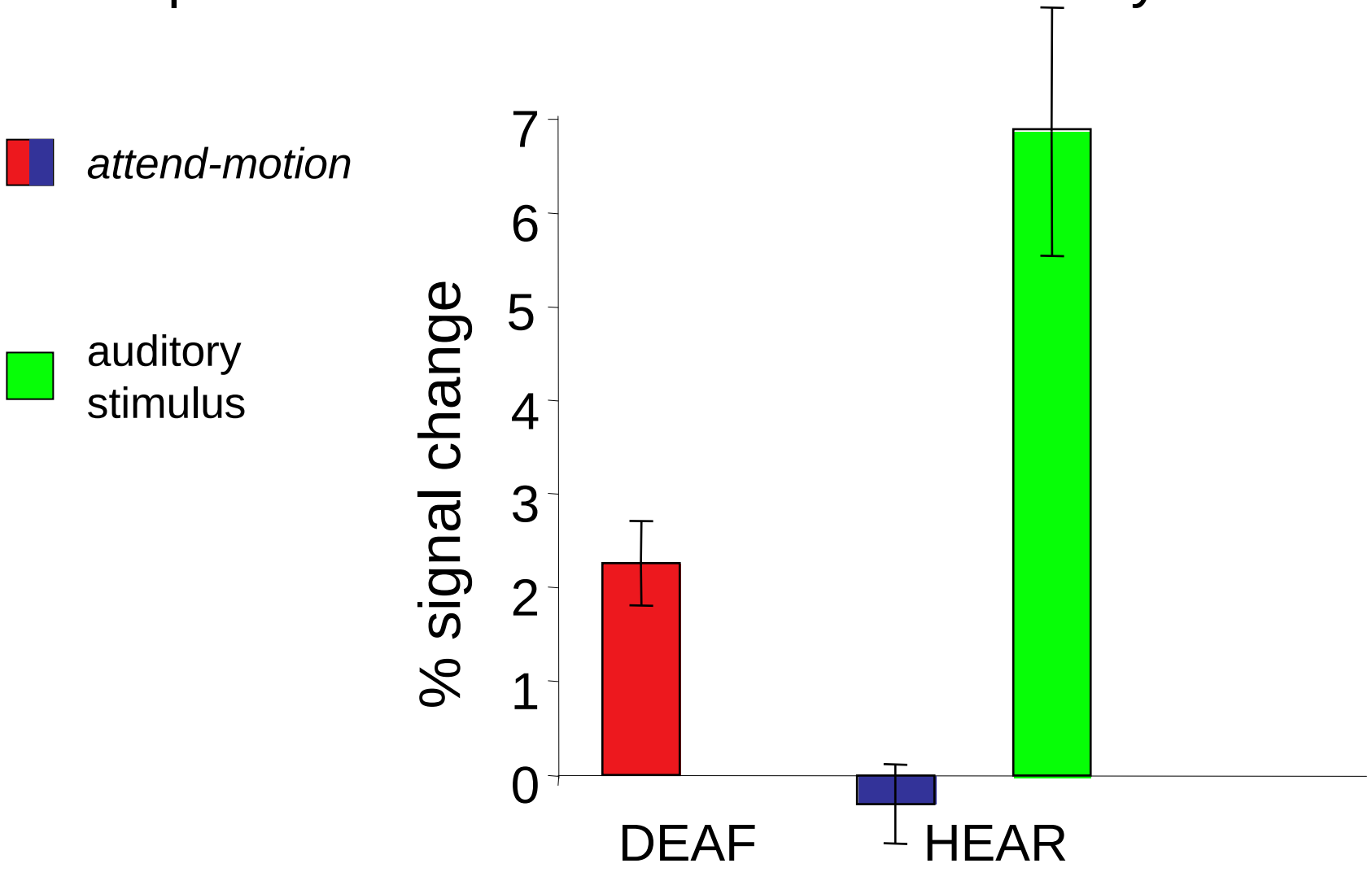
E.g. visual cortex responding to sound in people who are blind

Auditory cortex responding to vision in people who are deaf

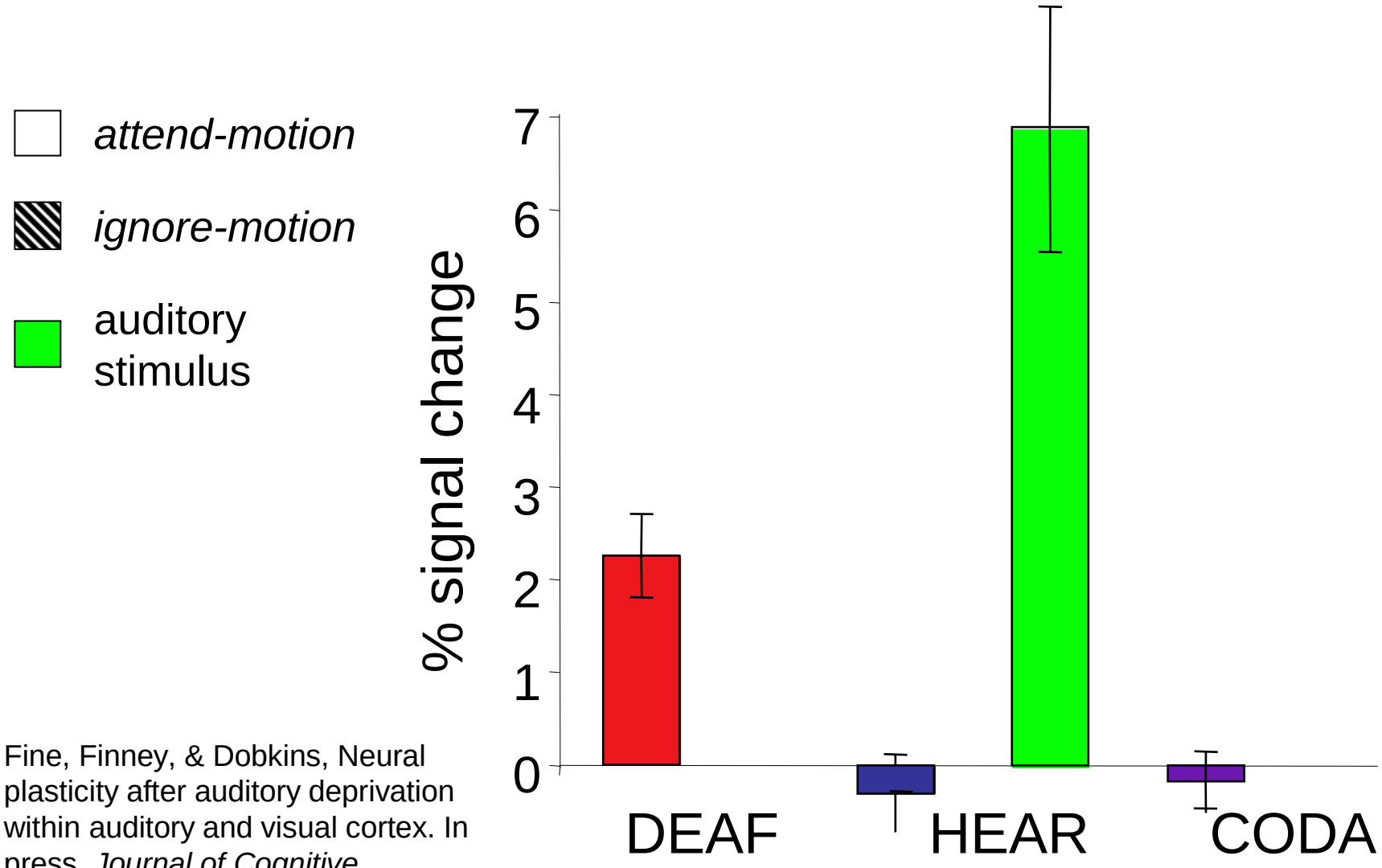
An example of cross-modal plasticity in deaf subjects:

Auditory cortex responds to visual stimuli in deaf observers

Responses to visual stimuli within auditory cortex



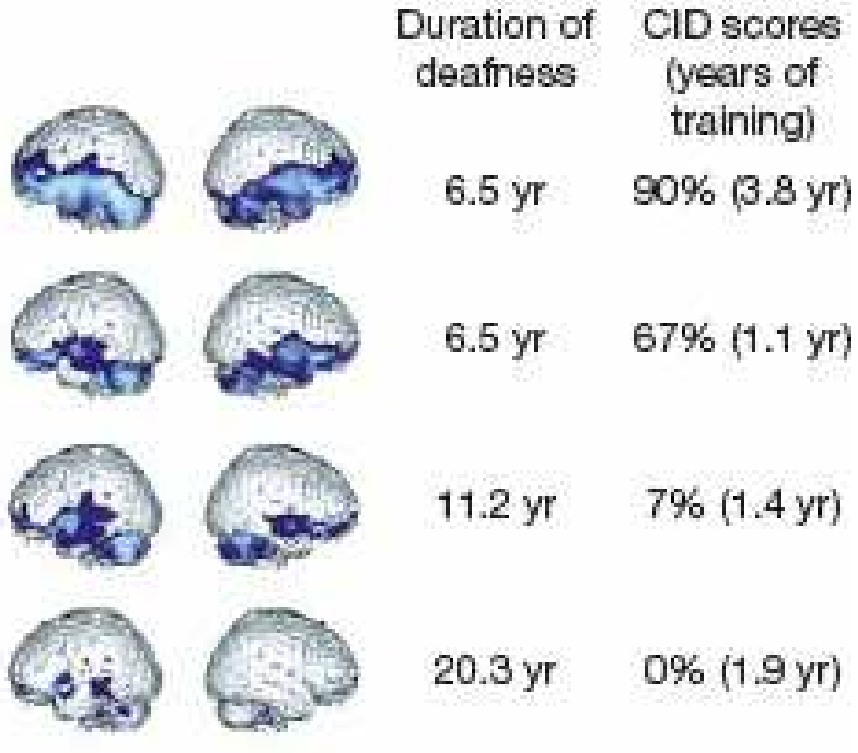
Caused by auditory deprivation, not sign-language

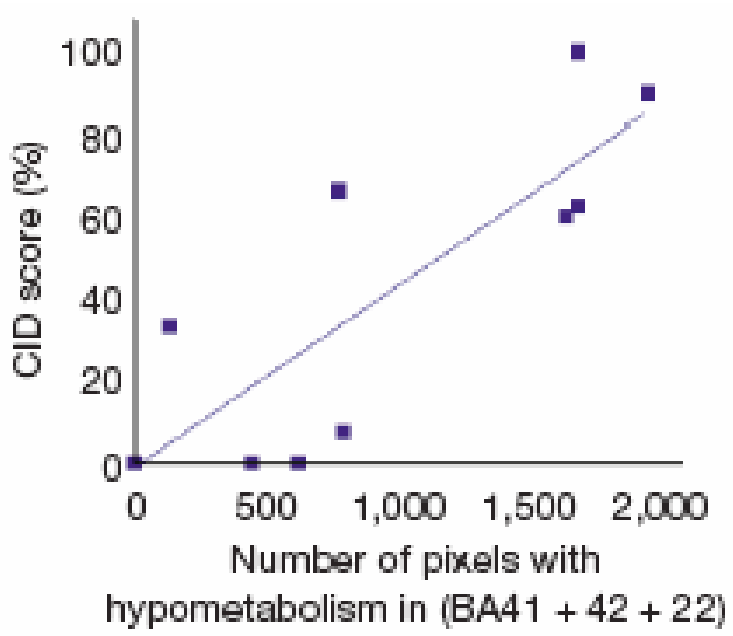


Fine, Finney, & Dobkins, Neural plasticity after auditory deprivation within auditory and visual cortex. In press, *Journal of Cognitive Neuroscience*

Auditory recovery - cochlear implant

Activation of auditory cortex, and ability to understand speech declines with duration of deafness.

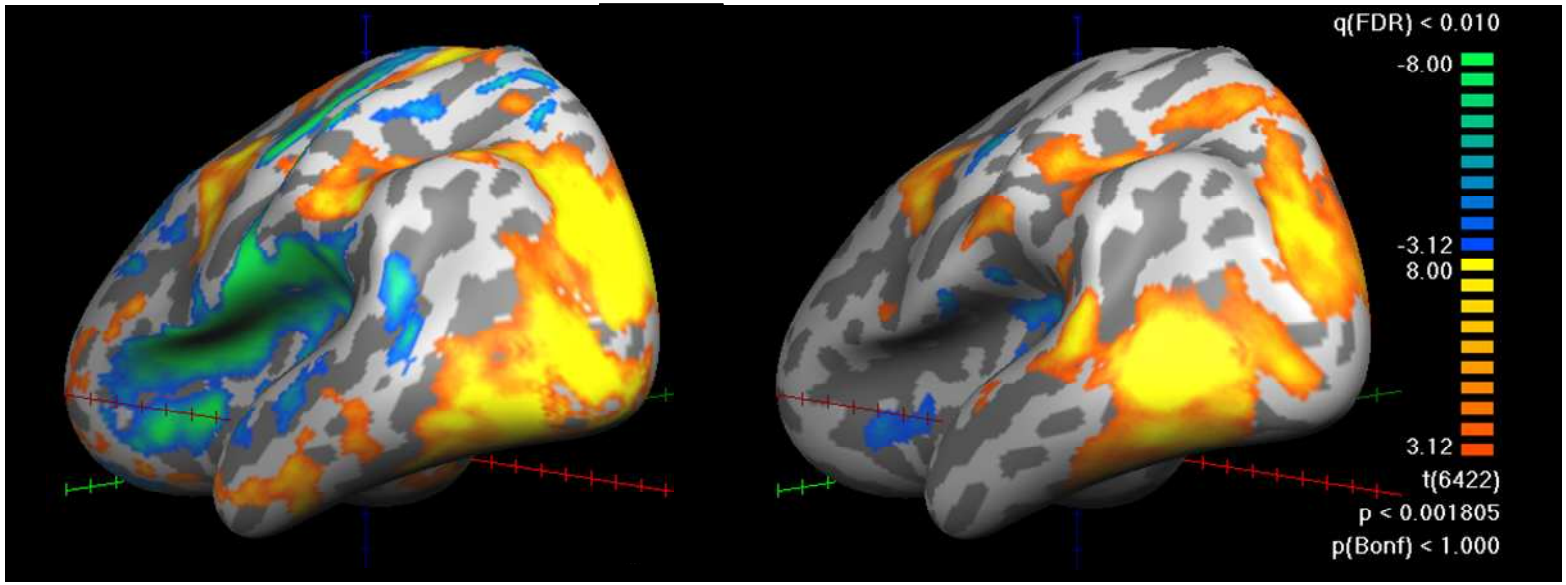




Lee et al., Nature, 2001

There are many examples of cross-modal plasticity in blind subjects:

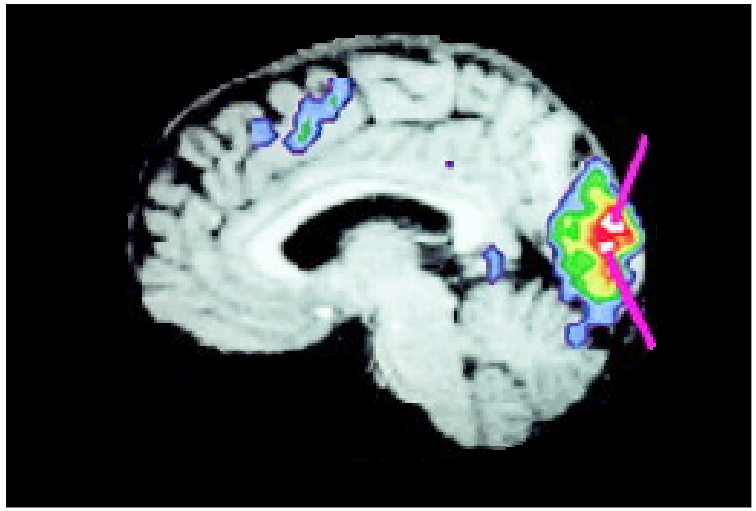
Visual cortex responds to both tactile and auditory stimuli in blind observers

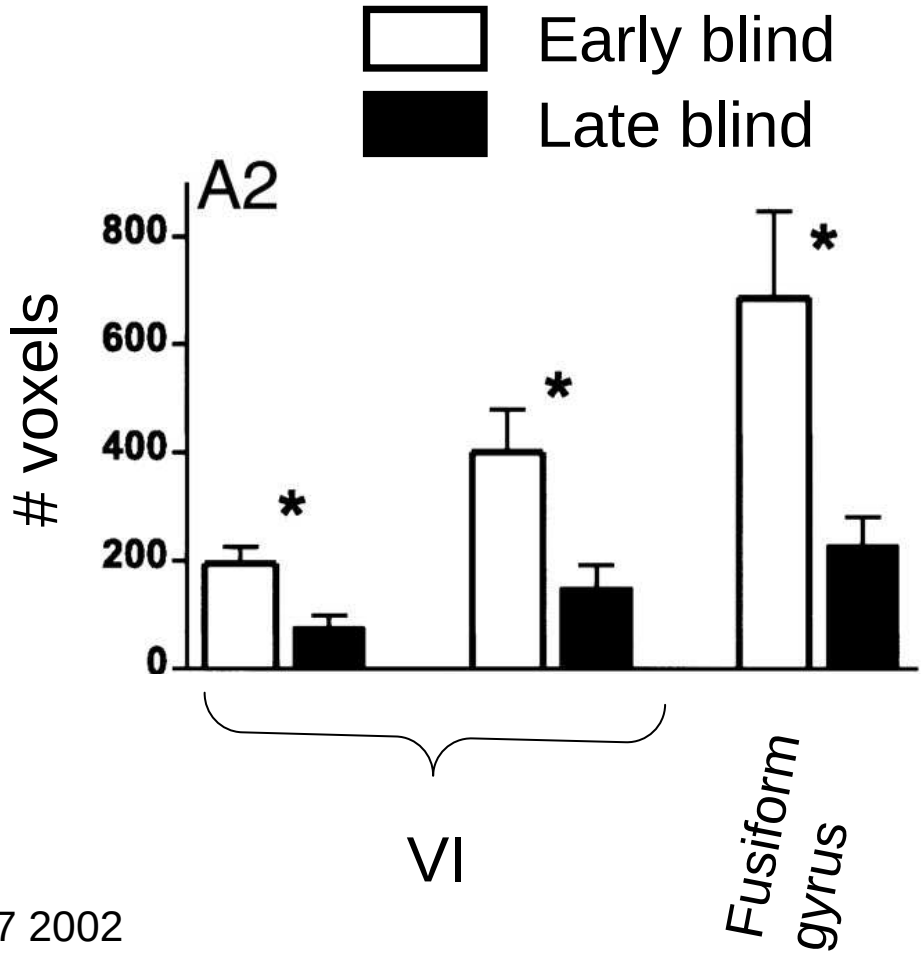


Regions in the left hemisphere that respond differently to tactile trigrams (left) and auditory trigrams (right) in blind than in sighted subjects. Warm colors represent stronger responses within blind subjects.

Cross modal plasticity for Braille

Early vs. late blind subjects





Burton, H. et al. J Neurophysiol 87: 589-607 2002

Thank you!