Computational Neuroimaging: Measuring the Mind

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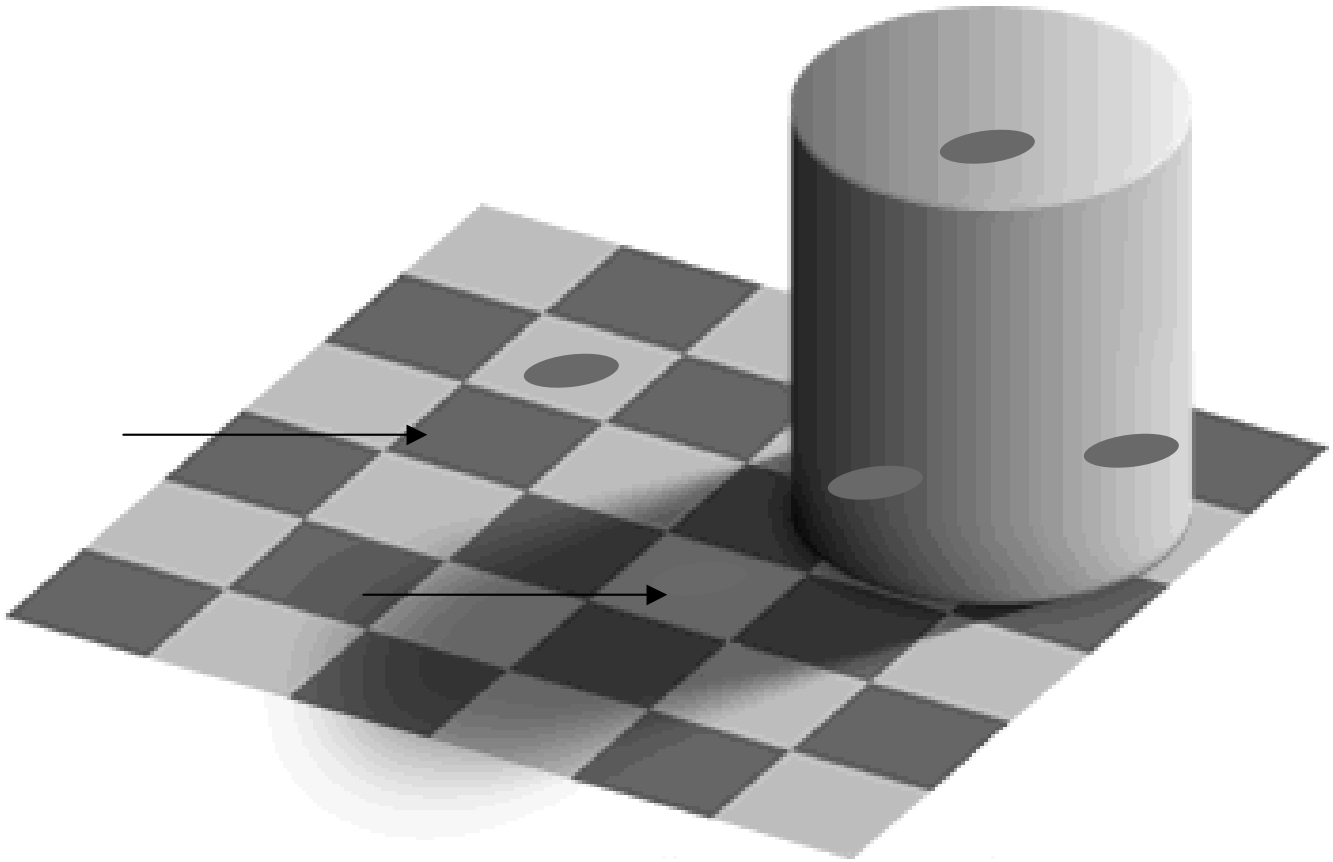
Outline

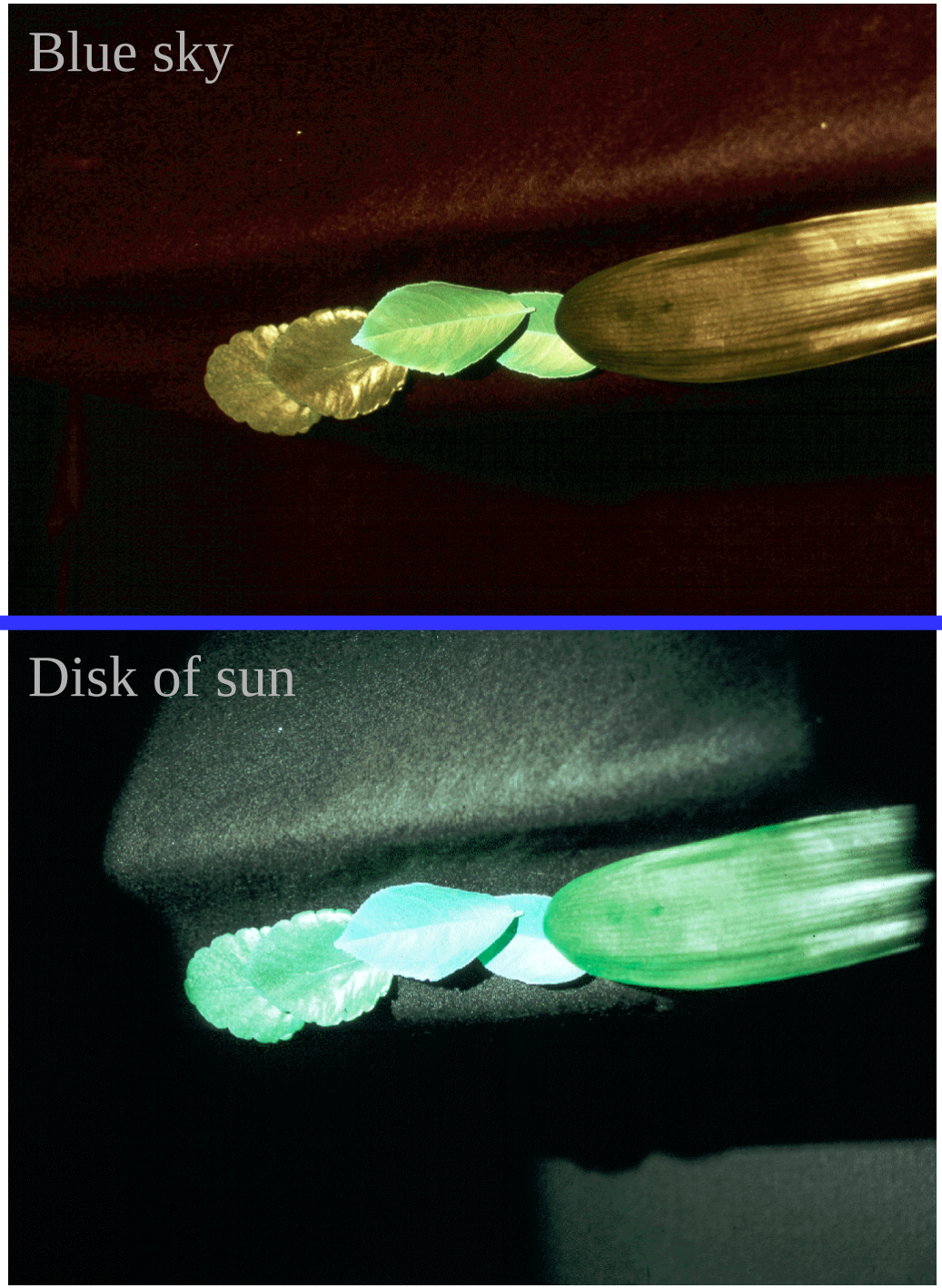
- Neural computations
- Neuroimaging and functional MRI (fMRI)
- Measuring the Visual Mind
  - Visual field maps and visual areas
  - Cortical damage and recovered sight
  - Color

Shadows

(Adelson, MIT)

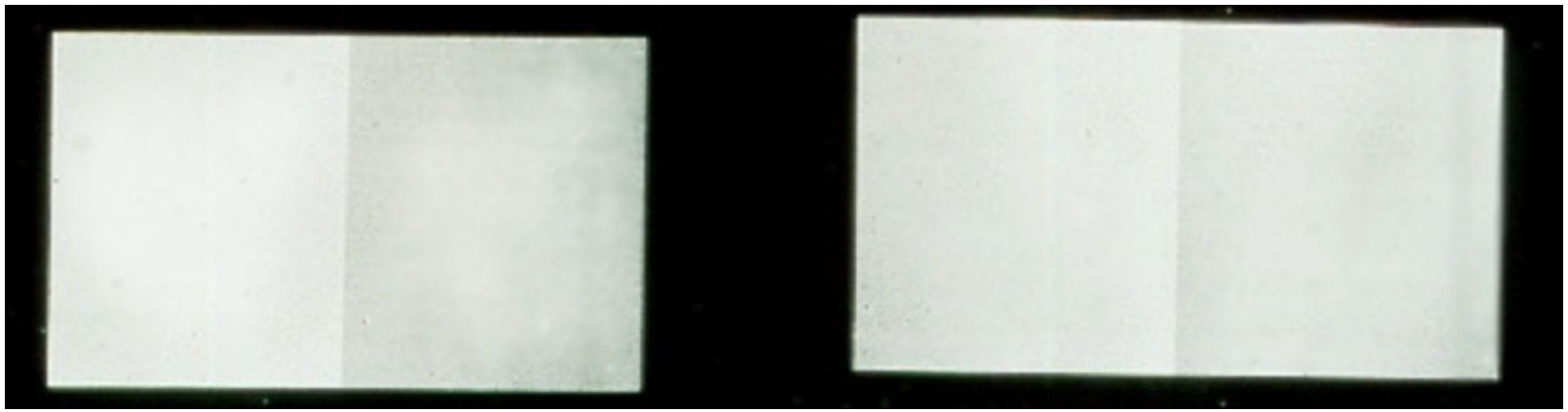


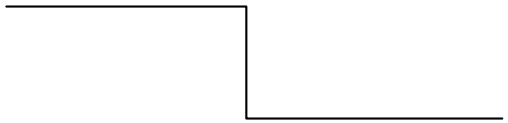
Daylight Illumination (Color)



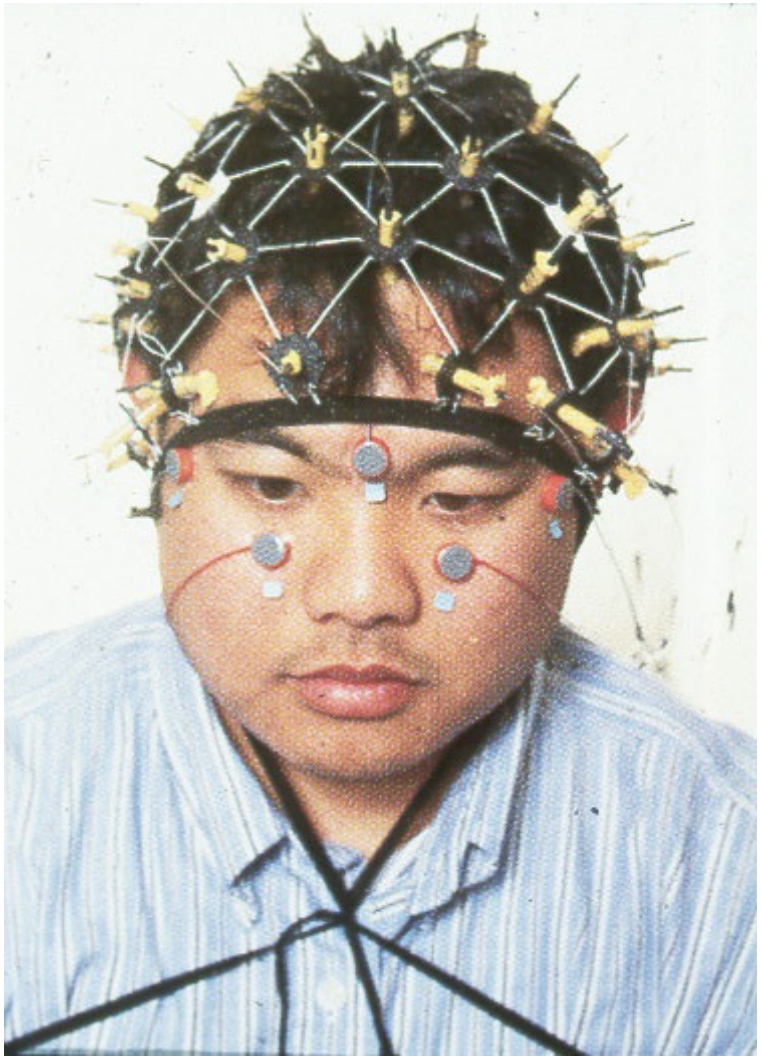
Courtesy S. Tominaga

Edges Determine Lightness





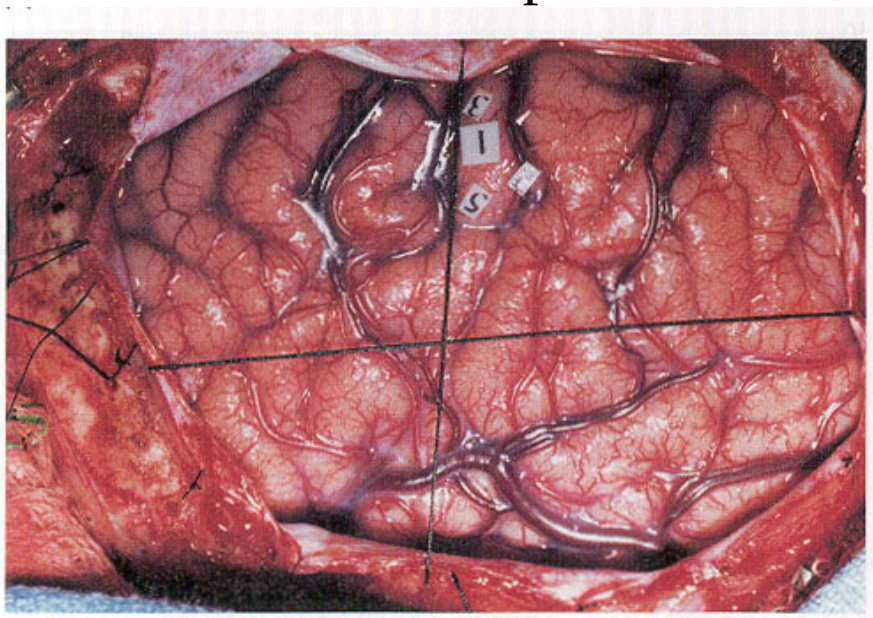
Electroencephalograms (EEG)



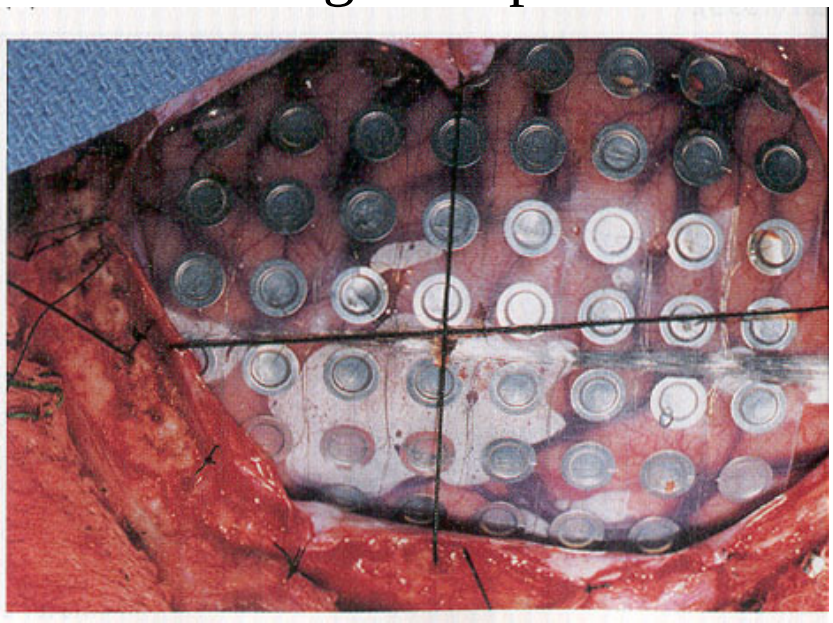
- Measures electrical activity
- Poor spatial localization
- Good temporal resolution

Cortical Implants

Prior to implant



The grid implant

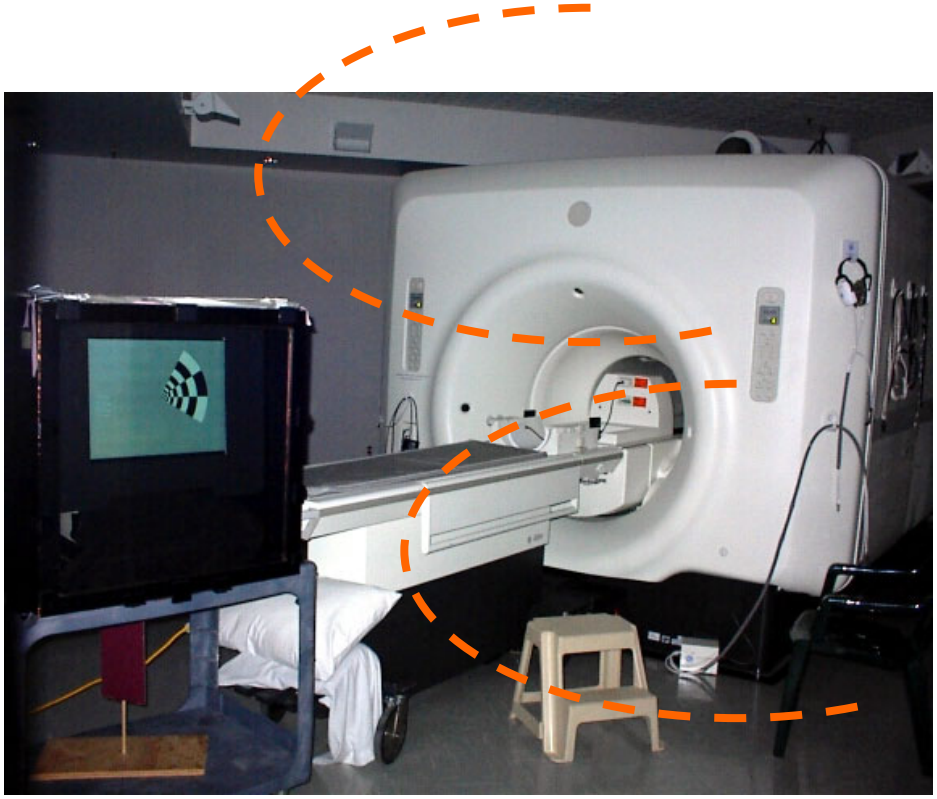


Used for analysis of epileptiform activity
Mainly effective in motor areas

Positron Emission Tomography

- Inject short-lived radioisotopes
- Use tomography to detect radioactive locations
- Spatial resolution ~ 1-2 cm
- Temporal resolution ~ 20 sec
- Cannot study individual subjects in detail

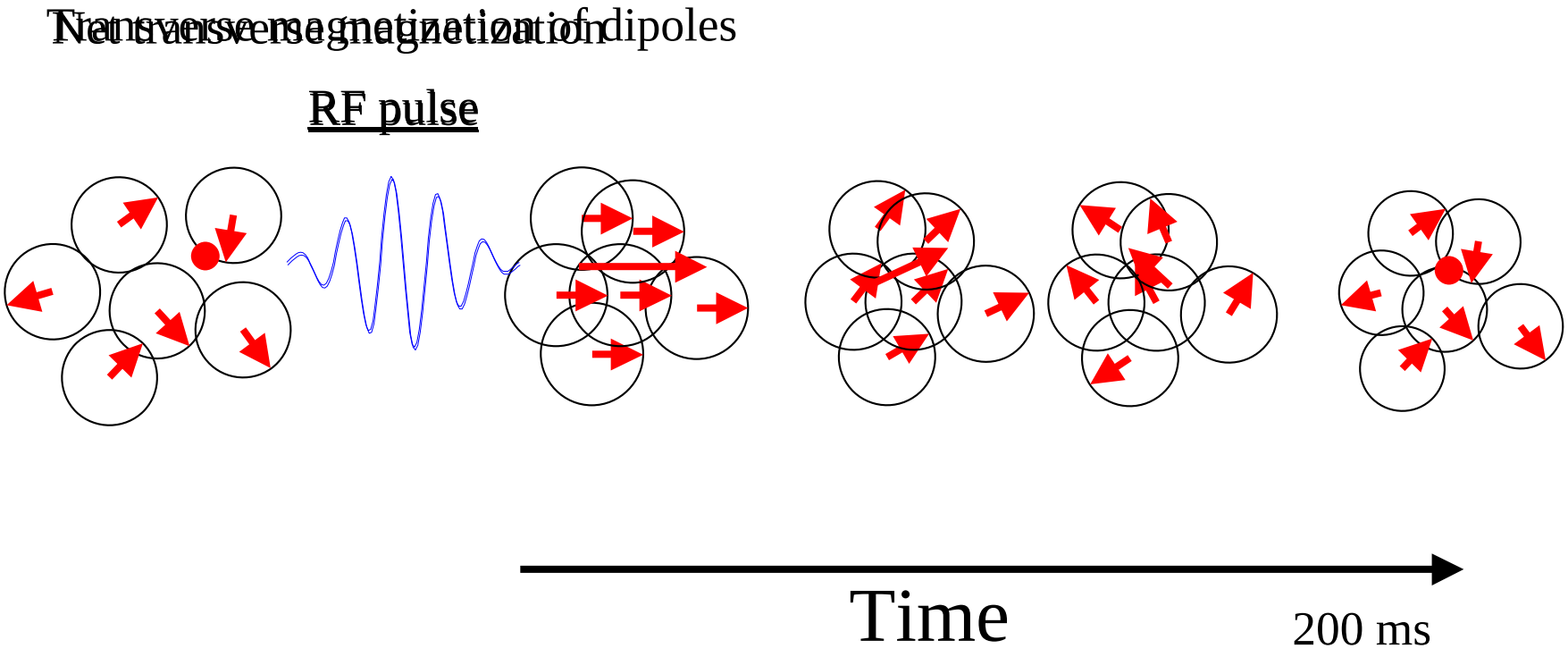
MR Scanner



- Non-invasive
- Measures intrinsic signal (dipole relaxation)
- Spatial resolution ~ 2 mm
- Temporal resolution ~ 5 sec
- Can study individual subjects in detail

The fMRI Signal

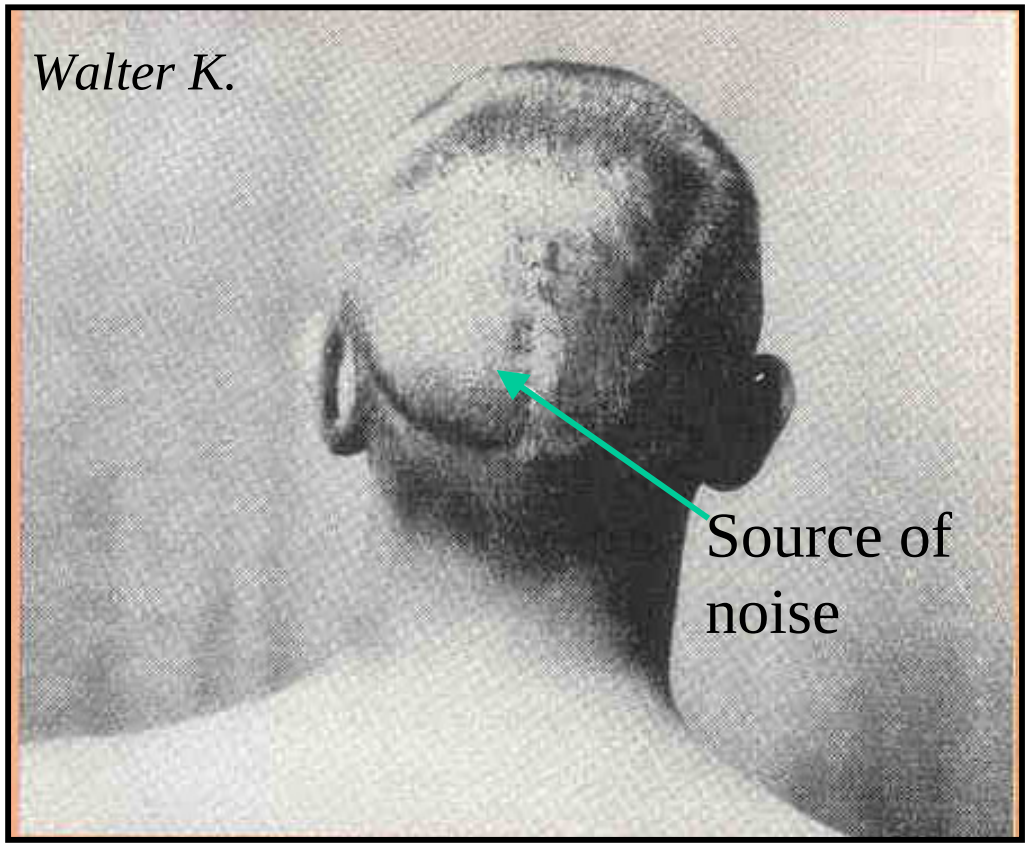
T2 Relaxation



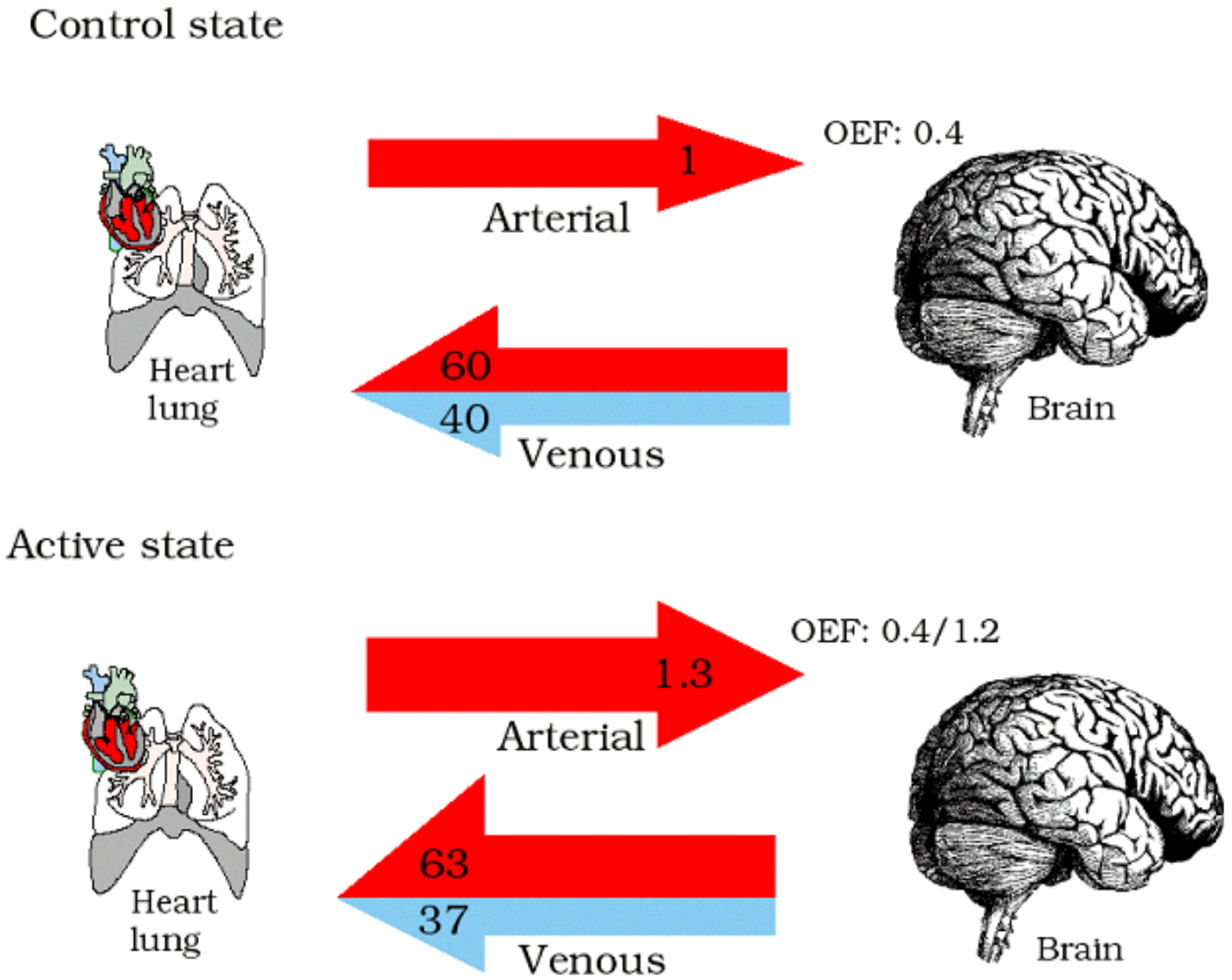
Observations Upon the Vascularity of the Human Occipital Lobe During Visual Activity

J.F. Fulton, M.D. (1928)

- *Subject noted that 'the noise in the back of his head increased in intensity when he was using his eyes.'*
- *No increase for hearing, touch or smell*
- *Increased more when he tried harder*



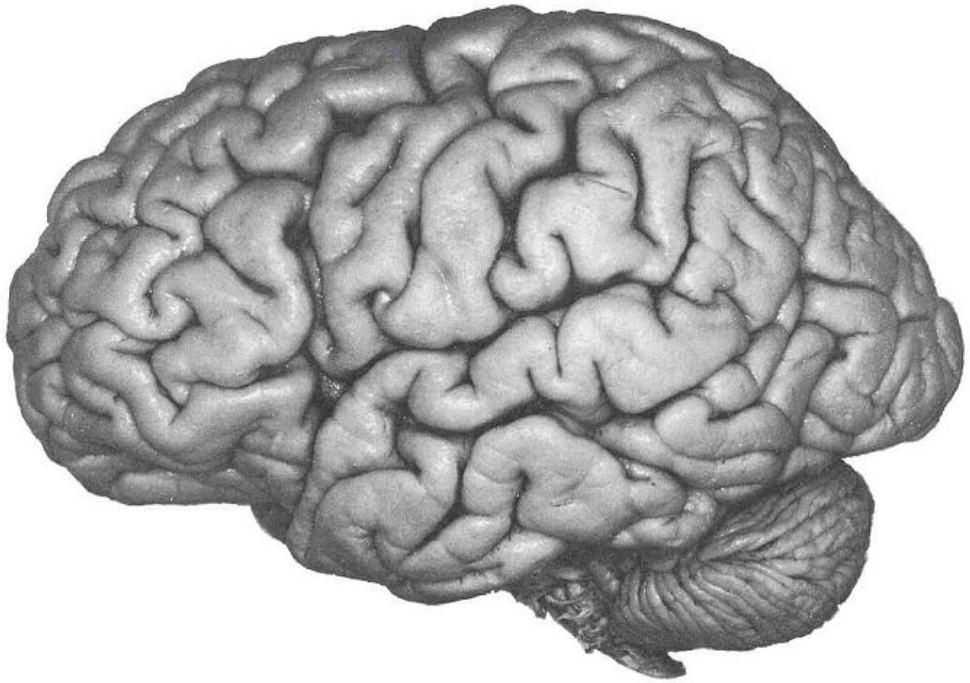
fMRI Measures Blood Oxygenation



Human Brain Numbers

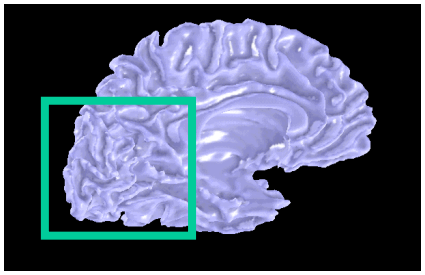
(Braitenberg and Schutz, 1991)

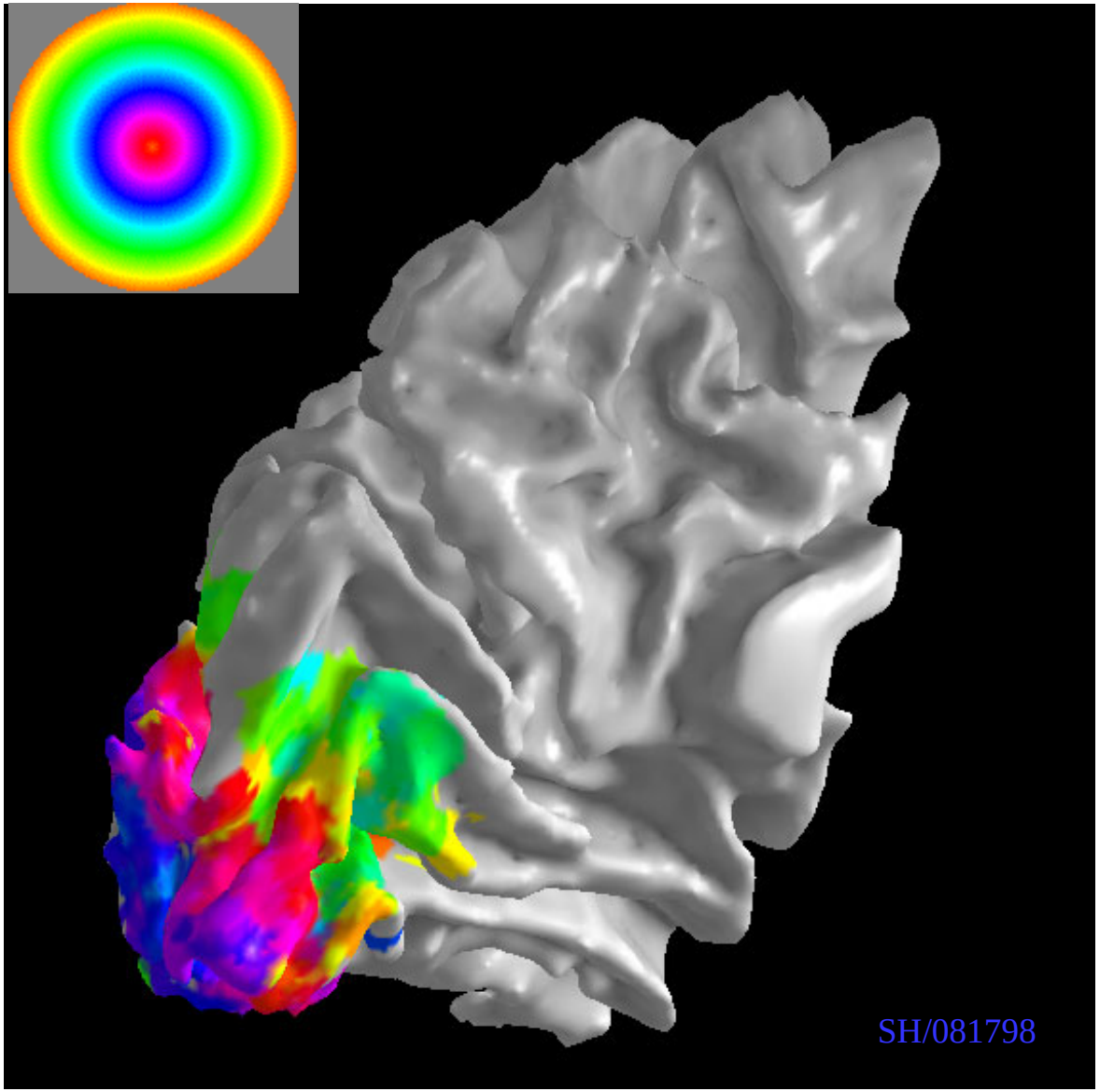
Neurons are the computational elements
White matter connects the neurons via axons
The connection is called the synapse



- Neurons: 10^{11}
- Synapses: 10^{14}
- Synapses/neuron 10^{3}
- Surface area of each hemisphere: 25 x 30 cm^2
- Most connections are local (10-100 um); some span many cm
- Neurons/ mm^3: 10^4-10^6
- Axon length per mm^3: 3 km

Eccentricity Maps



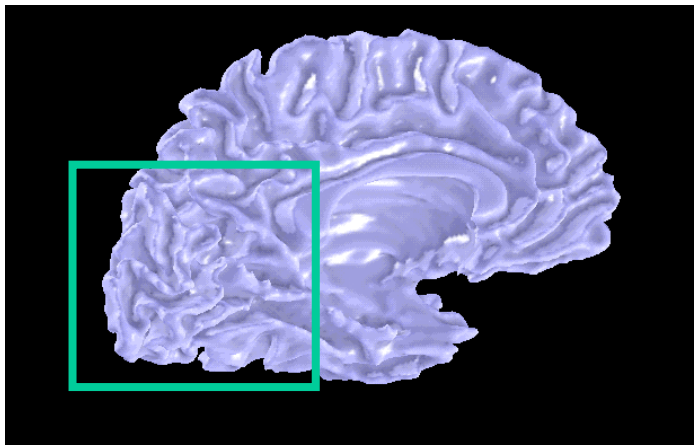


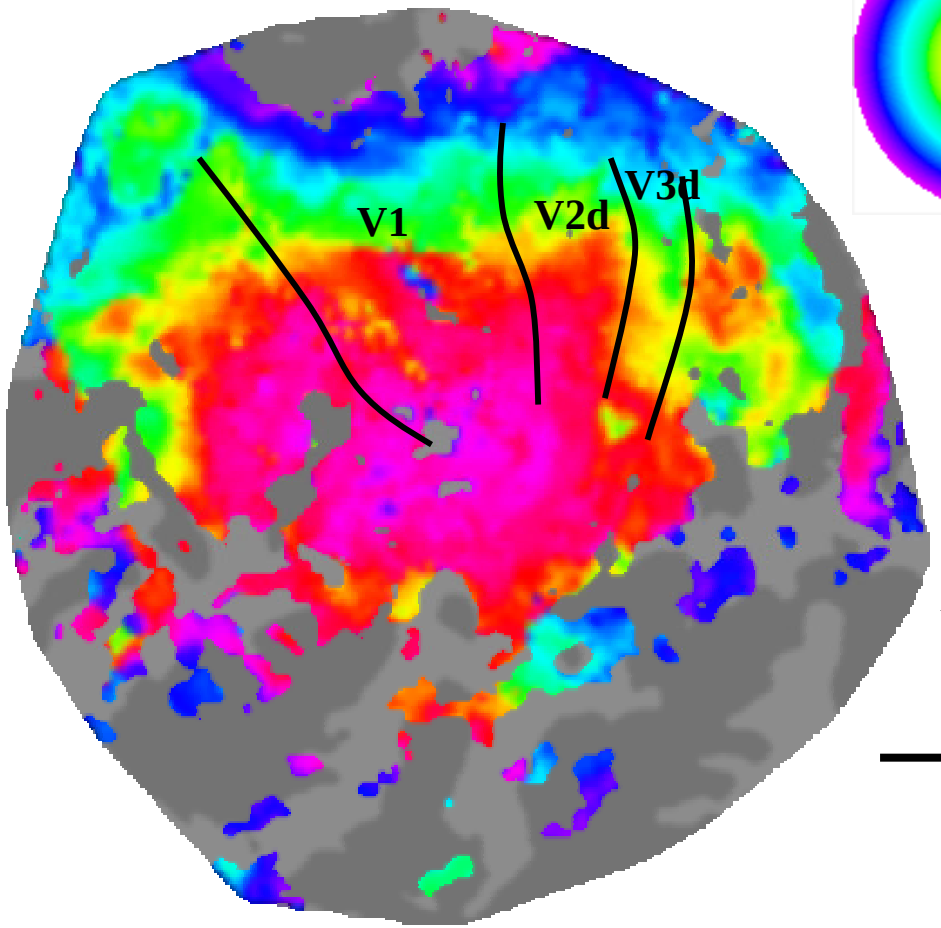
Eccentricity Map

Flattened Representation

20 deg

60 mm radius unfold



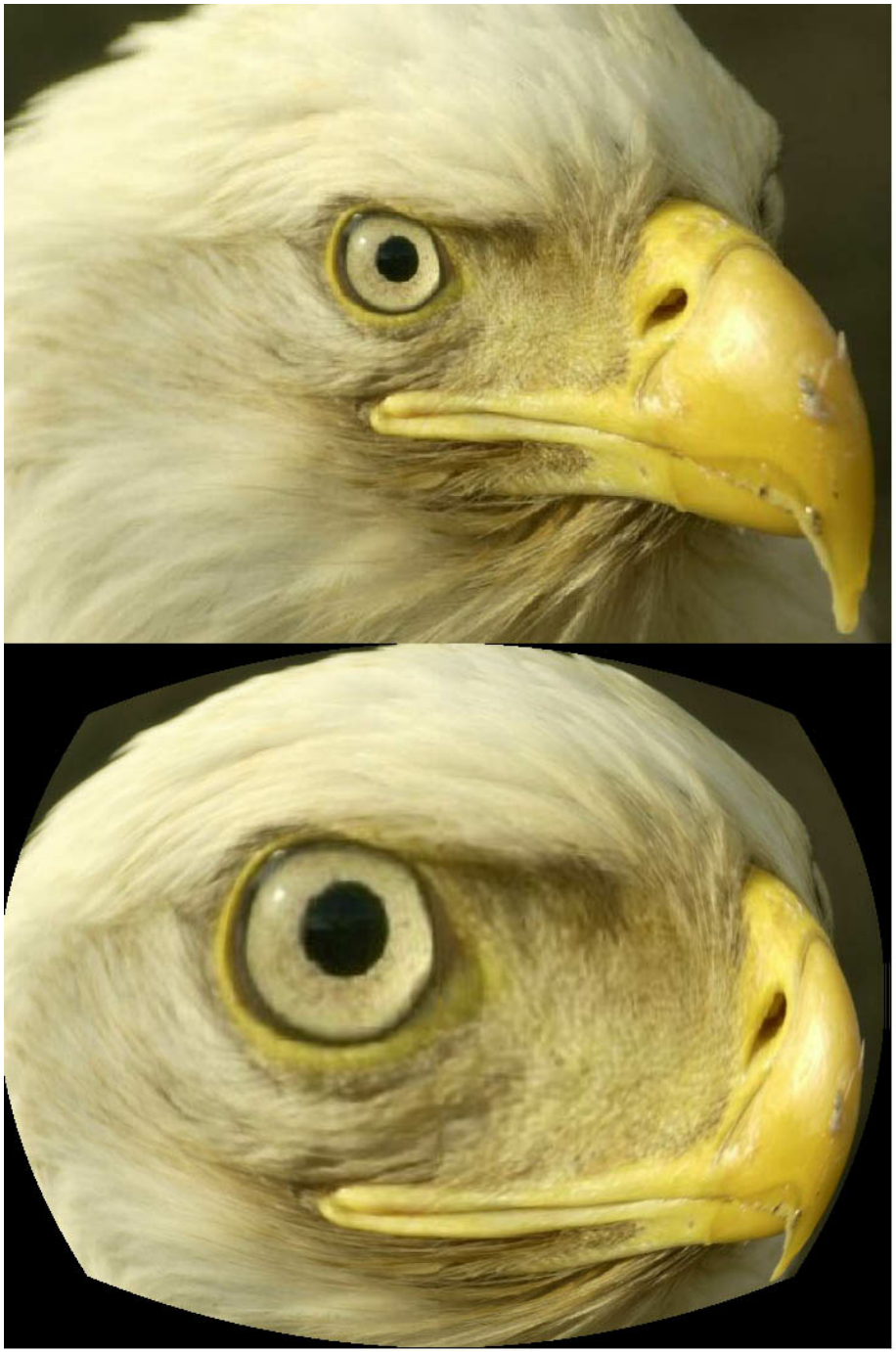


WAP

Cortical Representation

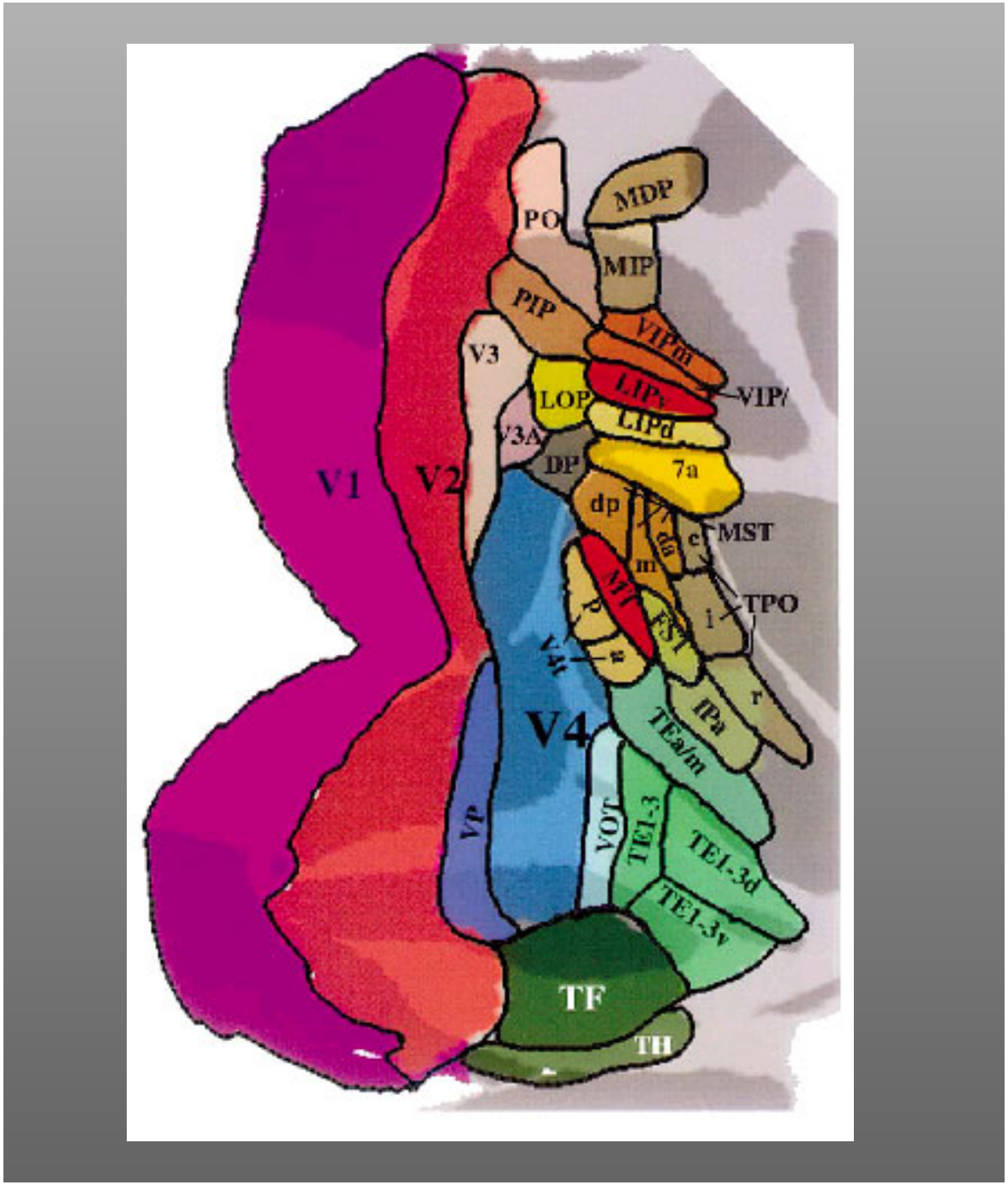
(Image courtesy Dave Cardinal www.cardinalphoto.com)

Cortical map of the image

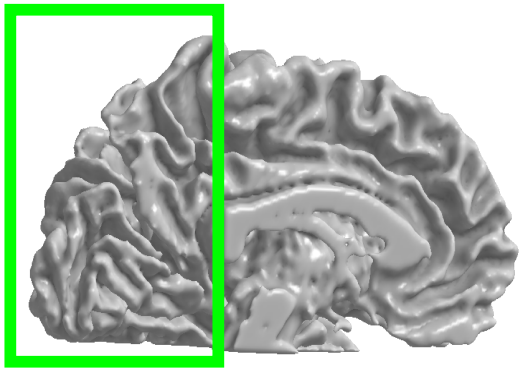


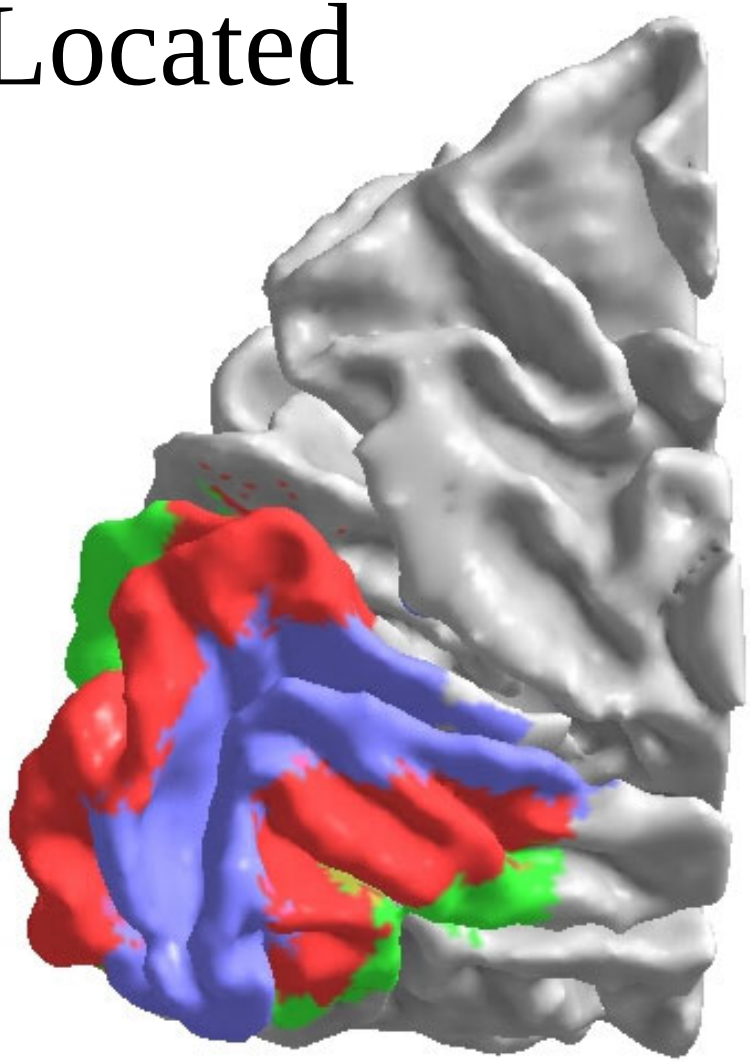
The Visual Pathways Include Multiple Specialized Areas

(Van Essen et al., 2001)



Several Human Visual Areas Can Be Located



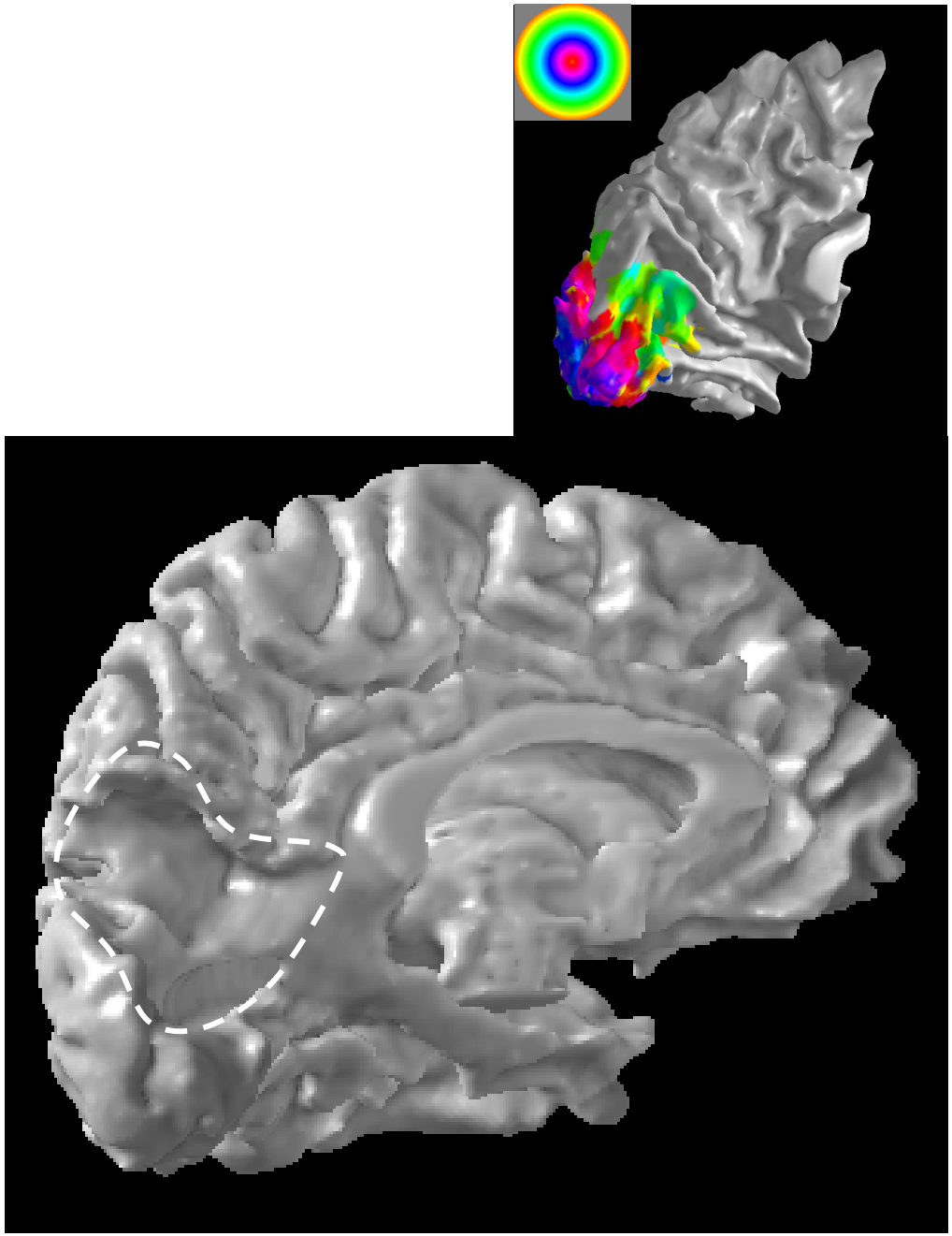


Visual area

V1
V2
V3

Blindsight

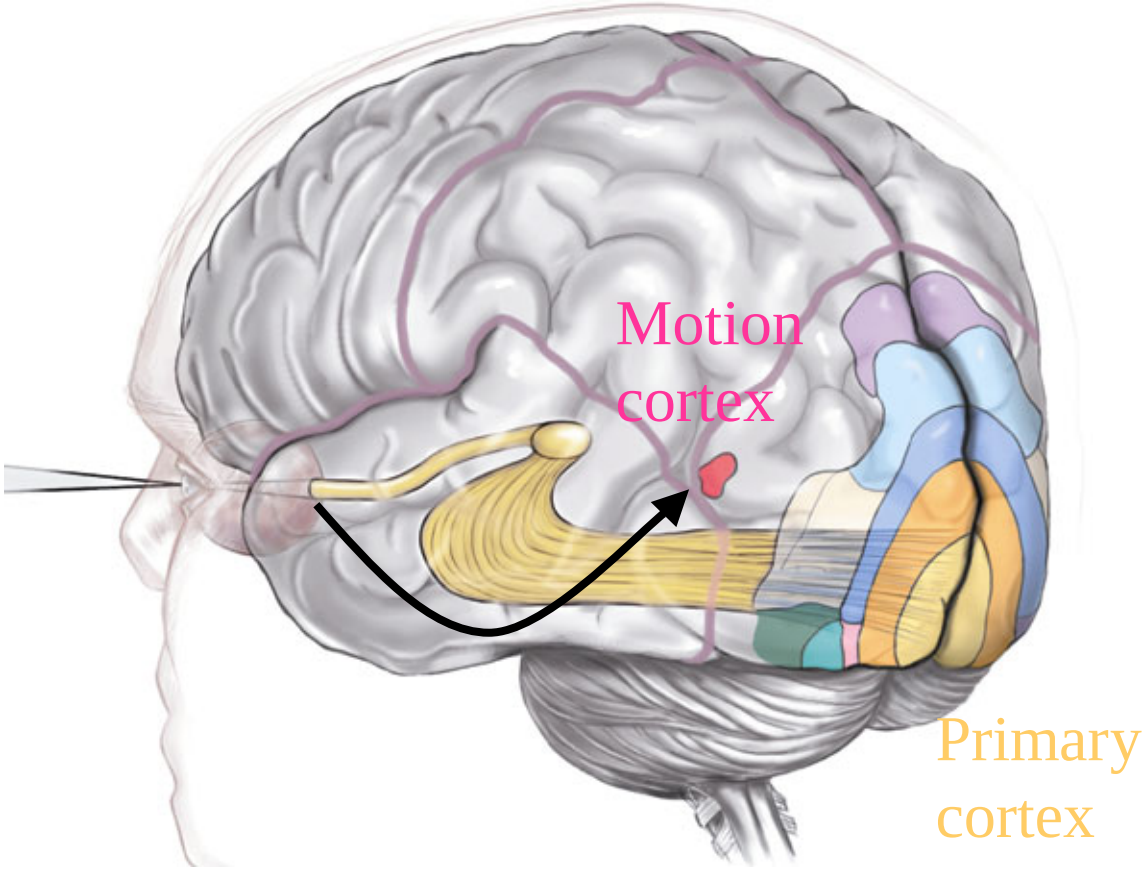
- *Subject GY*
- *Bicycle accident at 8 yrs*
- *Damage to left hemisphere*
- *Blinded on right visual field (macular sparing)*
- *Sees rapidly moving targets*



Multiple Visual Pathways

- *Classic hypothesis was one pathway into cortex*

- *Now, we realize there are paths from the retina to at least two cortical areas*



Recovered Sight

(Gregory, 1968)

SB

- Born in 1900, lost sight in both eyes because of corneal infections
- Prior to 2 years of age; kept bandaged to reduce puss
- Went to a school for the blind to learn a trade; married
- Received a corneal graft in London at the age of 52

Recovered Sight

(Sacks, 1993)

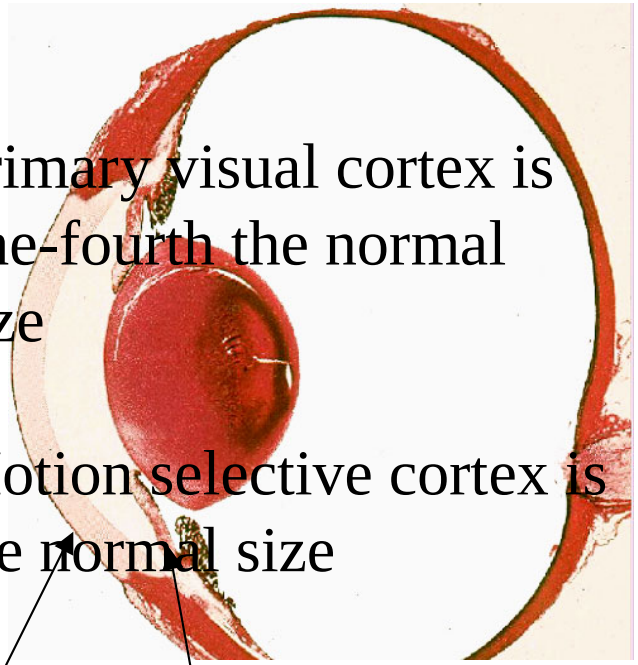
SB

During these first weeks [after surgery] I had no appreciation of depth or distance; street lights were luminous stains stuck to the window panes and corridors of the hospital were black holes. When I crossed the road the traffic terrified me, even when I was accompanied. I was very insecure while walking; indeed I am more afraid now than before the operation. (Virgil, May 10, 1993).

Recovered Sight

(Fine, Wade, Wandell)

- Chemical accident at 3 yrs
- One eye lost; other cornea destroyed
- Blind from age 3 through 46
- Stem cell replacement in right eye for both epithelium and stem cells



Primary visual cortex is one-fourth the normal size

Motion selective cortex is the normal size

Corneal epithelium cells

Limbic stem cells

Seeing Faces Is Special

(Margaret Thatcher Illusion)

•Thompson,P.(1980) Margaret Thatcher: a new illusion. Perception 9 483-4.

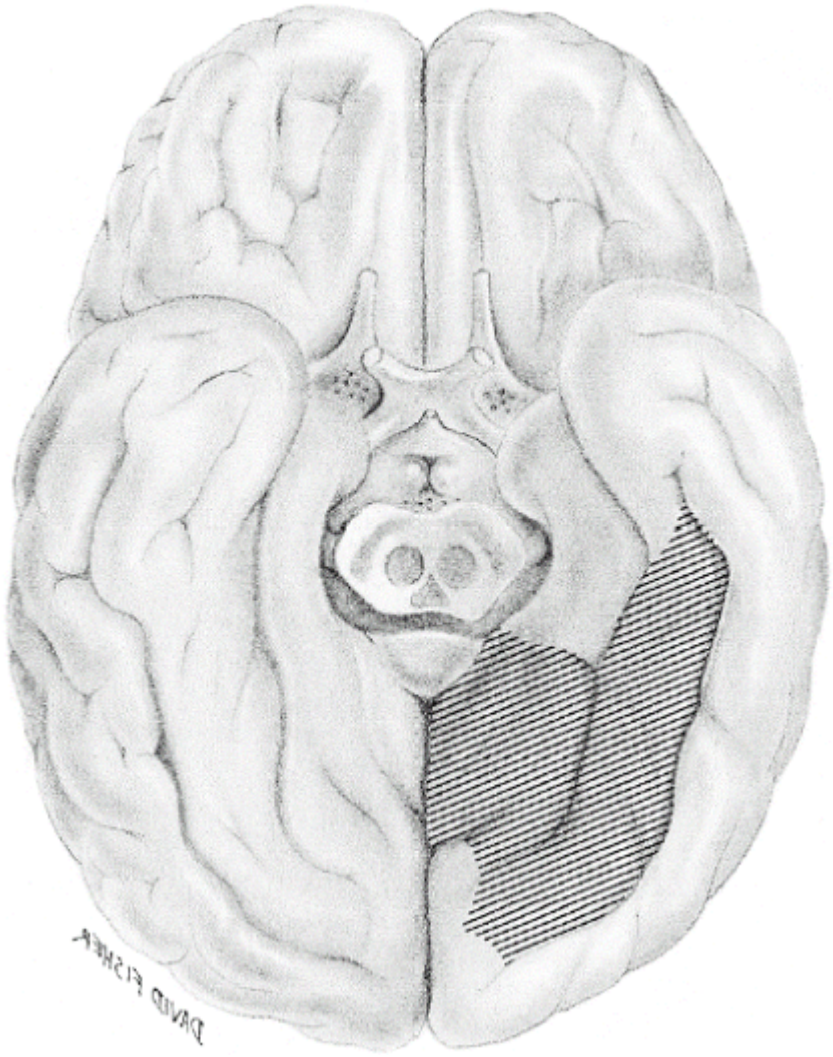
Seeing Faces Is Special

(Margaret Thatcher Illusion)

Ventral Occipital Cortex

GIRKIN AND MILLER

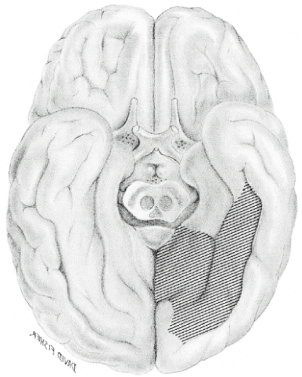
Surv Ophthalmol 45 (5)
March–April 2001



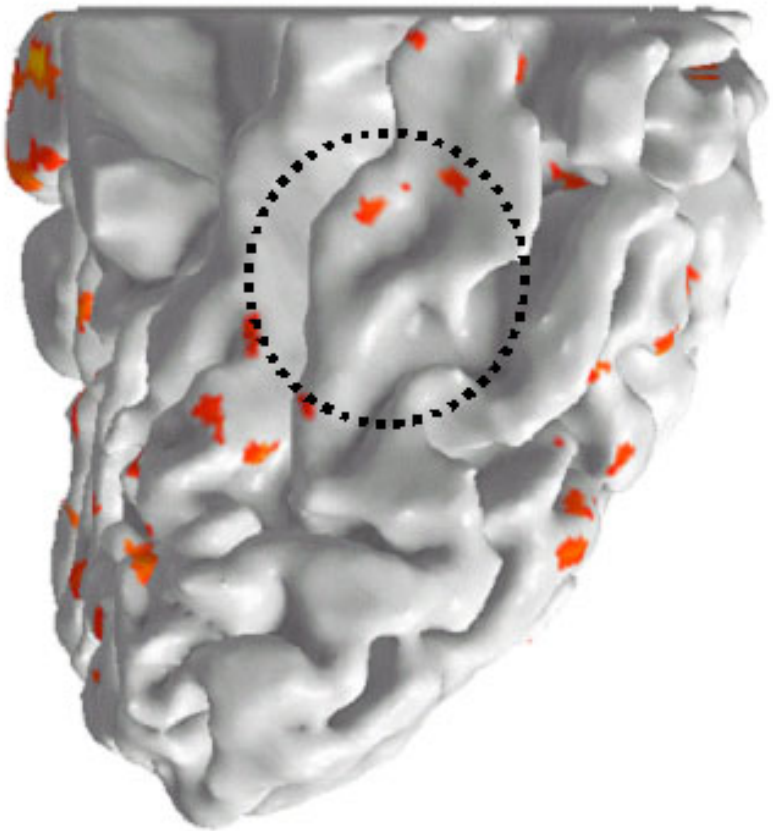
Face Perception

...

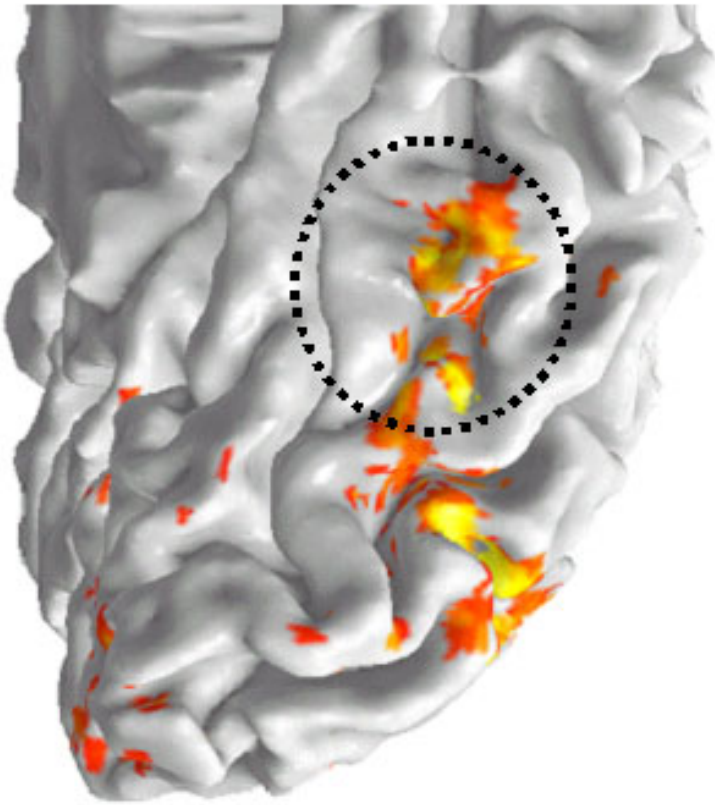
...



Michael May



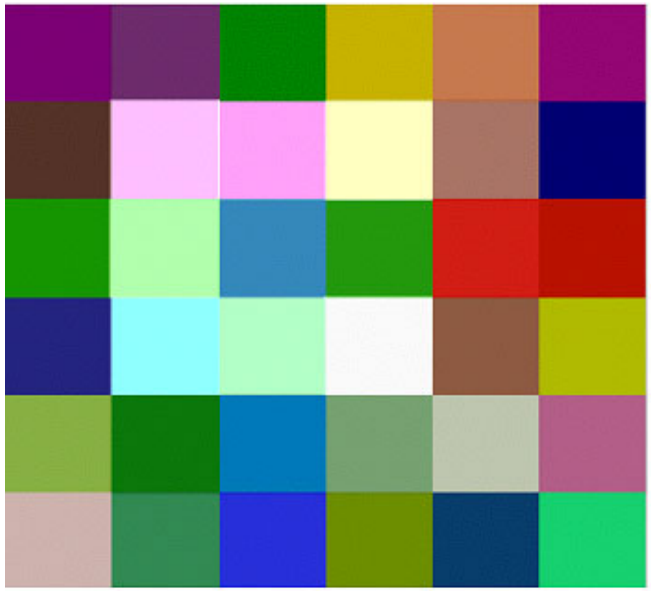
Normal Control



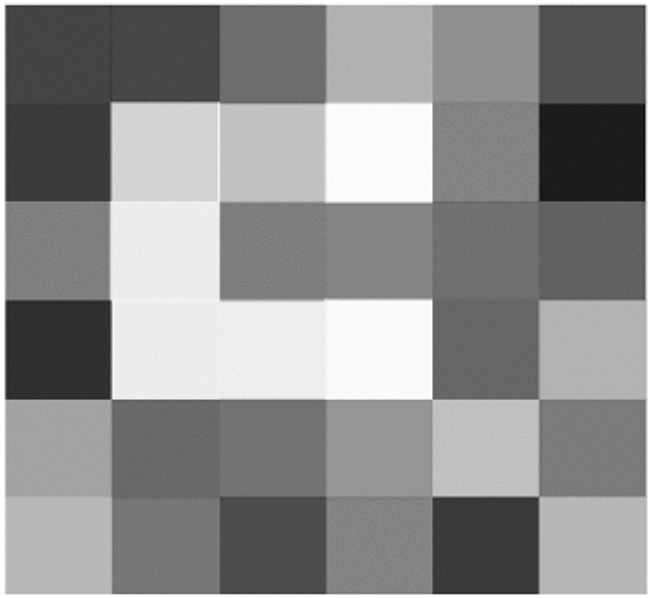
Color Exchange Measurements

(Semir Zeki; Edwin Land)

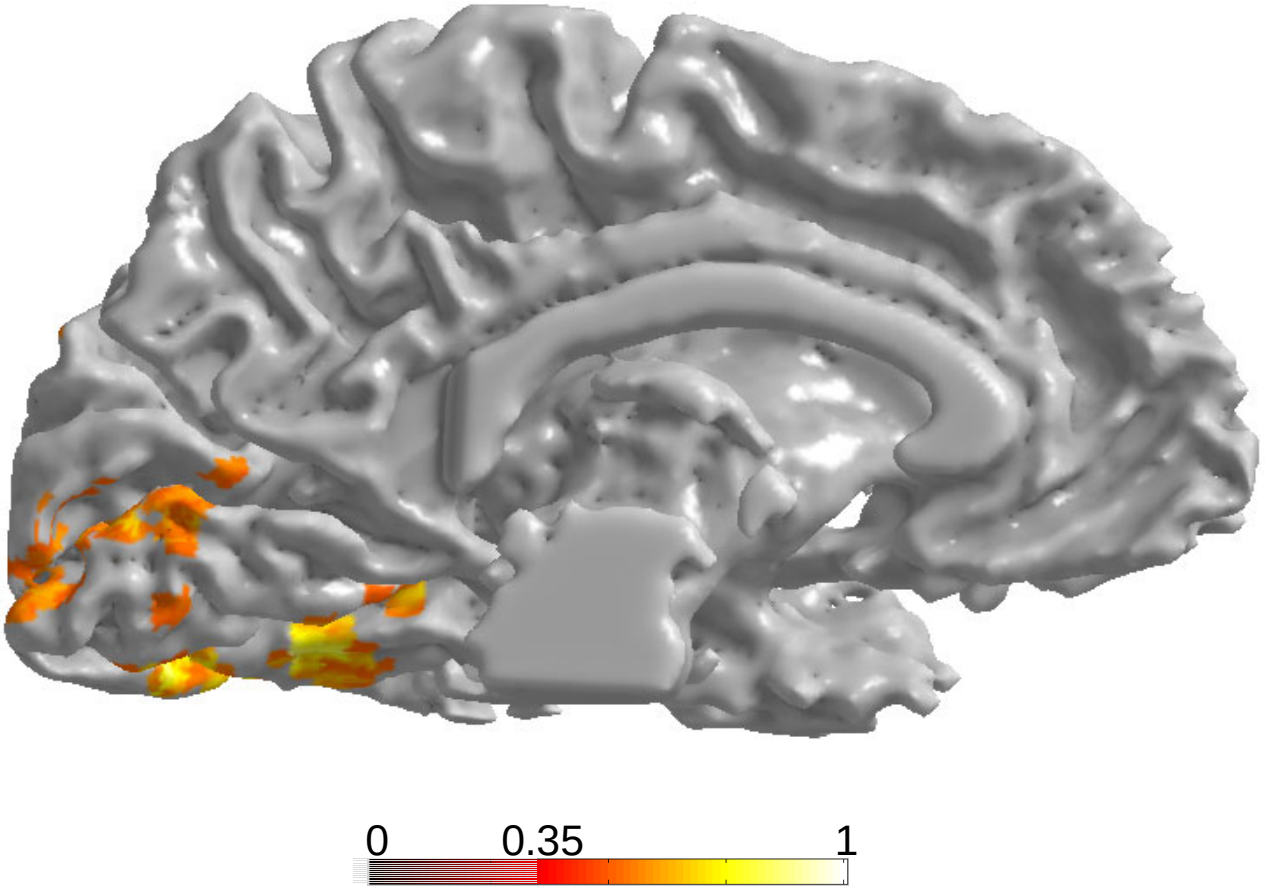
a)



b)

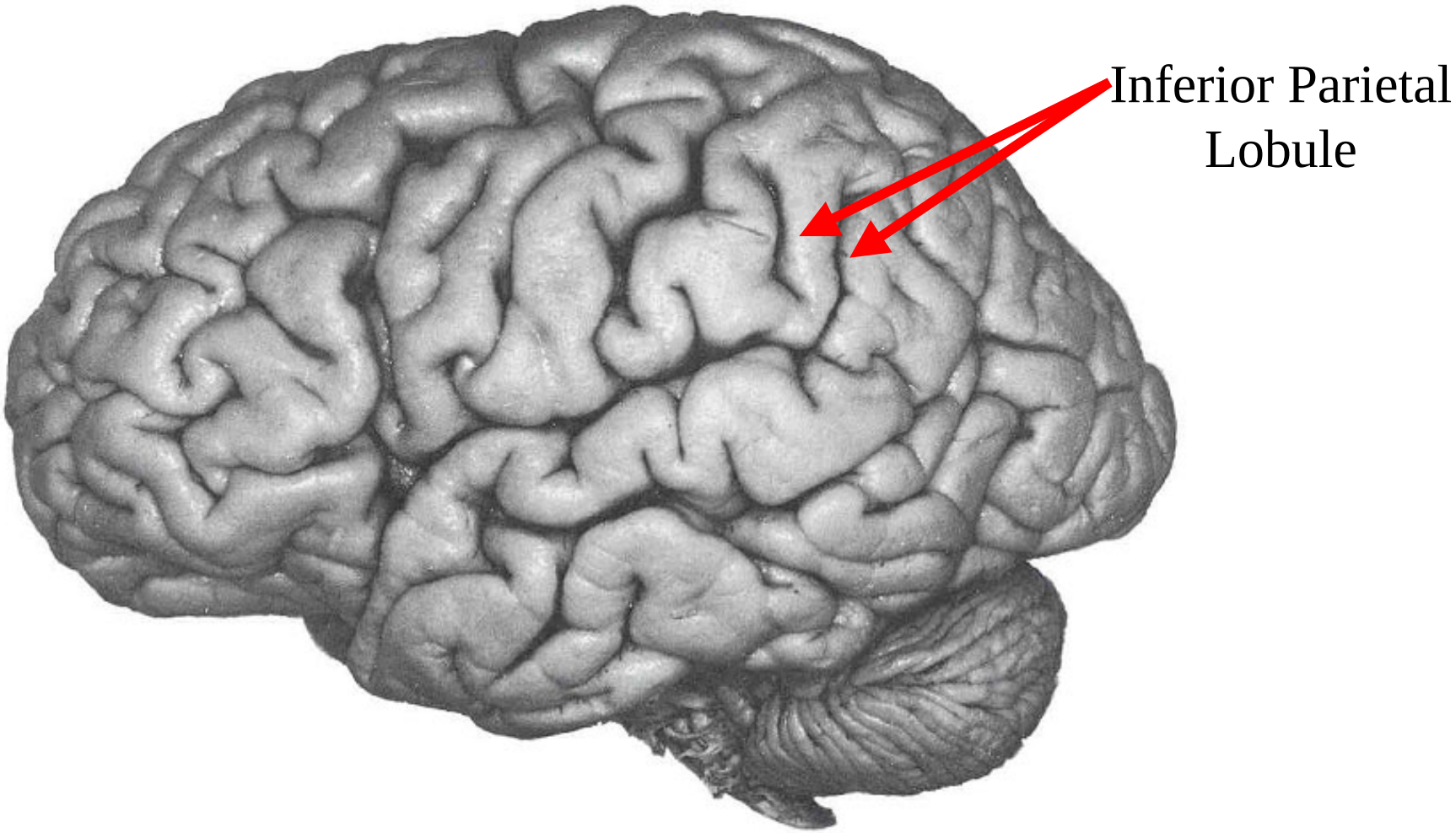


Locations Where Color Responses Exceed Achromatic Responses



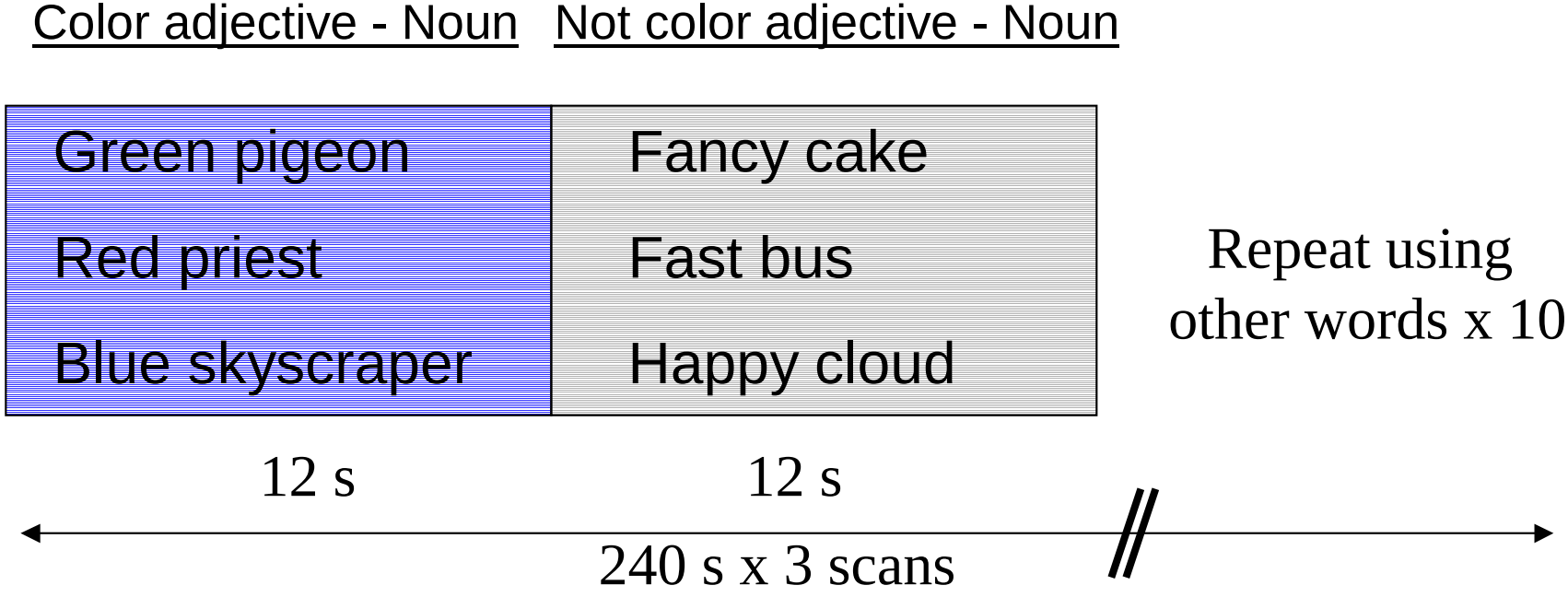
Color Anomia

(Meadows, 1974)



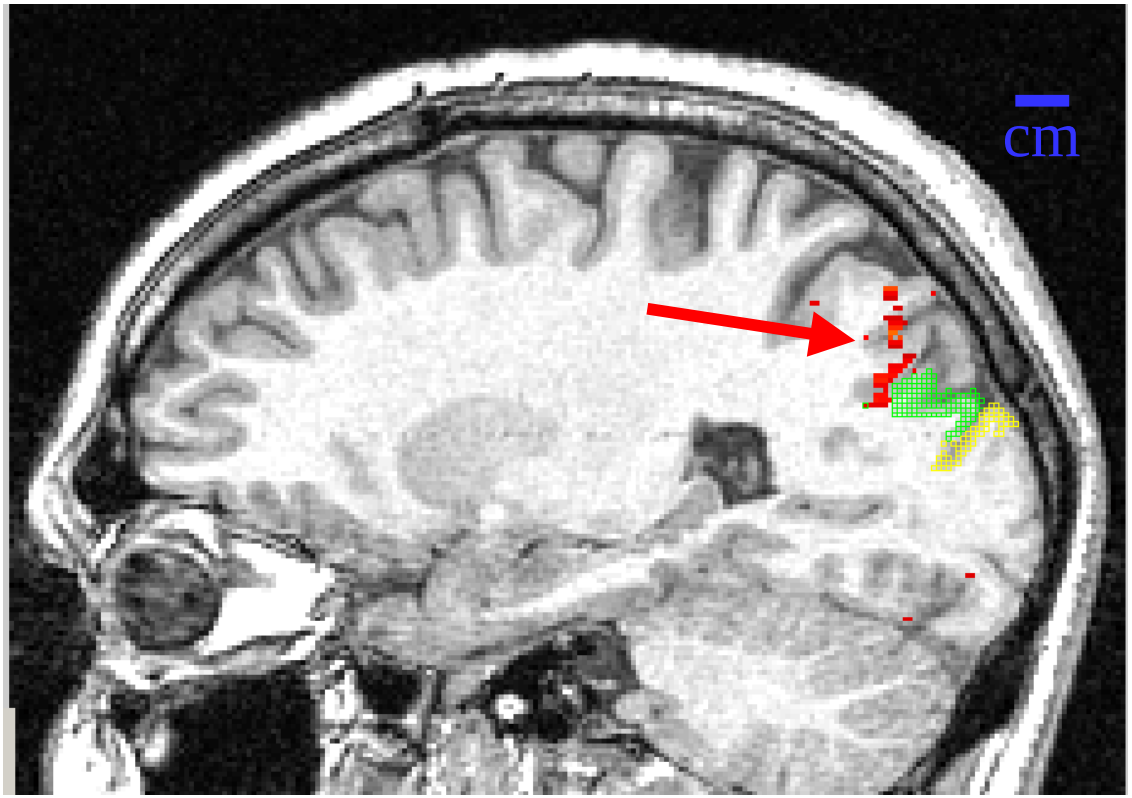
Color Word Experiment

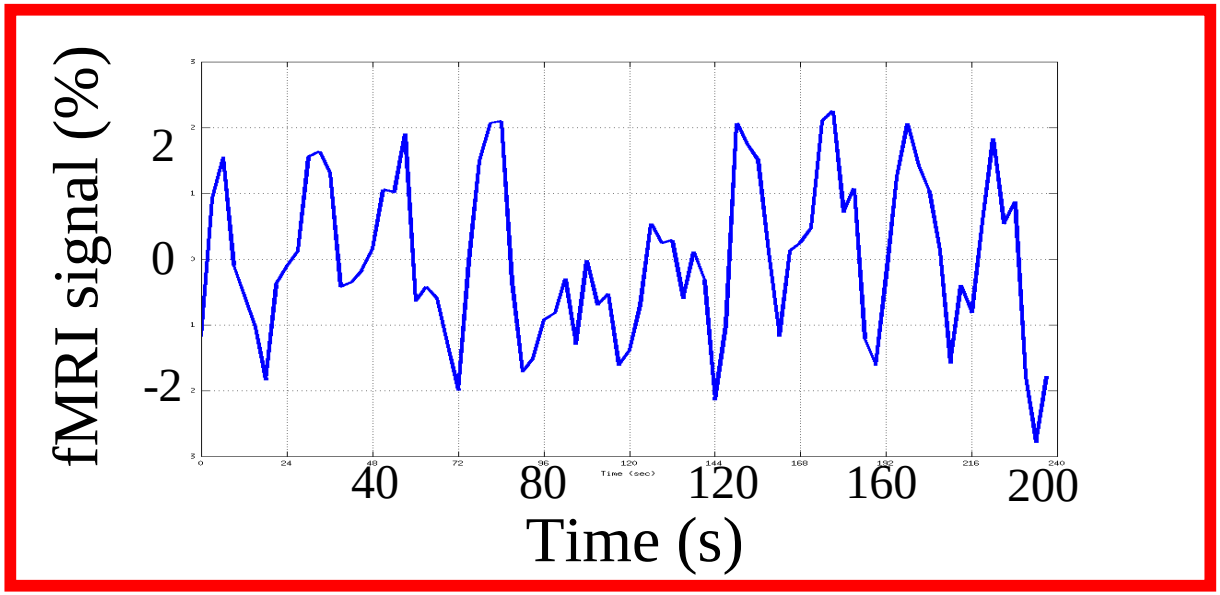
Subject reads adjective noun pair
Subject decides whether pairing is sensible
There is no right answer



But Activity is Strong

(fMRI; Wade et al.)





V3A

V7

Color Word

Thanks For Your Attention

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www.imageval.com

ALEX WADE

ALYSSA BREWER