Reduced Flip Angle Imaging

Outline

- Determinants of Imaging Time
- TR, Saturation and Image Quality
- Reduced Flip Angle Techniques
  - FLASH (=SPGR)
  - FISP (=GRASS)
- Gradient Echoes
- Applications of Shallow Flip Imaging
- Ultra-Fast Imaging

Determinants of Imaging Time

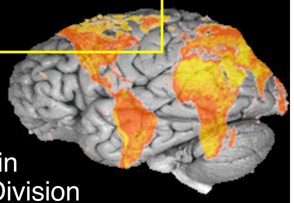
Scan Time =

Repetition Time (TR)
x Number of Phase Encodes
x NEX (Averages)
x Number of 3D Steps

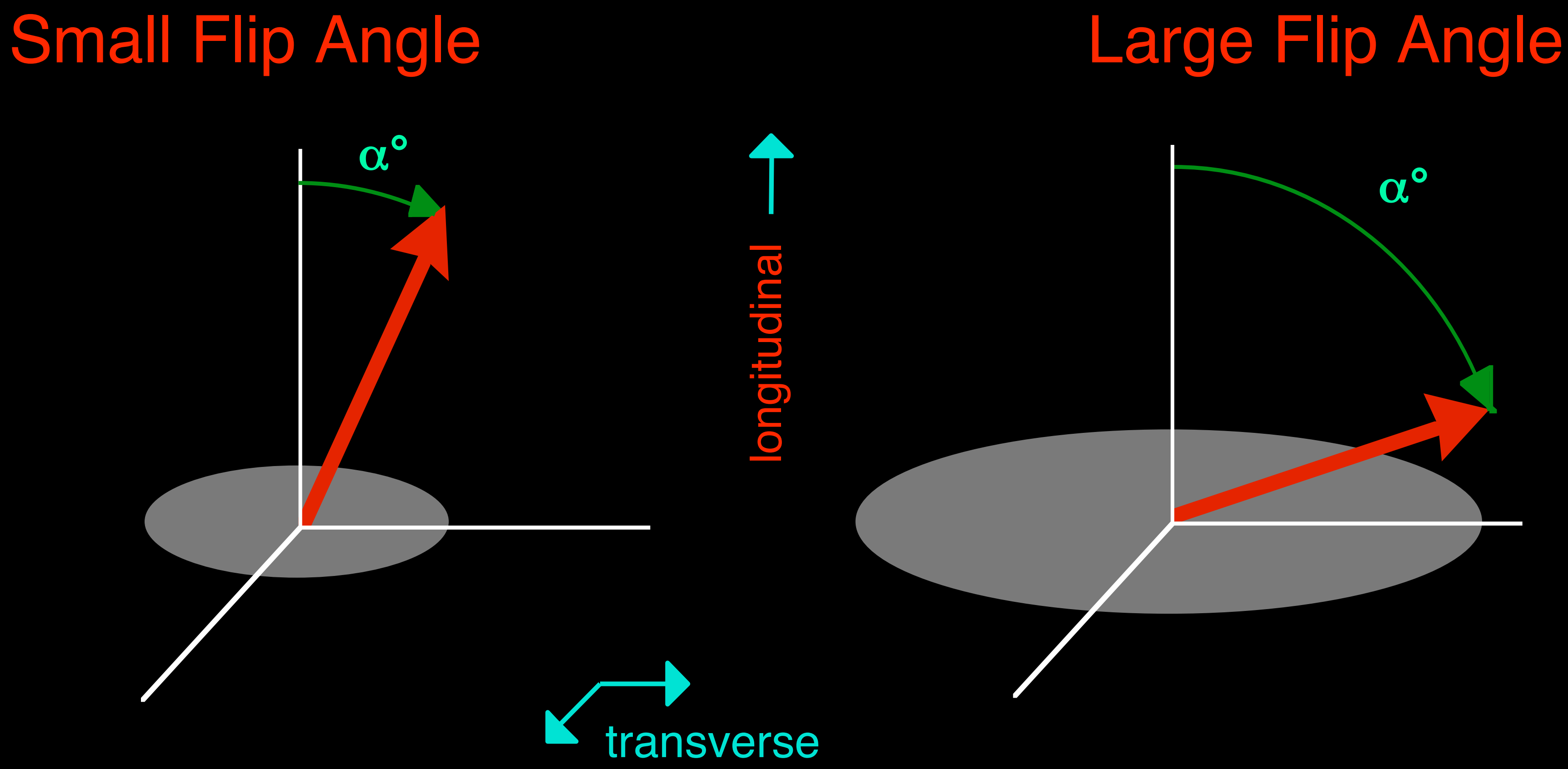
TR and Image Quality

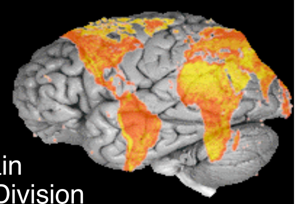
Reduced TR Yields:

- Decreased Scan Time
- Increased T1 Contrast
- Reduced (Useable) T2 Contrast
- Reduced Signal to Noise Ratio
- Increased Power Deposition
- Reduced Slice Coverage

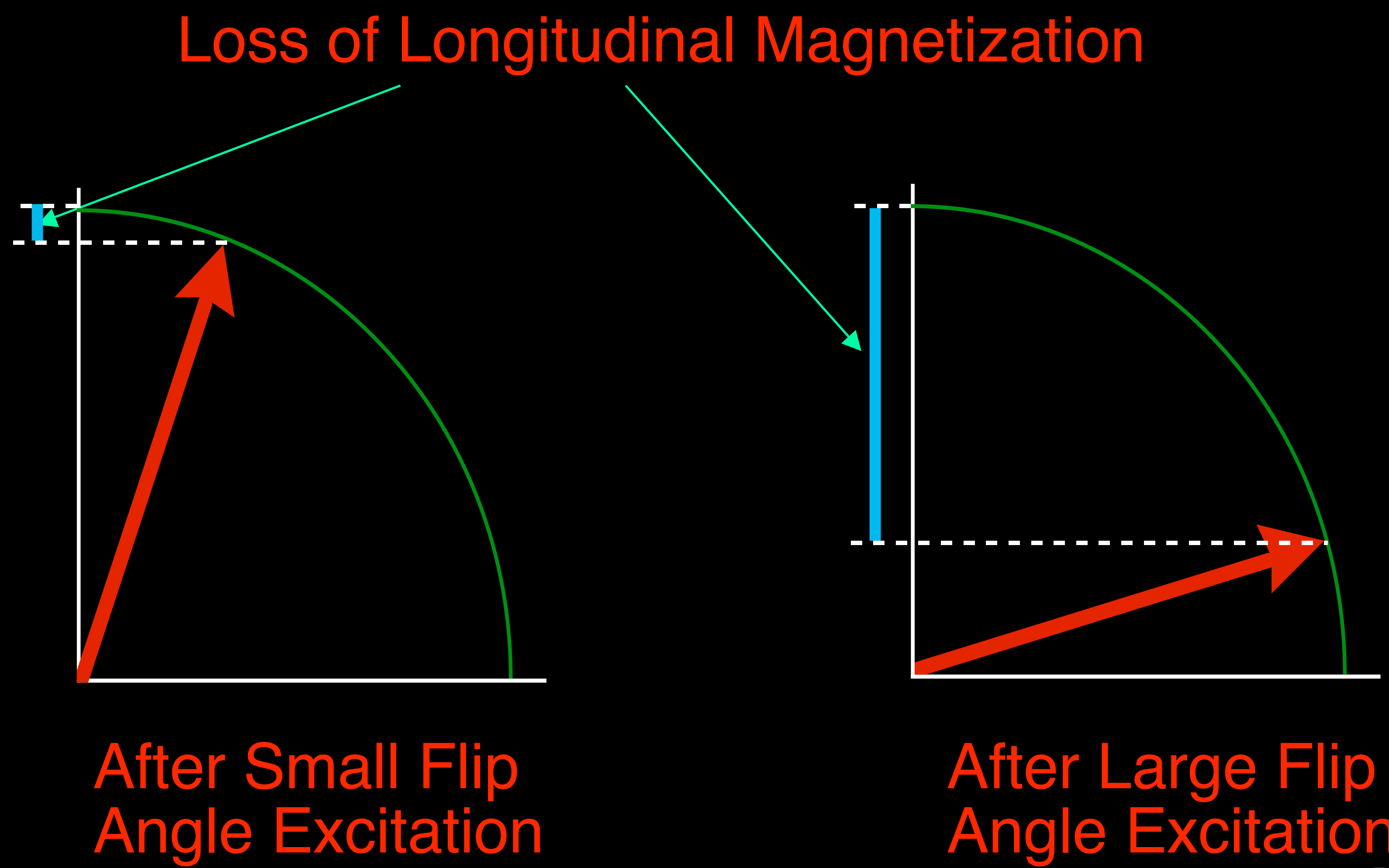


Signal and Flip Angle





Small and Large Flip Angle



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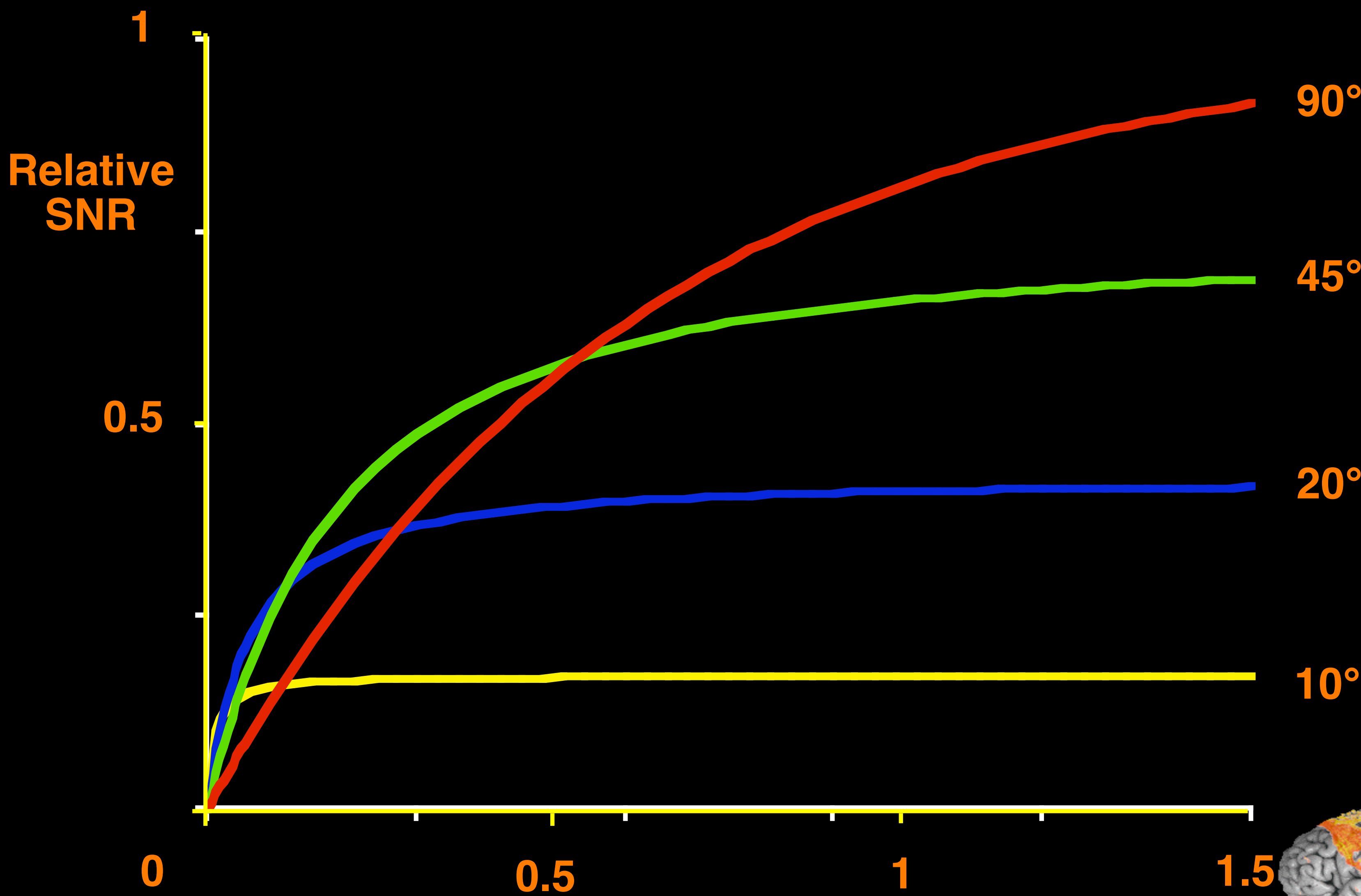
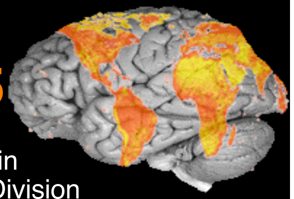
Flip Angle and TR/T1





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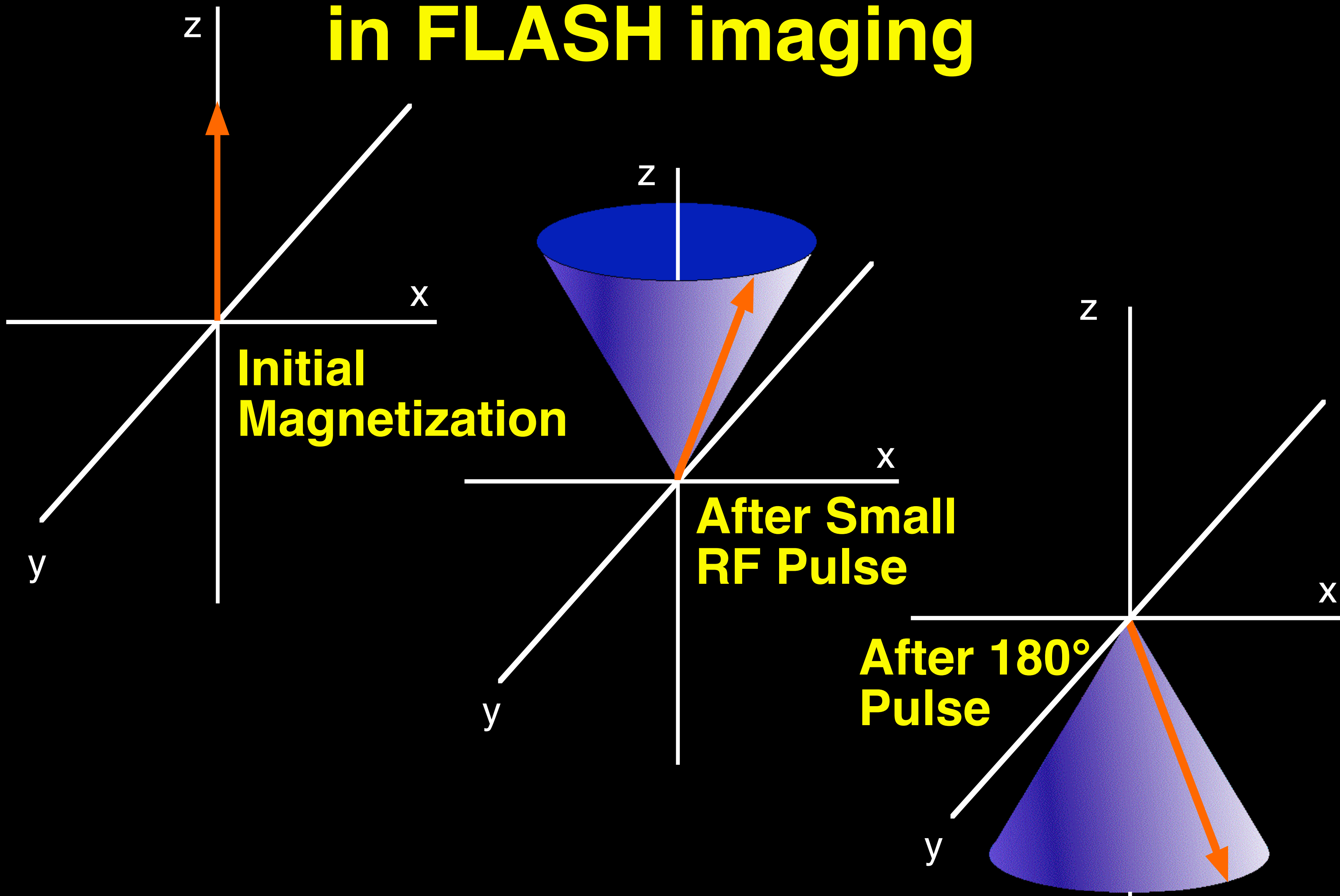
Large Flip Angles

TR \ TE	Short	Long
Long	Proton Density	T2*-Weighted
Short	T1-Weighted	

Small Flip Angles

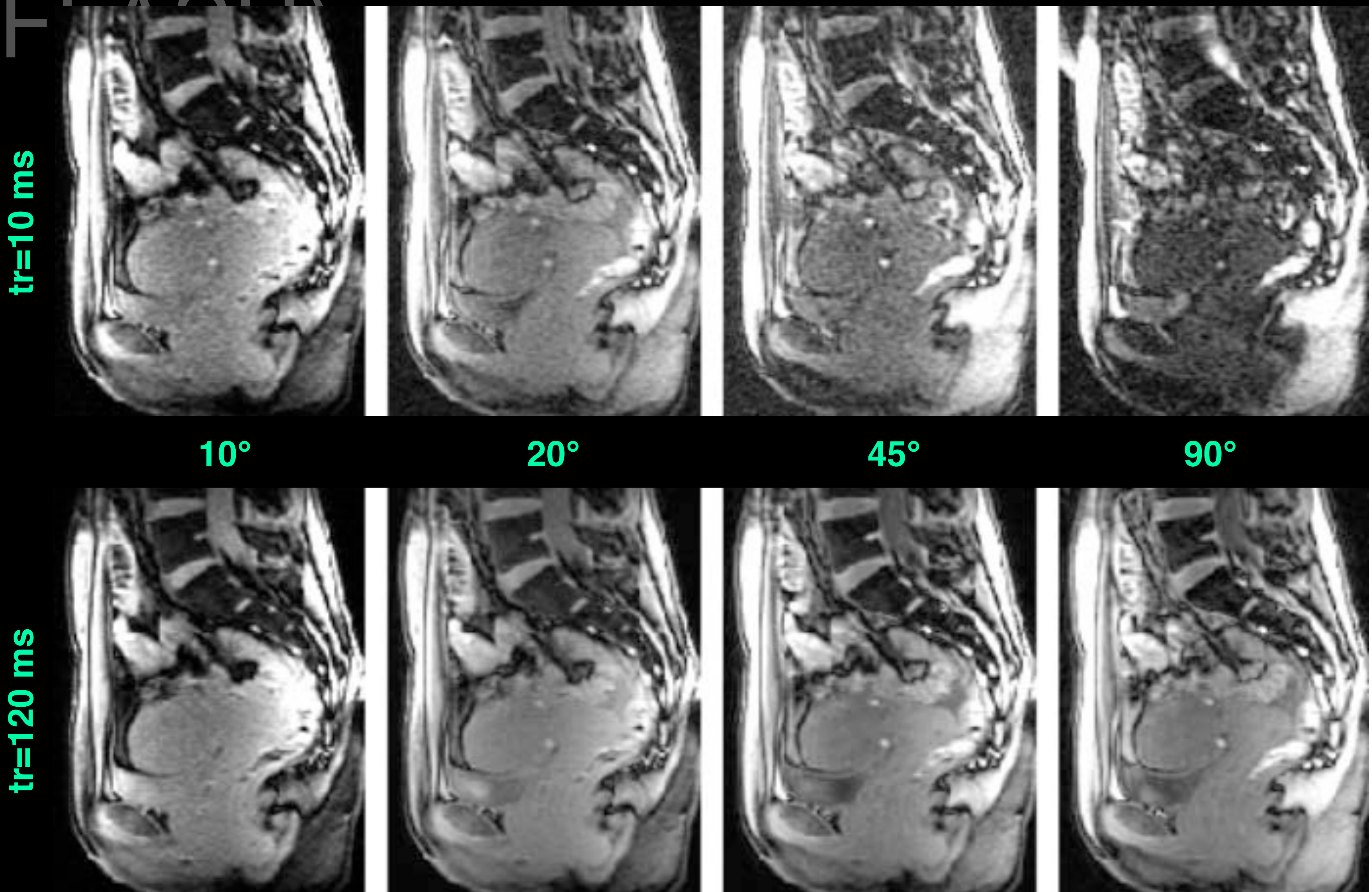
TR \ TE	Short	Long
Long	Proton Density	T2*-Weighted
Short	Proton Density	T2*-Weighted

A 180° Pulse is not used in FLASH imaging



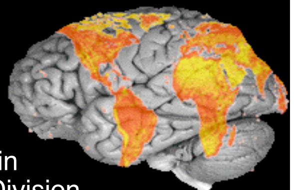
Cohen

(examples - FLASH)



TR & Flip Angle Combinations Having Similar Contrast (FLAS

TR	Flip Angle
3000	90°
2400	60°
1700	40°
750	20°
250	10°



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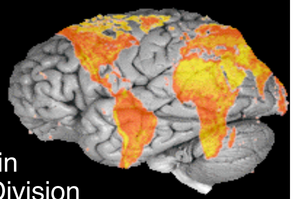
T2 and T2*

T2: Transverse Magnetization Decay from Spin-Spin Interactions

T2*: Transverse Magnetization Decay from Local Magnetic Field Variations



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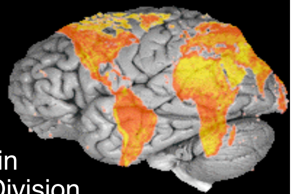
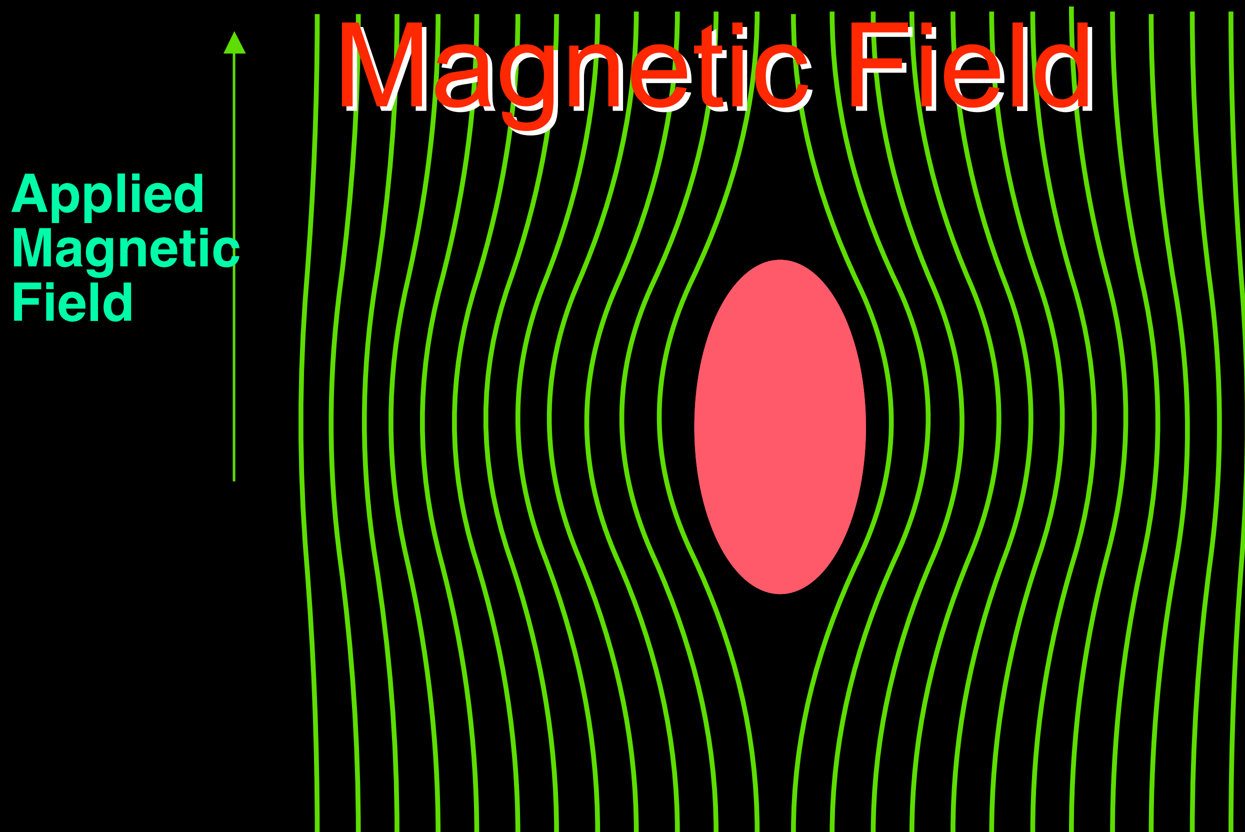
Magnetic Susceptibility

The Extent to Which a Substance Becomes "MAGNETIZED" when Placed Within a Magnetic Field



Magnetic Susceptibility

Objects with Susceptibility Different than Air Distort the Magnetic Field



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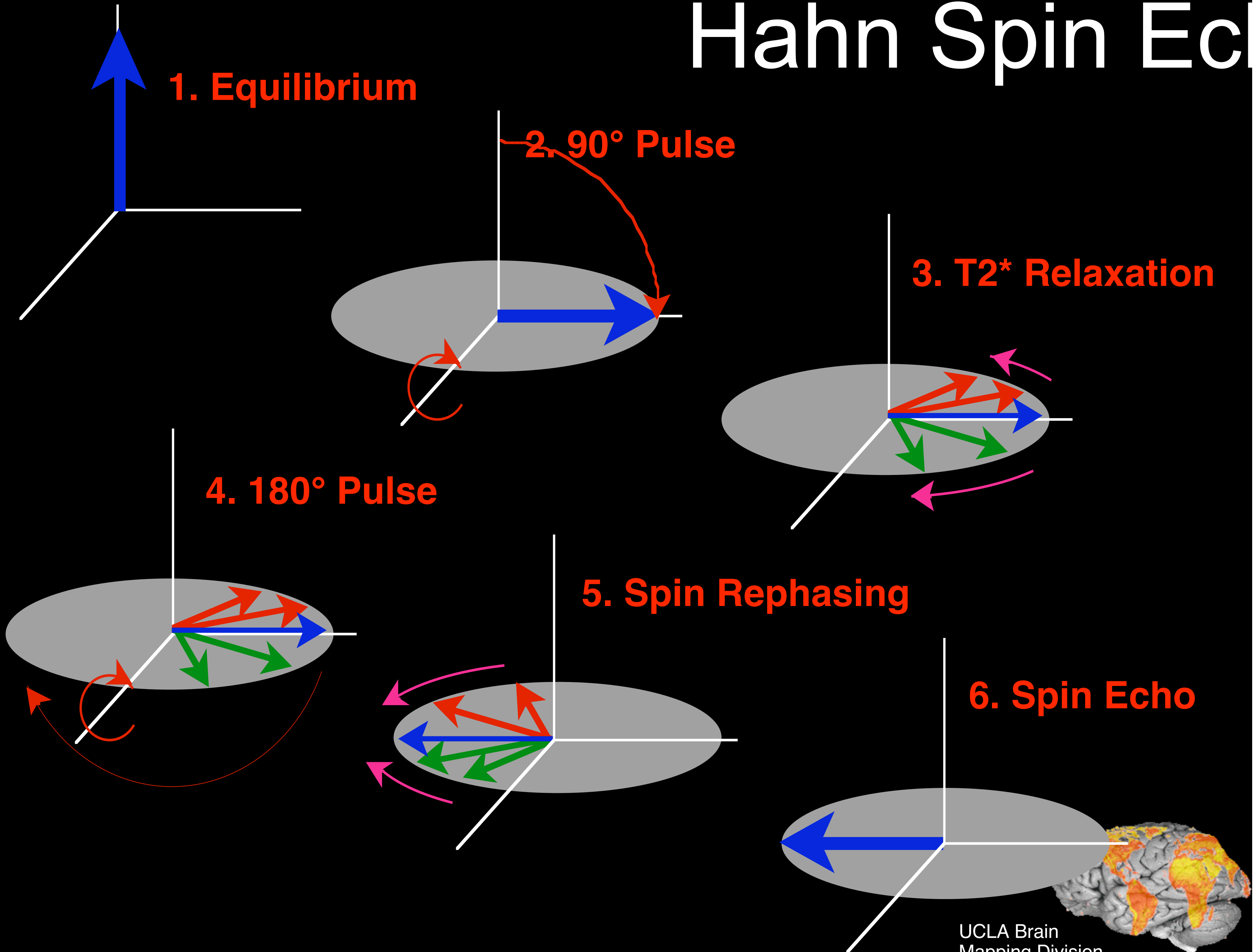
Hahn Spin Ec


1. Equilibrium
2. 90° Pulse
3. T2* Relaxation
4. 180° Pulse
5. Spin Rephasing
6. Spin Echo
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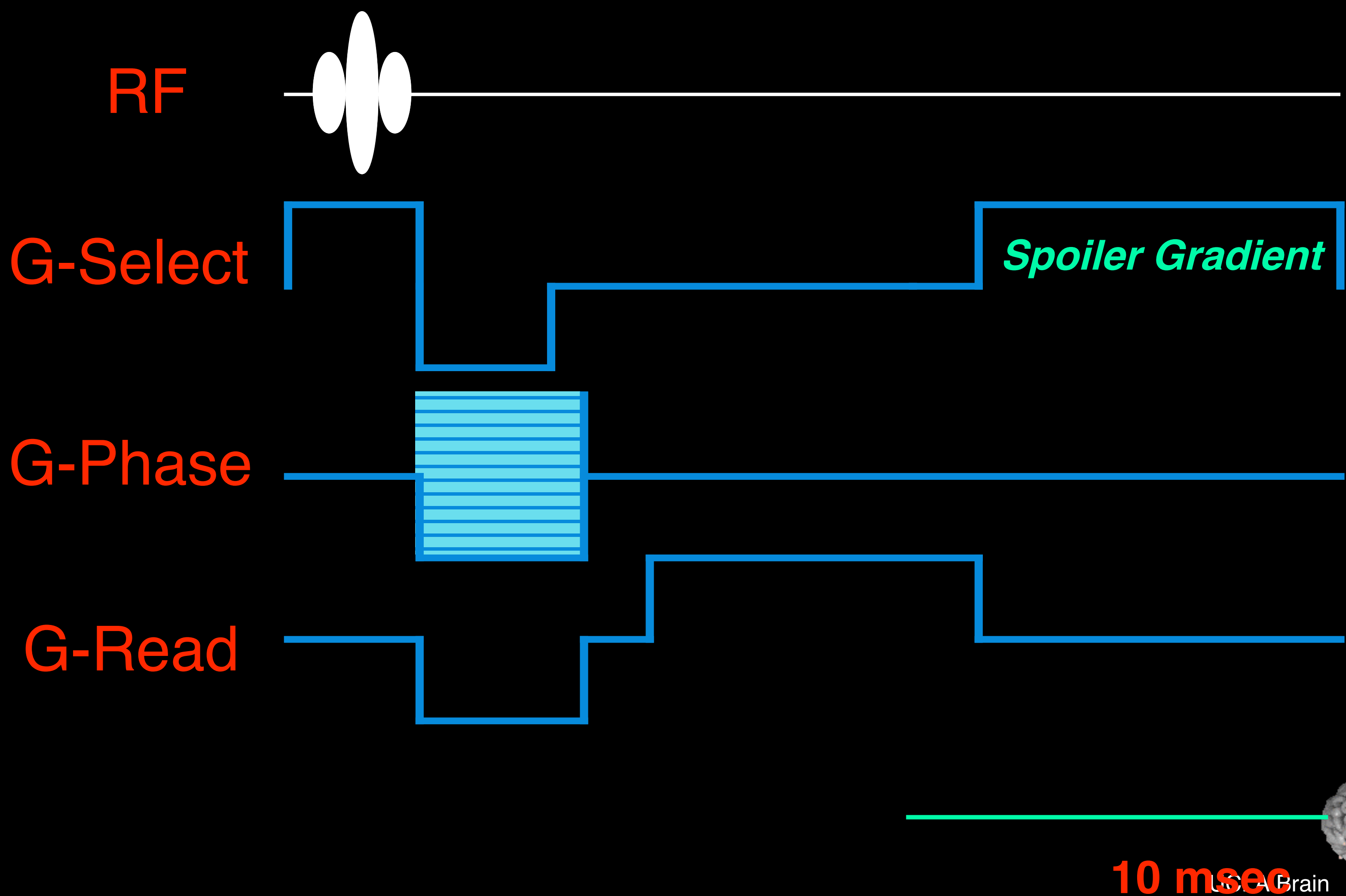
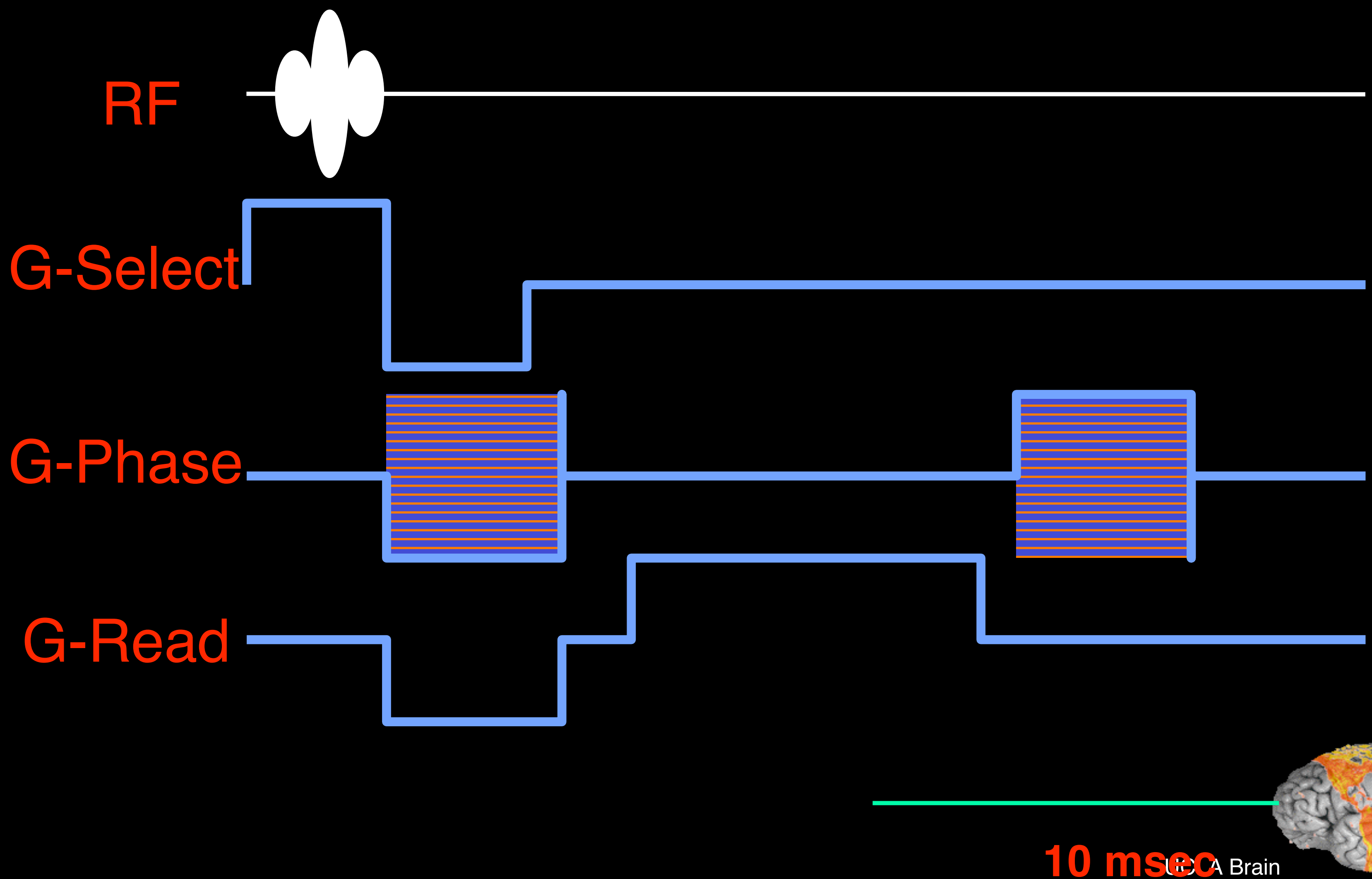
FLASH Timing Diagram



FISP (GRASS) Timing Diagram



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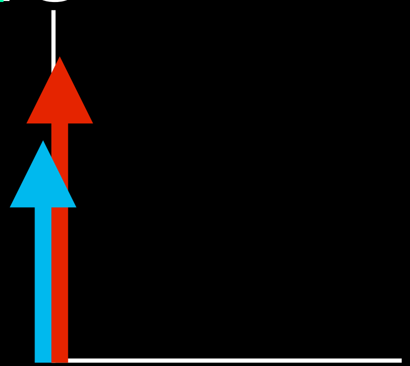
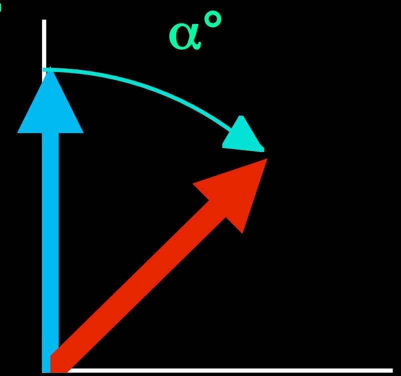
the FLASH Magnetization Cycle

1.



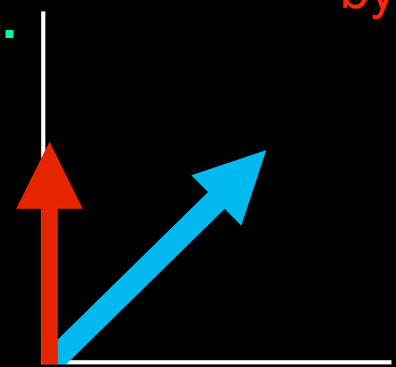
Longitudinal Recovery

2.



α° RF pulse followed by data collection

3.



Spoiling of transverse magnetization

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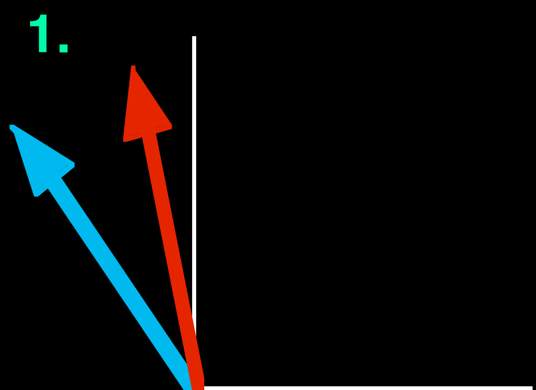
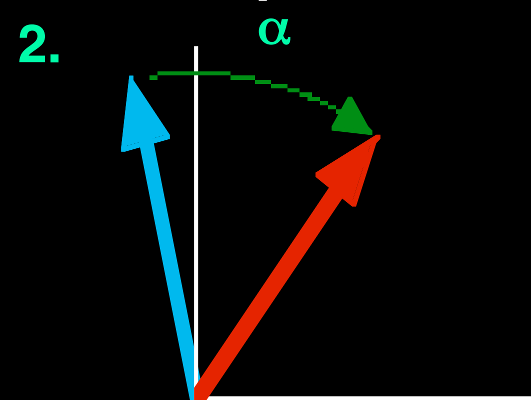
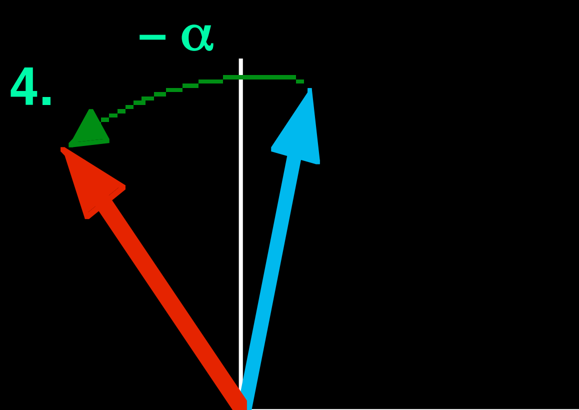
The GRASS (FISP) Magnetizatio



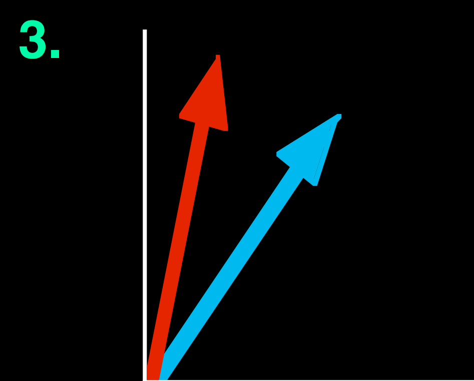
Longitudinal Recovery
and T2* relaxation



α degree RF pulse
and data collection



α degree RF pulse
and data collection



Longitudinal Recovery
and T2* relaxation

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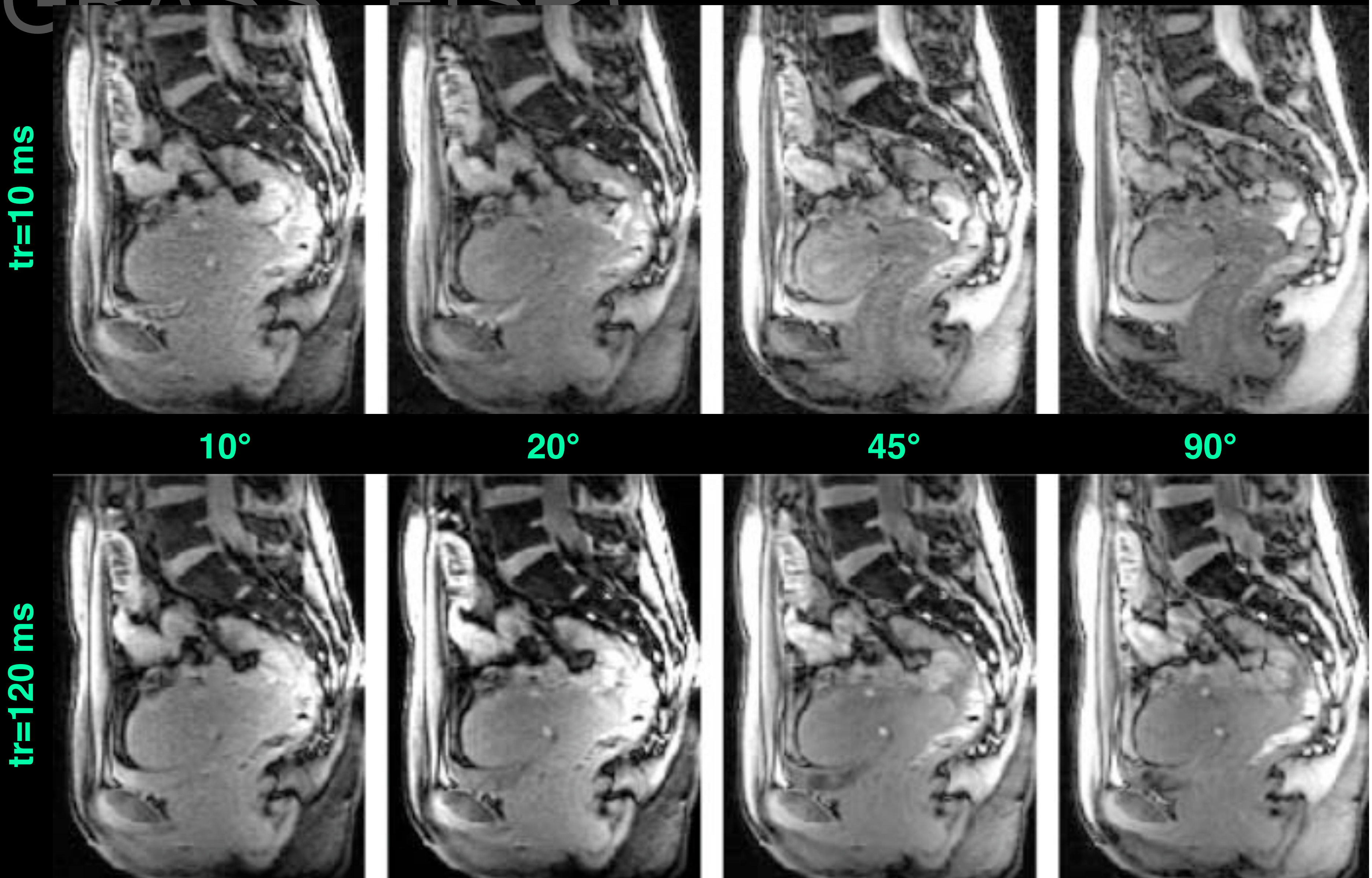
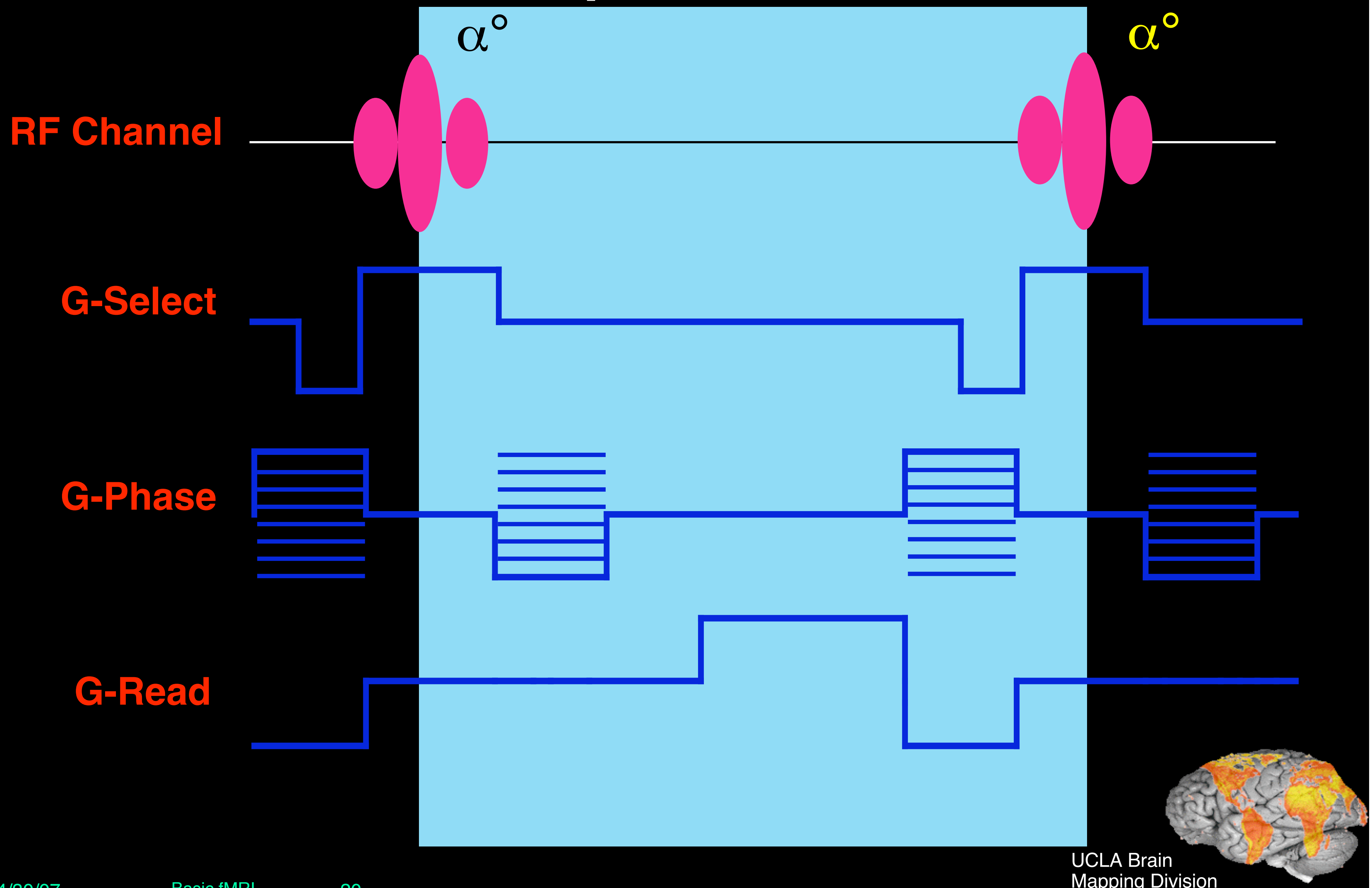
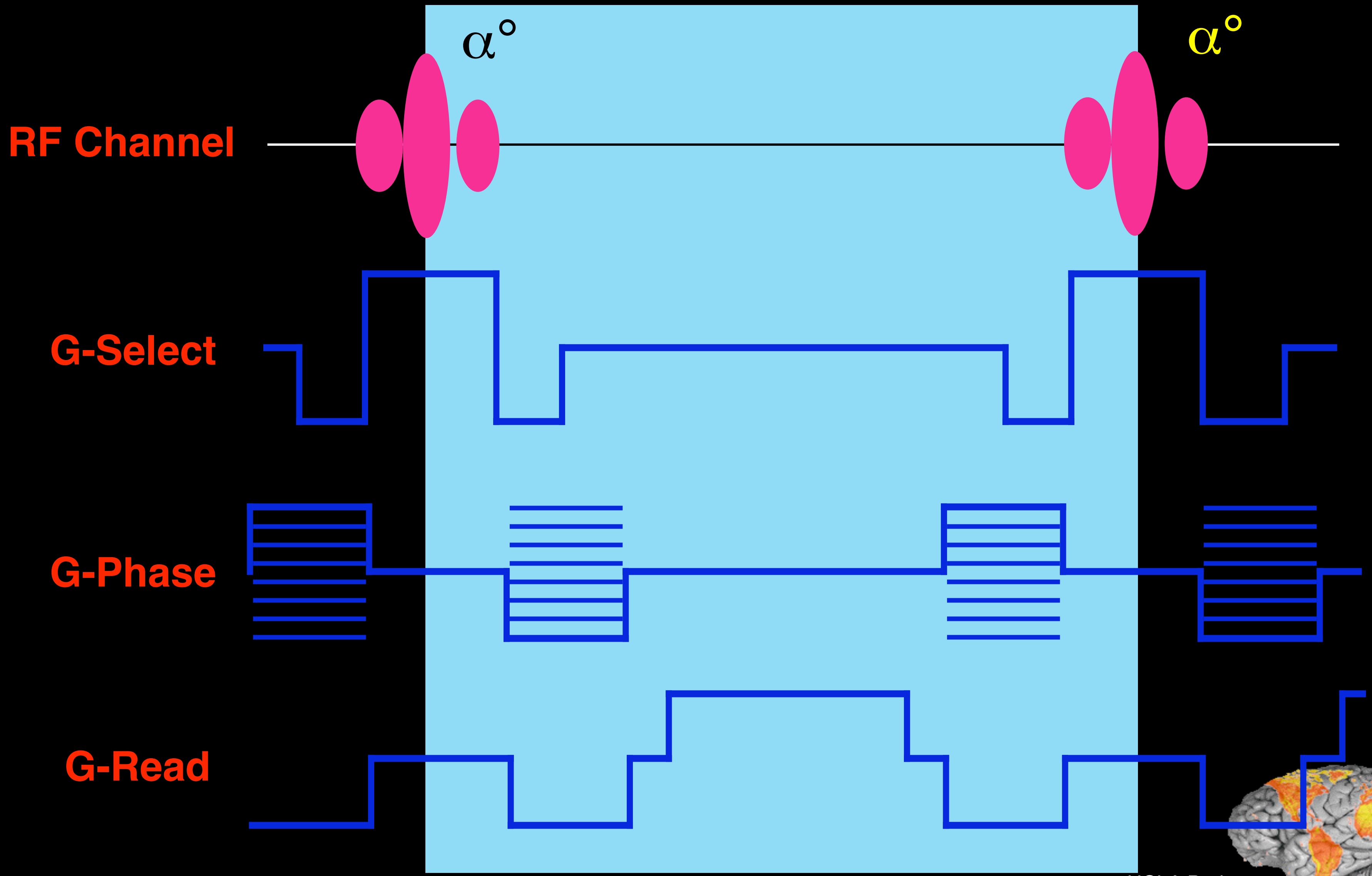
(examples - GRASS–FISP)



CE-FAST Sequence



SSFP Sequence



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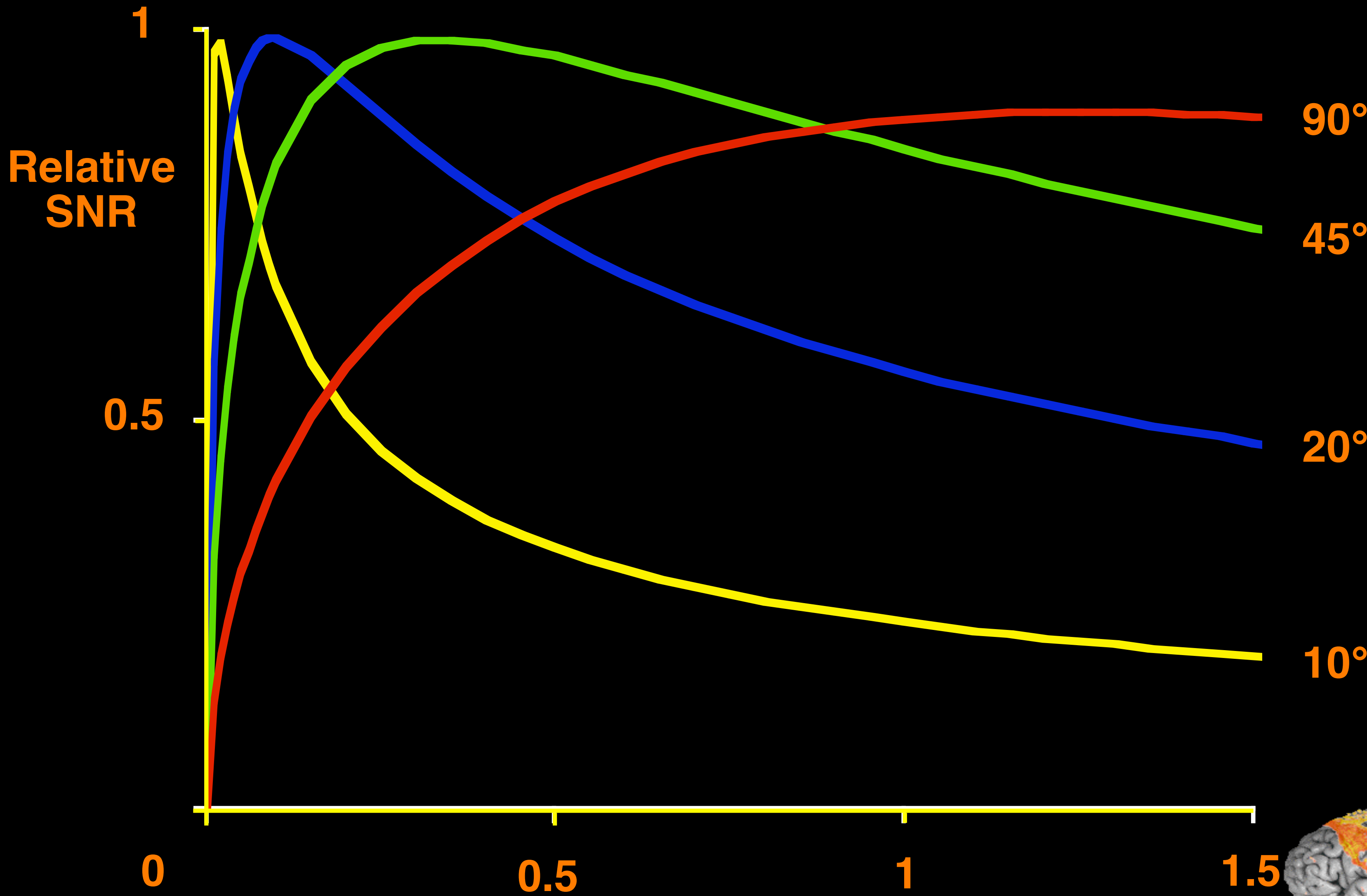
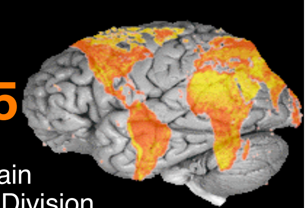
SNR vs. TR/T1

Assuming Constant Imaging Time





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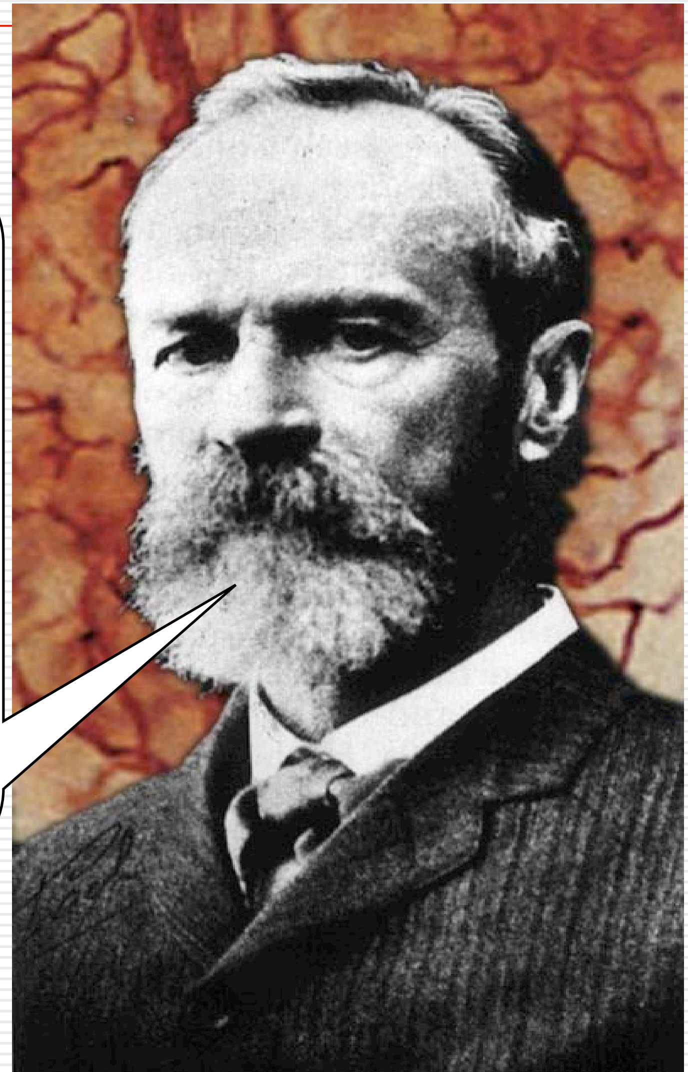
fMRI: What it Offers/What it doesn't

- Principles of functional MRI
- Performance Examples
- Theoretical Limitations
- Practical Limitations
- What Next?
- How do we get it? What does it cost?

William James (1890)

"We must suppose a very delicate adjustment whereby the circulation follows the needs of the cerebral activity.

*Blood very likely may rush to each region of the cortex according as it is most active, but of this we know **nothing**."*

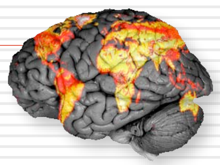


Brain "Activation" Leads to:

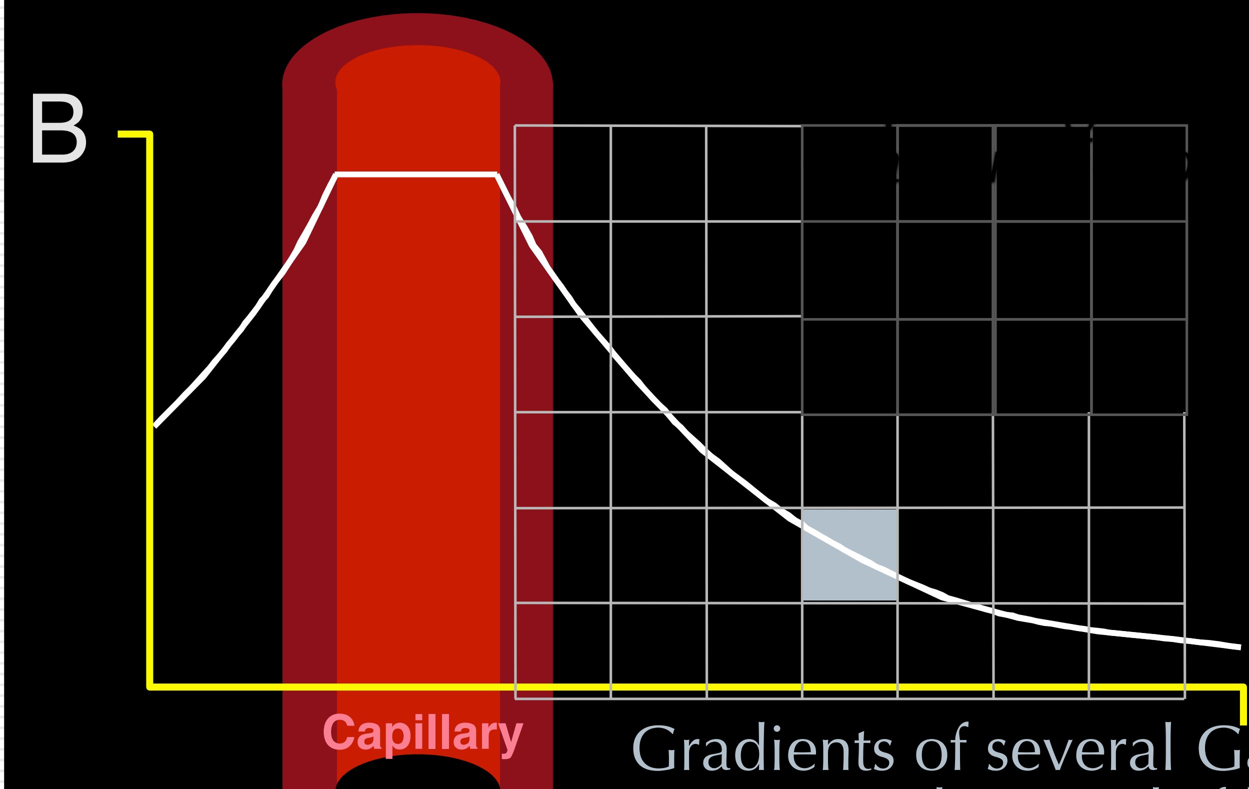
CBF	Increased	$+\Delta R1$
CBV	Increased	$+\Delta R2$ (C+)
O_2 Utilization	Increased slightly?	
Venous $[O_2]$	Increased	$-\Delta R2^*$
Glucose Utilization	Increased	? Lactate

$R1=1/T1$

$R2=1/T2$

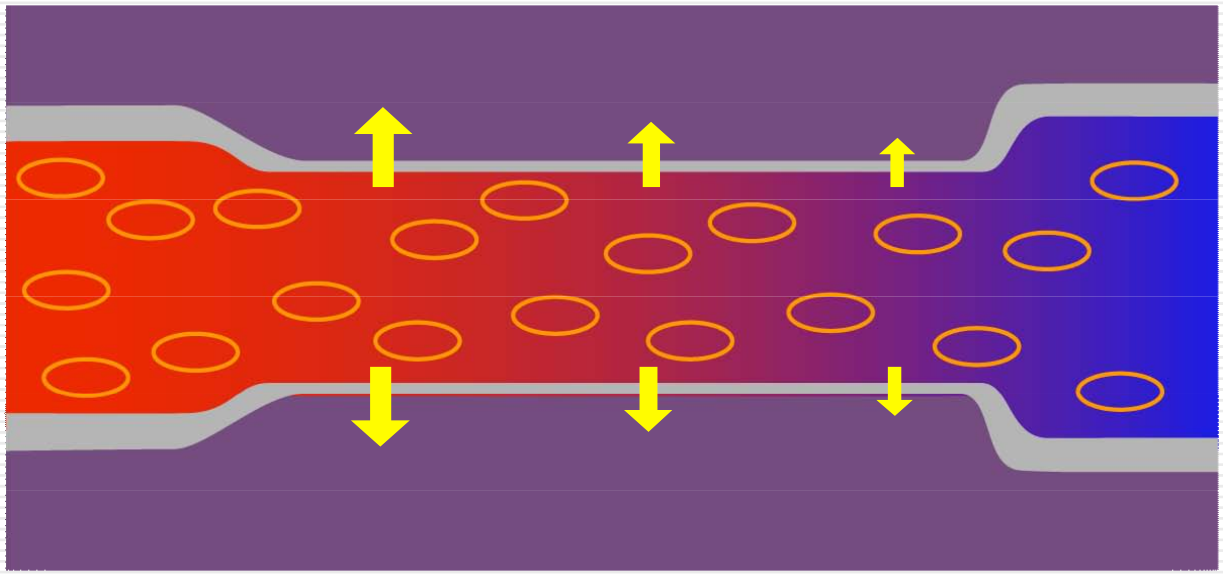


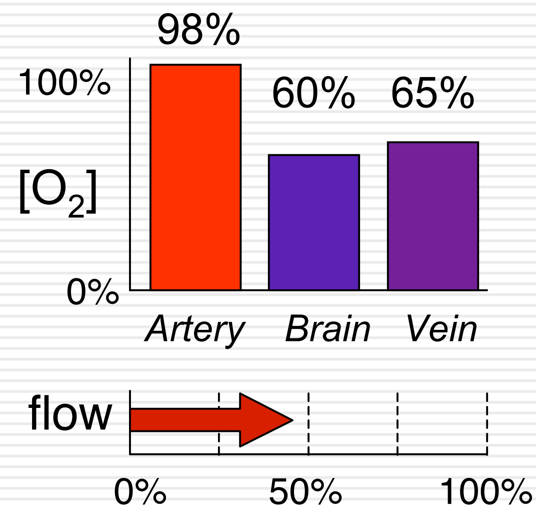
Signal Losses from Spin Dephasing



Gradients of several Gauss/cm may exist near deoxy-Hb-filled capillaries.

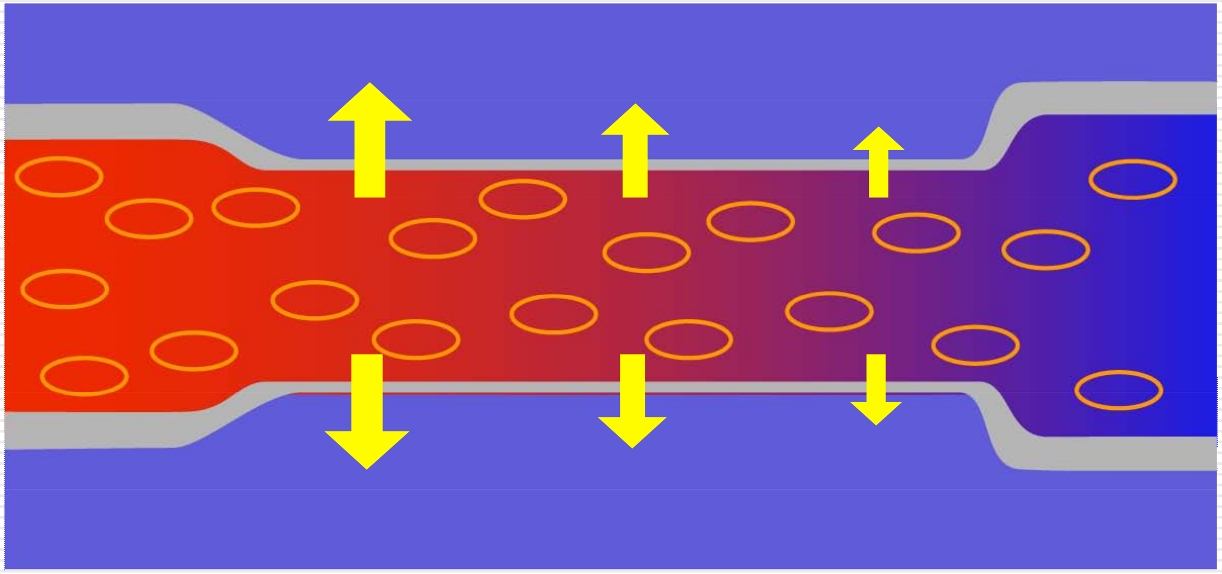
Why Does Venous O_2 Increase? (1)

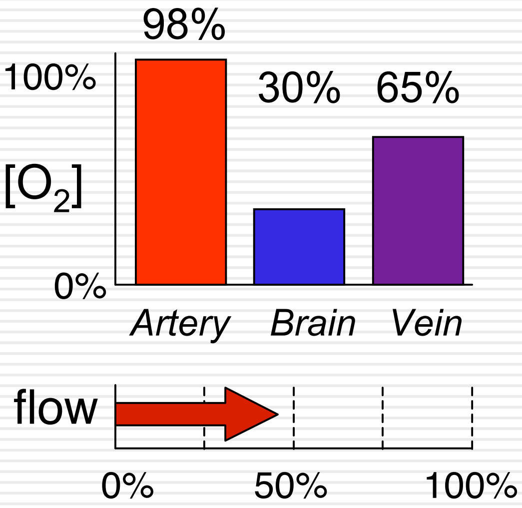




Under normal conditions oxygen diffuses down its concentration gradient from the capillary to the brain parenchyma

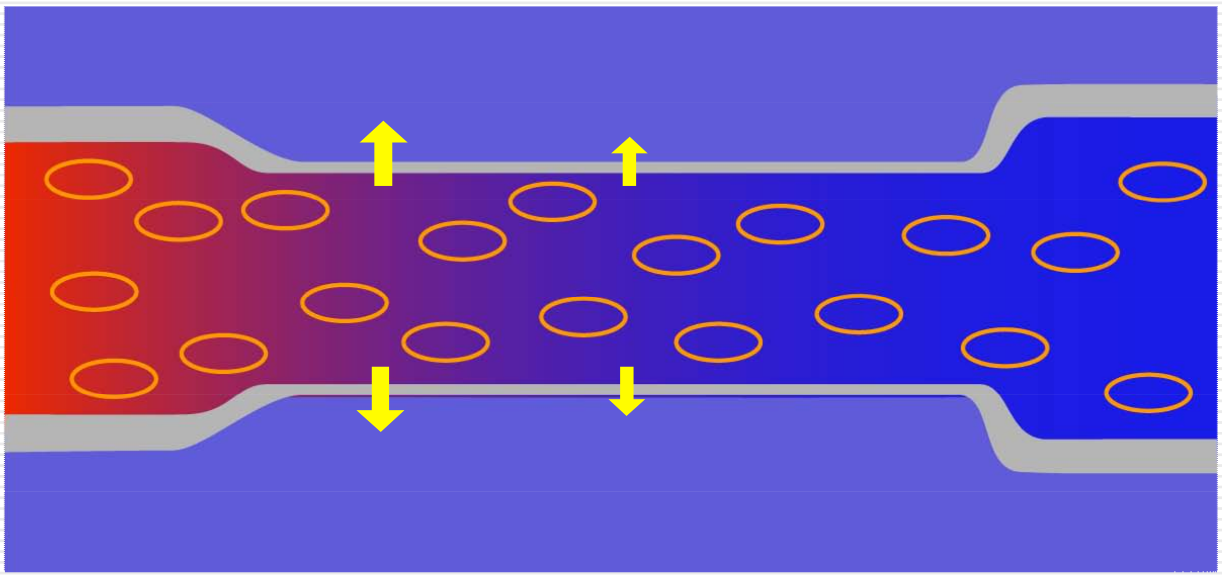
Why Does Venous O_2 Increase? (2)

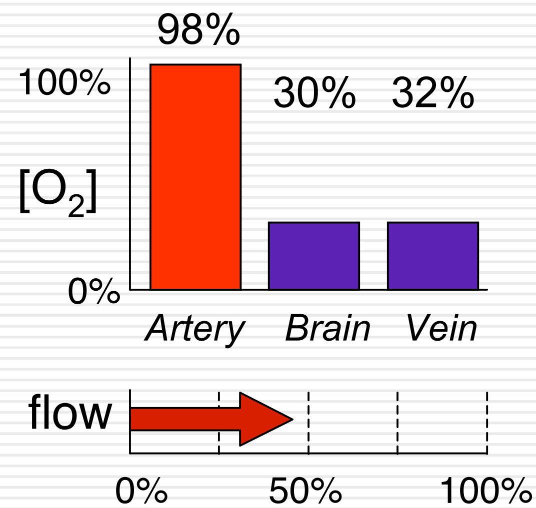




As the brain becomes more active, the oxygen consumption increases, increasing the transluminal oxygen gradient.

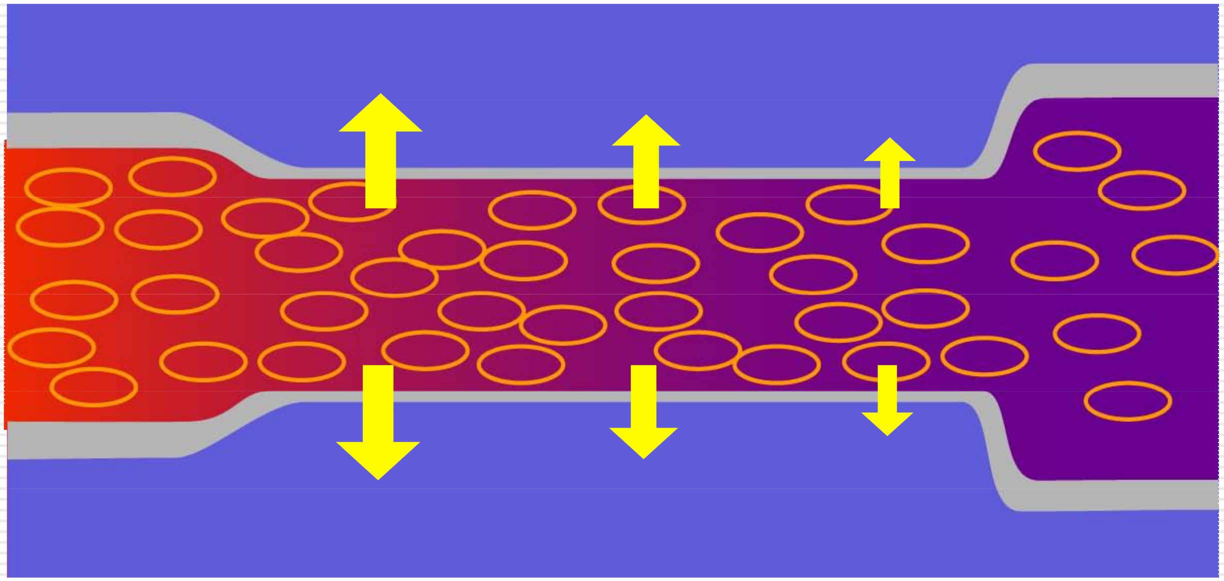
Why Does Venous O_2 Increase? (3)

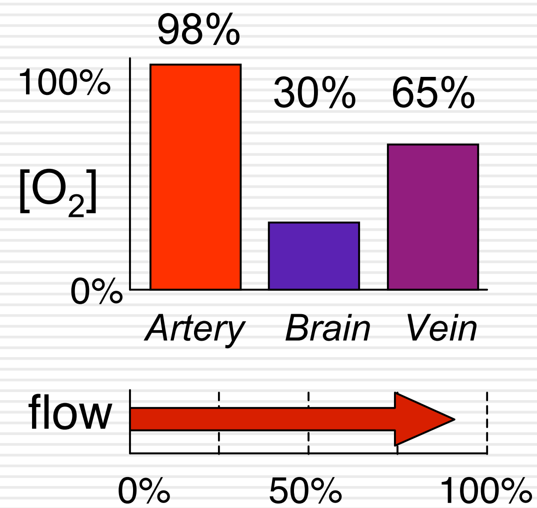




As oxygen flows across the capillary lumen it is depleted in the capillary and no further oxygen can be delivered

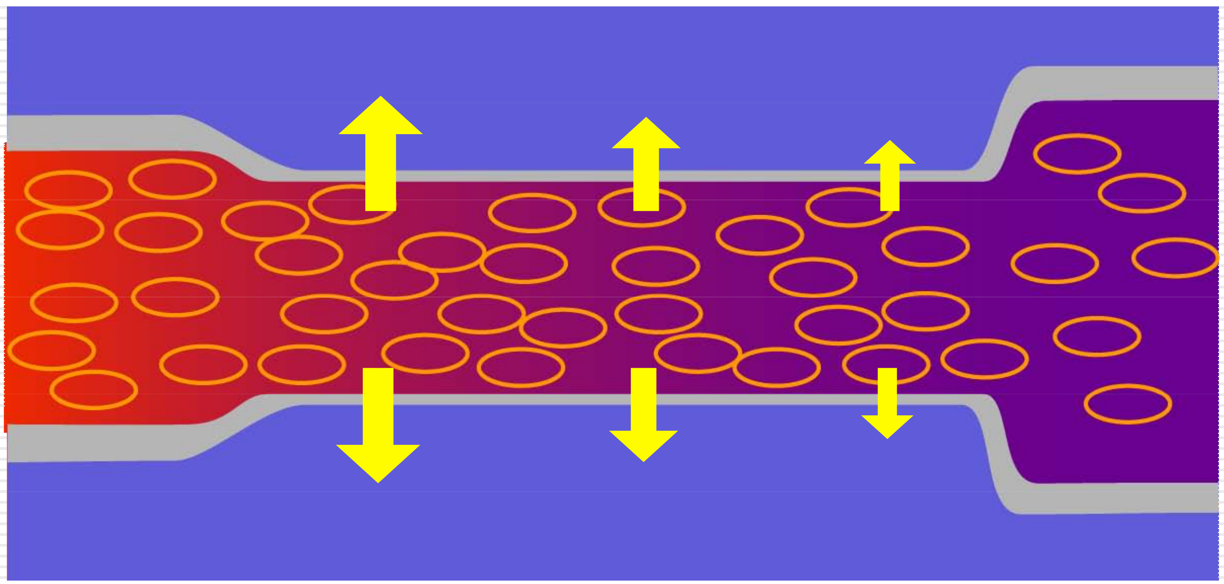
Why Does Venous O_2 Increase? (4)

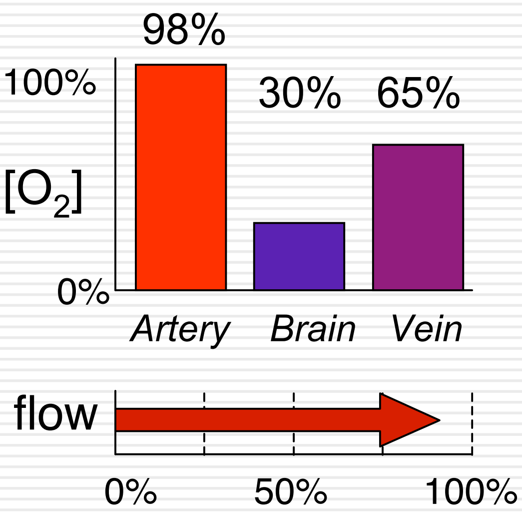




The vascular system responds by increasing blood flow so that more oxygenated blood is available throughout the capillary

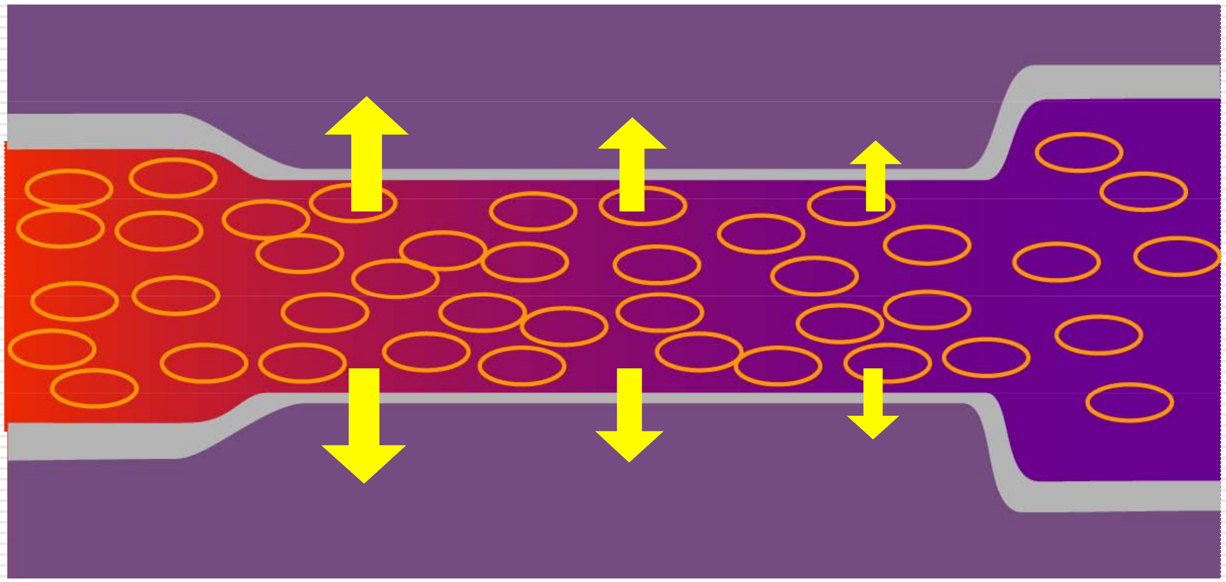
Why Does Venous O_2 Increase? (5)

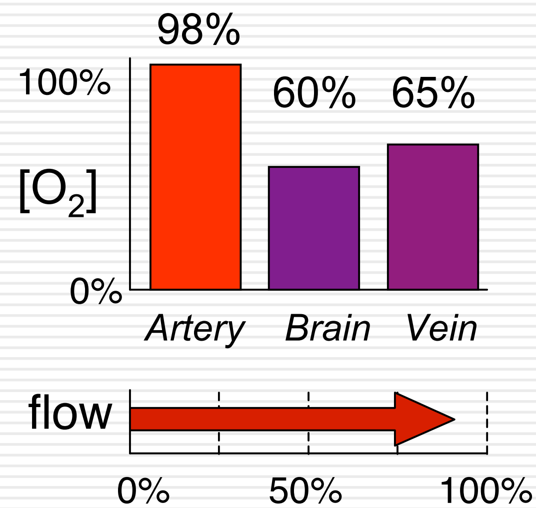




Because the blood flow is increased more oxygenated blood passes into the venous end of the capillary

Why Does Venous O_2 Increase? (6)





Because the blood flow is increased more oxygenated blood passes into the venous end of the capillary

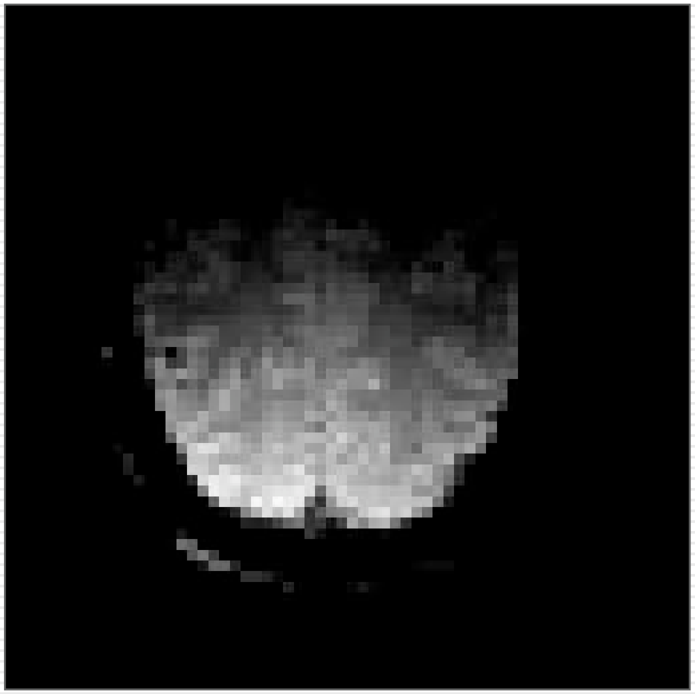
BOLD Contrast & Field Strength

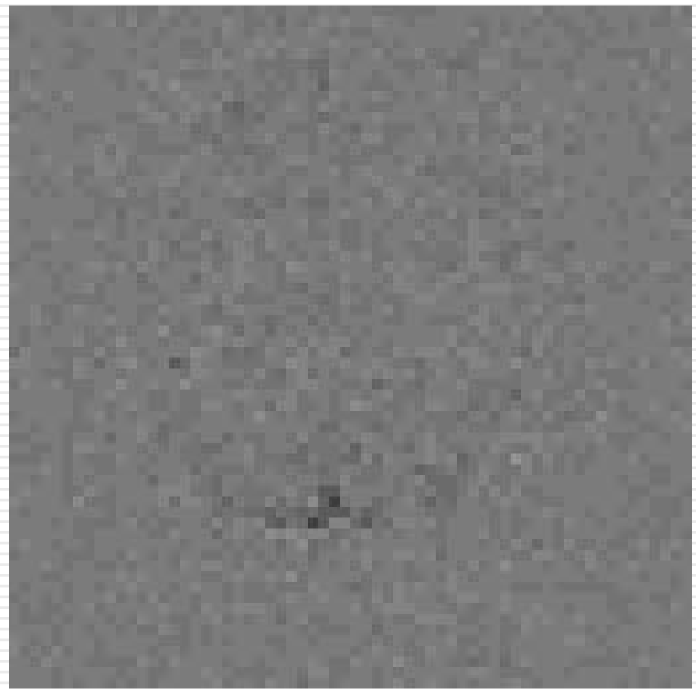
- BOLD Contrast arises from susceptibiity differences
- The absolute field distortion (from BOLD) is proportional to the magnetic field strength
- The absolute change in MRI signal is proportional to *both* the field distortion and the signal strength.

BOLD *should* go as kB_0^2

fMRI

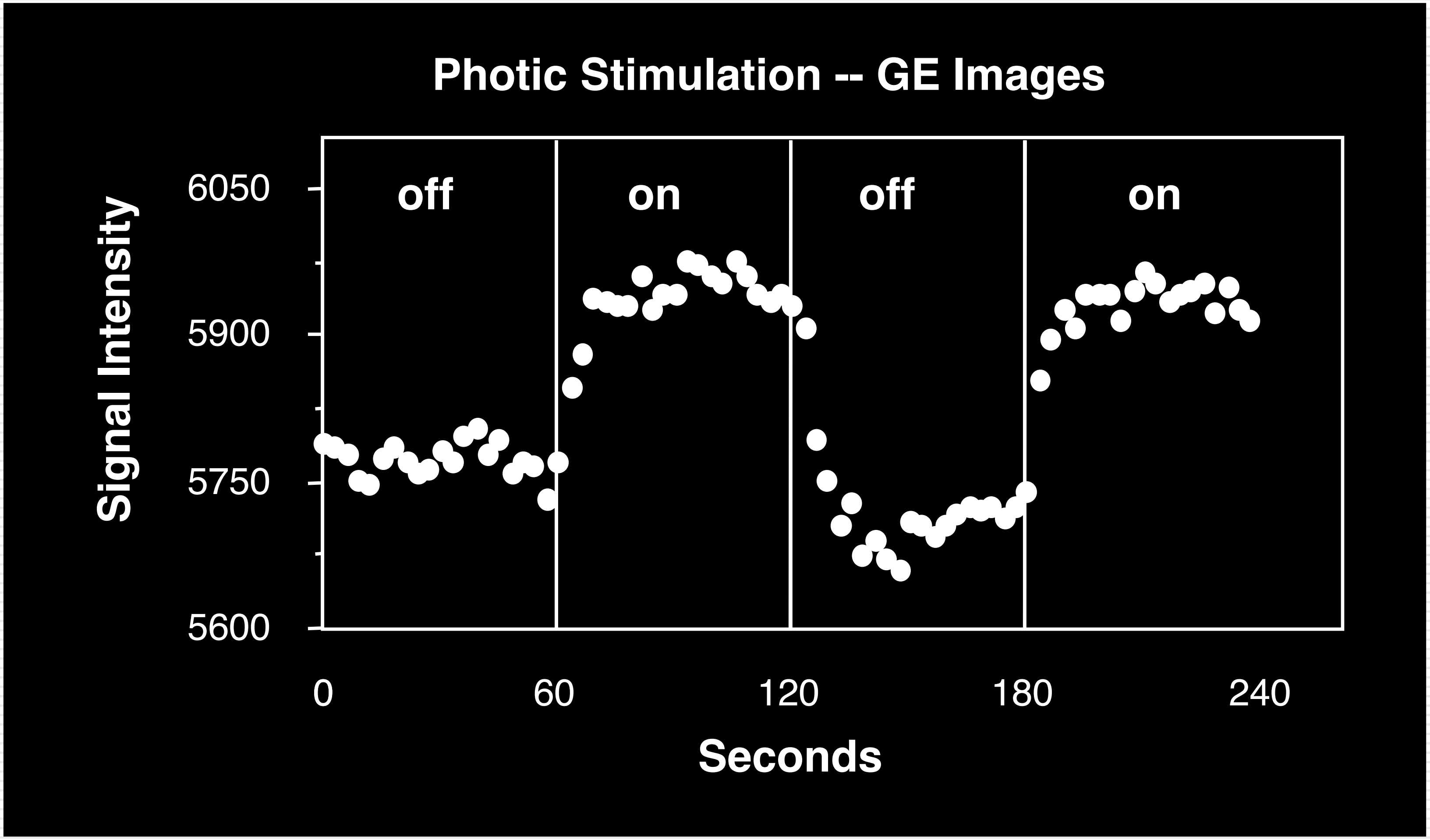
explores intensity variations in MR signal





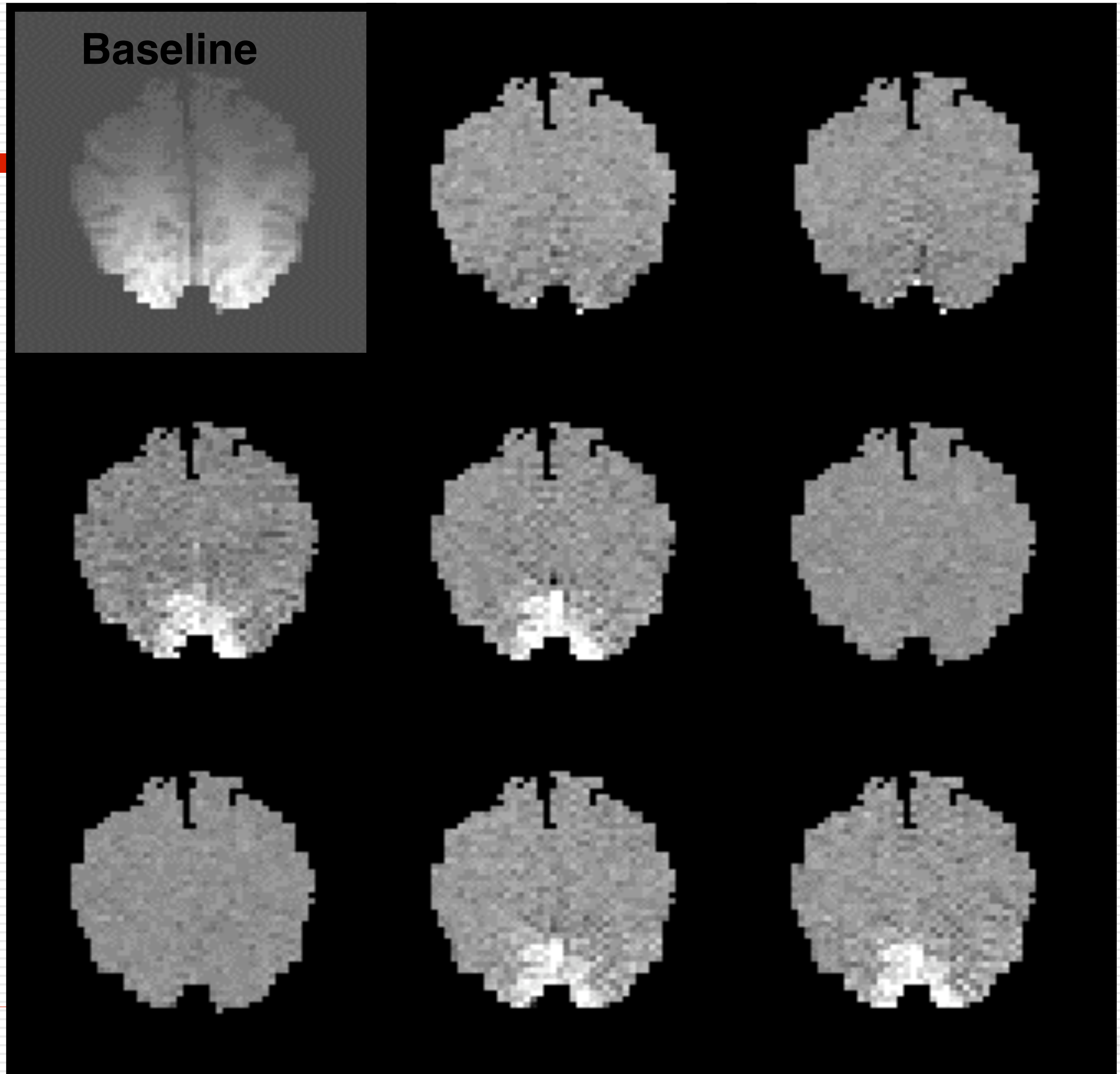
intensity variations reflect venous [O2]

Gradient-Recalled Echo



Ken Kwong

Inversion Recovery
TE=42   TR=3000
TI = 1100
Thickness=10



4/30/07
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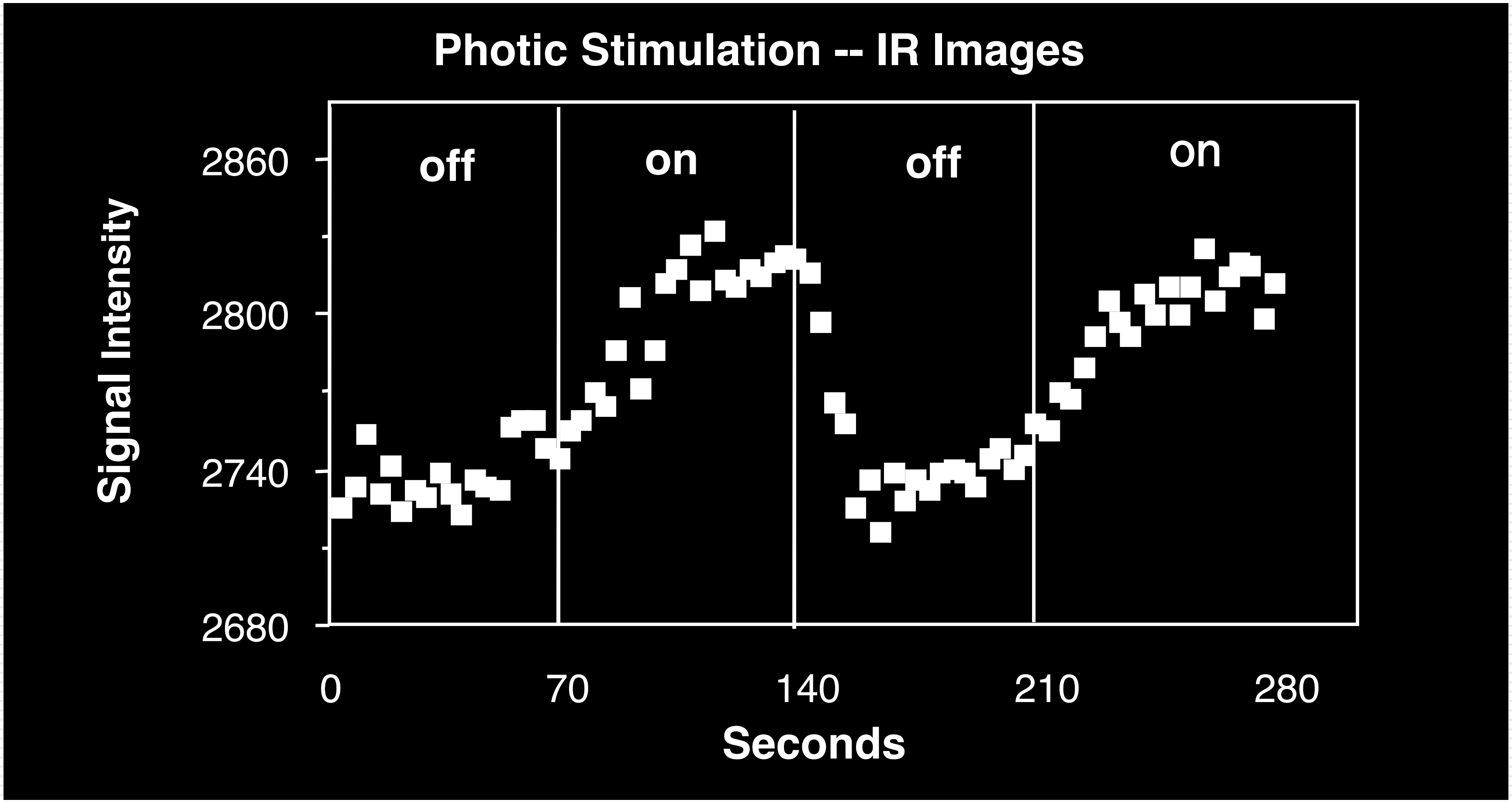
Inversion Recovery



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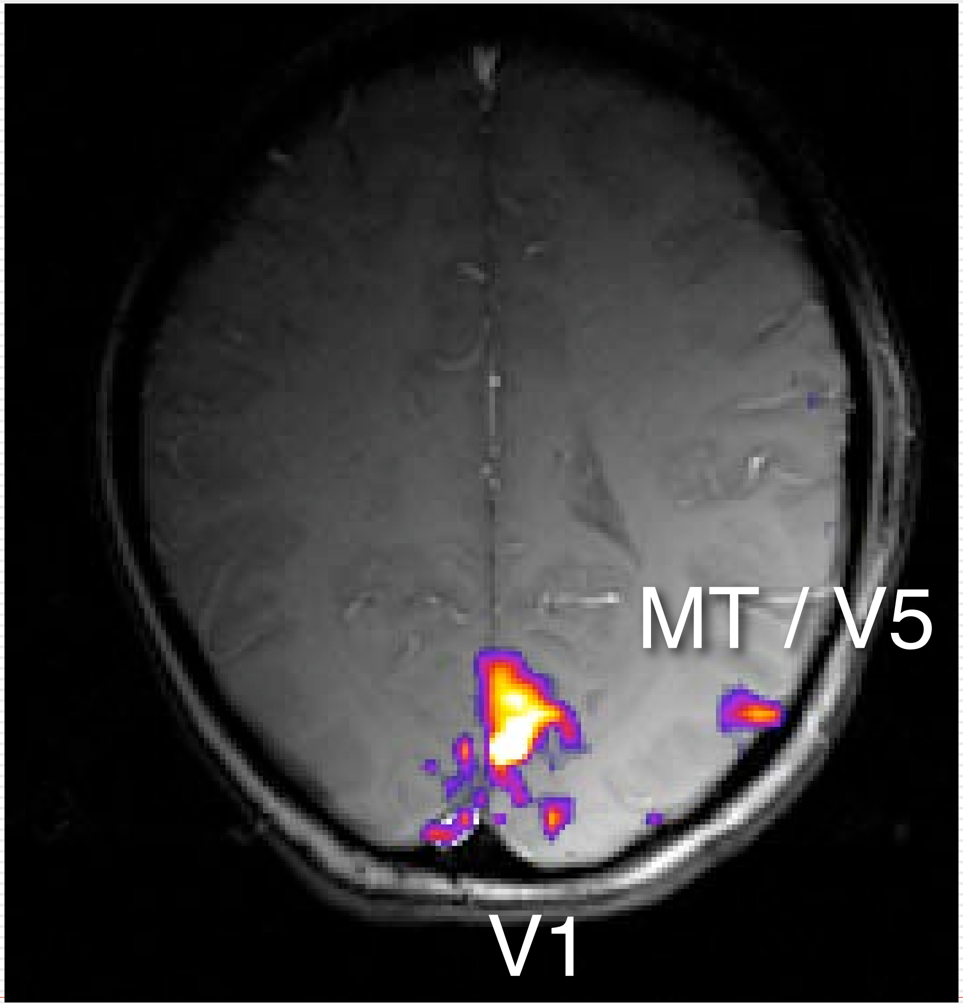
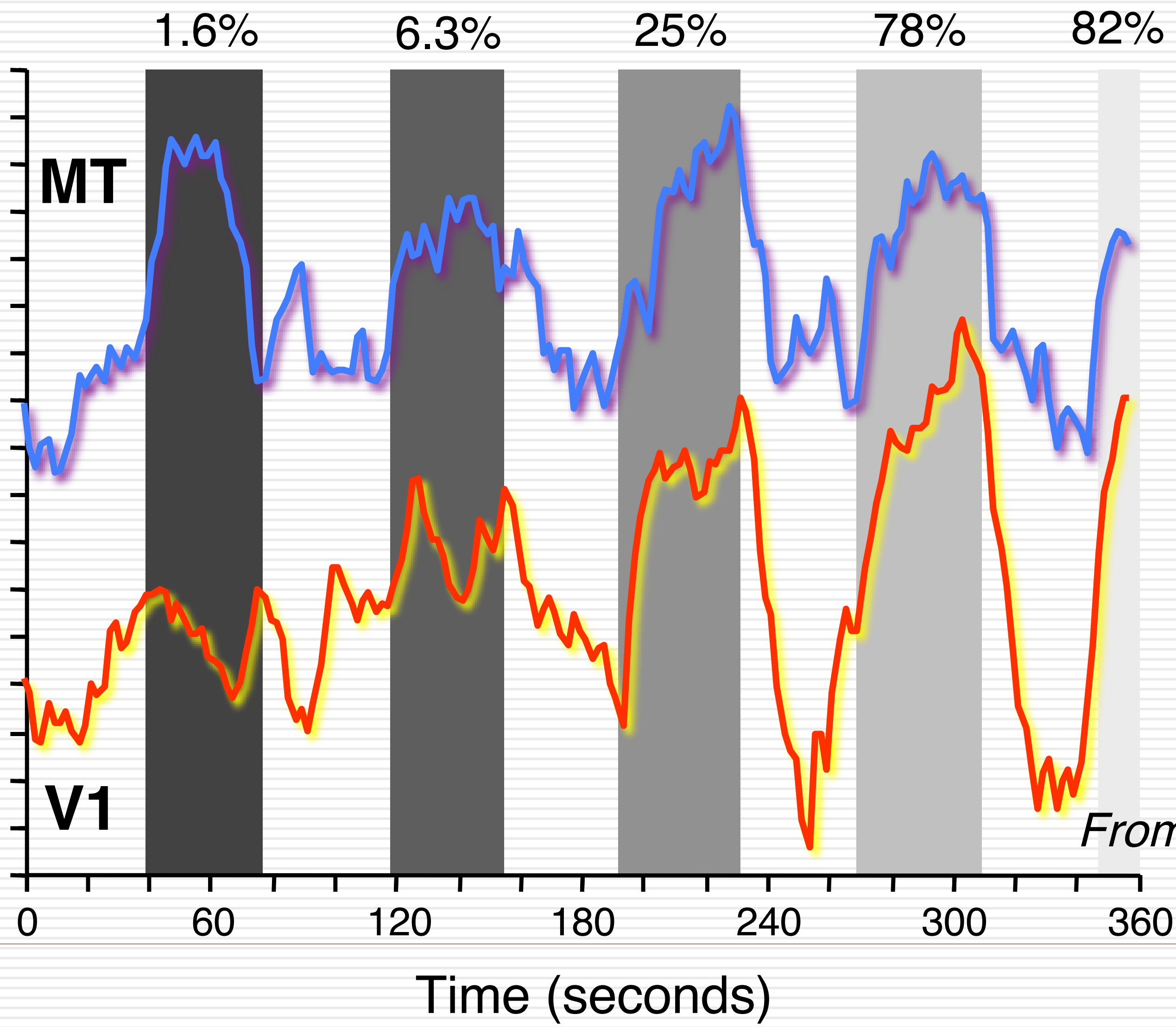
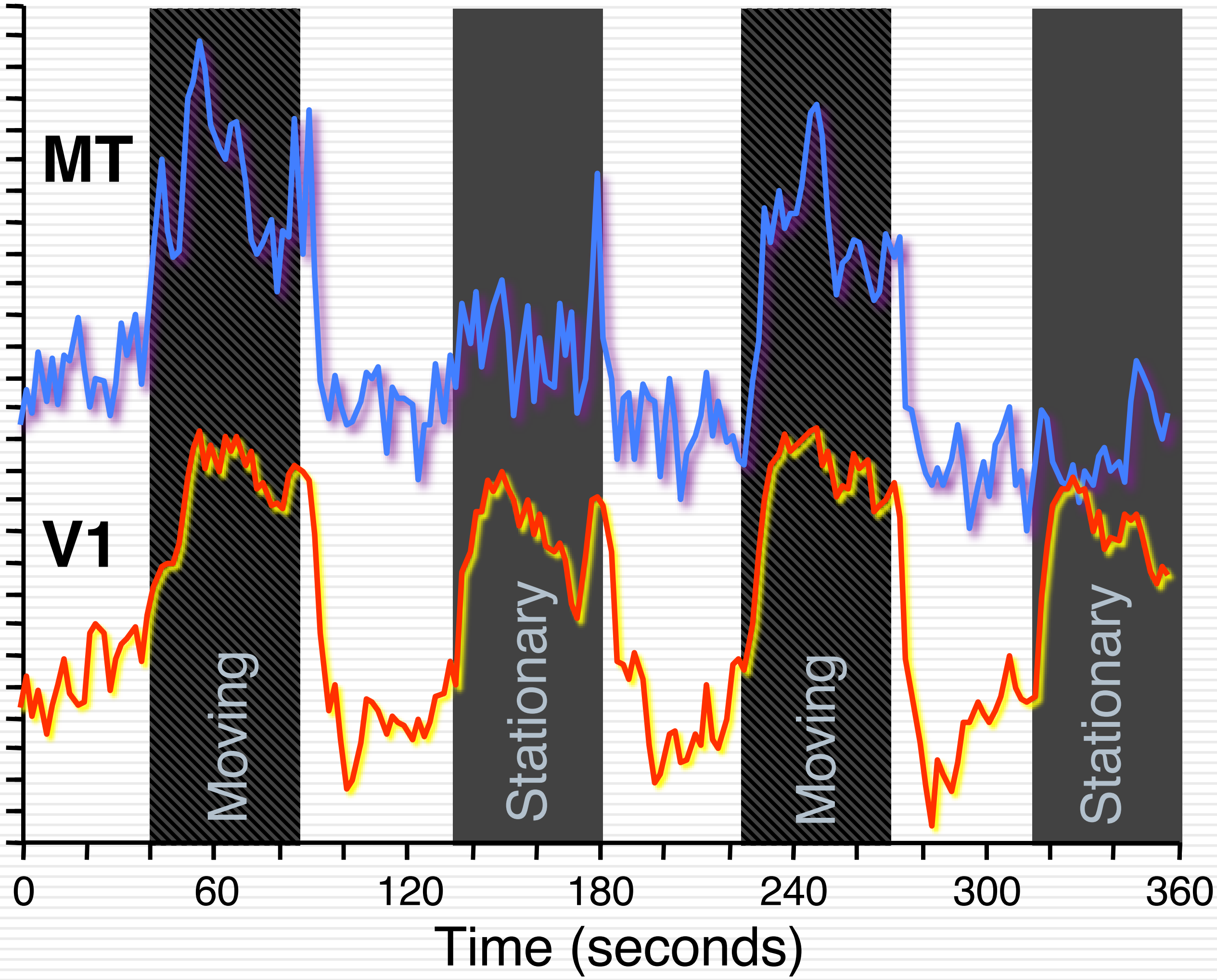
Activation with Moving Visual Stimuli



Contrast Response Test

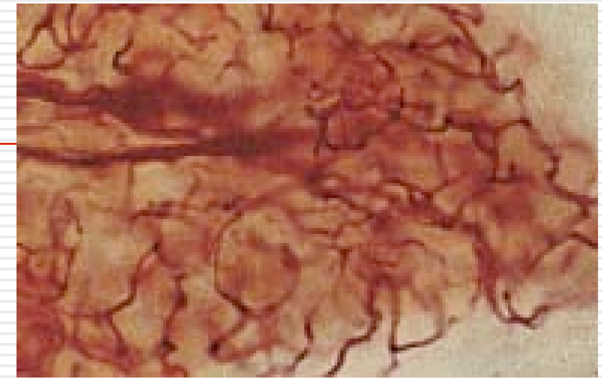


Motion Sensitivity Test



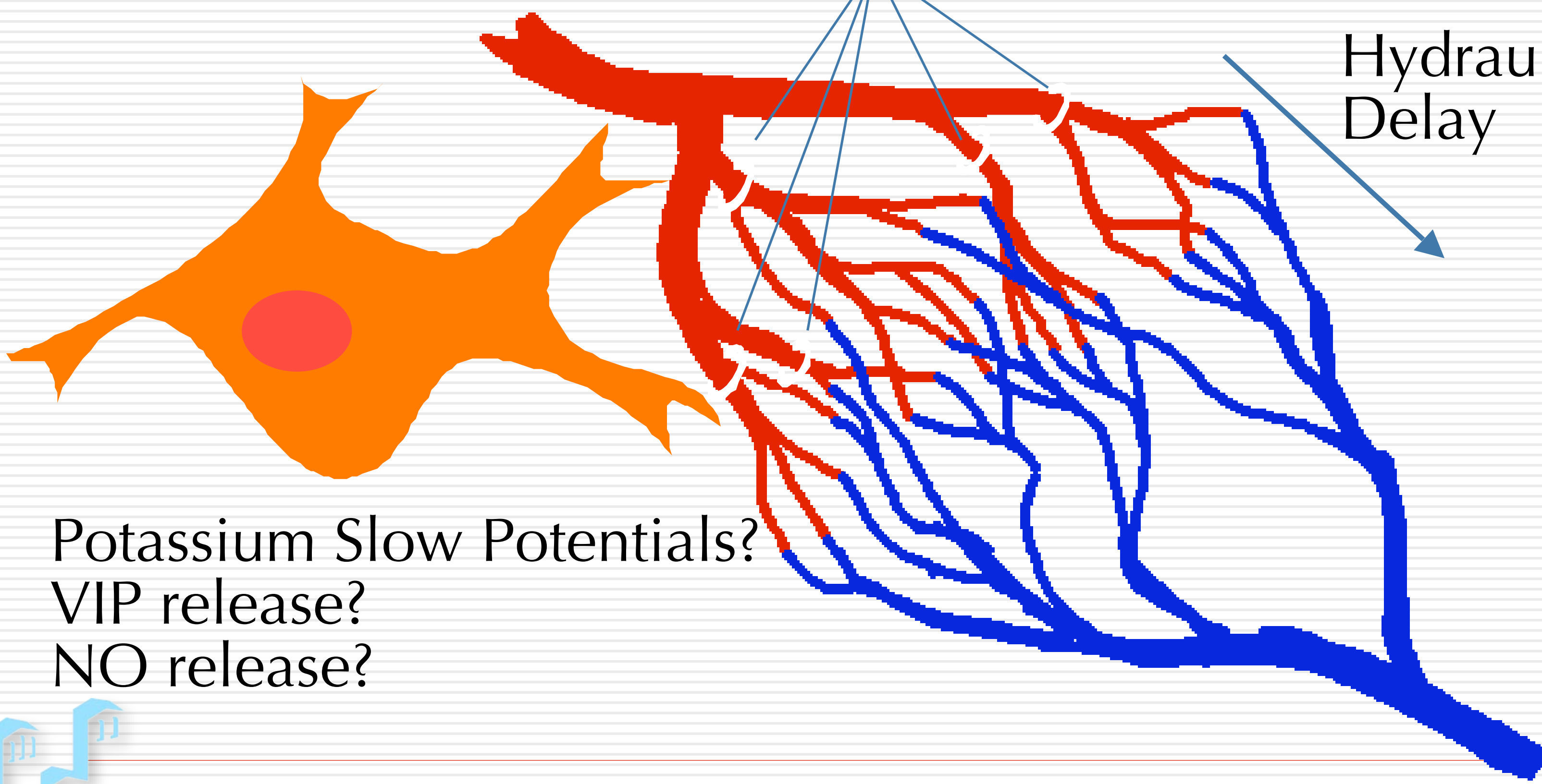
From R. Tootell

Neurovascular Coupling and *f*MRI latency



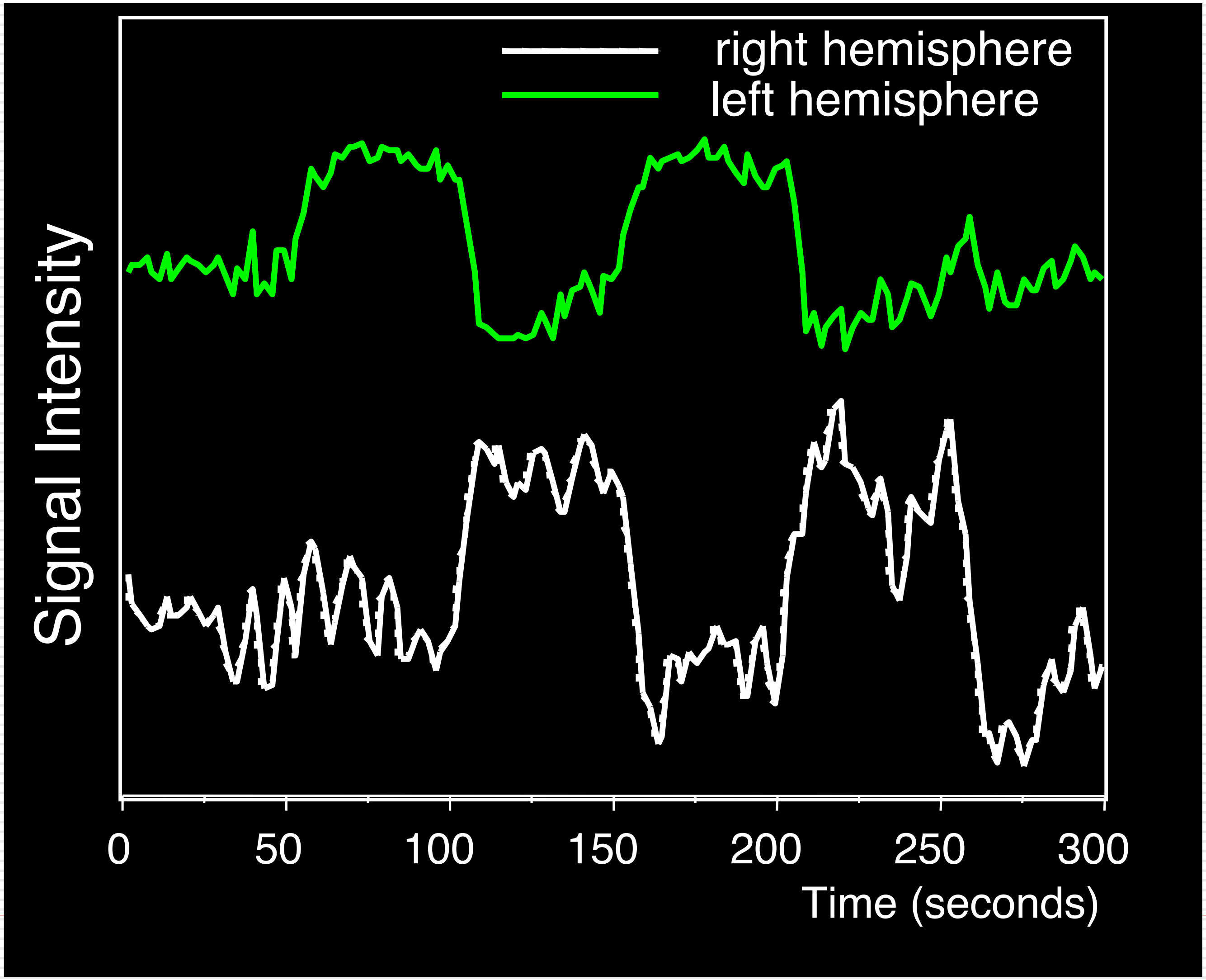
Pre-capillary Sphincters

Hydraulic Delay



Potassium Slow Potentials?
VIP release?
NO release?

Hemifield Alternation



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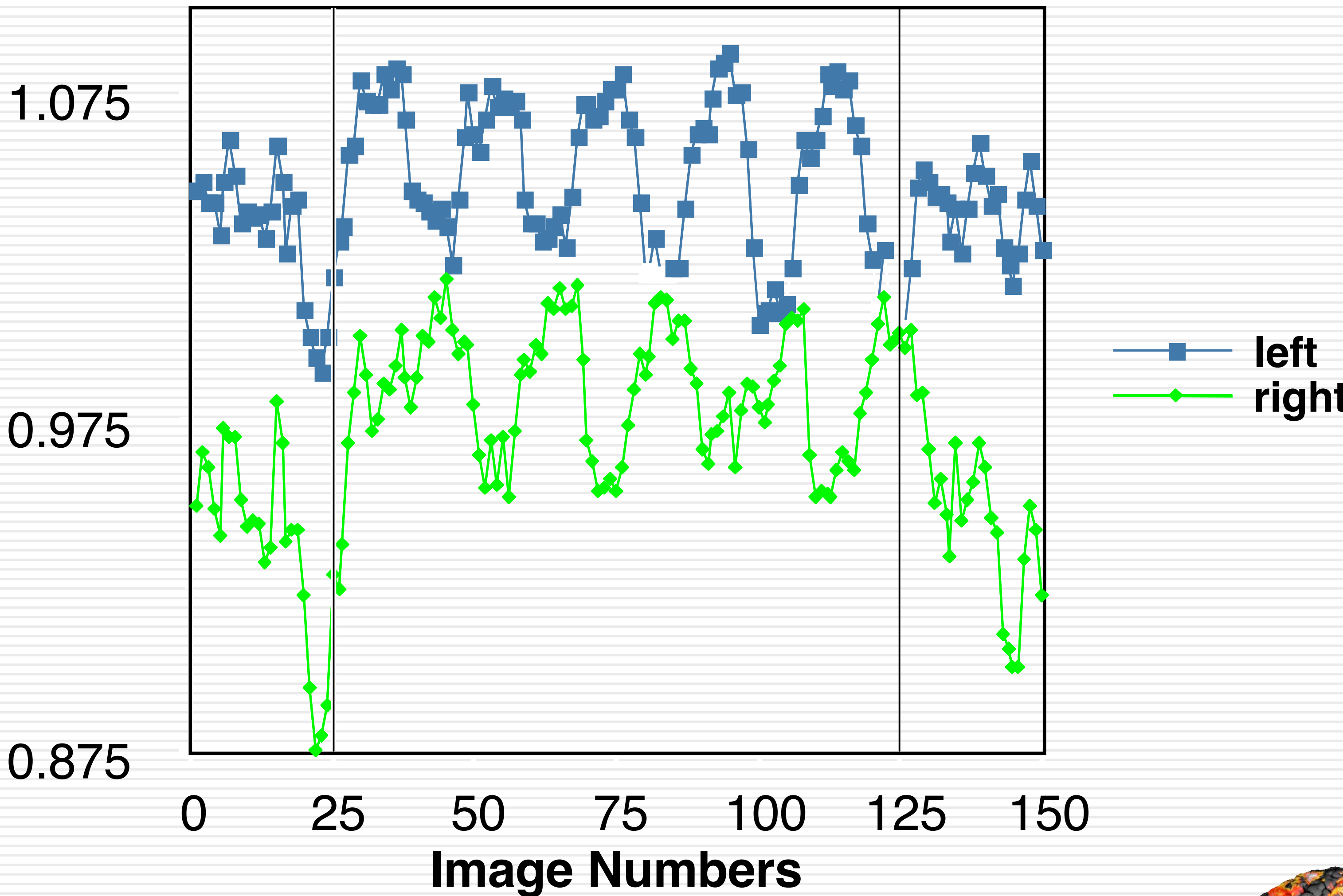
Hemifield Alternation 20 seconds



Linear Systems Approach

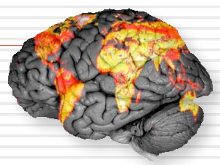
$x(t) \longrightarrow$

- Linear
- Time-Invariant
- (LTI) System

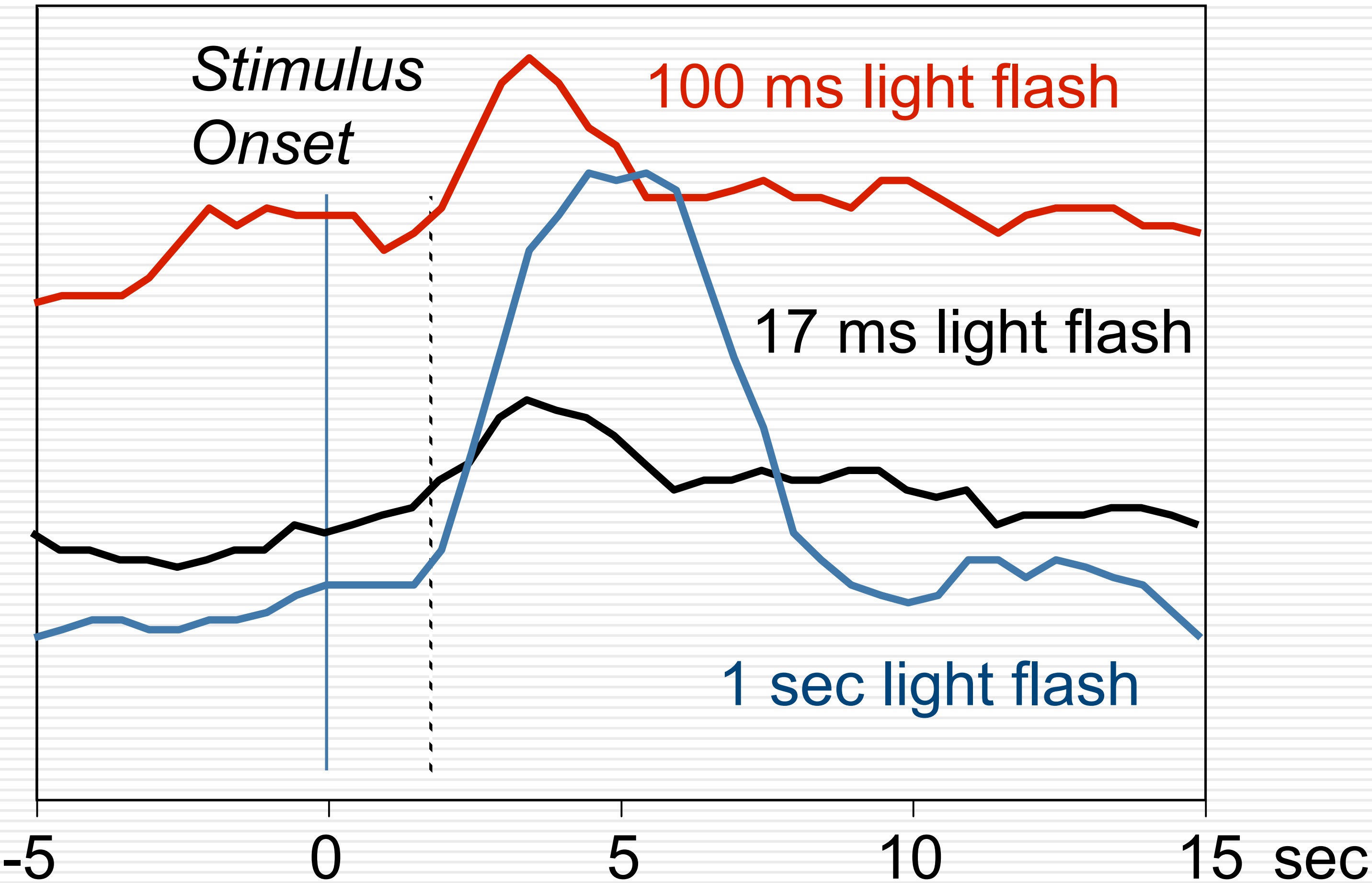
$\longrightarrow y(t) = f[x(t)]$

In an LTI system, given two inputs A & B:

$$f(\mathrm{A} + \mathrm{B}) = f(\mathrm{A}) + f(\mathrm{B})$$



Response Latency vs. Stimulus Duration
Average of 10 recordings



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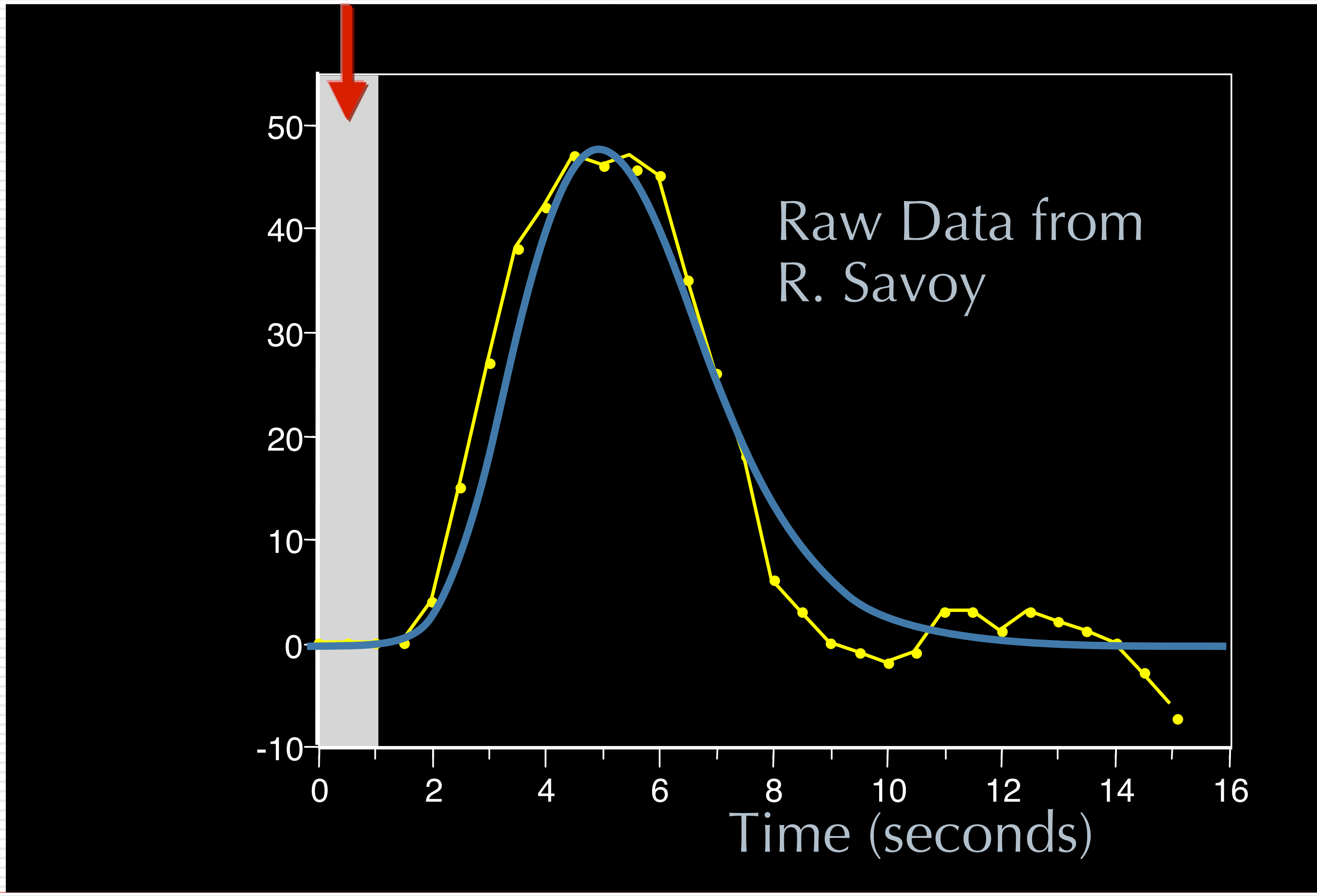
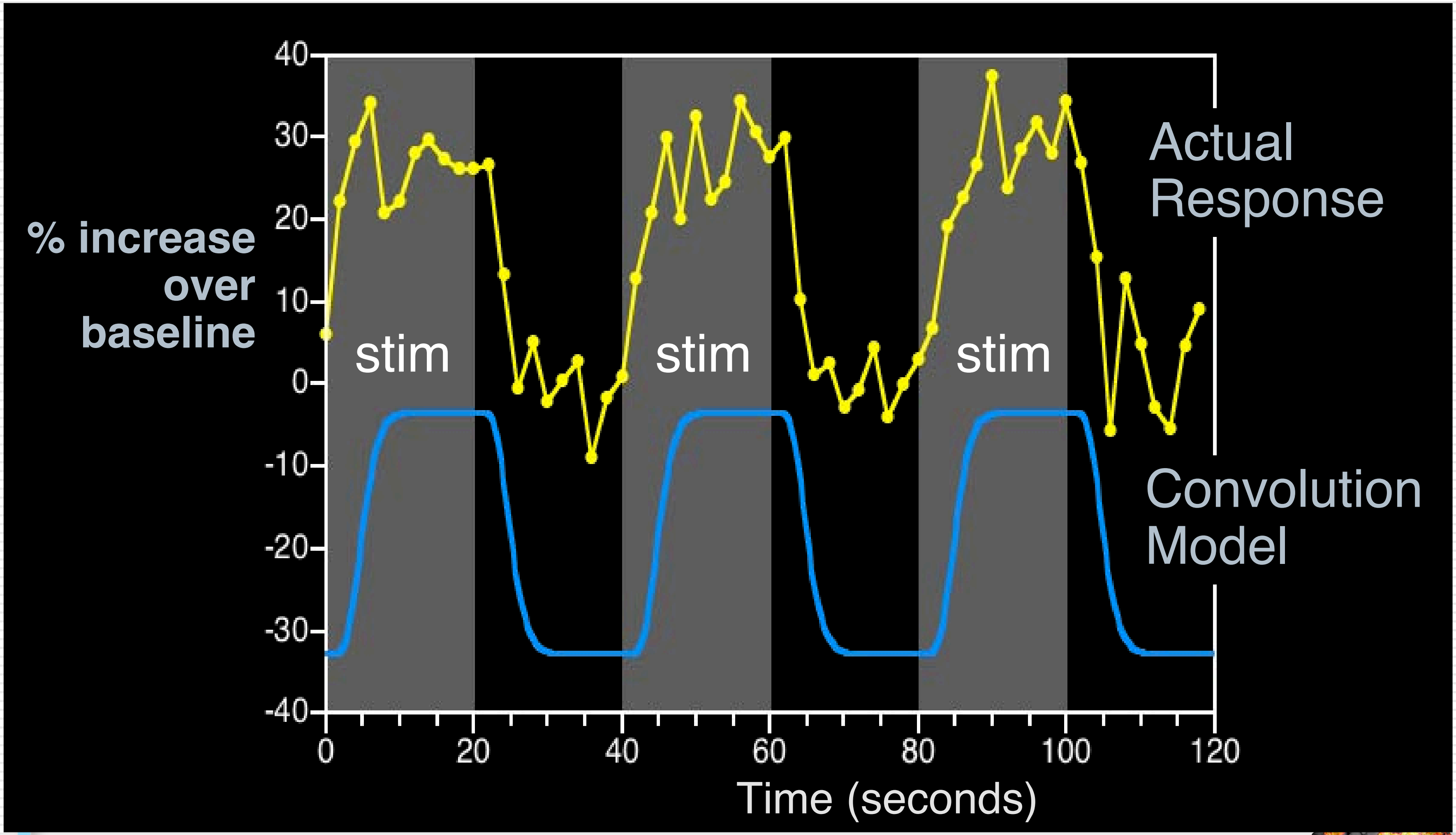
Data courtesy of Robert Savoy

Brain Impulse Response



Convolution of Impulse Responses with Stimuli



Linear Systems Approach

$x(t)$ →

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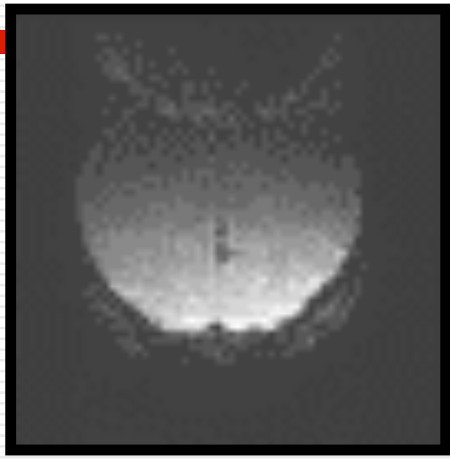
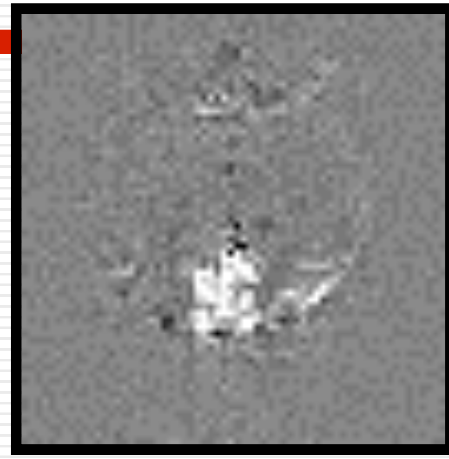
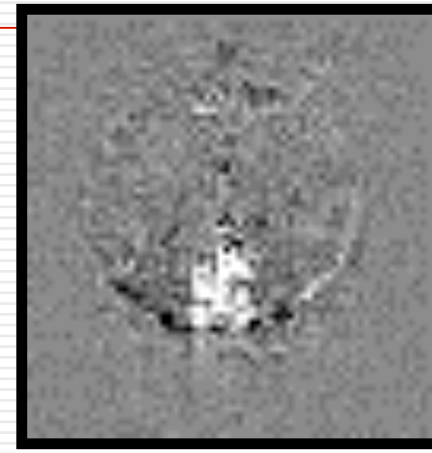
Binocular vs Monocular Activation



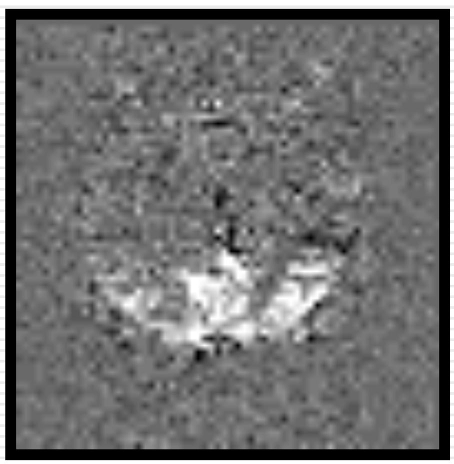
baseline



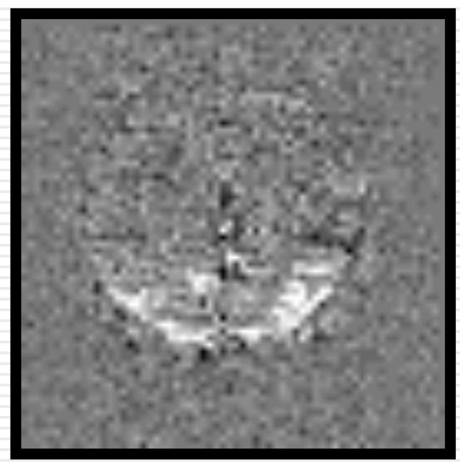
Binocular



Monocular

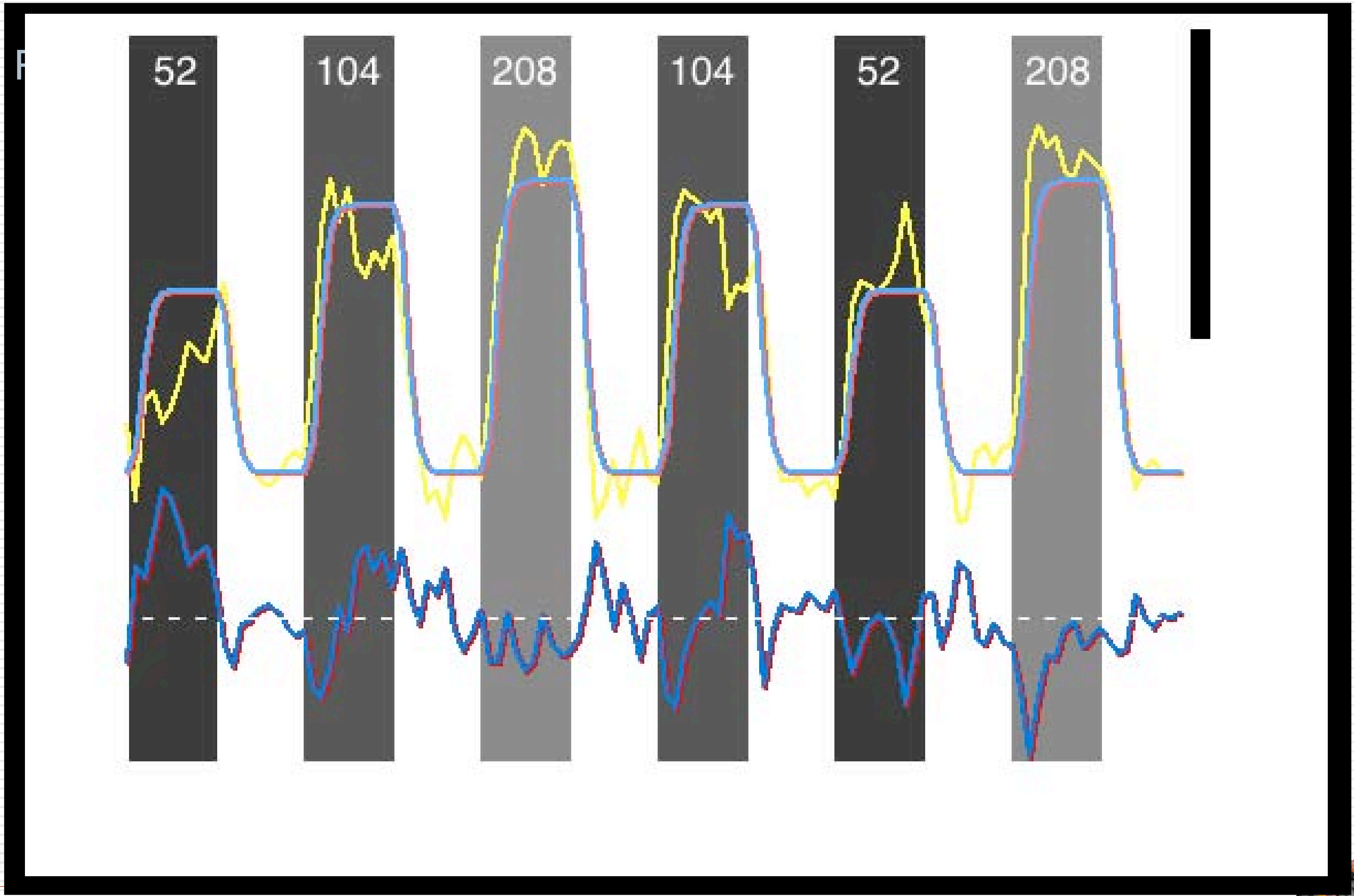


Bino minus Mono



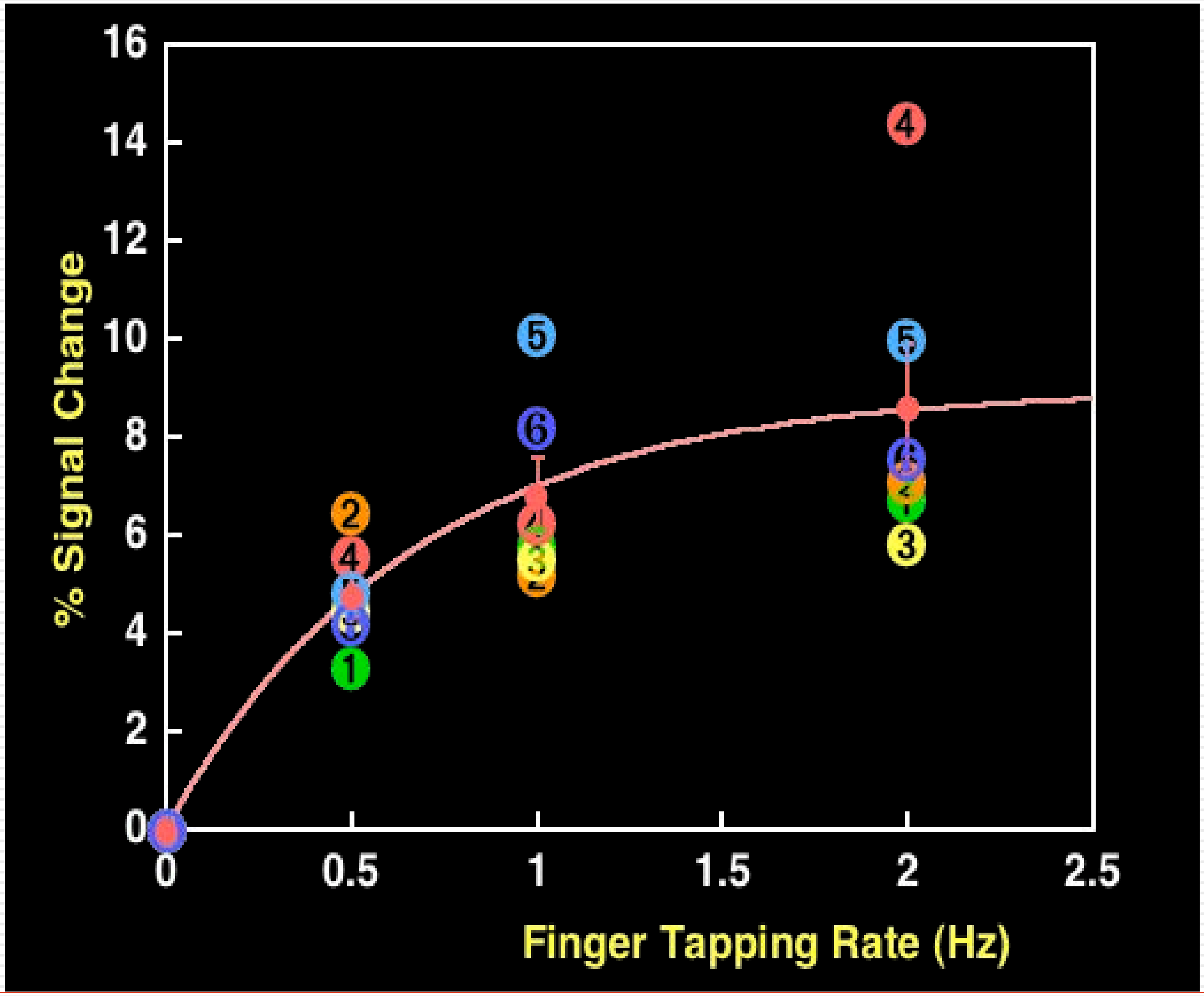
Extrastriate activation

Amplitude-weighted Linear Estimate



4/30/07

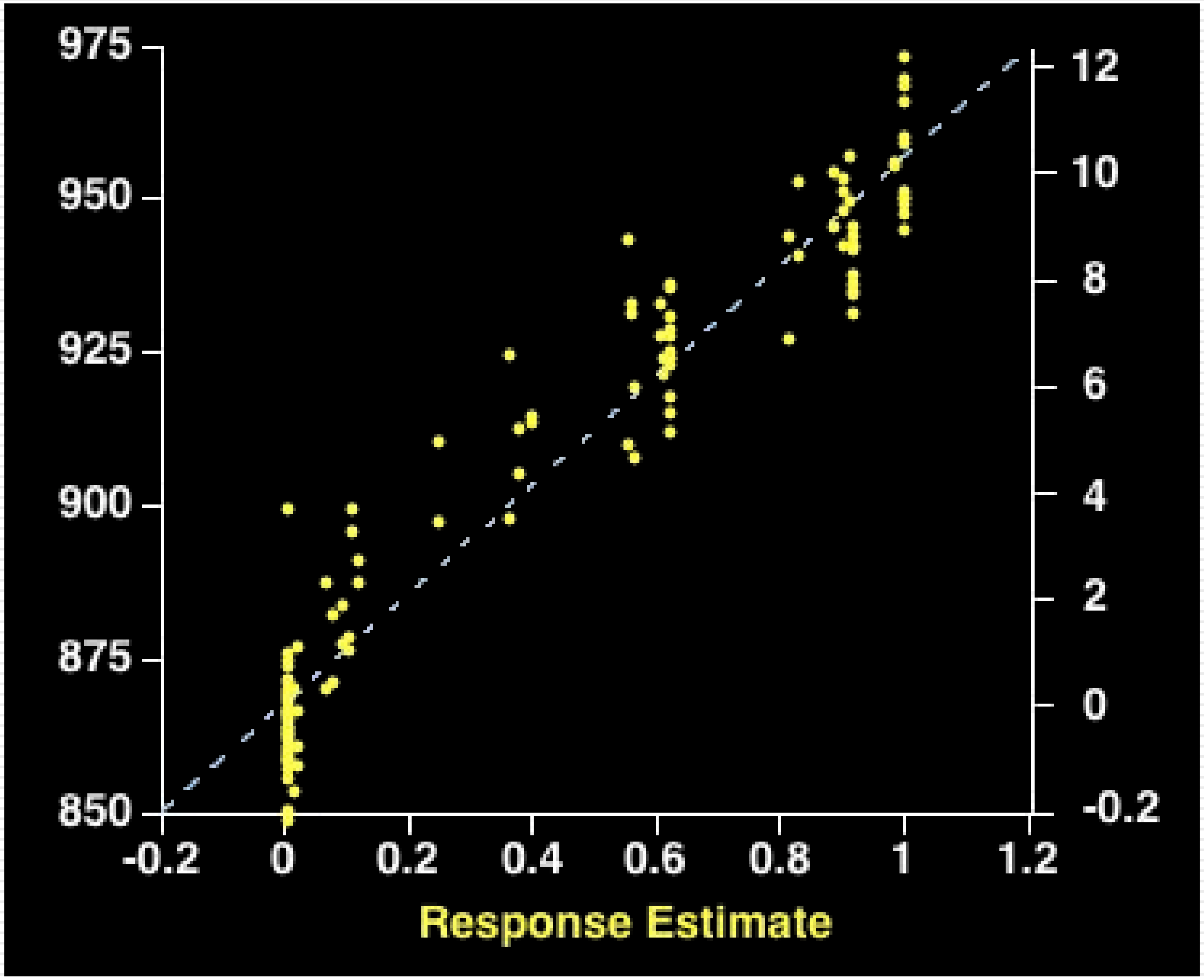
Repeated Rate Fits



(1.5 T conventional data)

Estimated vs. Actual *f*MRI Response

Signal Intensity



Signal Change (%)

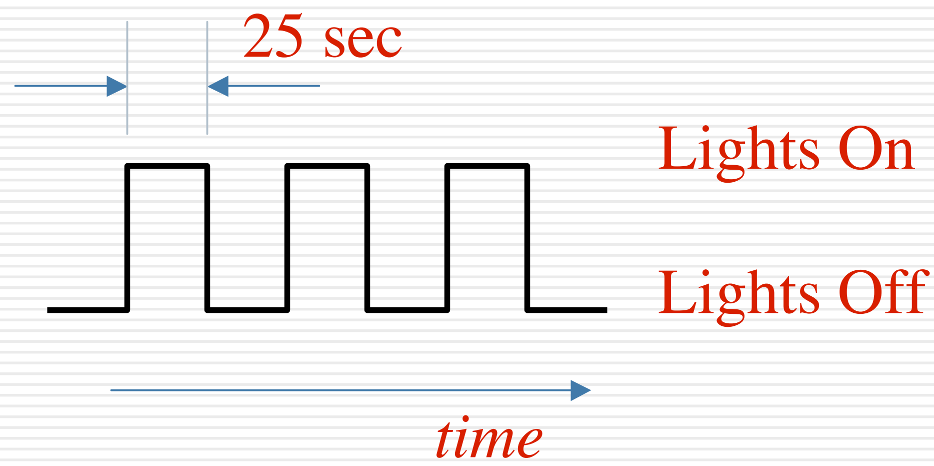
4/30/07

Some Theoretical Considerations

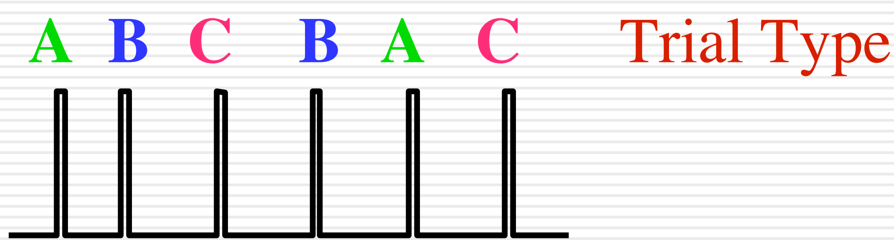
- Study Designs:
  - *Blocked*
  - *Single Trial*
- Predicting Responses
- Sources of Variance
- Resolution Limits:
  - *Temporal*
  - *Spatial*

Blocked vs. Single Trial

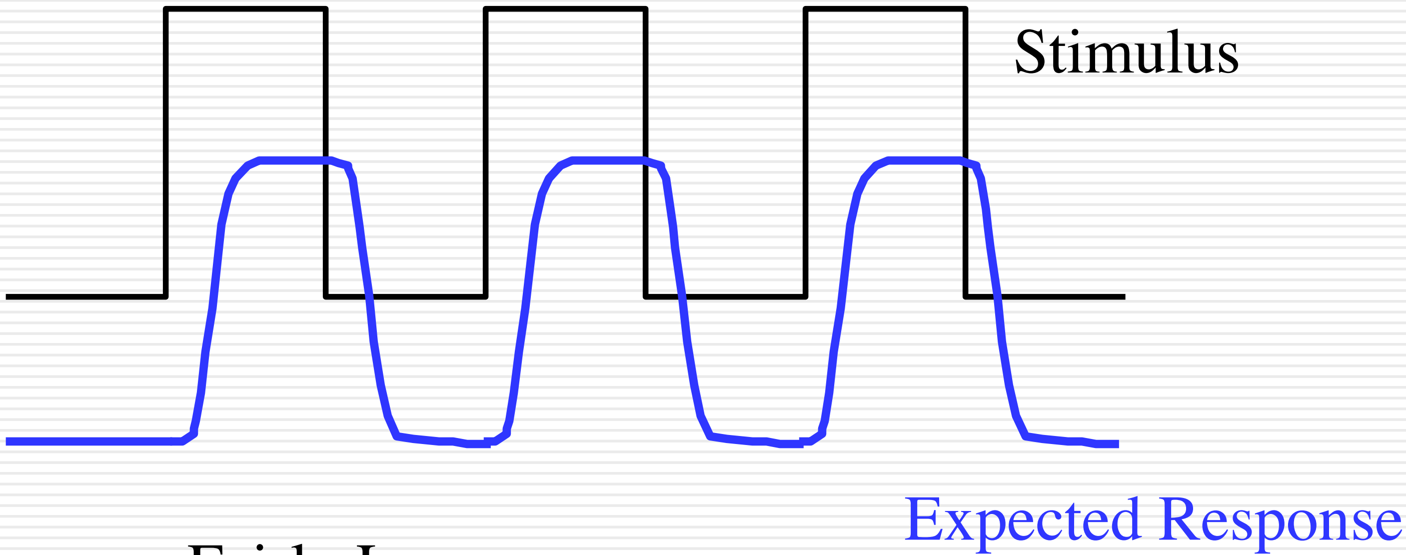
Typical Blocked Design



Typical Single Trial Design



Blocked Experiments



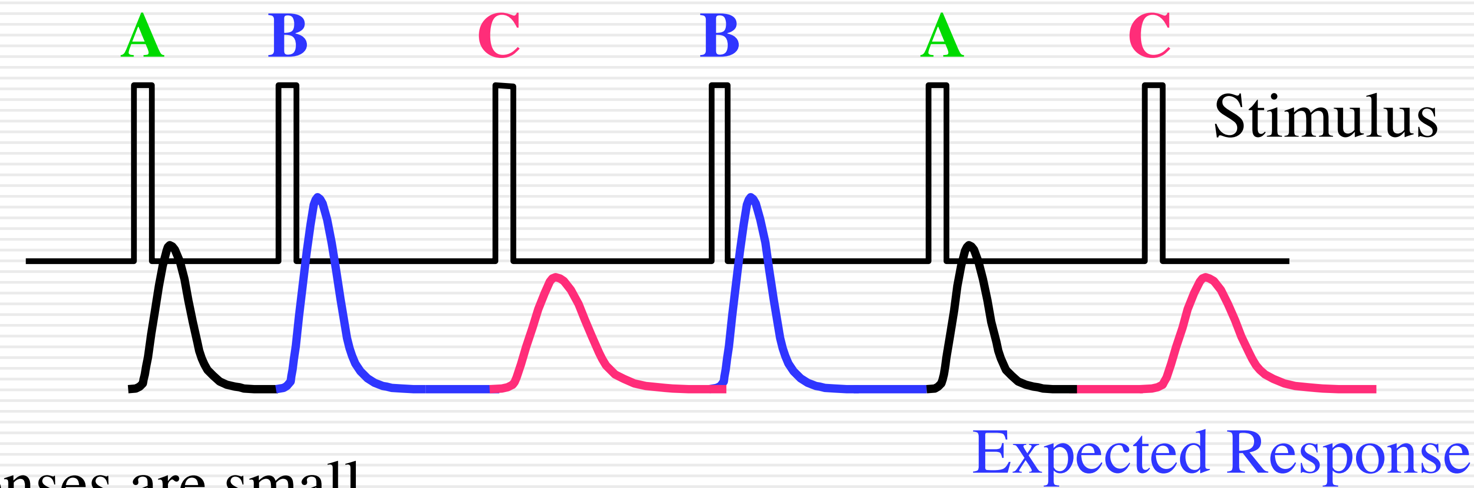
•Responses are Fairly Large

•Data are Easy to Analyze

•With Long Blocks, Time course can be Ignored

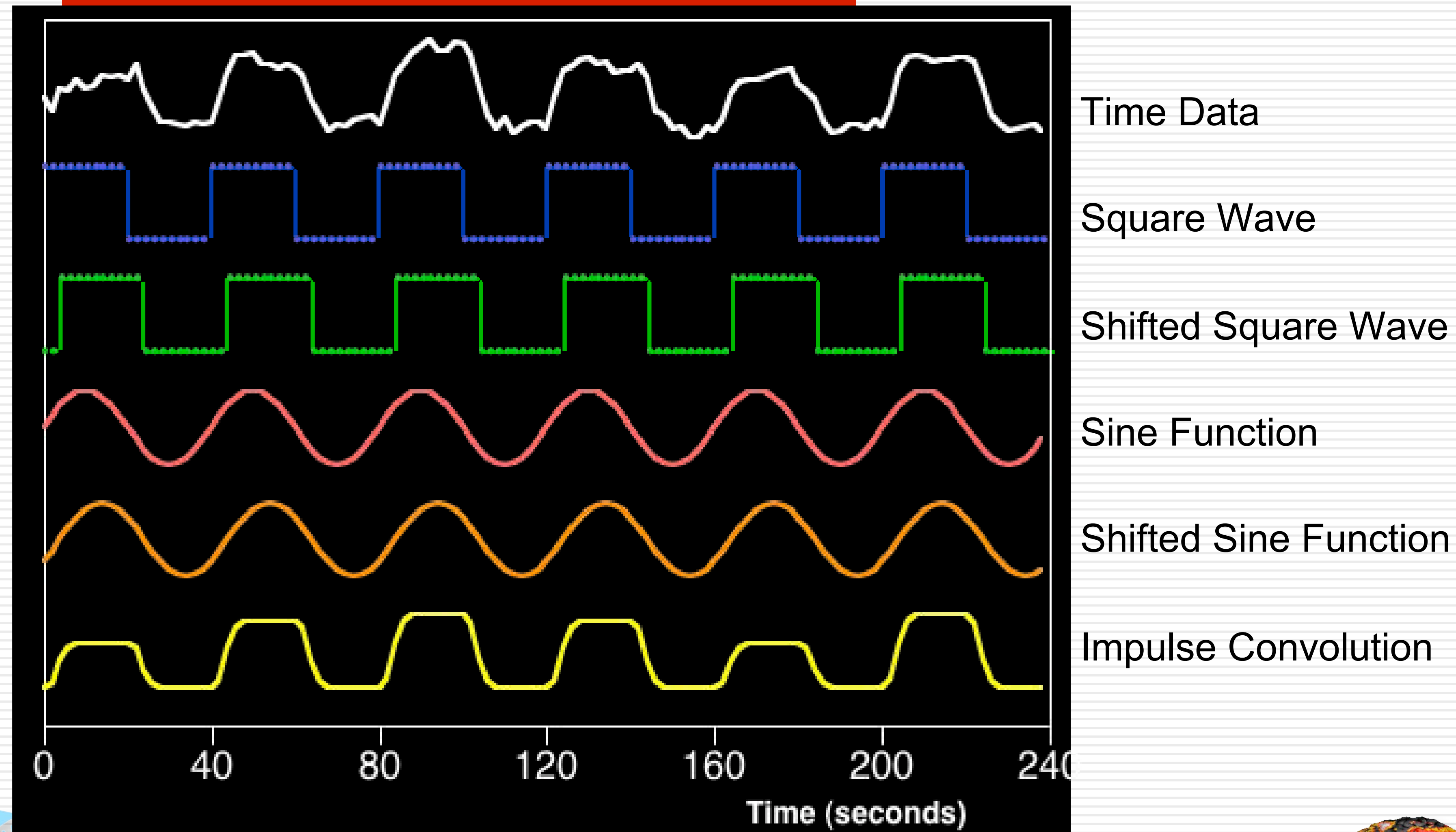
•All trials within a block are treated as Identical

Single Trial Designs

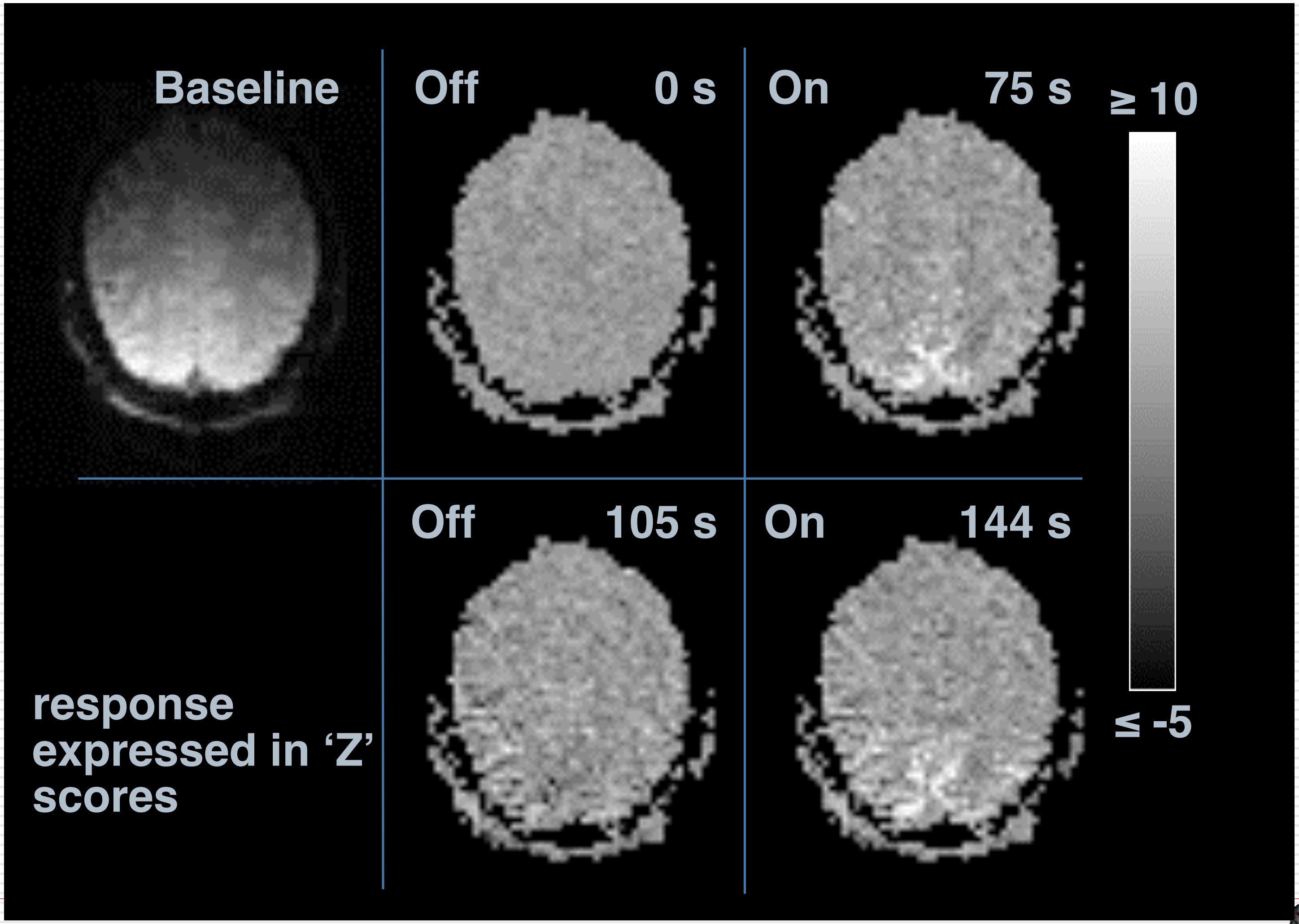


- Responses are small
- Useful contrast/noise is low
- Data are more Challenging to Analyze
- Exact Time course is Modeled or a Dependent Variable
- Suitable for Randomized Stimulus Designs

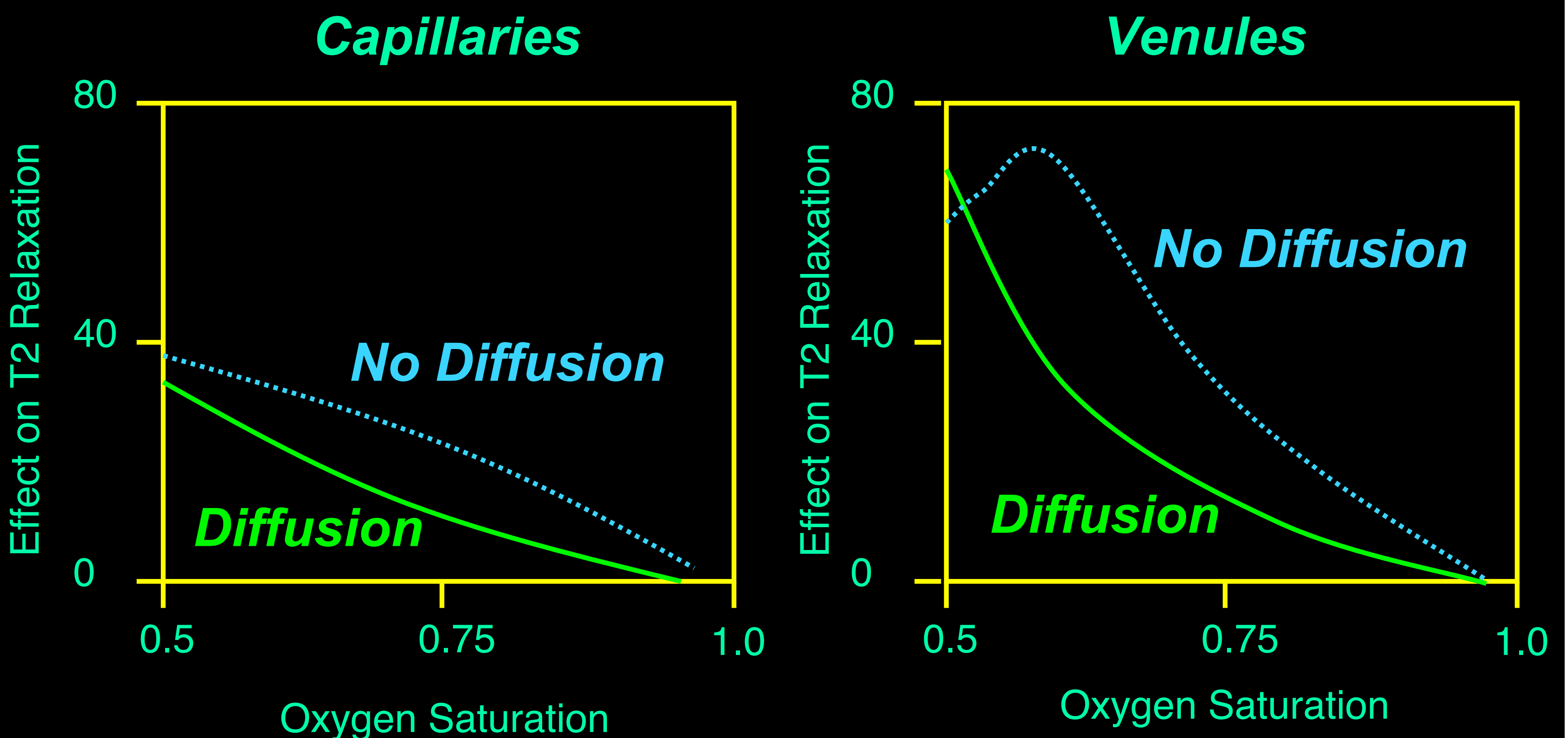
Reference Functions Used in *f*MRI



8 Hz checkered flash stimulation



Intravascular BOLD Effects



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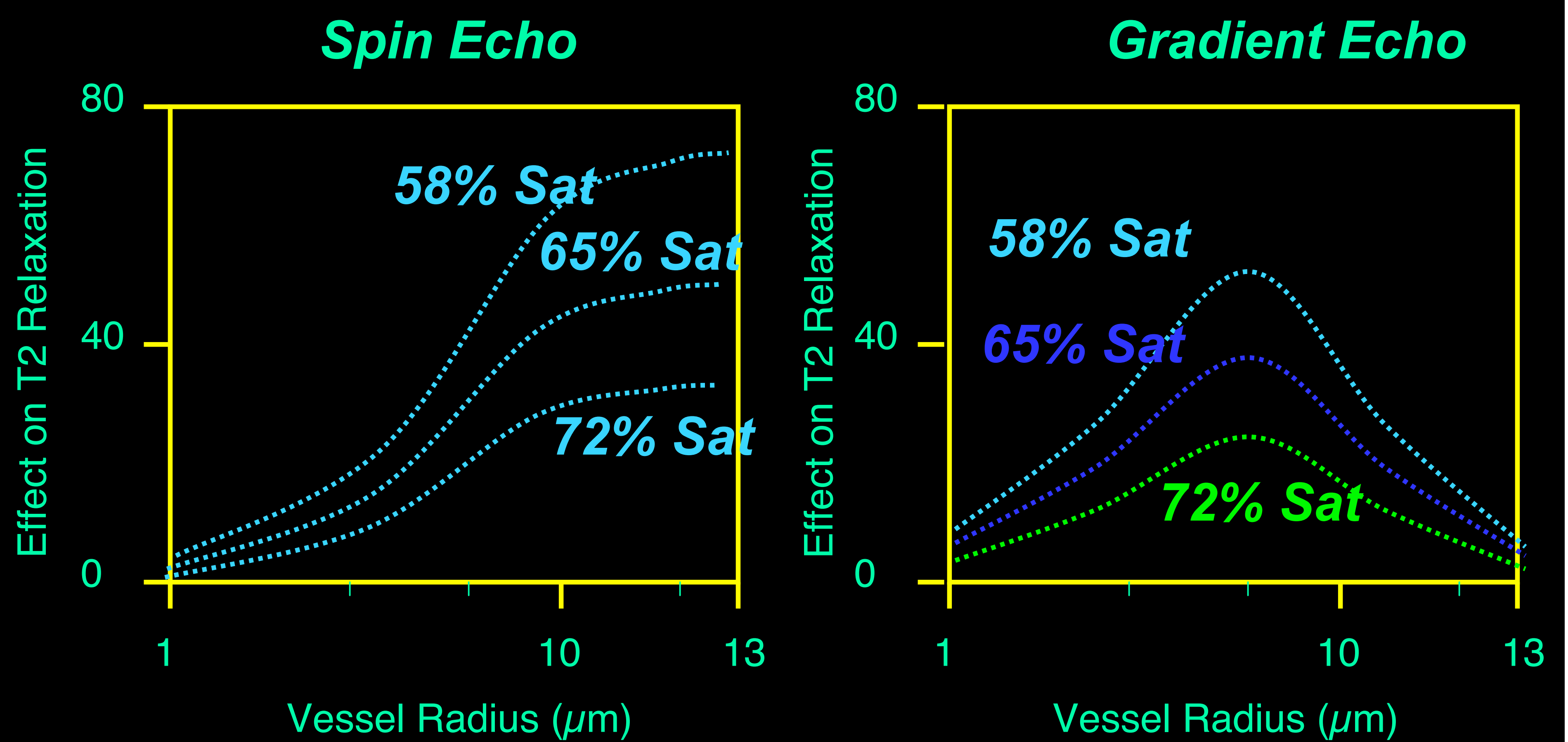
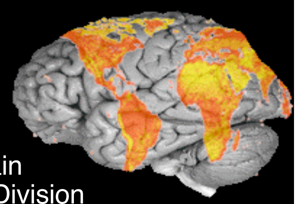
Extravascular BOLD Effects (@1.5T)





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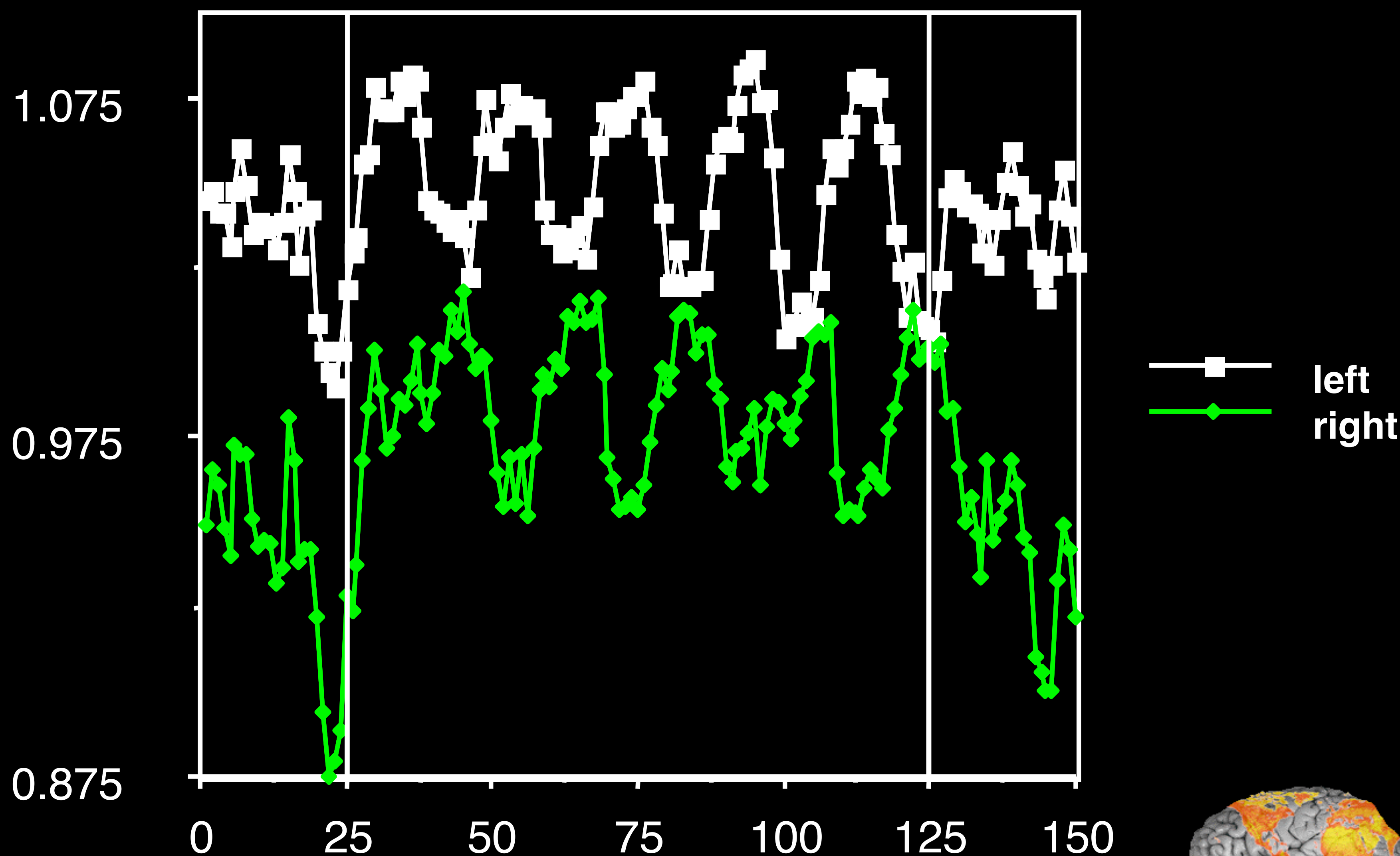
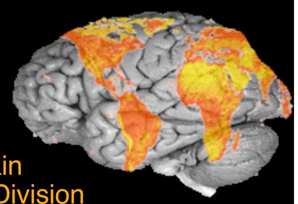
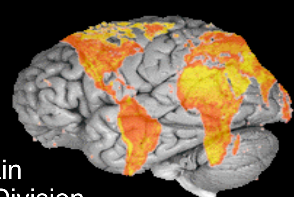
mifield Alternation - 20 seconds





Some Applications of *f*MRI

Pre-surgical evaluation
Cognitive Neuroscience
Neuropyschiatric Disorders



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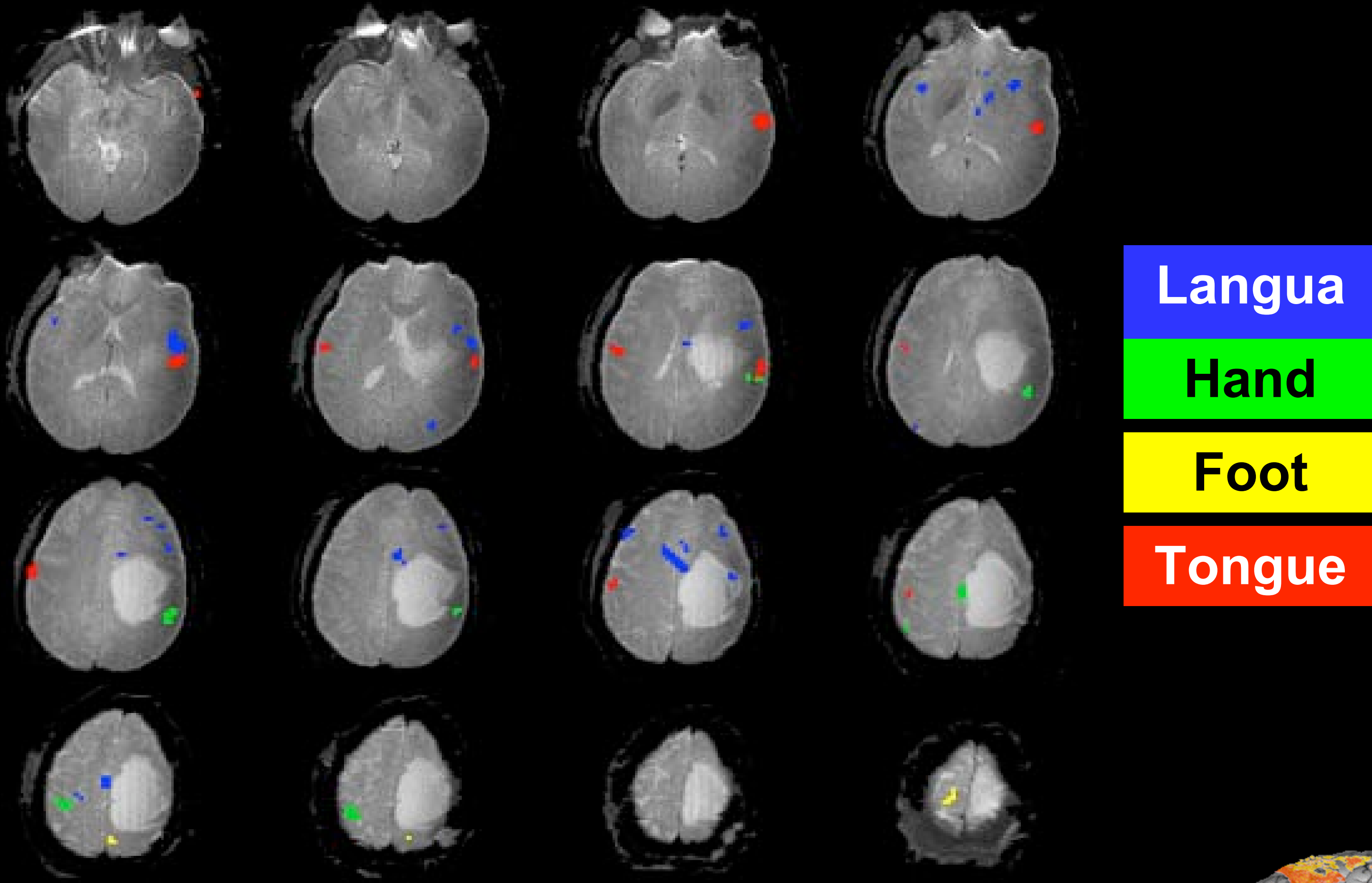
Clinical Example

Clinical Mapping Summary



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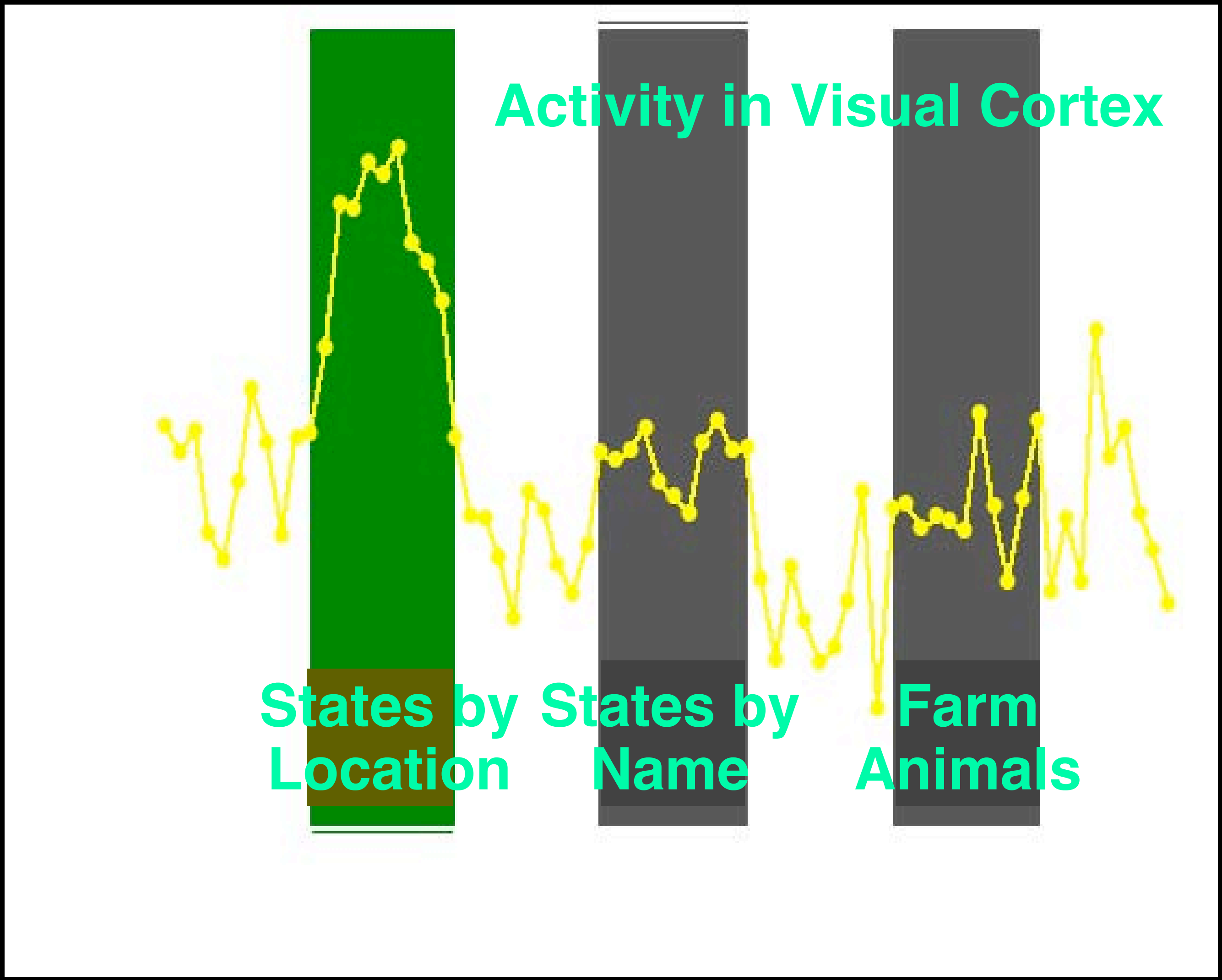
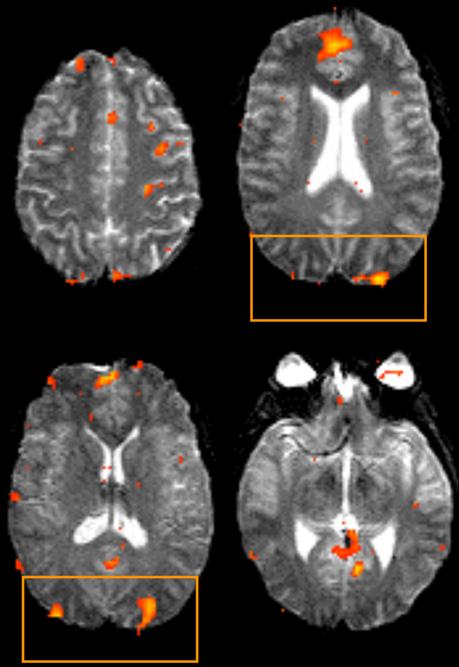
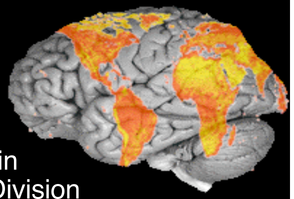
Geographic Imagery





Monique Cherrier



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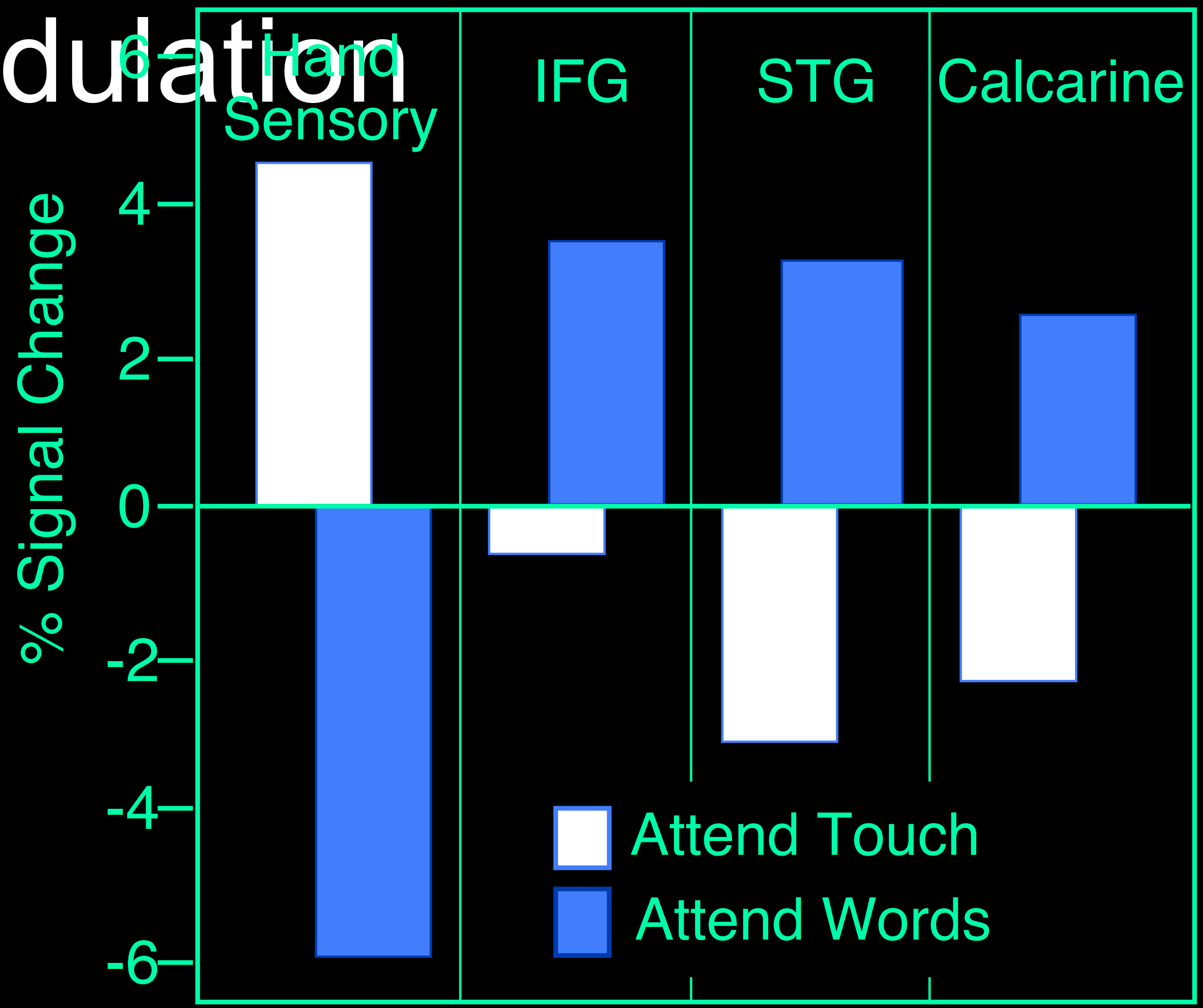
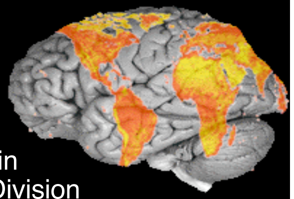
Attentional Modulation

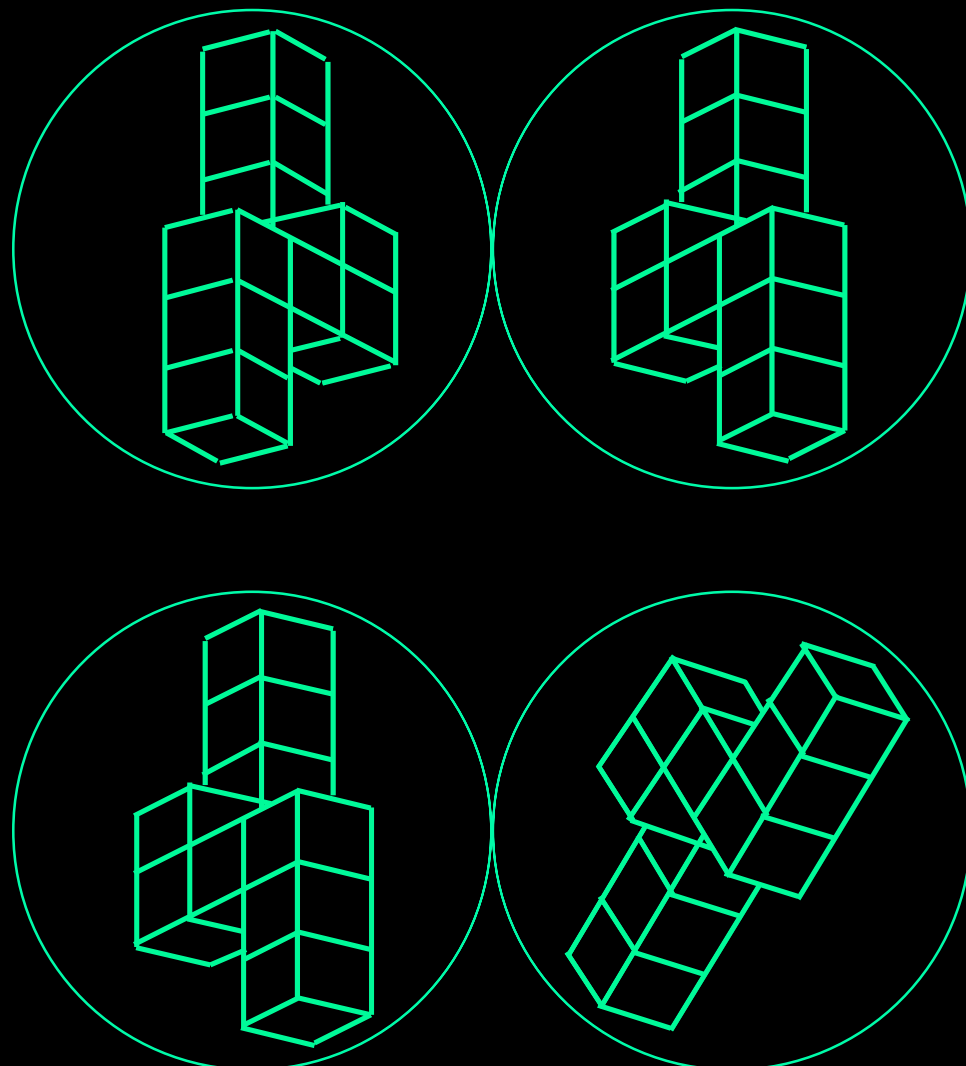




Mental Rotation - Stimuli

Control

Task



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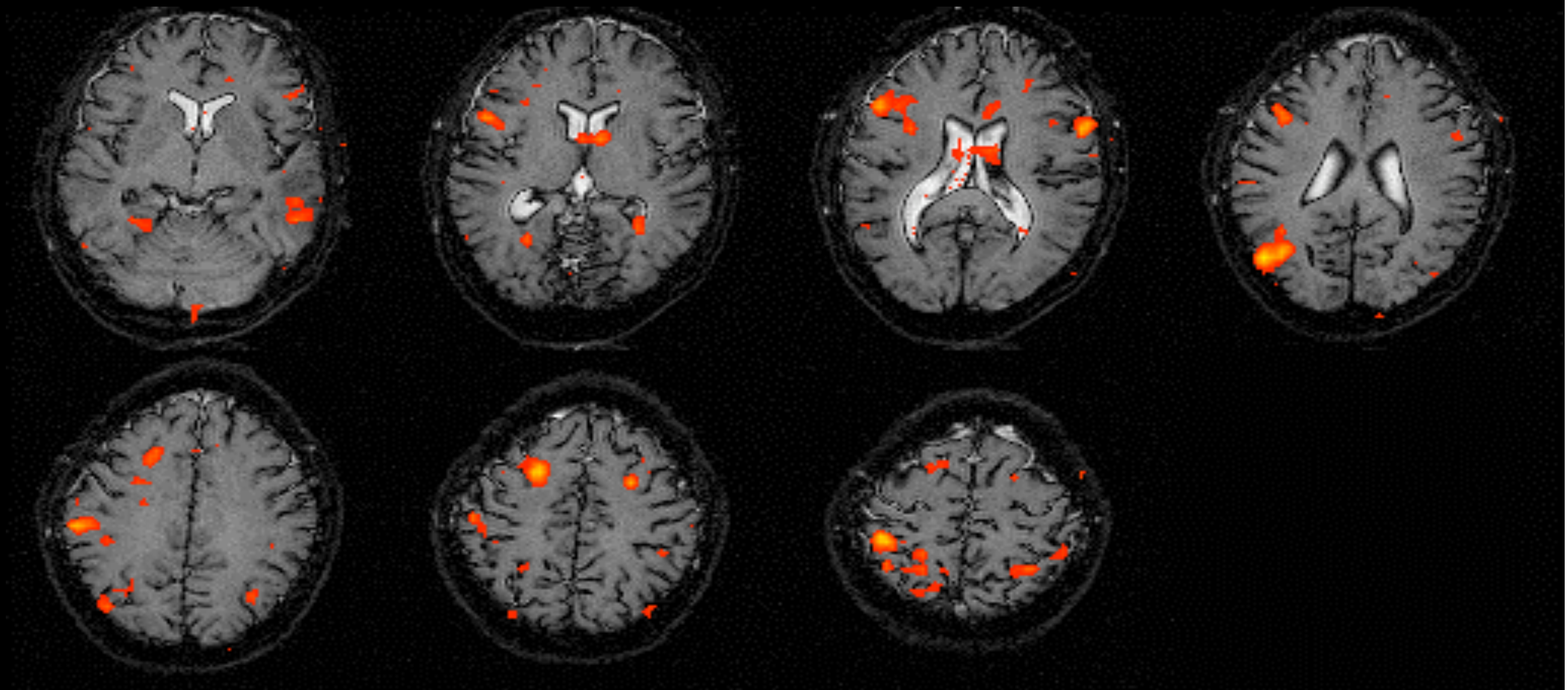
Mental Rotation - Localization



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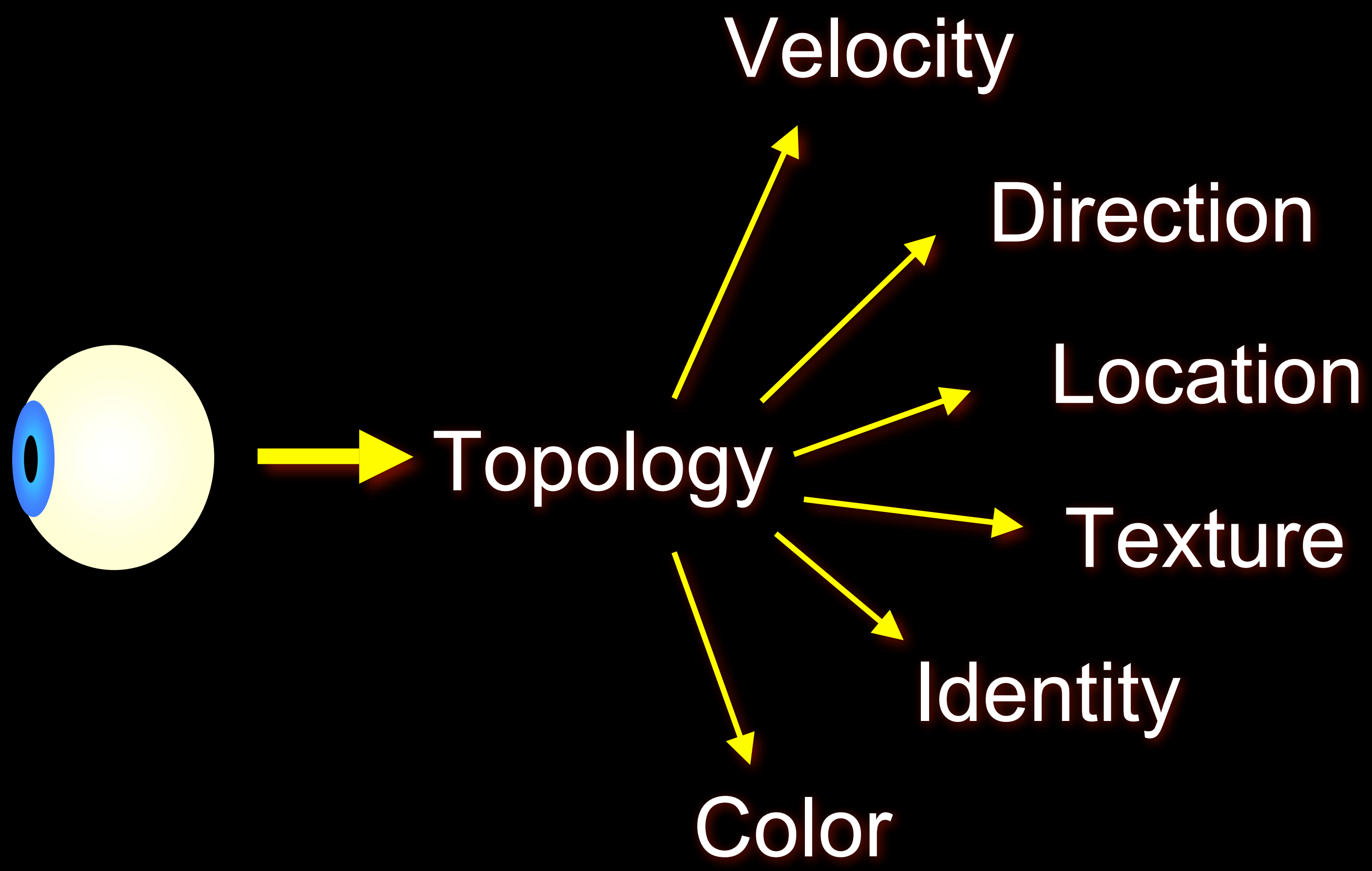
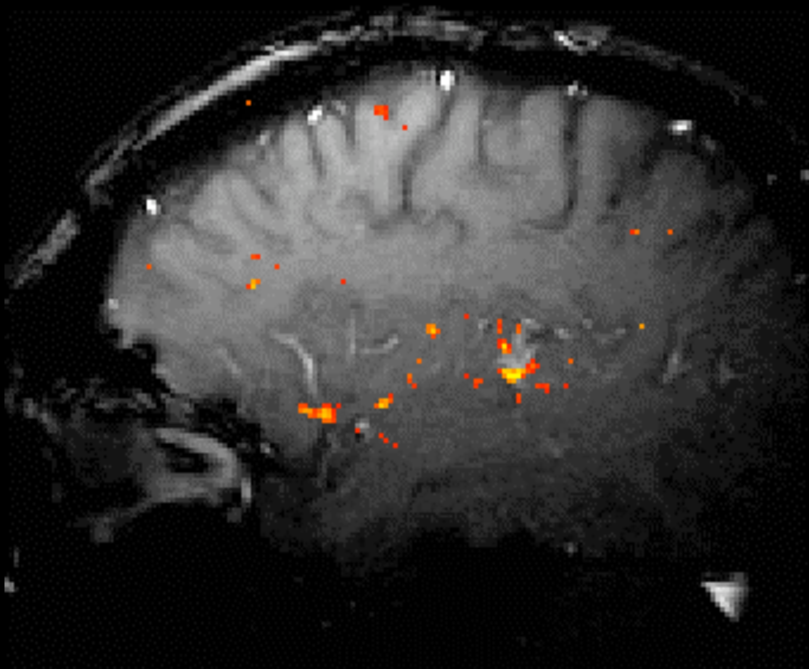
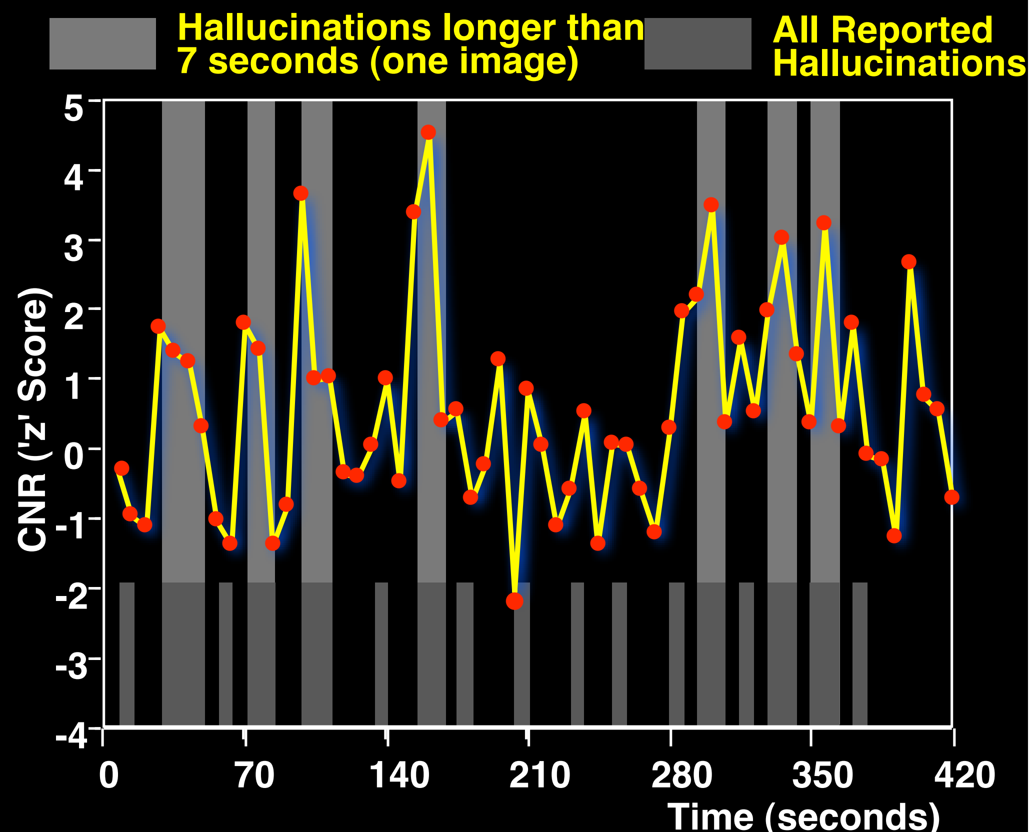
Distinct Visual Pathways



Results - Auditory Hallucinations





With Michael Green

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Some Theoretical Considerations

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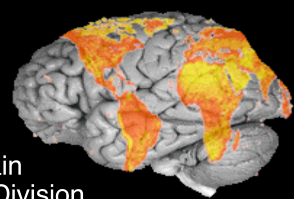

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