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 =

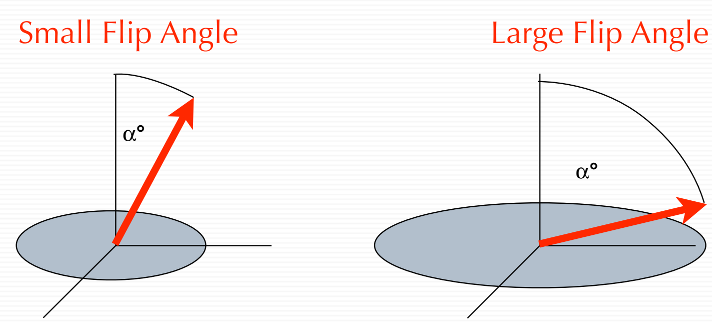
Repetition Time (TR)
x Number of Phase Encodes
x NEX (Averages)
x Number of 3D Steps

TR and Image Quality

Reduced TR Yields:

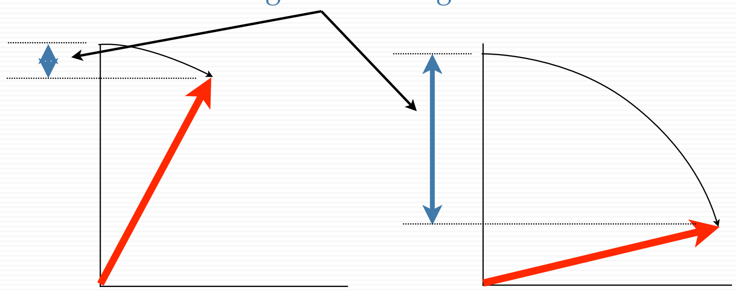
- Decreased Scan Time
- Increased T1 Contrast
- Reduced (Useable) T2 Contrast
- Reduced Signal to Noise Ratio
- Increased Power Deposition
- Reduced Slice Coverage

Signal and Flip Angle



Small and Large Flip Angle

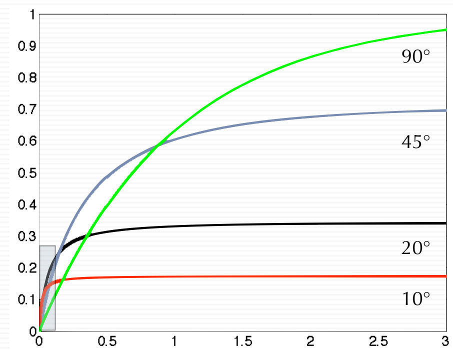
Loss of Longitudinal Magnetization

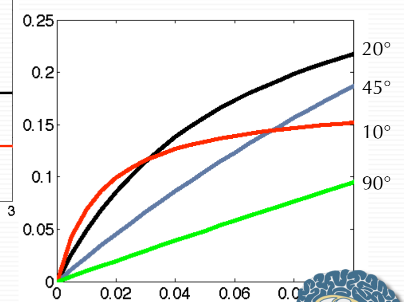


Small Flip Angle

Large Flip Angle

Flip Angle and TR/T1



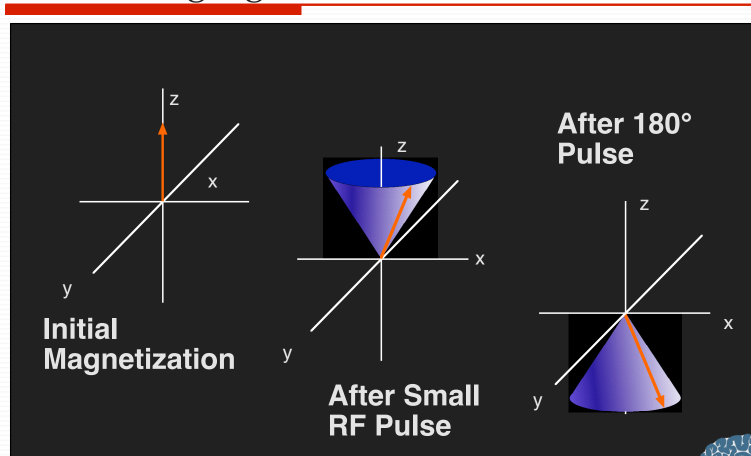


Contrast and Flip Angle

rge Flip Angles	Short	Long
Long	Proton Density	T2* Weighted
Short	T1 Weighted	

nall Flip Angles	Short	Long
Long	Proton Density	T2* Weighted
Short	Proton Density	T2* Weighted

A 180° Pulse is not used in FLASH imaging



T2 and T2*

T2: Transverse Magnetization Decay from Spin-Spin Interactions

T2*: Transverse Magnetization Decay from Local Magnetic Field Variations

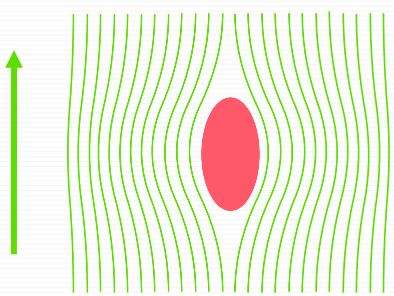
Magnetic Susceptibility

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

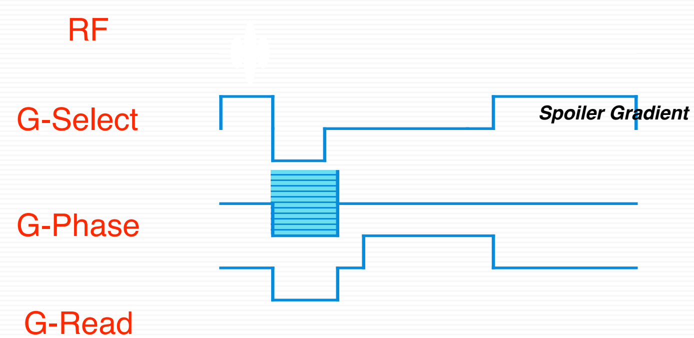
Magnetic Susceptibility

Objects with Susceptibility Different than Air Distort the Magnetic Field

Applied Magnetic Field

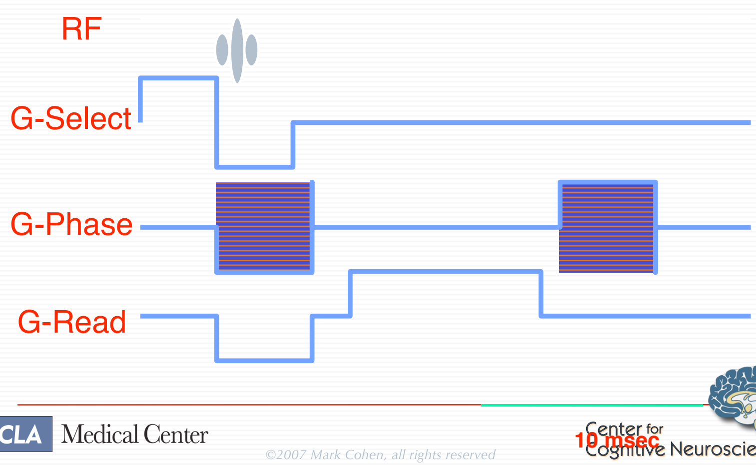


FLASH Timing Diagram

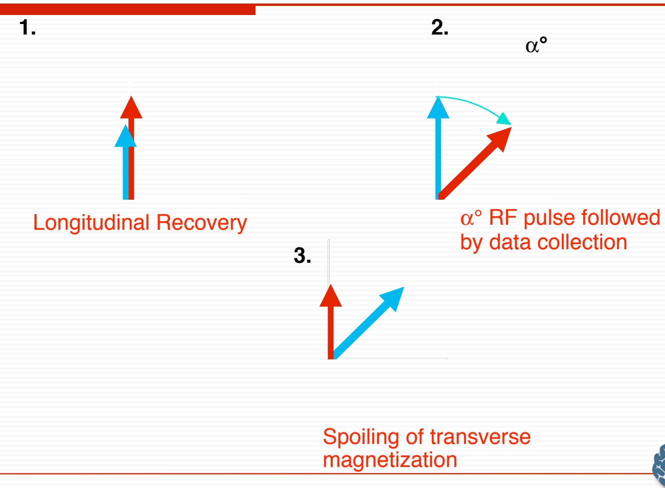


10 msec

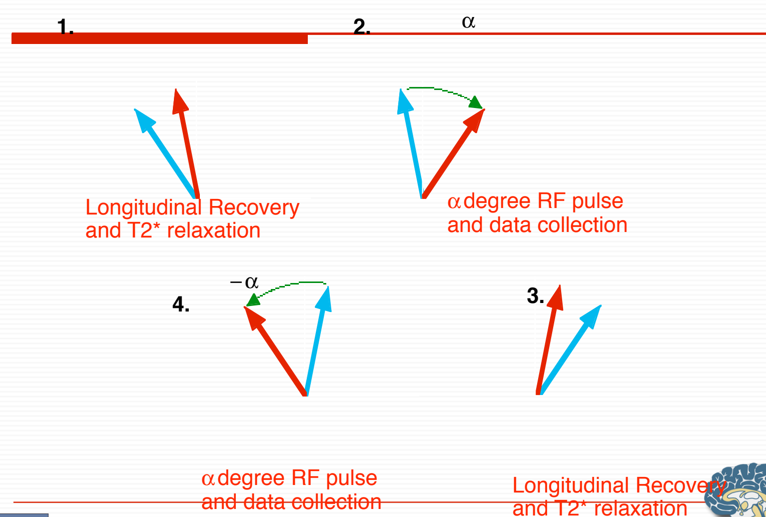
FISP (GRASS) Timing Diagram



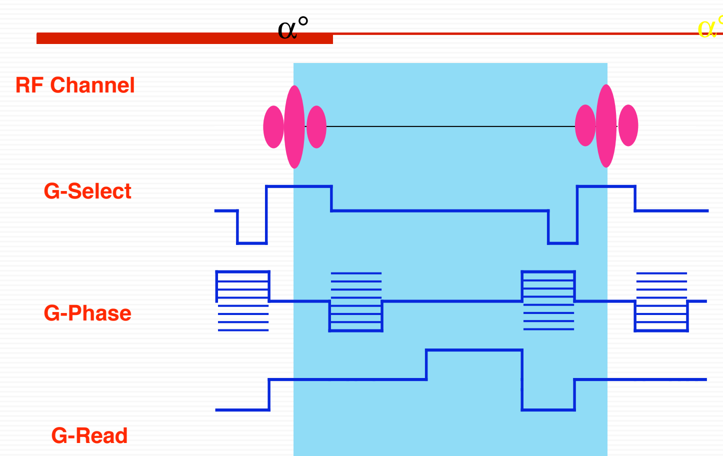
the FLASH Magnetization Cycle



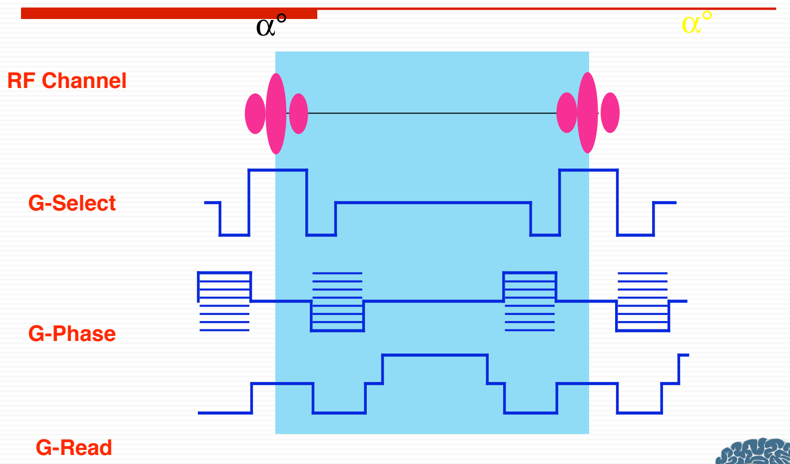
The GRASS (FISP) Magnetization Cycle



CE-FAST Sequence



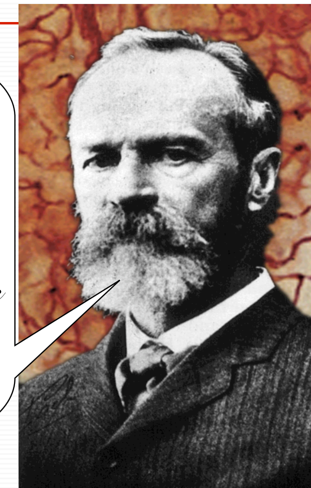
SSFP Sequence



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."



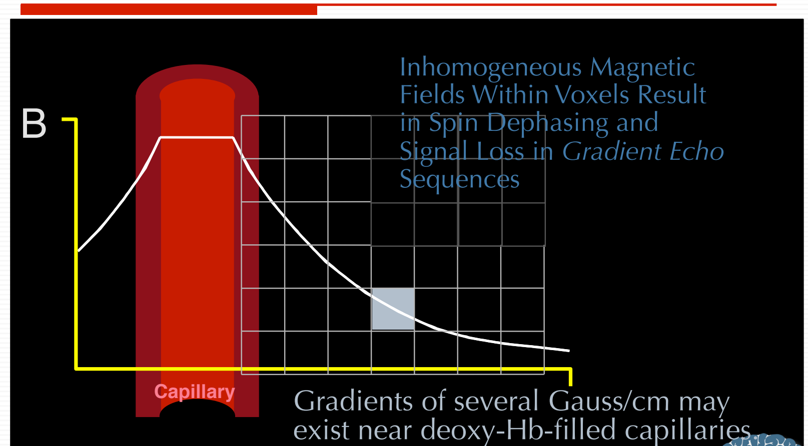
Brain "Activation" Leads to:

CBF	Increased	+ΔR1
CBV	Increased	+ΔR2 (C+)
O_2 Utilization	Increased slightly?	
Venous $[O_2]$	Increased	-ΔR2*
Glucose Utilization	Increased	? Lactate

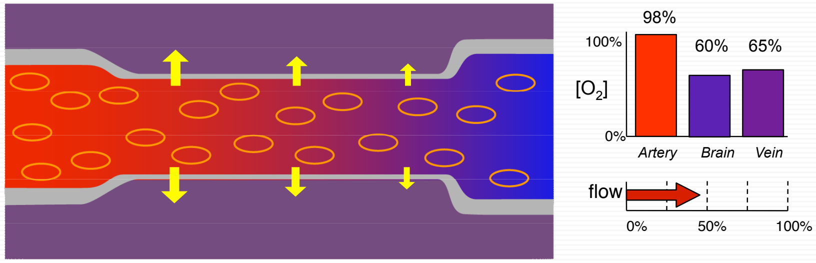
R1=1/T1

R2=1/T2

Signal Losses from Spin Dephasing

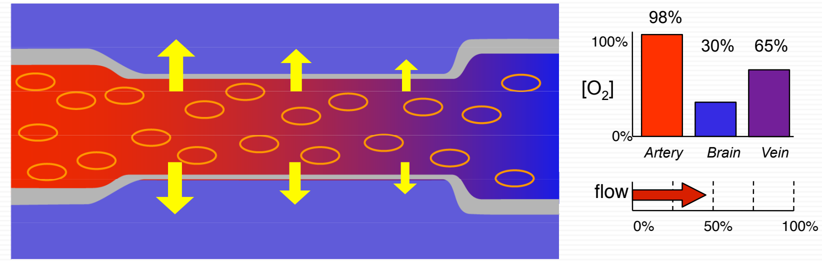


Why Does Venous O_2 Increase? (1)



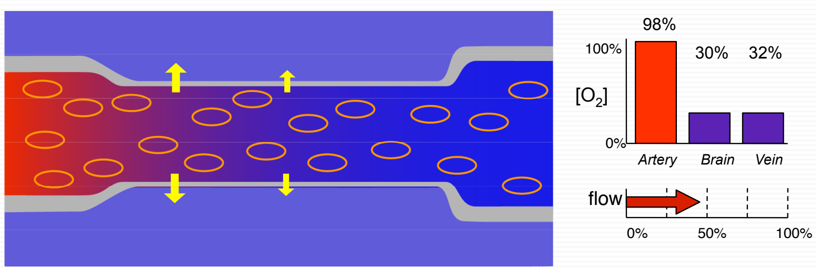
Under normal conditions oxygen diffuses down its concentration gradient from the capillary to the brain parenchyma

Why Does Venous O_2 Increase? (2)



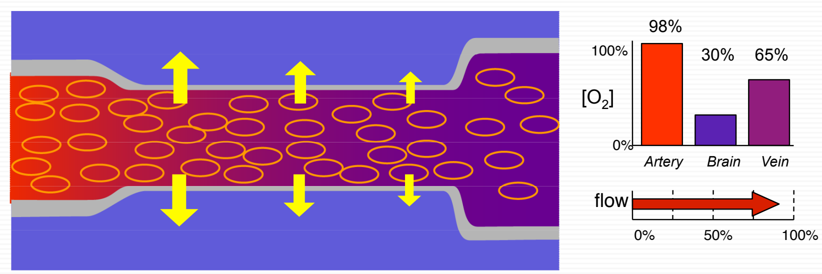
As the brain becomes more active, the oxygen consumption increases, increasing the transluminal oxygen gradient.

Why Does Venous O_2 Increase? (3)



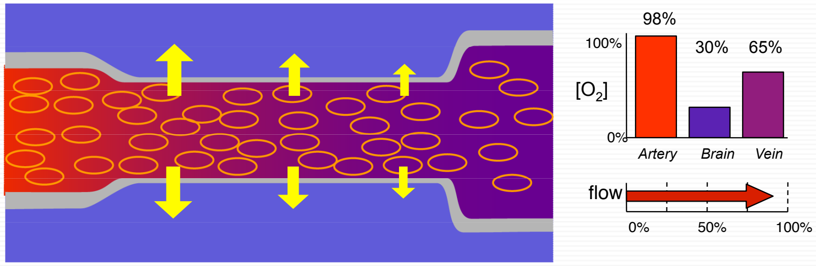
As oxygen flows across the capillary lumen it is depleted in the capillary and no further oxygen can be delivered

Why Does Venous O_2 Increase? (4)



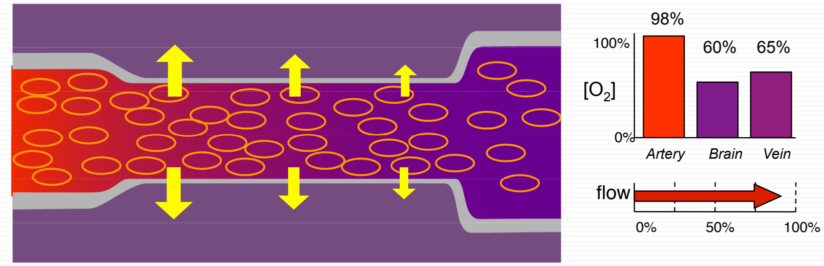
The vascular system responds by increasing blood flow so that more oxygenated blood is available throughout the capillary

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

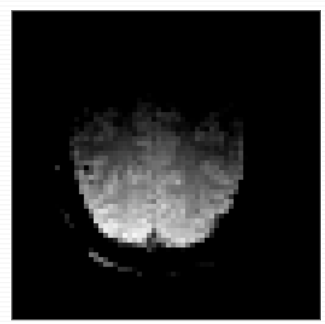
BOLD Contrast & Field Strength

- 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

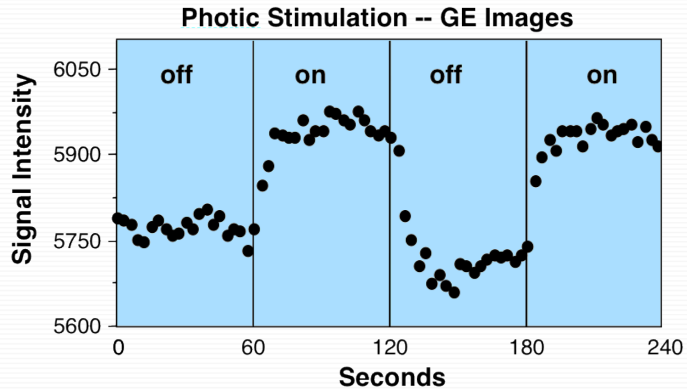
fMRI

explores intensity variations in MR signal



intensity variations reflect venous [O2]

Gradient-Recalled Echo



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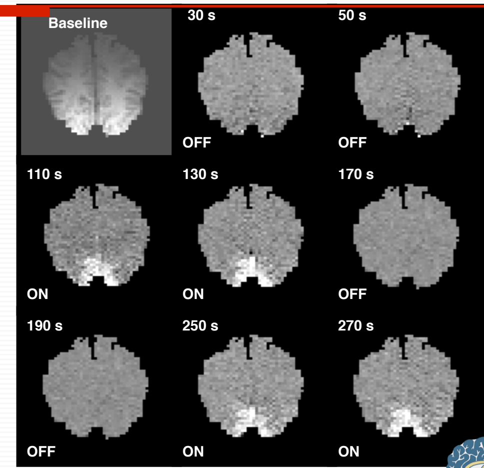
Inversion Recovery
TE=42 TR=3000
TI = 1100
Thickness=10



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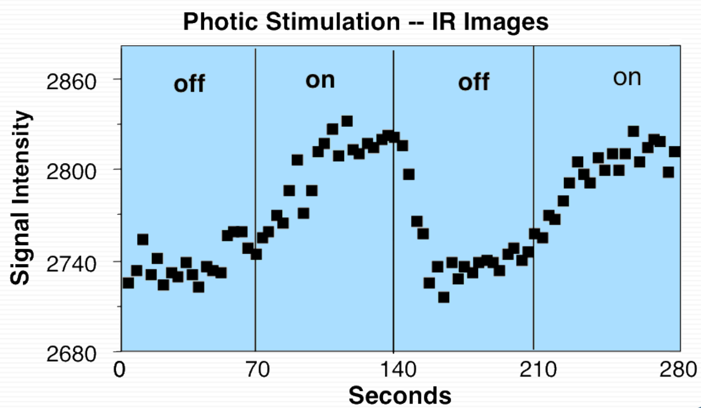
Inversion Recovery



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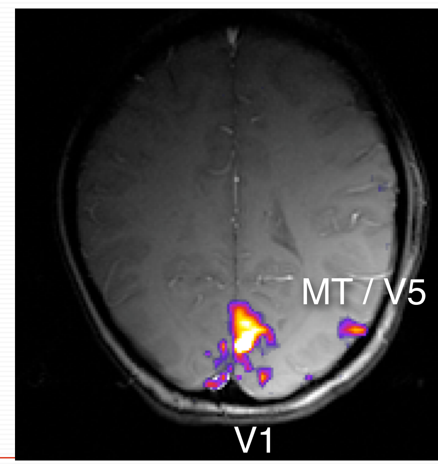
Activation with Moving Visual Stimuli



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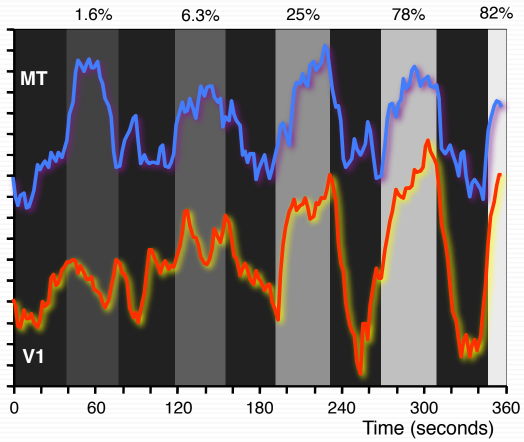
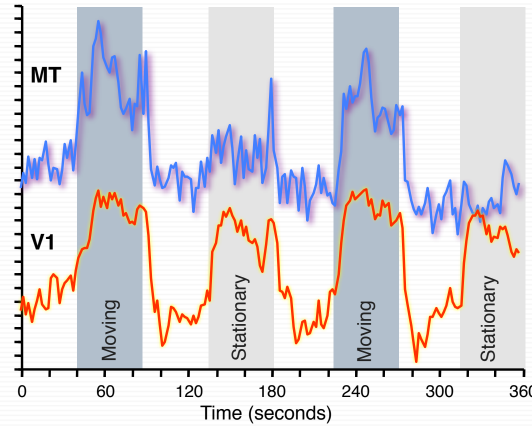
Contrast Response Test



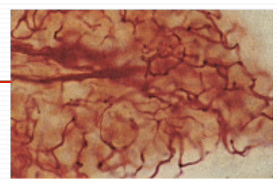
From R. Tootell

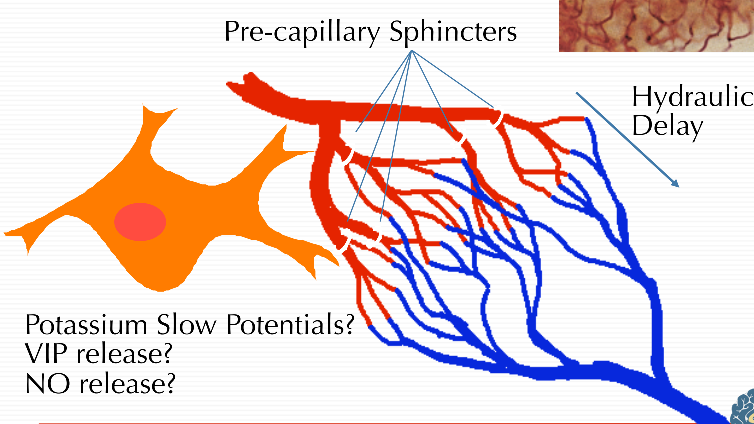
Motion Sensitivity Test



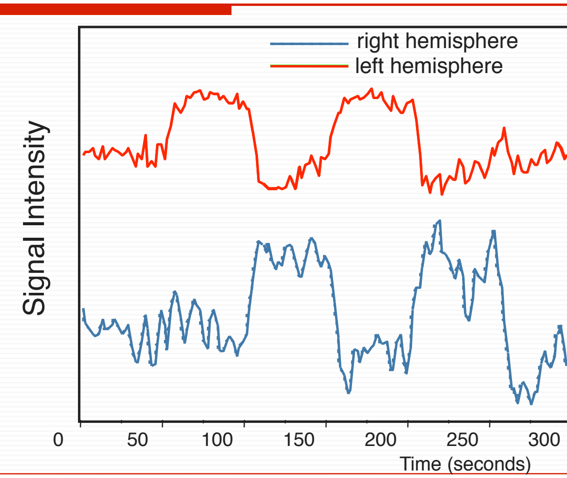
From R. Tootell

Neurovascular Coupling and *ƒ*MRI latency

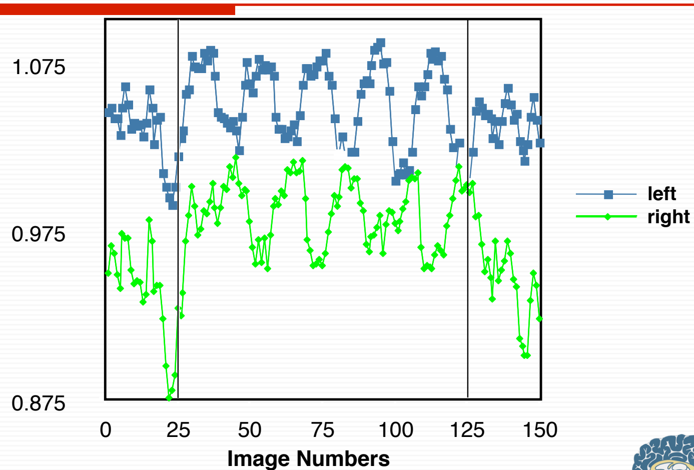




Hemifield Alternation



Hemifield Alternation 20 seconds



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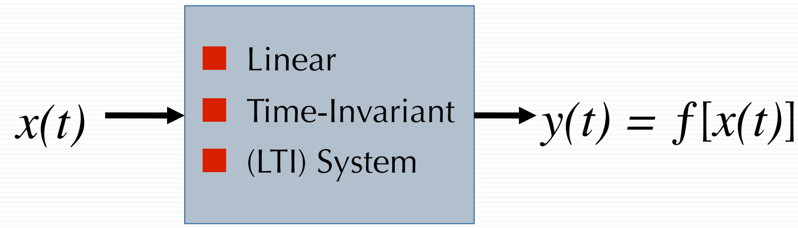
Linear Systems Approach



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

$f(A + B) = f(A) + f(B)$

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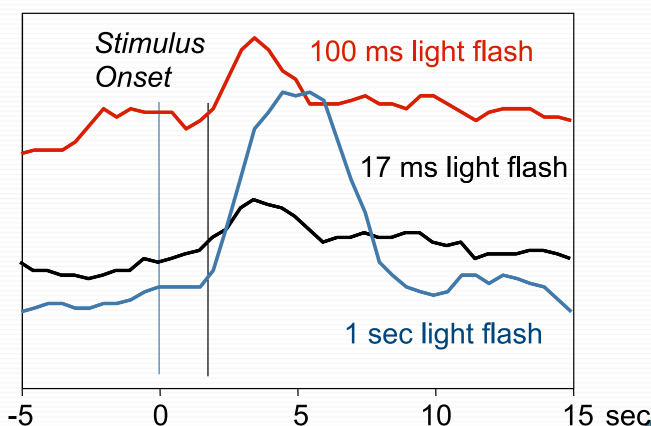
Response Latency vs. Stimulus Duration Average of 10 recordings



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Data courtesy of Robert Savoy

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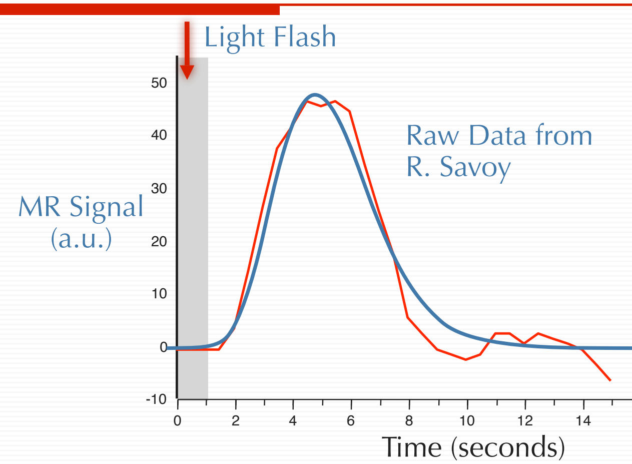
Brain Impulse Response



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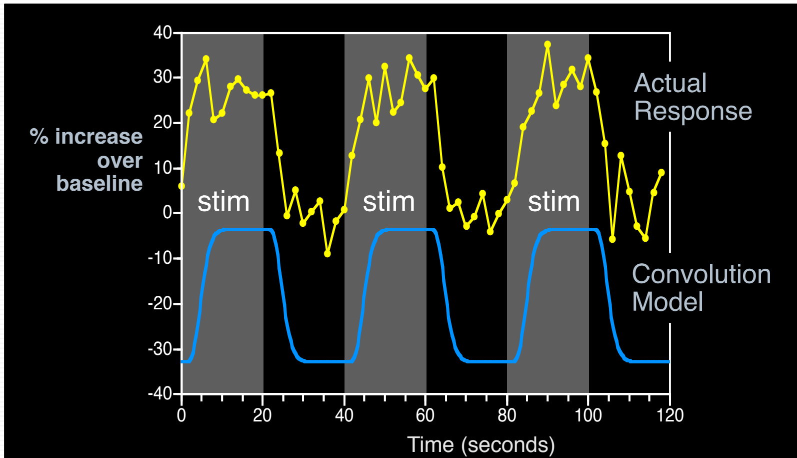
Convolution of Impulse Responses with Stimuli



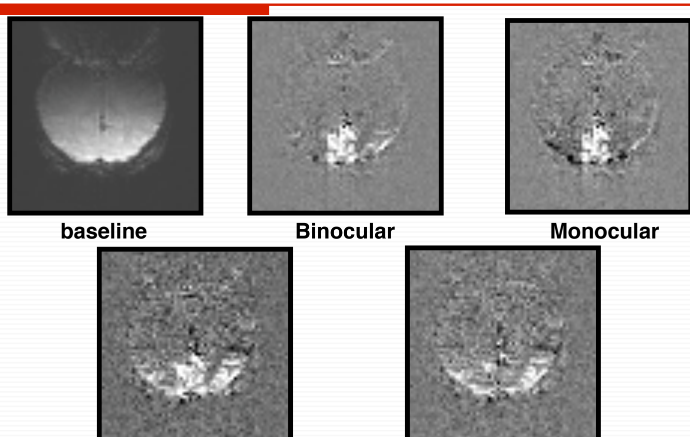
Linear Systems Approach

$x(t)$ → [■ Linear ■ Time-Invariant ■ (LTI) System] → $y(t) = f[x(t)]$

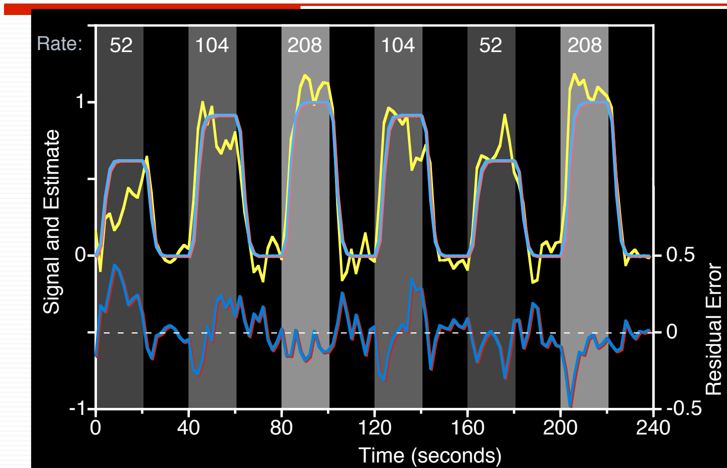
In an LTI system, given two inputs A & B:

$f(A + B) = f(A) + f(B)$

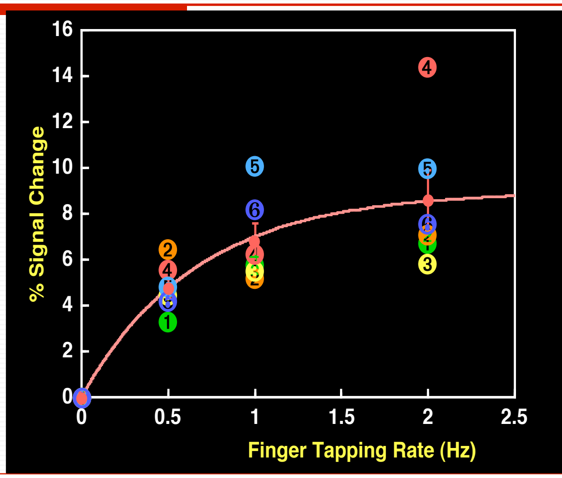
Binocular vs Monocular Activation



Amplitude-weighted Linear Estimate

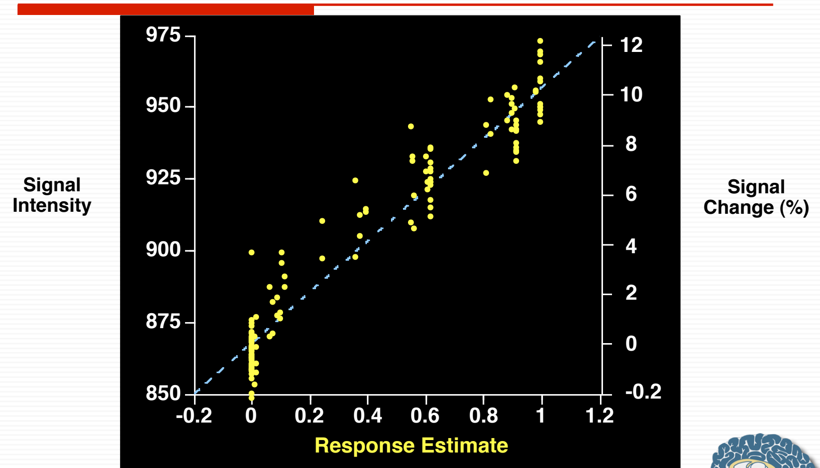


Repeated Rate Fits



(1.5 T conventional data)

Estimated vs. Actual *f*MRI Response

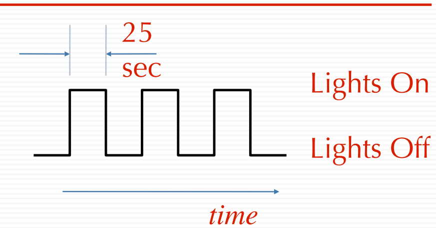


Some Theoretical Considerations

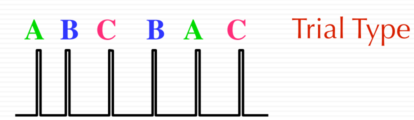
- Study Designs:
  - *Blocked*
  - *Single Trial*
- Predicting Responses
- Sources of Variance
- Resolution Limits:
  - *Temporal*
  - *Spatial*

Blocked vs. Single Trial

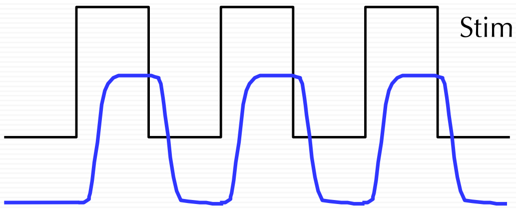
Typical Blocked Design



Typical Single Trial Design

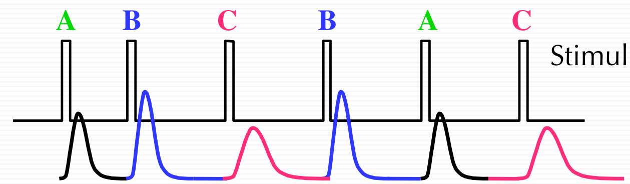


Blocked Experiments



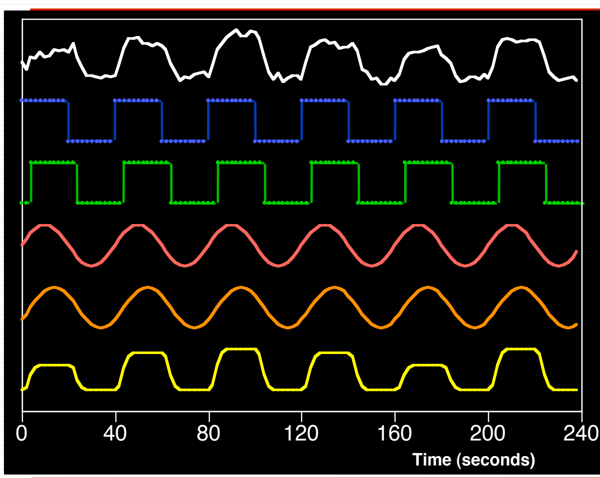
•Responses are Fairly Large
•Data are Easy to Analyze
•With Long Blocks, Time course can be Ignored
•All trials within a block are treated as Identical

Single Trial Designs



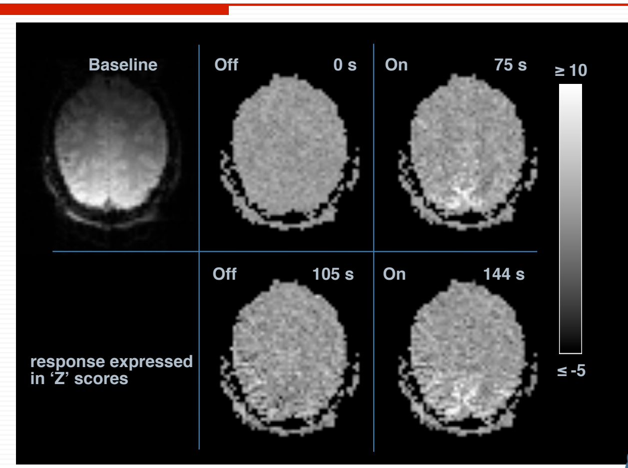
•Responses are small
•Useful contrast/noise is low
•Data are more Challenging to Analyze
•Exact Time course is Modeled or a Dependent Variable
•Suitable for Randomized Stimulus Designs

Reference Functions Used in ƒMRI

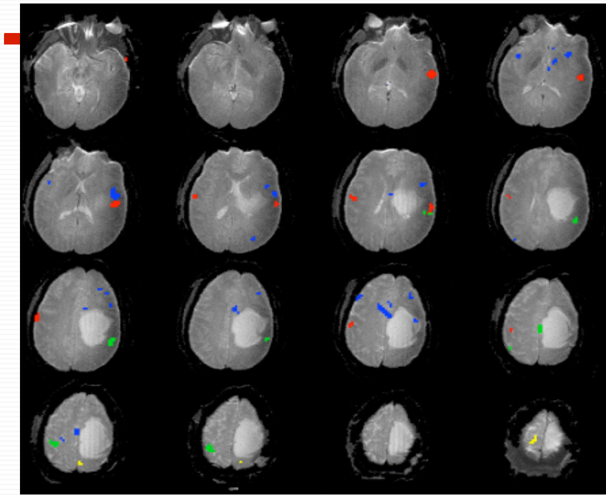


Time Data
Square Wave
Shifted Square Wave
Sine Function
Shifted Sine Function
Impulse Convolution

8 Hz checkered flash stimulation



Clinical Mapping Summary



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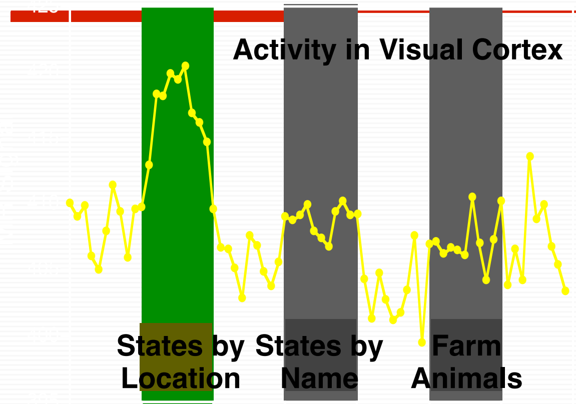
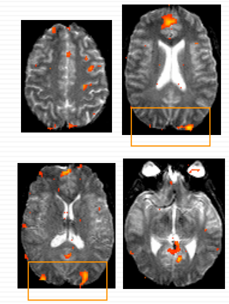
Geographic Imagery





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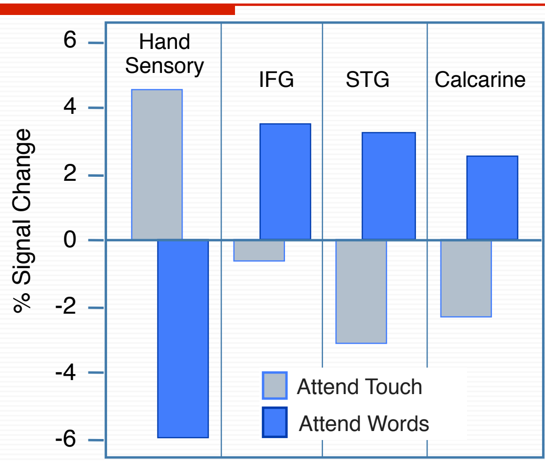
Attentional Modulation



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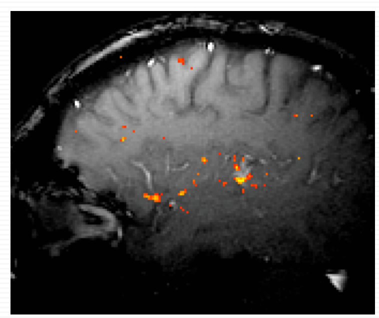
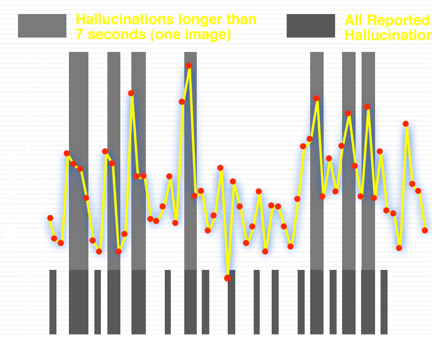
Results - Auditory Hallucinations





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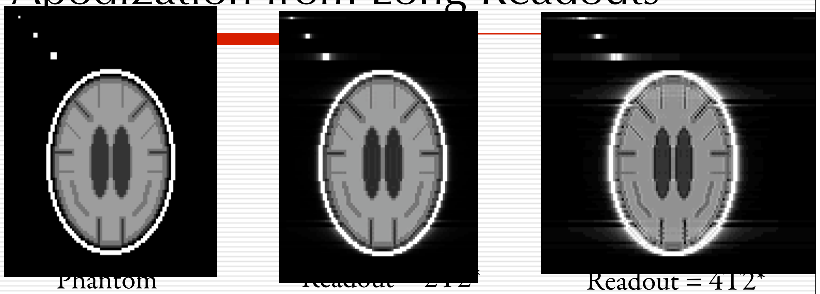
Apodization from Long Readouts



Phantom | Readout = 2T2* | Readout = 4T2*