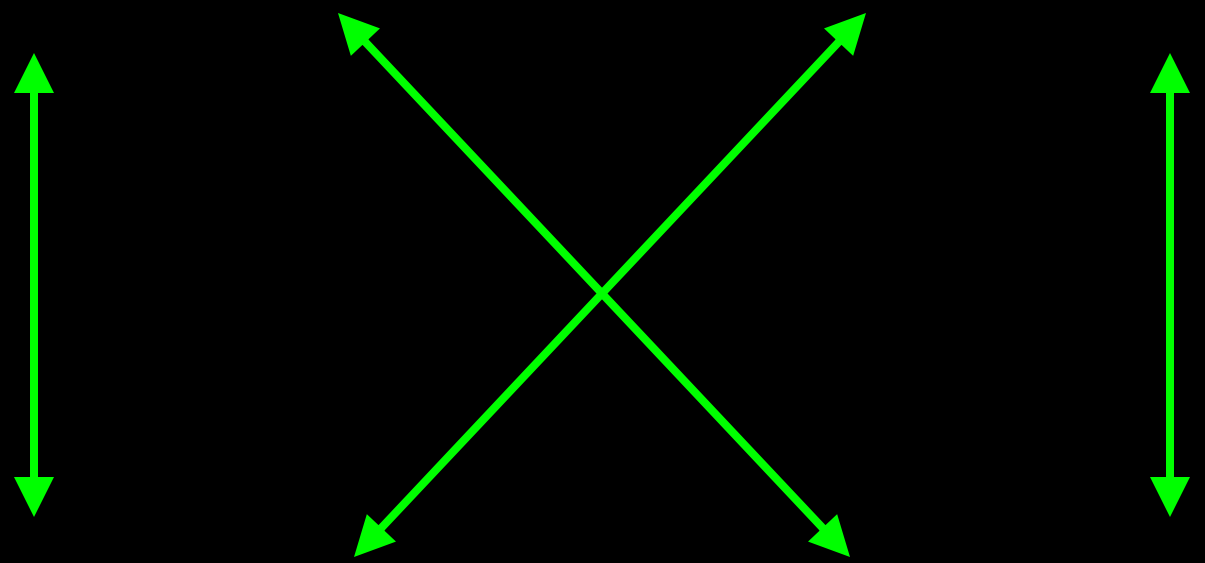
Starting up a Functional MRI Center

Peter A. Bandettini, Ph.D

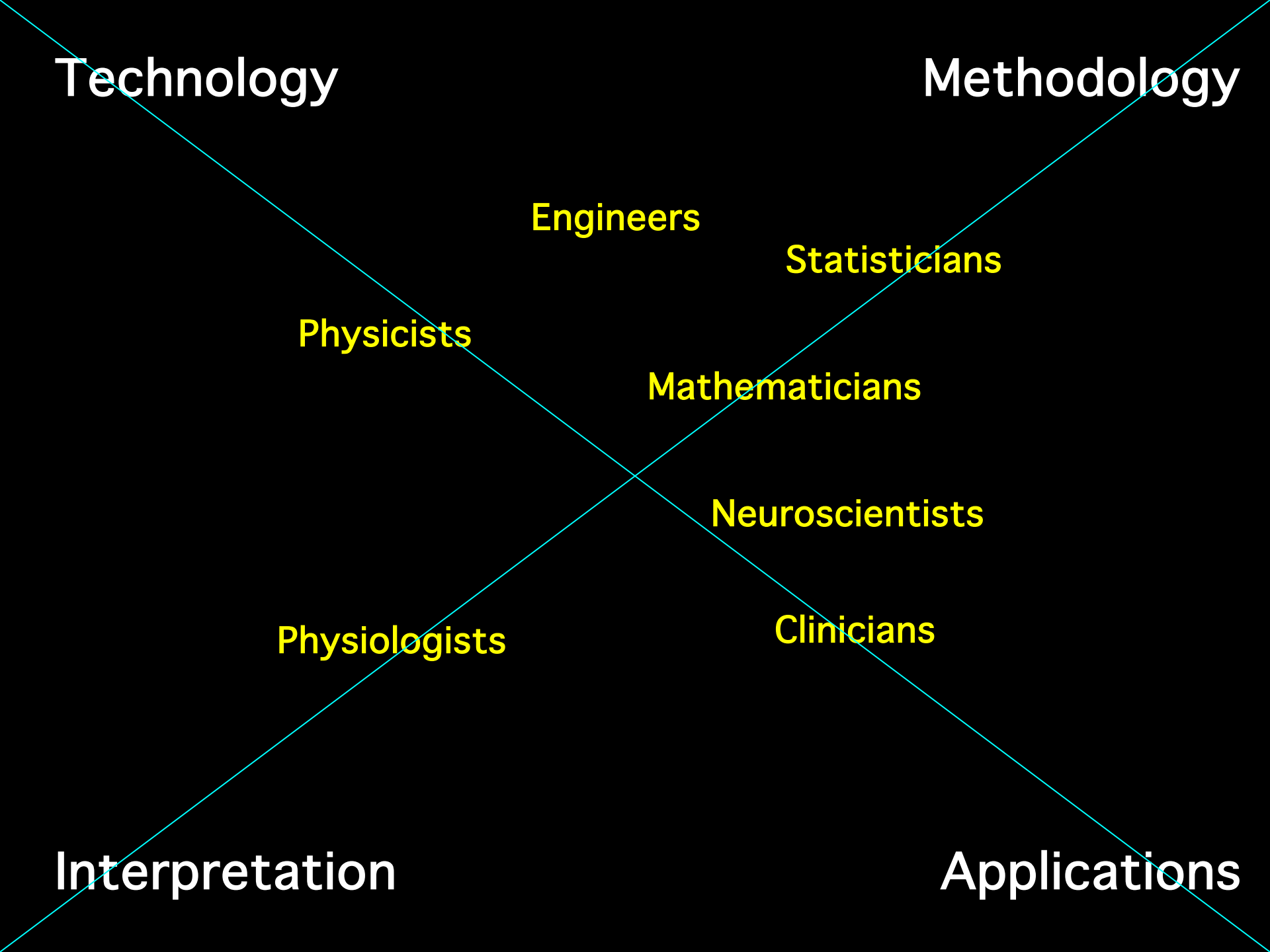
Unit on Functional Imaging Methods
&
3T Neuroimaging Core Facility

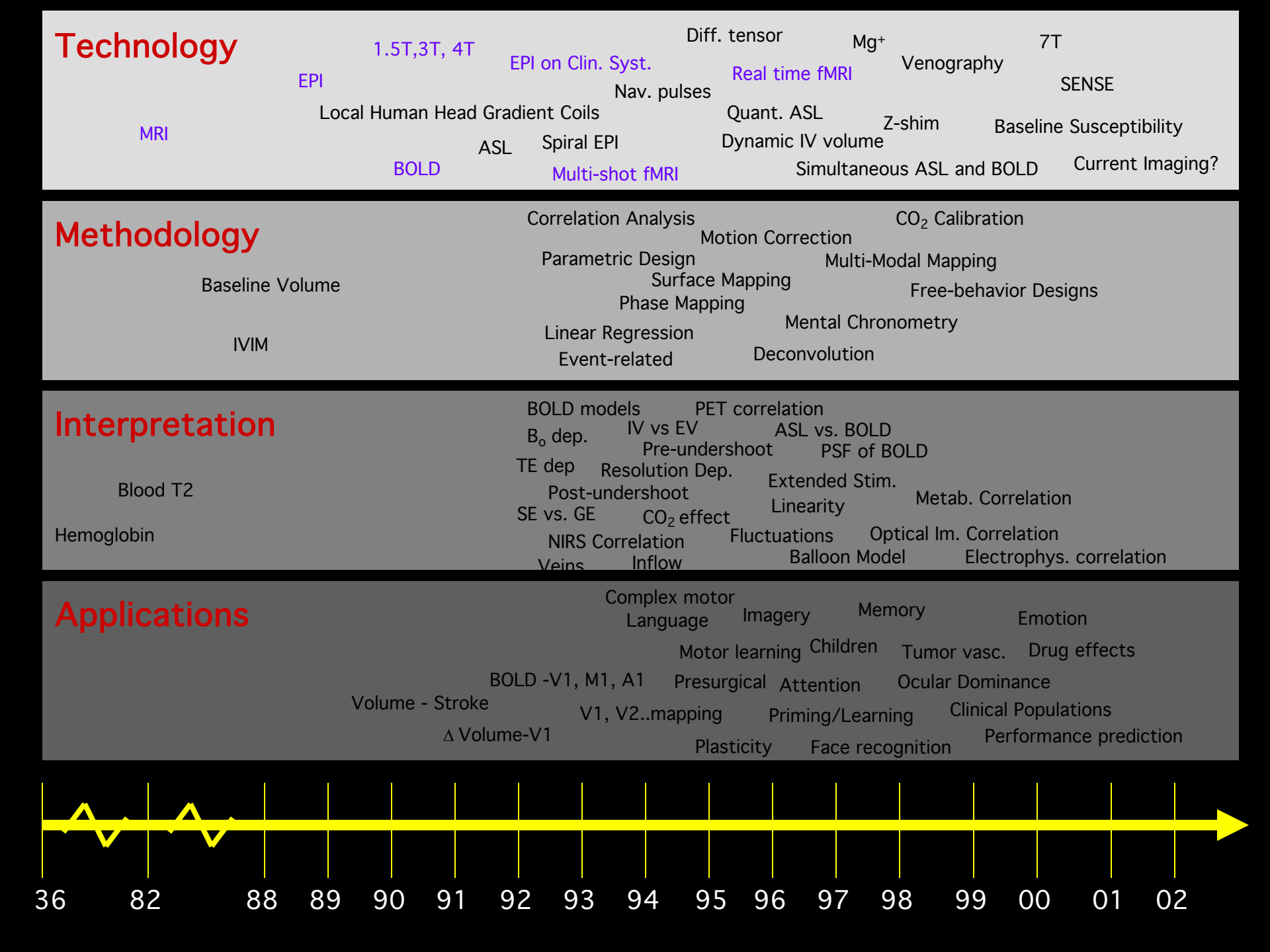
Laboratory of Brain and Cognition
National Institute of Mental Health

Technology ↔ Methodology



Interpretation ↔ Applications


Technology
Methodology
Engineers
Statisticians
Physicists
Mathematicians
Neuroscientists
Physiologists
Clinicians
Interpretation
Applications


Technology
1.5T,3T, 4T
Diff. tensor
Mg+
7T
EPI on Clin. Syst.
Venography
EPI
Real time fMRI
SENSE
Nav. pulses
Local Human Head Gradient Coils
Quant. ASL
Z-shim
Baseline Susceptibility
MRI
Dynamic IV volume
ASL
Spiral EPI
BOLD
Multi-shot fMRI
Simultaneous ASL and BOLD
Current Imaging?
Methodology
Correlation Analysis
CO2 Calibration
Motion Correction
Parametric Design
Multi-Modal Mapping
Baseline Volume
Surface Mapping
Free-behavior Designs
Phase Mapping
Mental Chronometry
Linear Regression
IVIM
Deconvolution
Event-related
Interpretation
BOLD models
PET correlation
IV vs EV
B0 dep.
ASL vs. BOLD
Pre-undershoot
PSF of BOLD
TE dep
Resolution Dep.
Extended Stim.
Blood T2
Post-undershoot
Metab. Correlation
Linearity
SE vs. GE
CO2 effect
Hemoglobin
Fluctuations
Optical Im. Correlation
NIRS Correlation
Balloon Model
Electrophys. correlation
Veins
Inflow
Applications
Complex motor
Language
Imagery
Memory
Emotion
Motor learning
Children
Tumor vasc.
Drug effects
BOLD -V1, M1, A1
Presurgical
Attention
Ocular Dominance
Volume - Stroke
V1, V2..mapping
Priming/Learning
Clinical Populations
Δ Volume-V1
Plasticity
Face recognition
Performance prediction
36
82
88
89
90
91
92
93
94
95
96
97
98
99
00
01
02

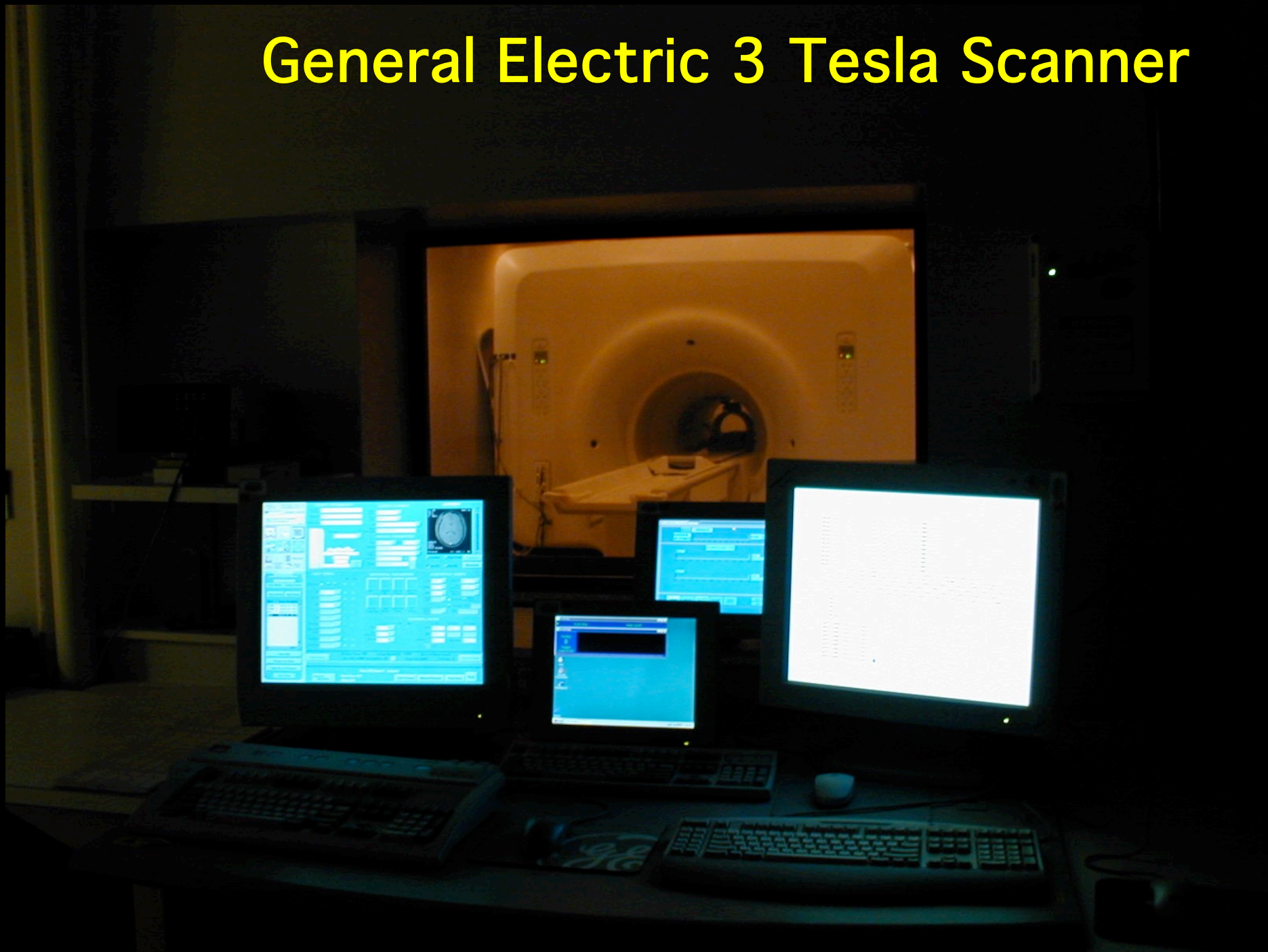
1. Purchasing a scanner
2. Data handling
3. Subject interface devices
4. Data processing
5. Personnel

1. Purchasing a scanner
2. Data handling
3. Subject interface devices
4. Data processing
5. Personnel

Purchasing a scanner

-field strength
-manufacturer
    -service
    -rf receivers (number and bandwidth
-field homogeneity
-stability
-shimming
-gradient homogeneity
-gradient performance
-programming environment
-real time?
-service contract
-other centers with the scanner

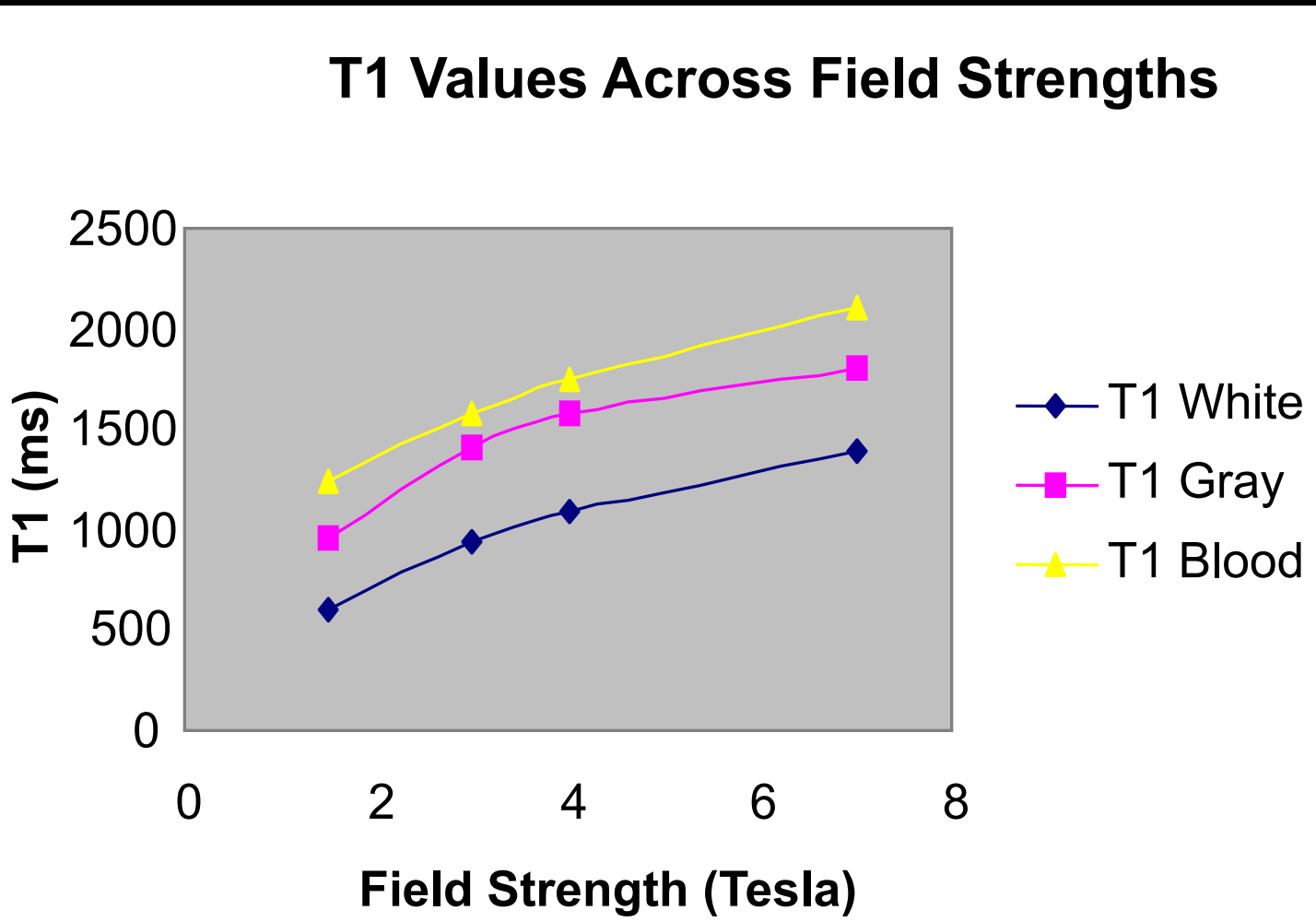
General Electric 3 Tesla Scanner

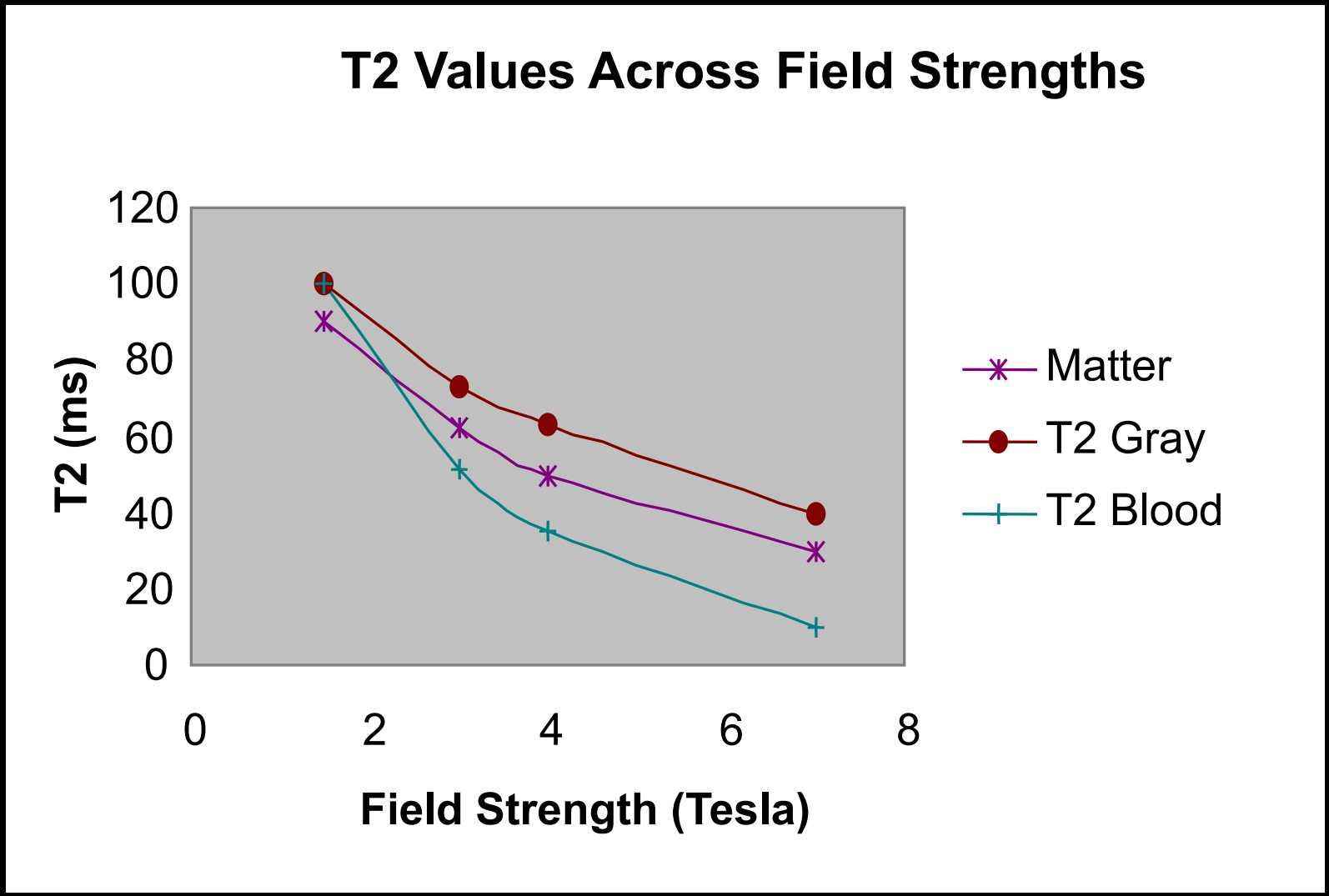


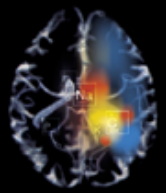
What Changes with Field Strength?

Tissue Relaxation Characteristics
Functional Contrast
Signal to Noise Ratio
Bo Inhomogeneity Effects

RF Power Deposition
Mechanical Force on Gradient Coil

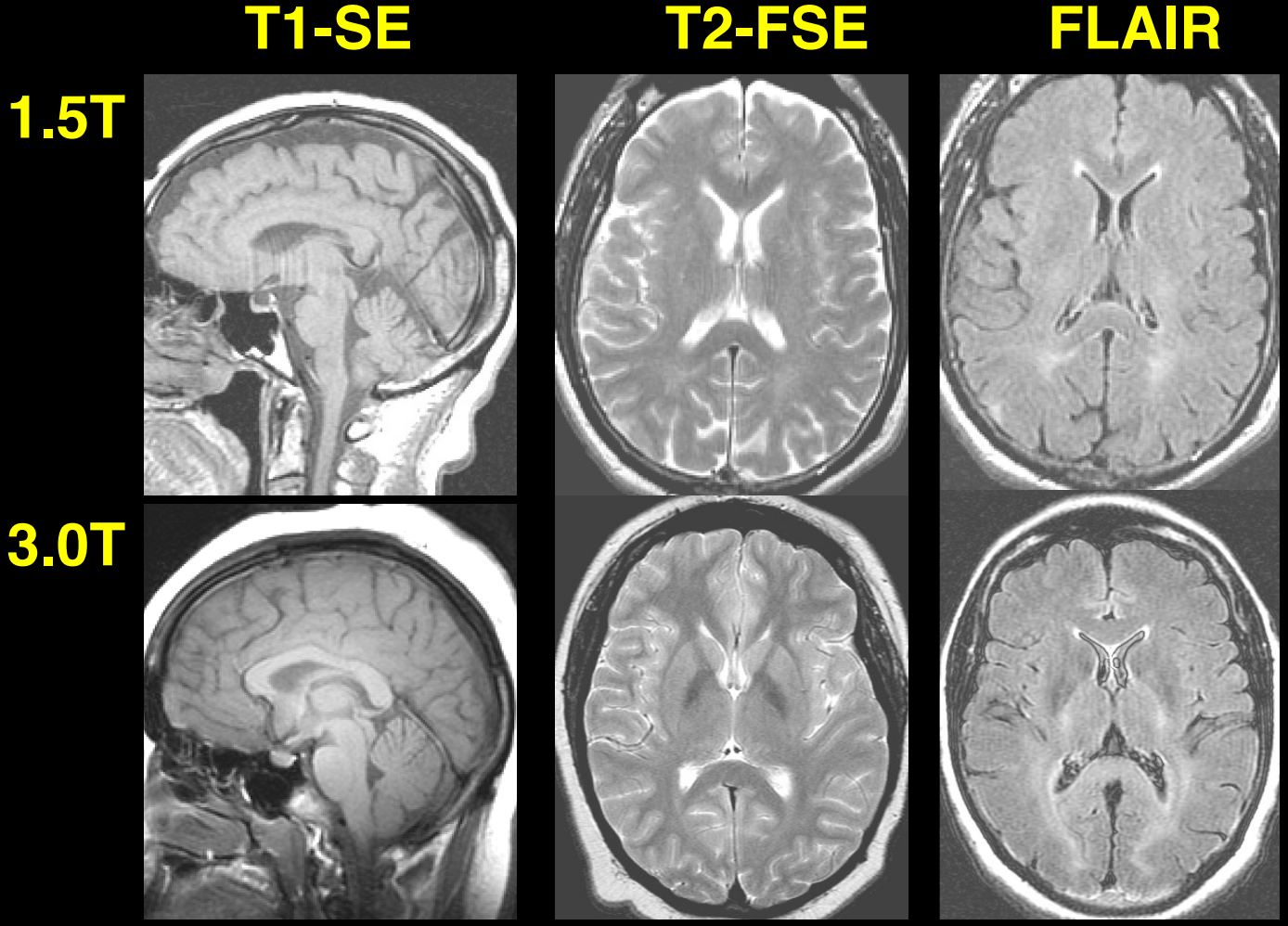

T1 Values Across Field Strengths
2500
2000
1500
1000
500
0
T1 (ms)
0
2
4
6
8
Field Strength (Tesla)
T1 White
T1 Gray
T1 Blood

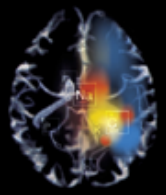

T2 Values Across Field Strengths
120
100
80
60
40
20
0
T2 (ms)
0
2
4
6
8
Field Strength (Tesla)
Matter
T2 Gray
T2 Blood



UIC
Thulborn

Whole Brain Anatomy





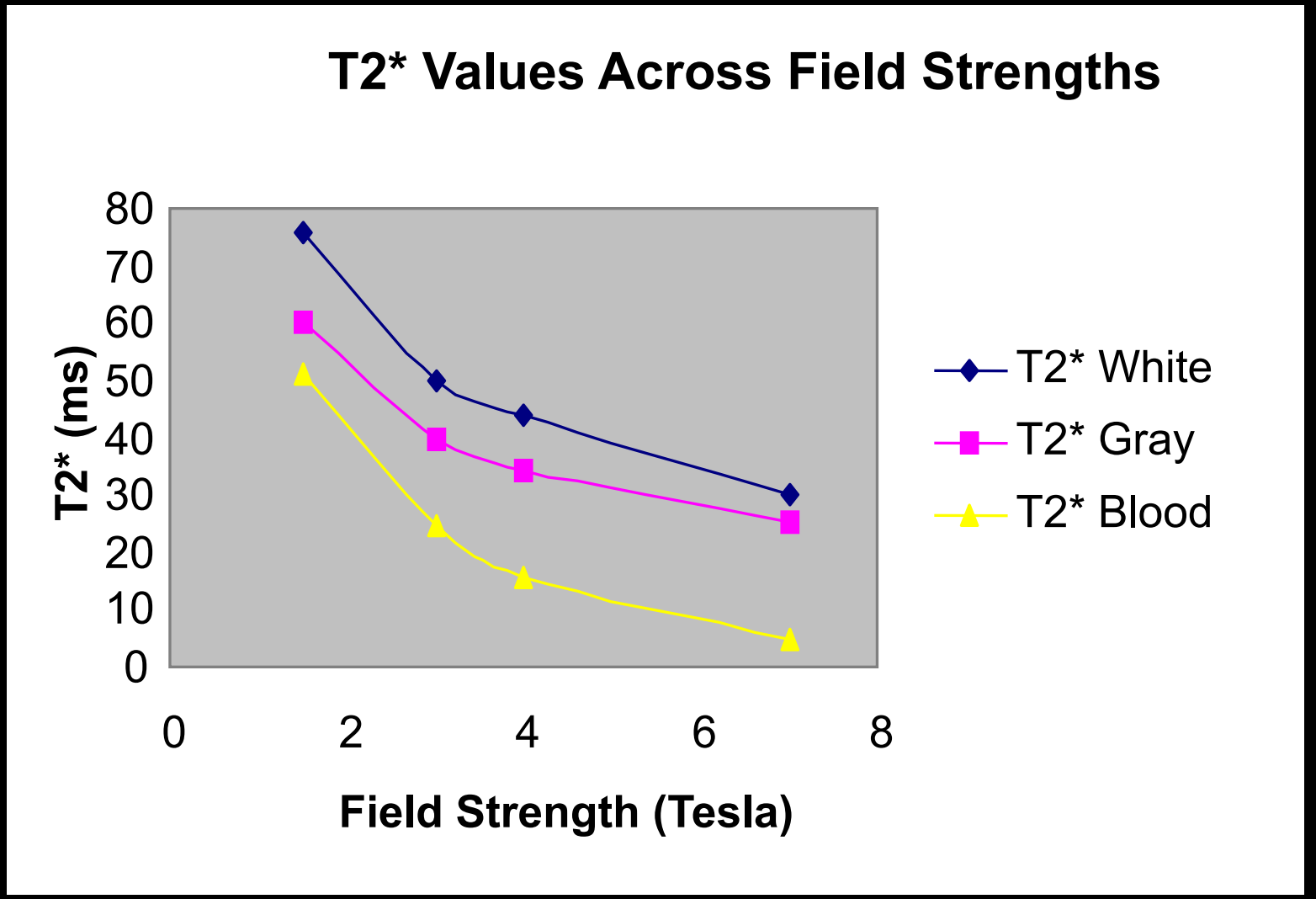
UIC
Thulborn

3.0T: 3D TOF MRA

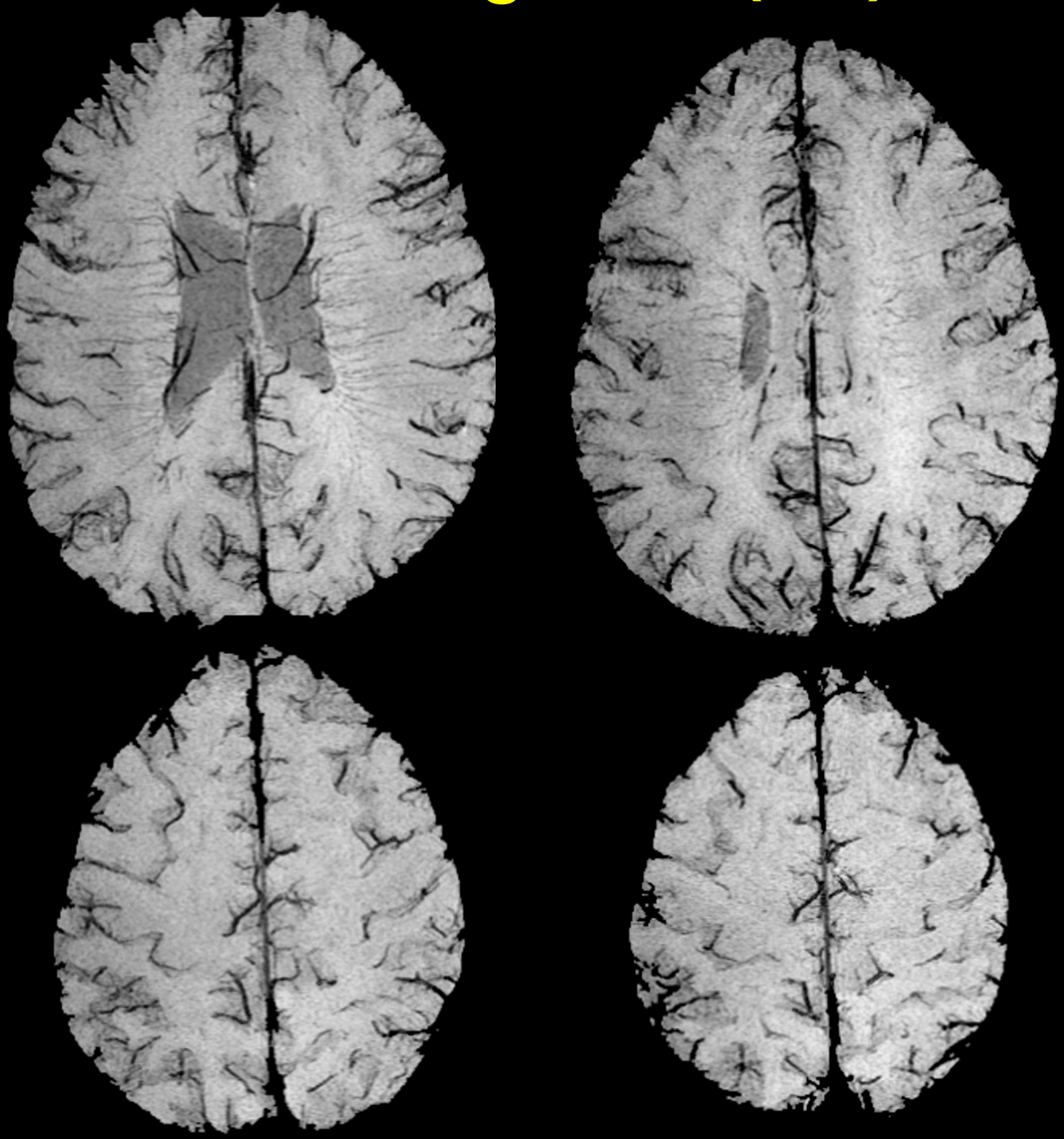
Longer T1 at 3.0T enhances flow effects and improves background suppression as well as allows higher spatial resolution

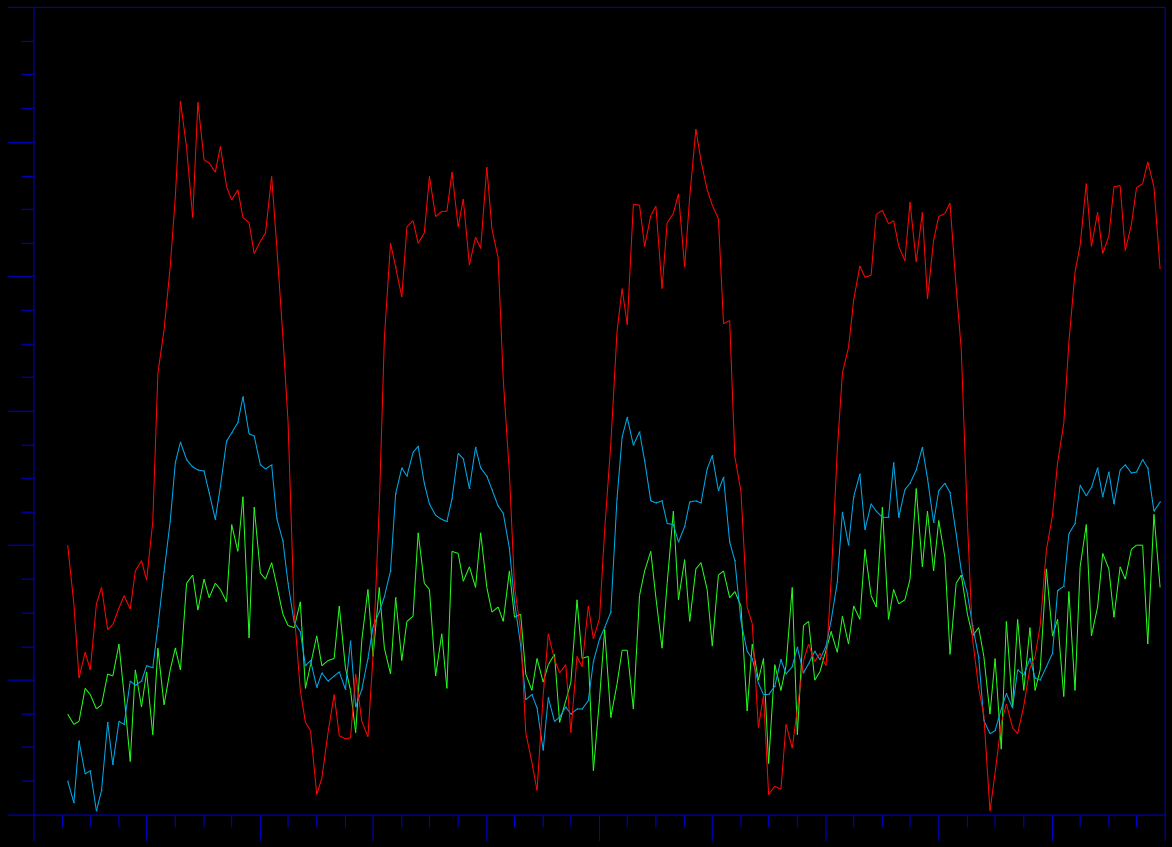
15 y.o. female patient

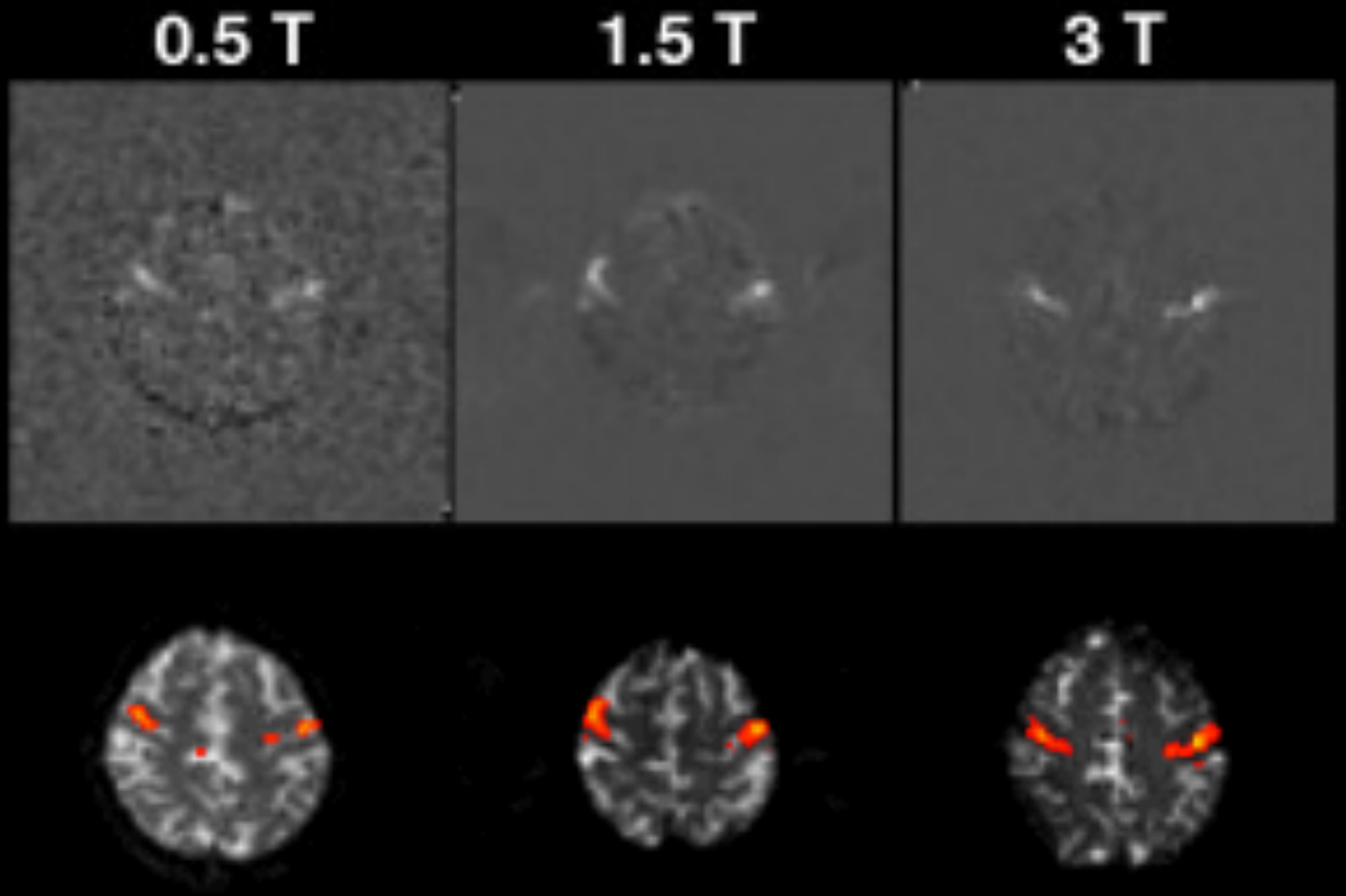
57 y.o. male patient


T2* Values Across Field Strengths
T2* (ms)
80
70
60
50
40
30
20
10
0
0
2
4
6
8
Field Strength (Tesla)
T2* White
T2* Gray
T2* Blood

Venograms (3T)






0.5 T
1.5 T
3 T

Magnetic Resonance in Medicine 45:595–604 (2001)

Neuroimaging at 1.5 T and 3.0 T: Comparison of Oxygenation-Sensitive Magnetic Resonance Imaging

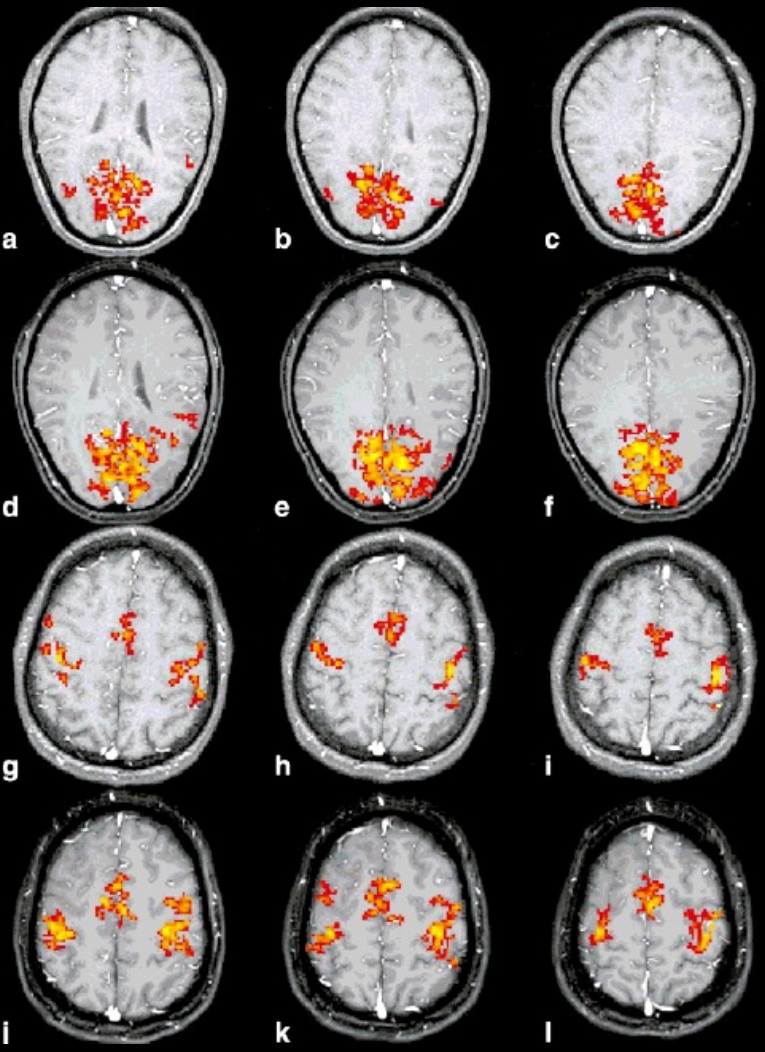
Gunnar Krüger,* Andreas Kastrup, and Gary H. Glover

1.5T

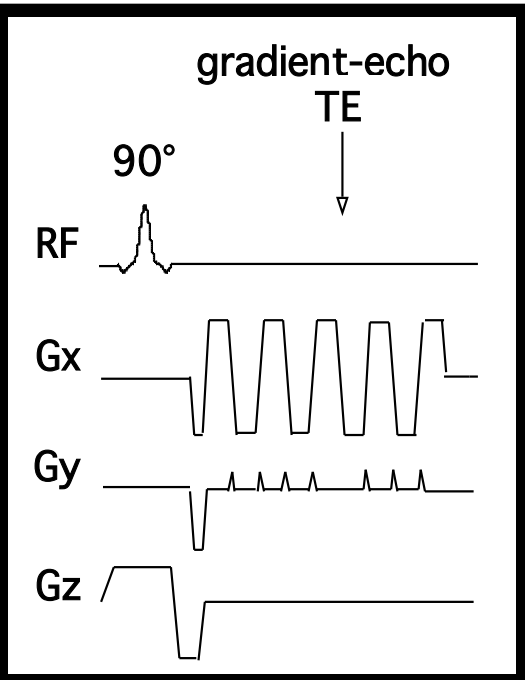
3T

1.5T

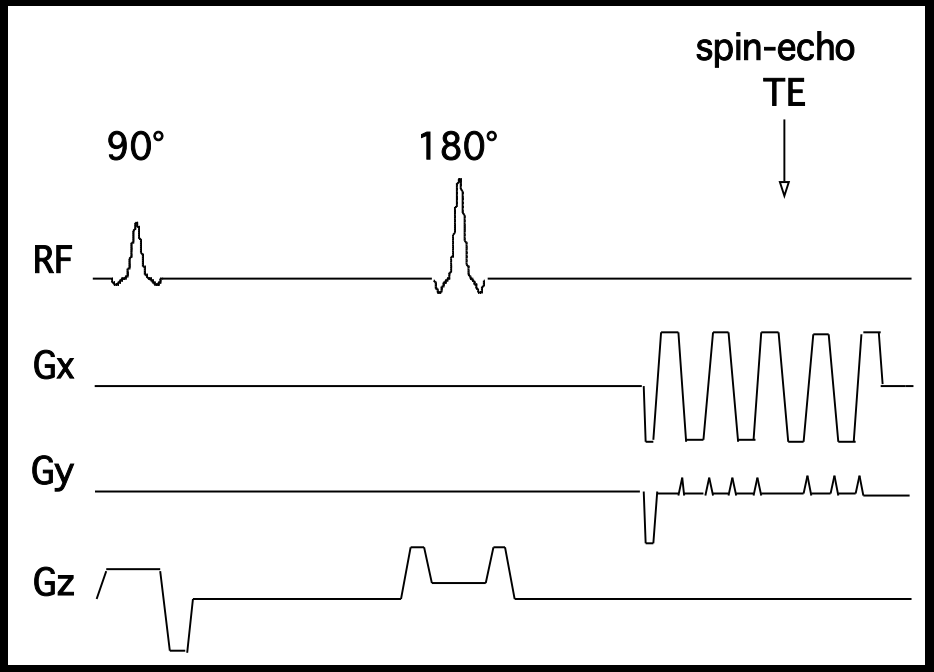
3T



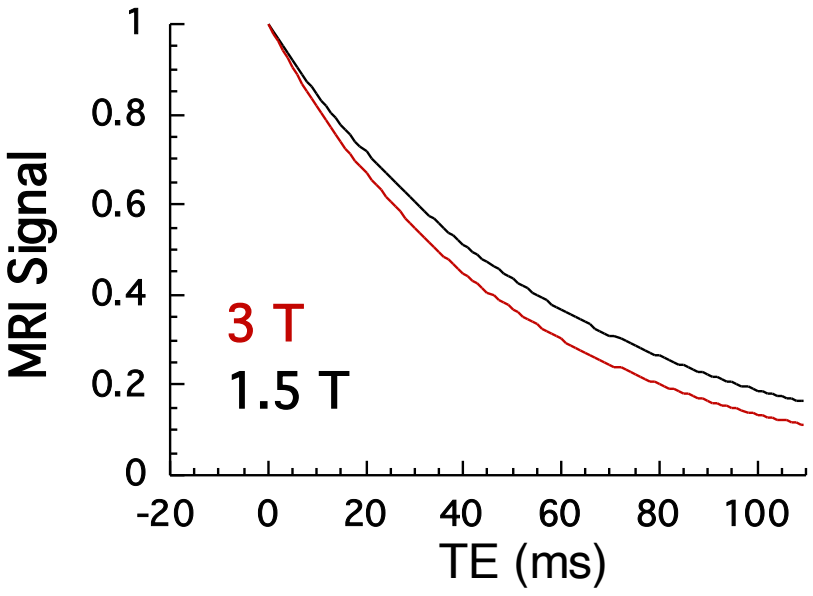
Gradient-Echo EPI



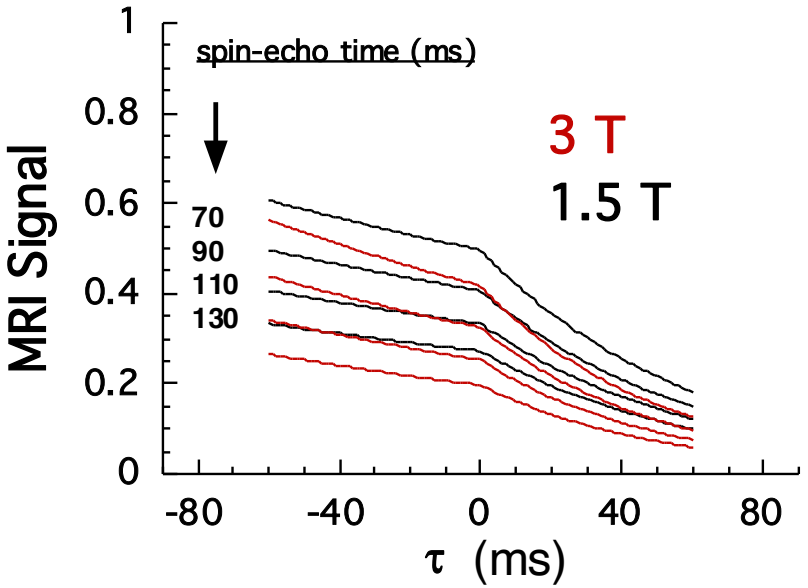
Spin-Echo EPI



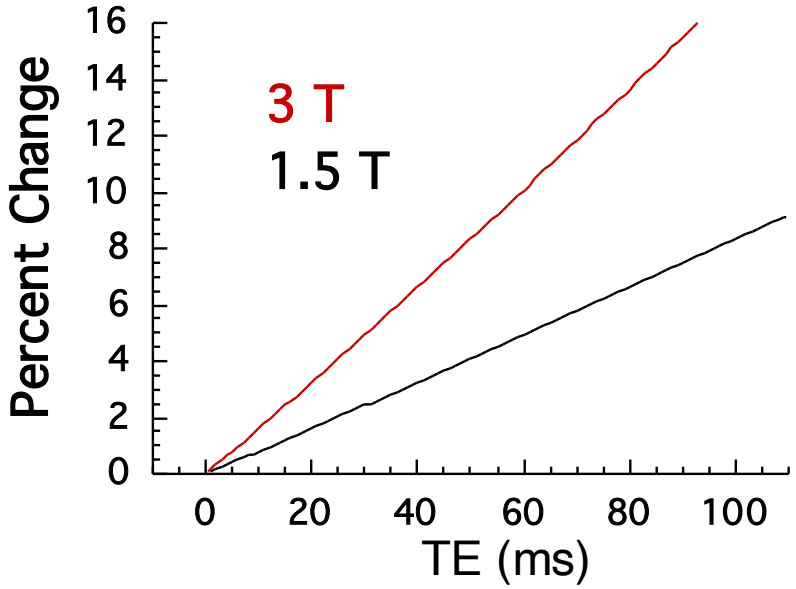
Gradient - Echo



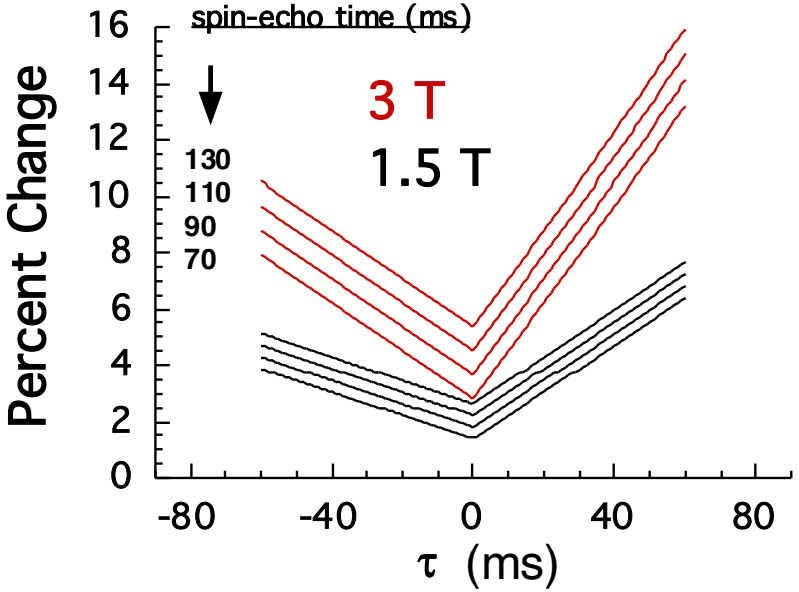
Asymmetric Spin - Echo



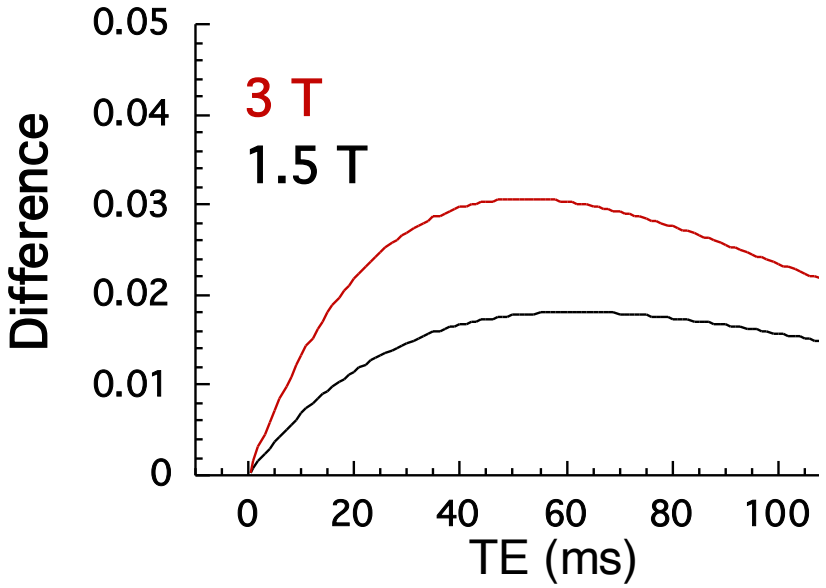
Gradient - Echo



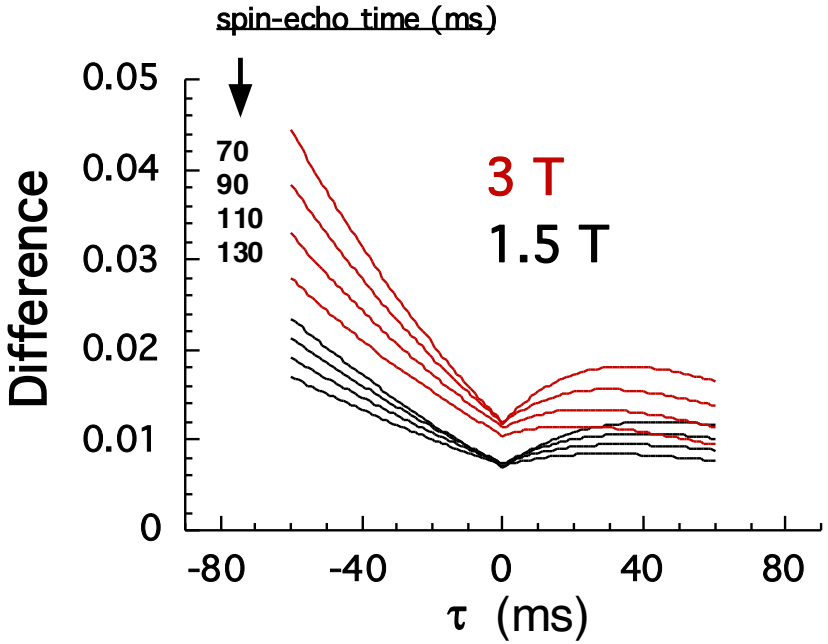
Asymmetric Spin - Echo



Gradient - Echo



Asymmetric Spin - Echo



Magnetic Resonance in Medicine 45:595–604 (2001)

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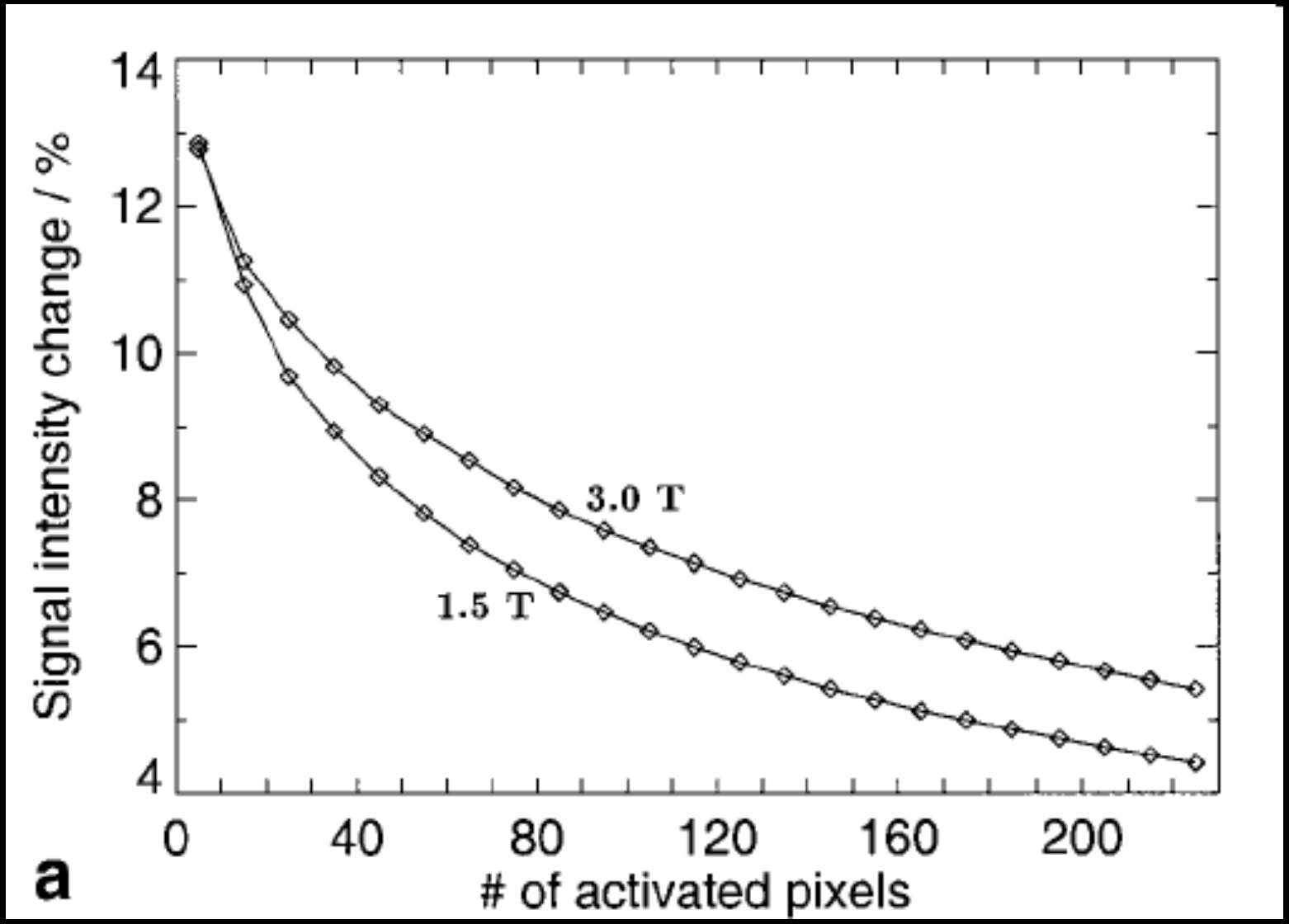
Gunnar Krüger,* Andreas Kastrup, and Gary H. Glover



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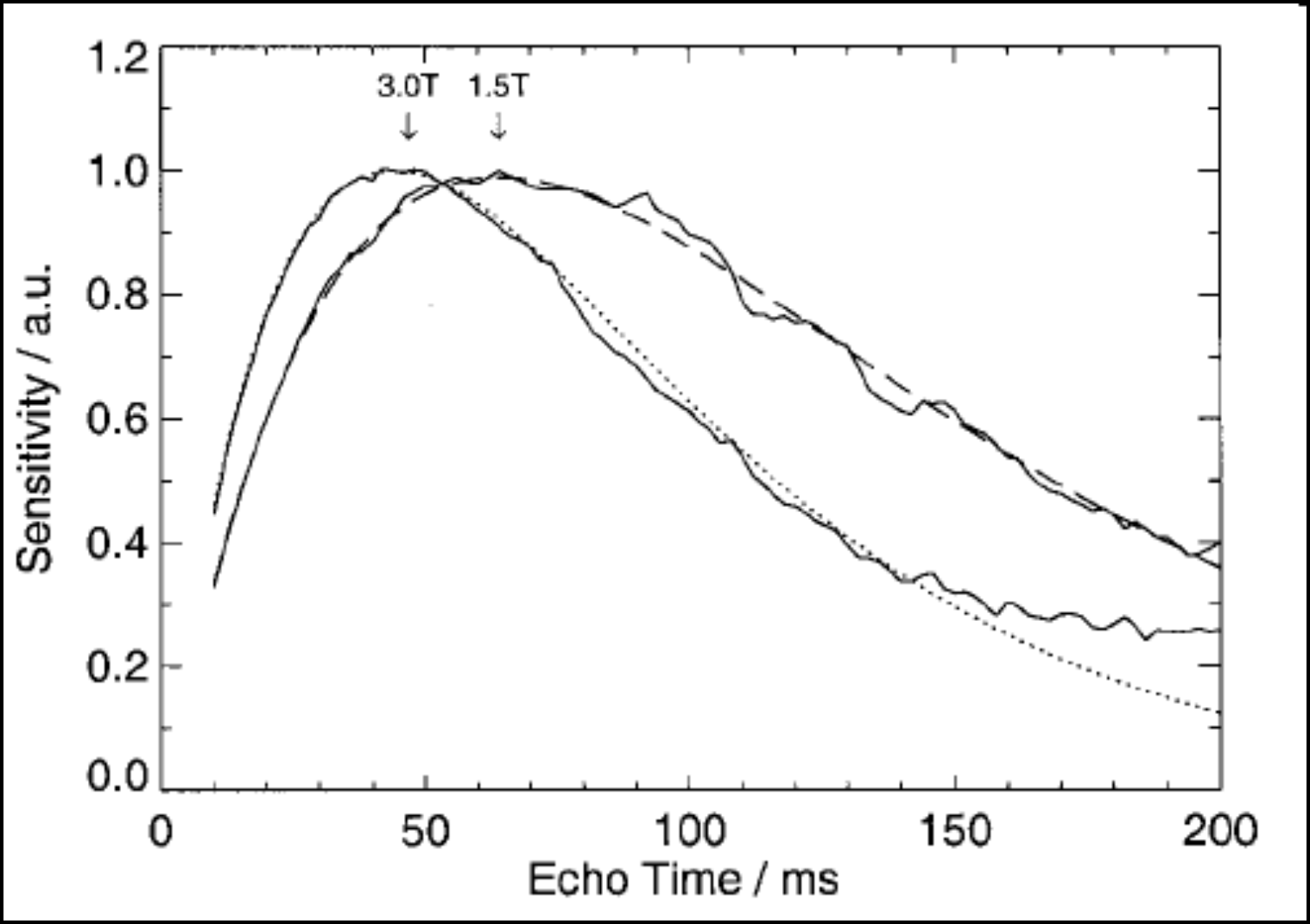
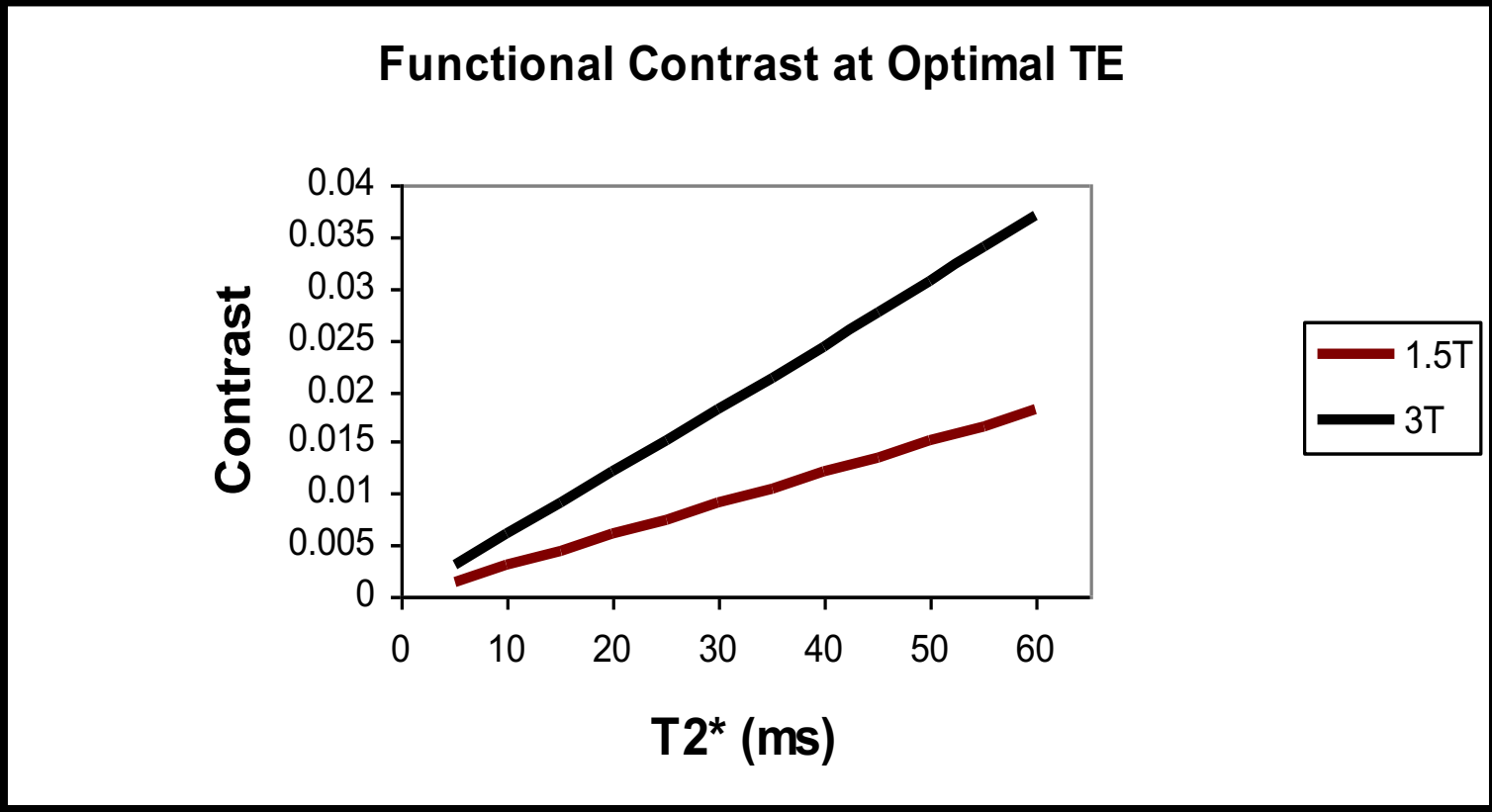
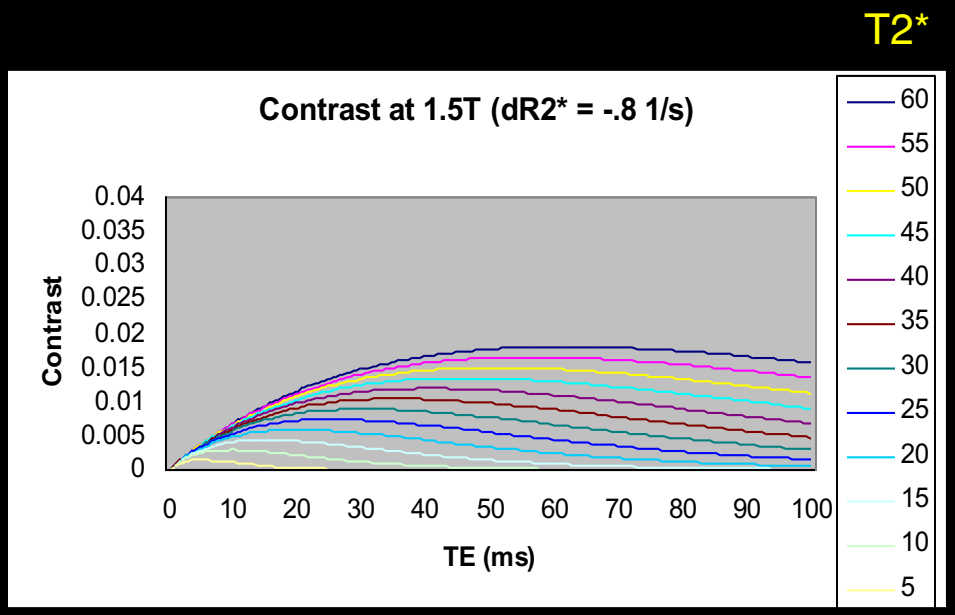
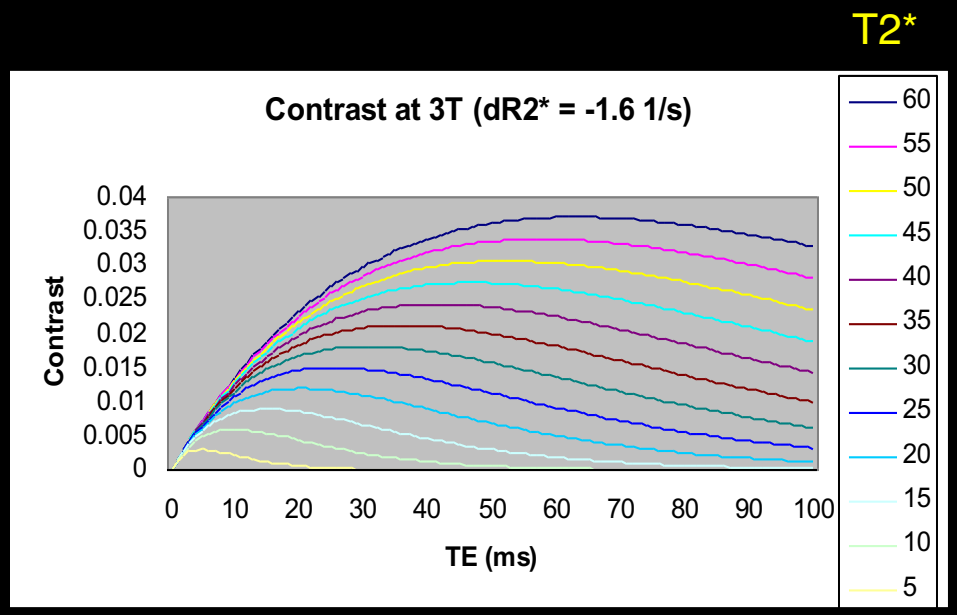
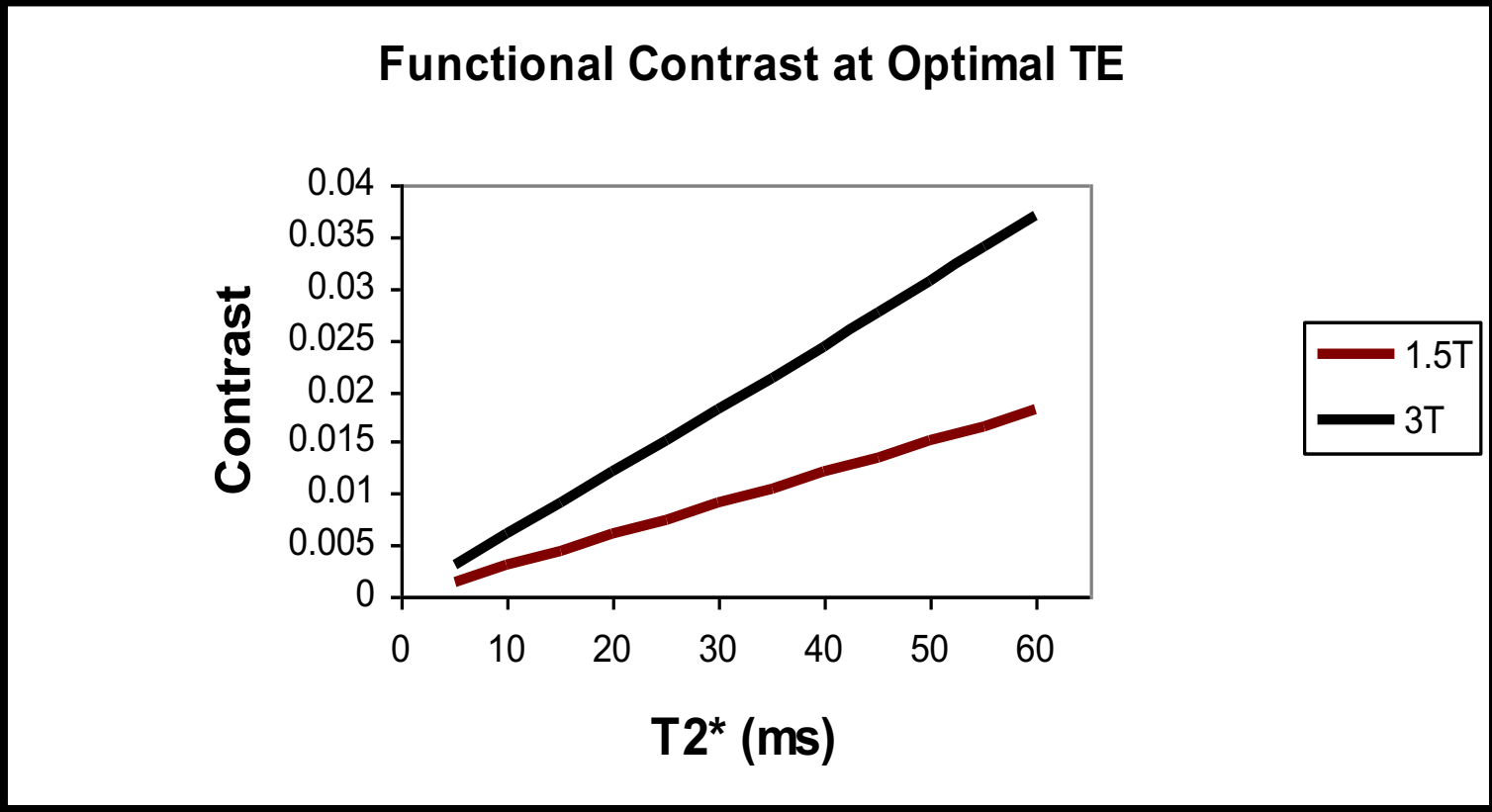



Functional Contrast at Optimal TE
Contrast
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
10
20
30
40
50
60
T2* (ms)
1.5T
3T

Contrast depends on:
activation-induced changes in T2* *and* resting T2*






Functional Contrast at Optimal TE
Contrast
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
10
20
30
40
50
60
T2* (ms)
1.5T
3T

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Neuroimaging at 1.5 T and 3.0 T: Comparison of Oxygenation-Sensitive Magnetic Resonance Imaging

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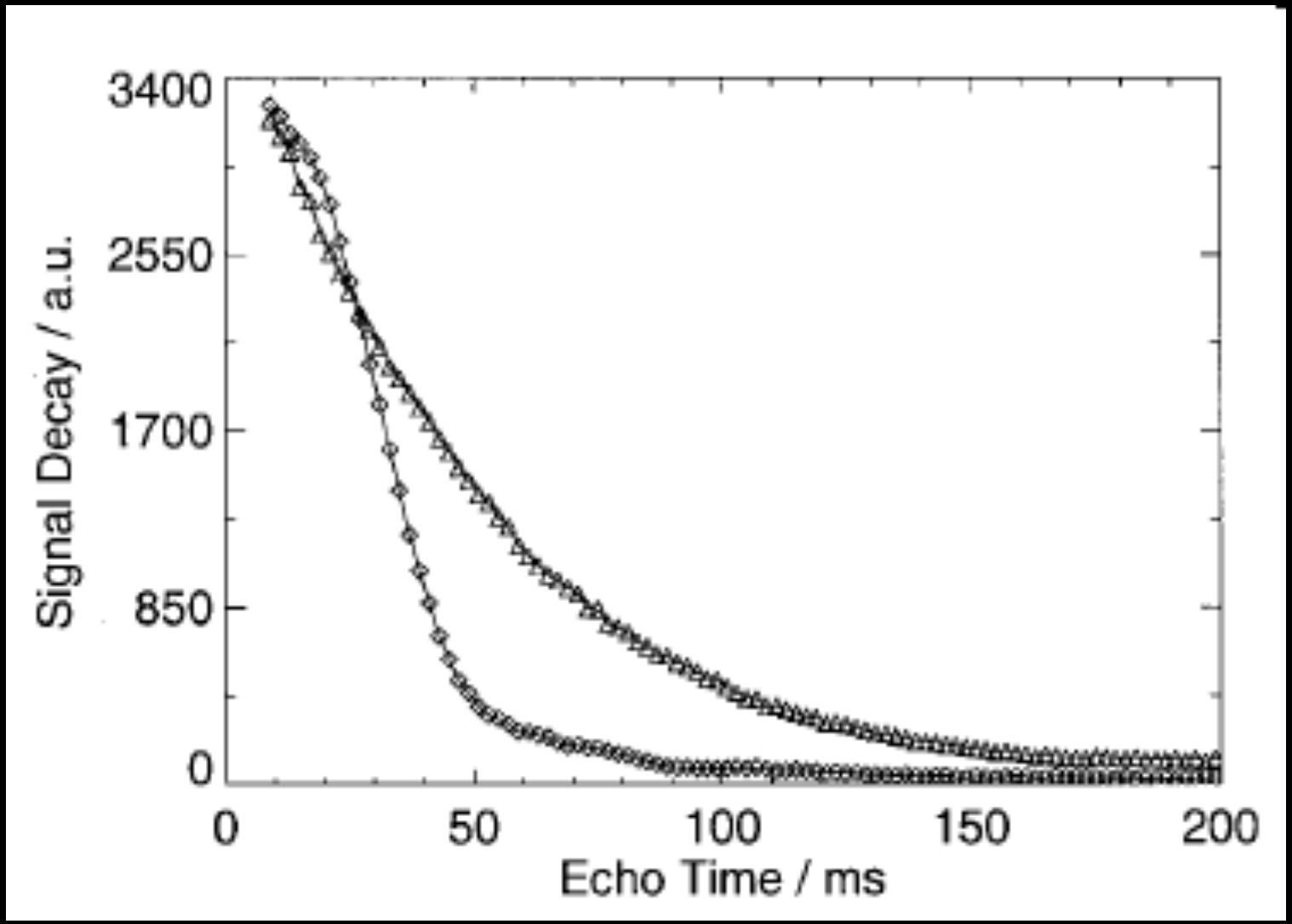
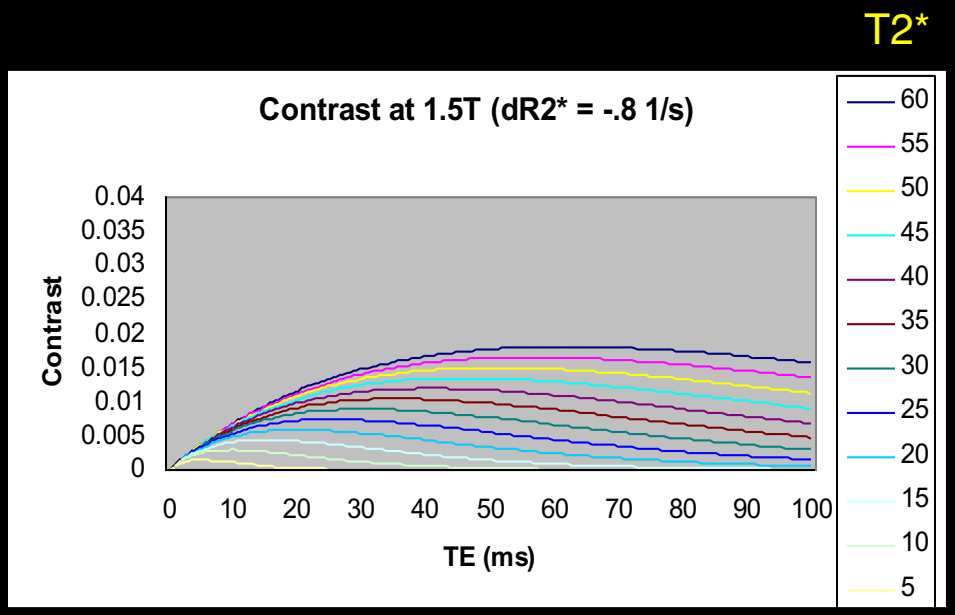
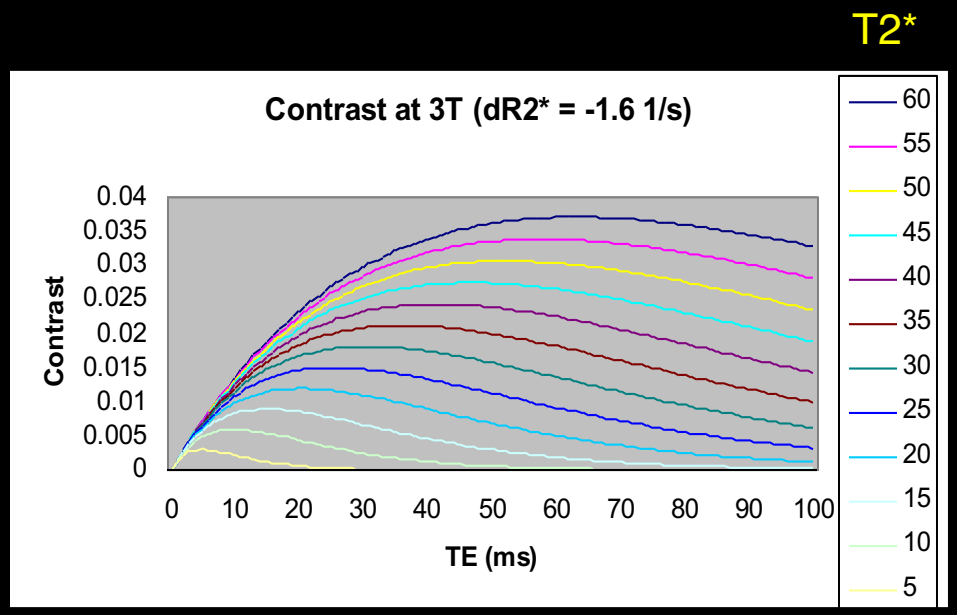
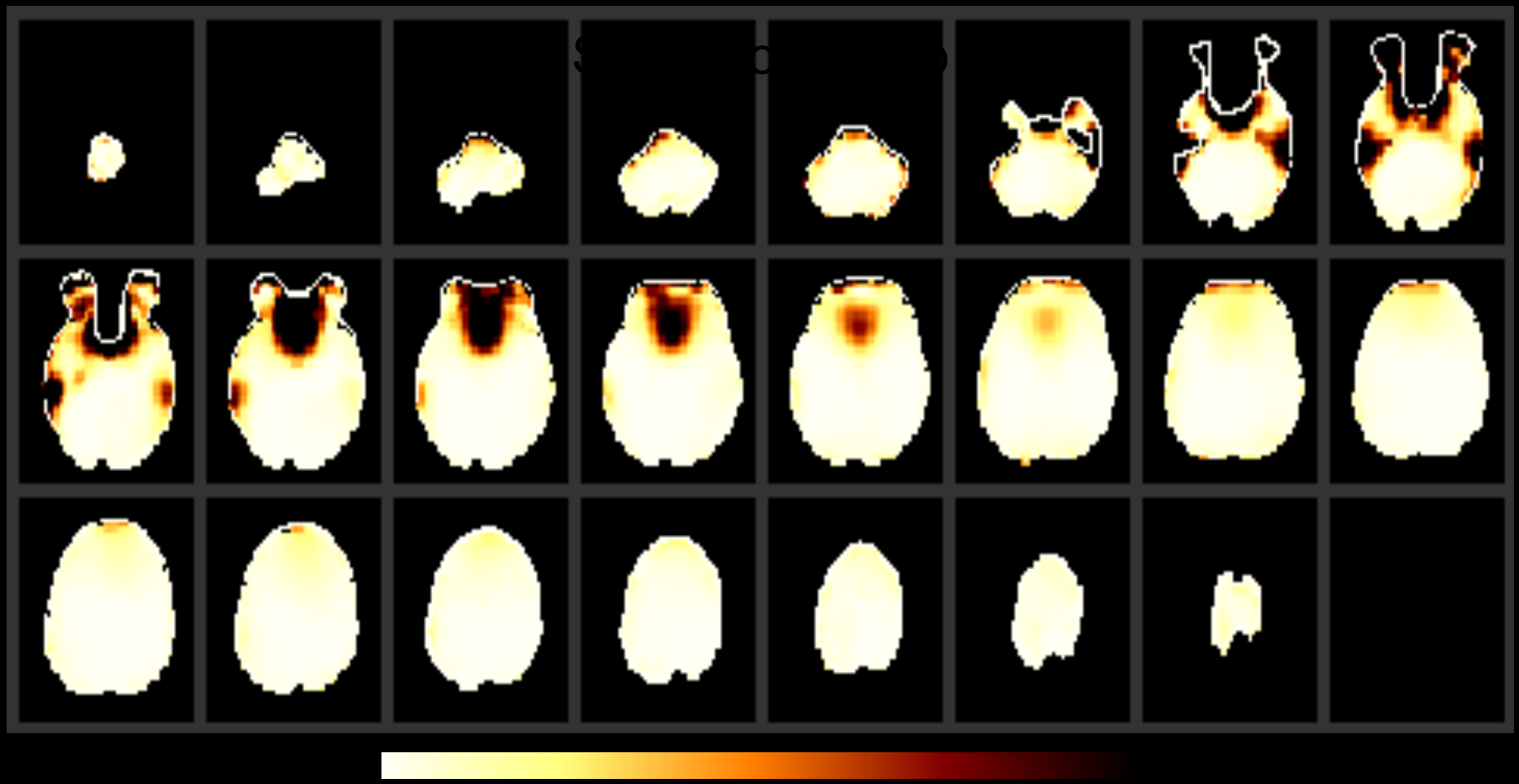


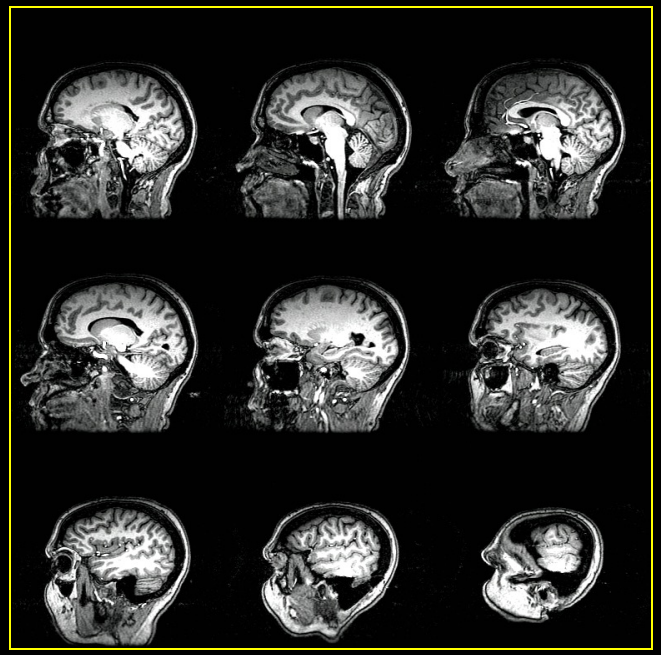
Contrast depends on:
activation-induced changes in T2* *and* resting T2*

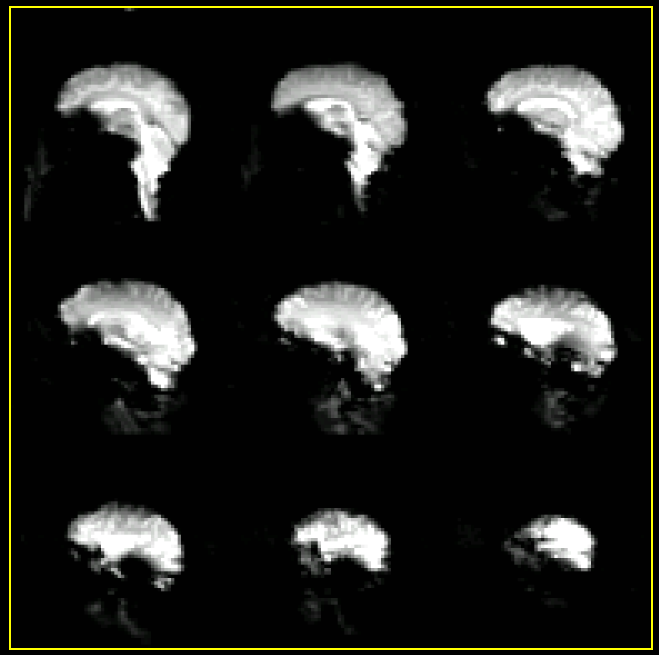


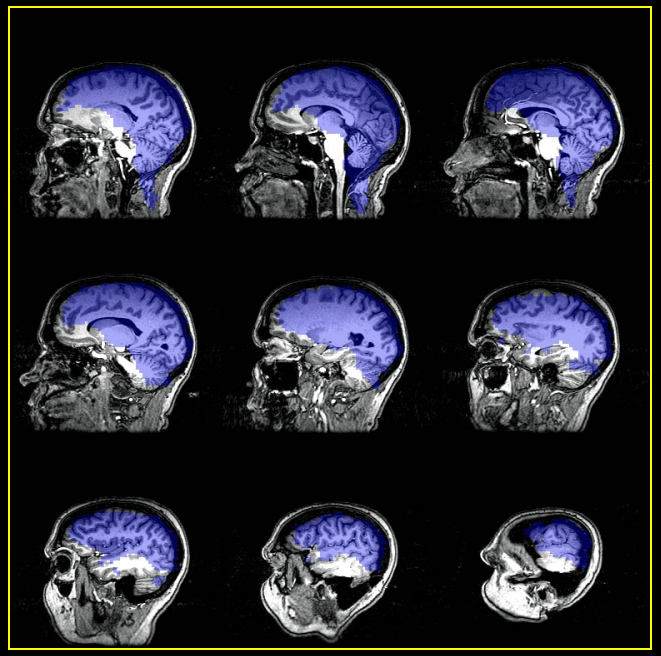


Gradient echo Signal Loss





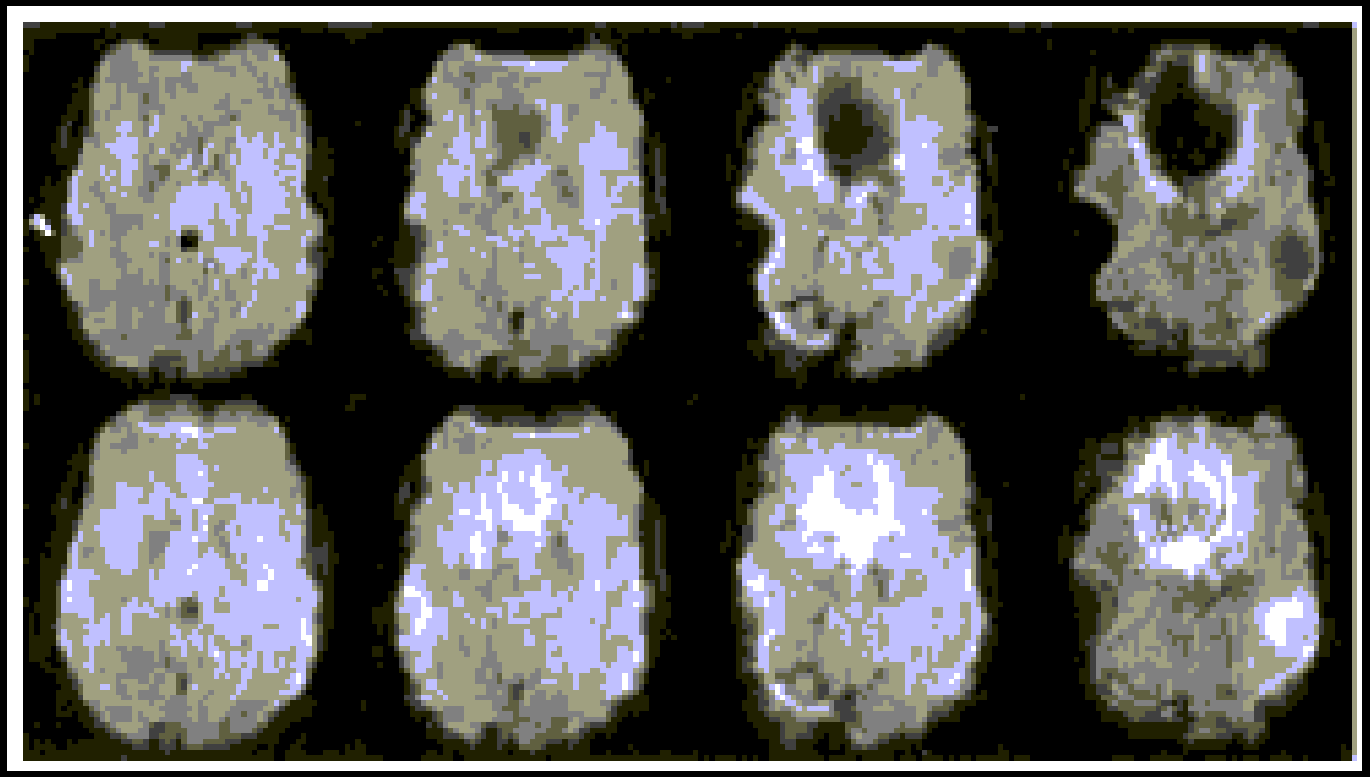




Magnetic Resonance in Medicine 42:290–299 (1999)

3D z-Shim Method for Reduction of Susceptibility Effects in BOLD fMRI

Gary H. Glover*



A Bit of a Mouth Full: Susceptibility Artifact Reduction Using Diamagnetic Passive Shims

J. L. Wilson, M. Jenkinson, and P. Jezzard

Centre for Functional Magnetic Resonance Imaging of the Brain, University of Oxford, John Radcliffe Hospital, Oxford OX3 9DU, U.K.

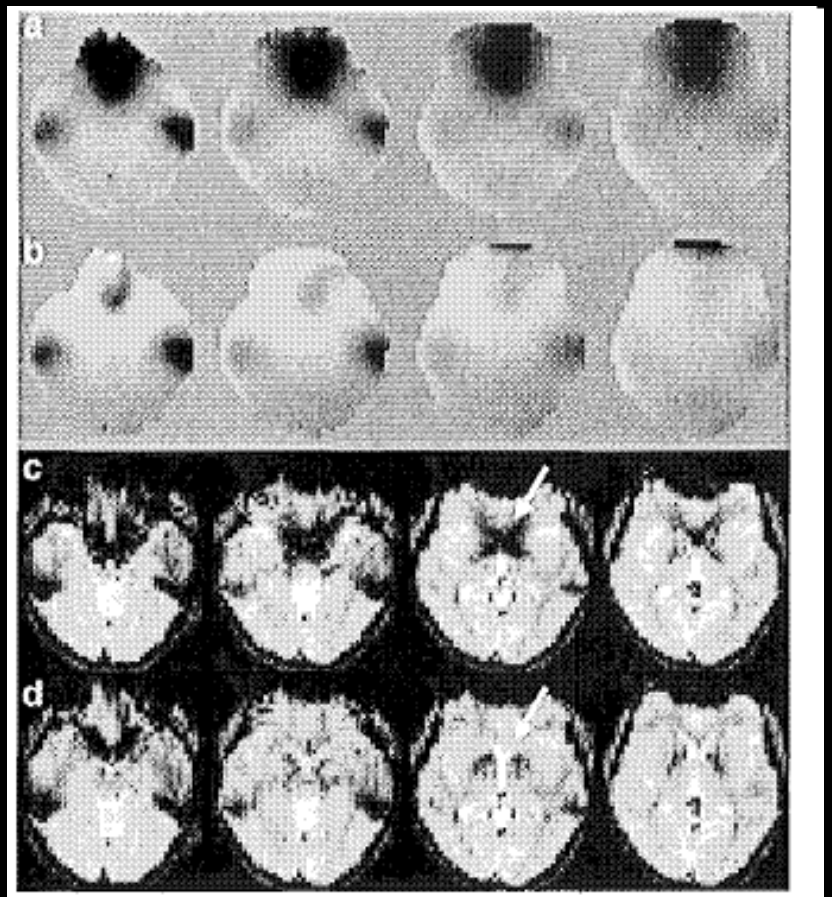
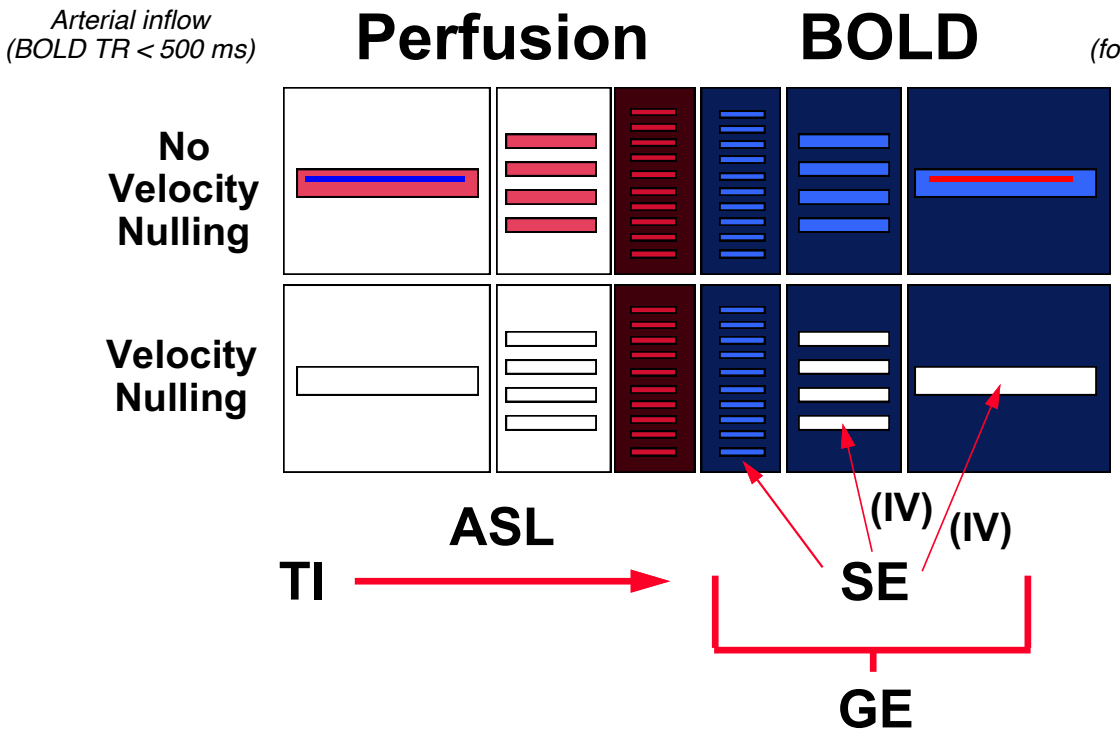
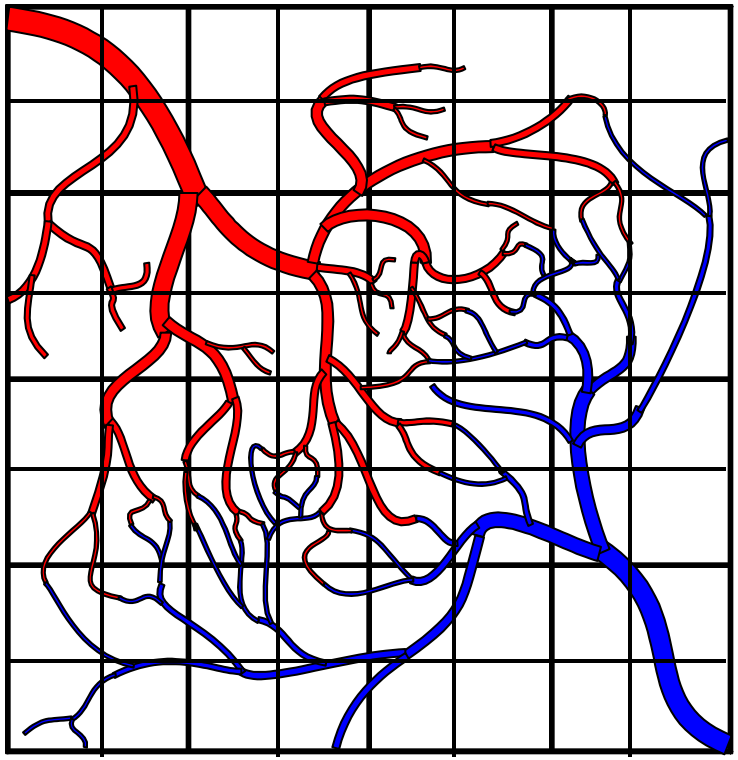


Figure 1: Brain masked axial B0 maps of the IFC are shown (a) without, and (b) with the mouth shim; range: −0.8 ppm (light) to +0.8 ppm (dark). Corresponding GE EPIs are shown (c) without, and (d) with the mouth shim. White arrows indicate a region of susceptibility artifact reduction.



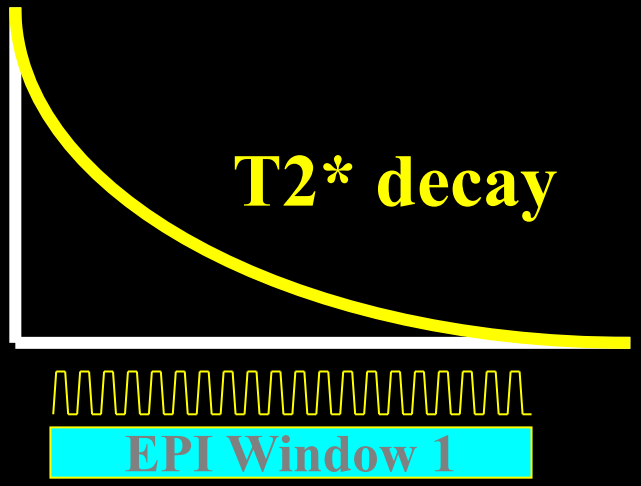
Pulse Sequence Sensitivity

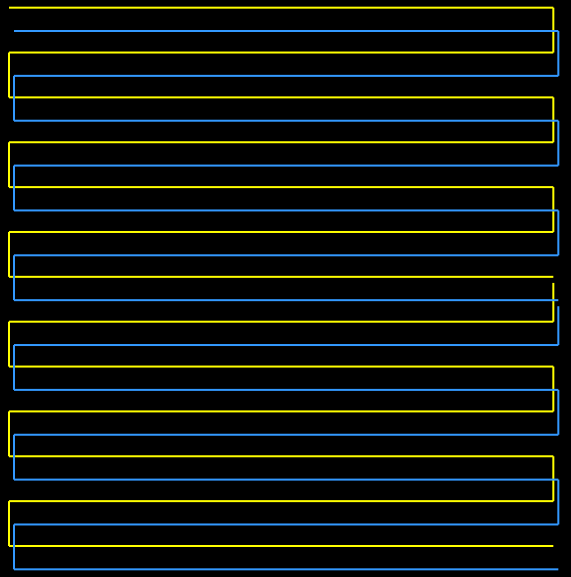
Spatial Heterogeneity

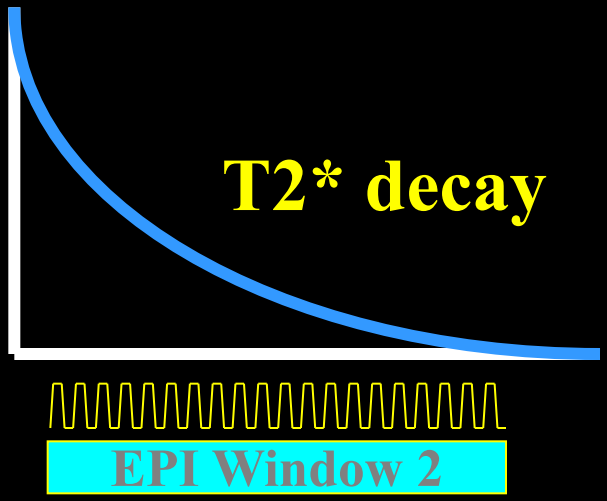


A few slides about Image Resolution and Noise...

Multishot Imaging

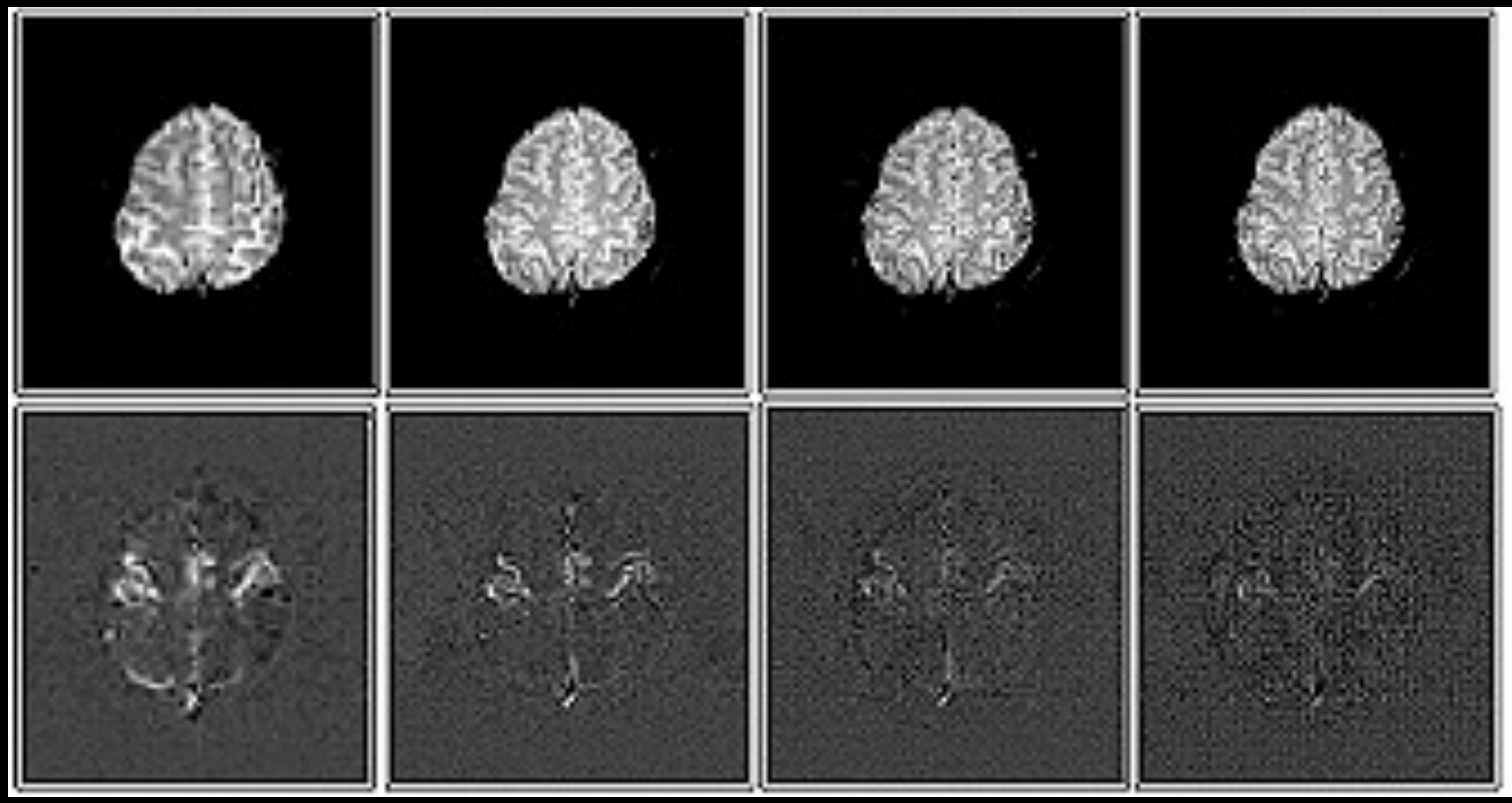




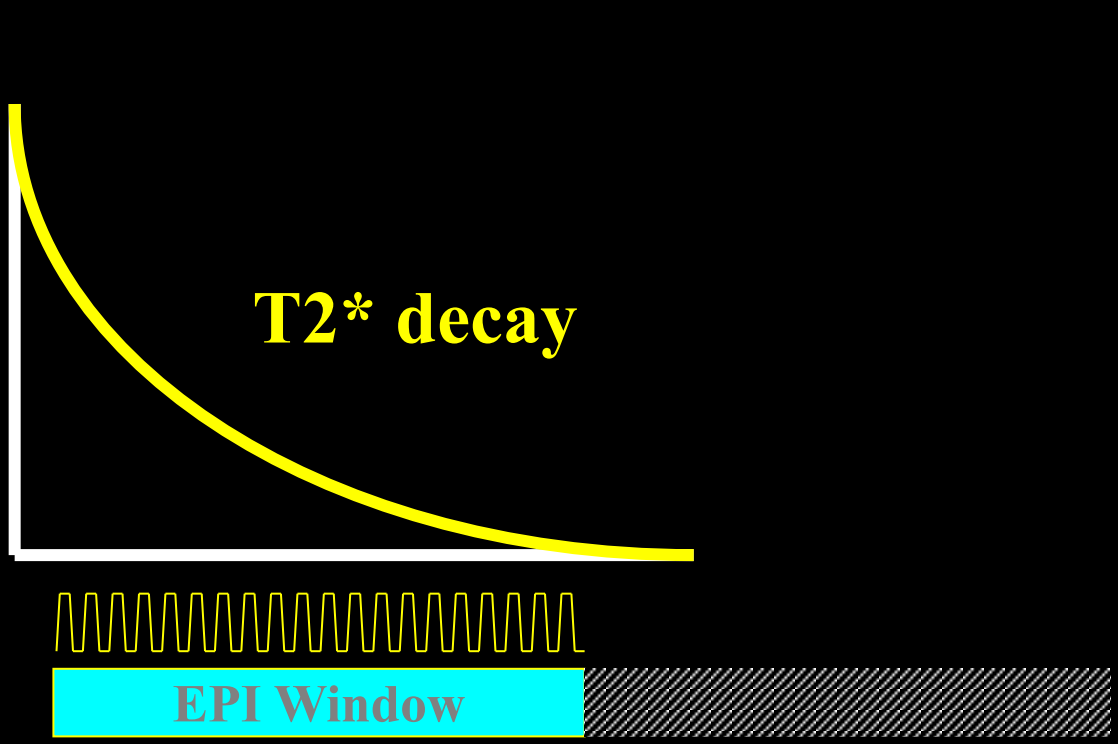


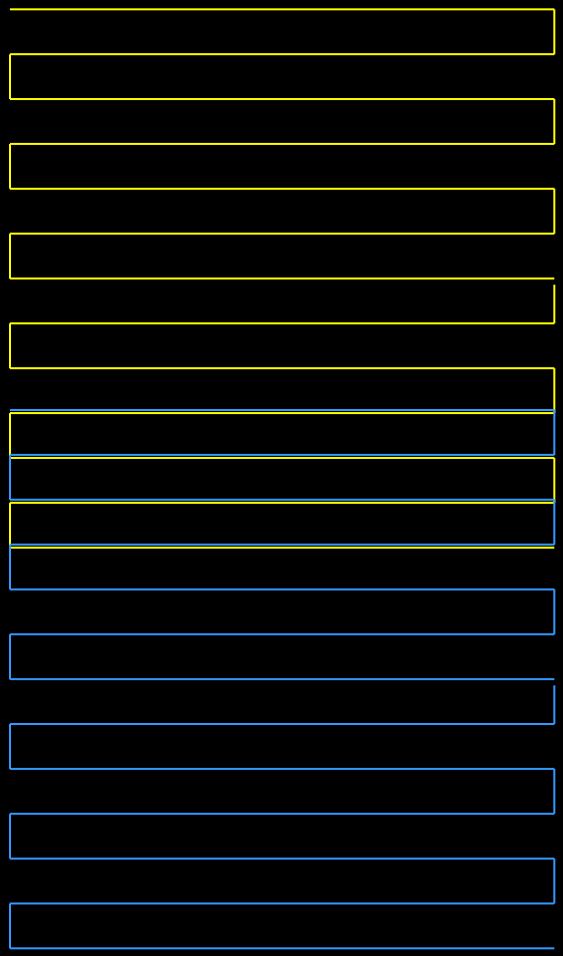
Multi Shot EPI

Excitations	1	2	4	8
Matrix Size	64 x 64	128 x 128	256 x 128	256 x 256

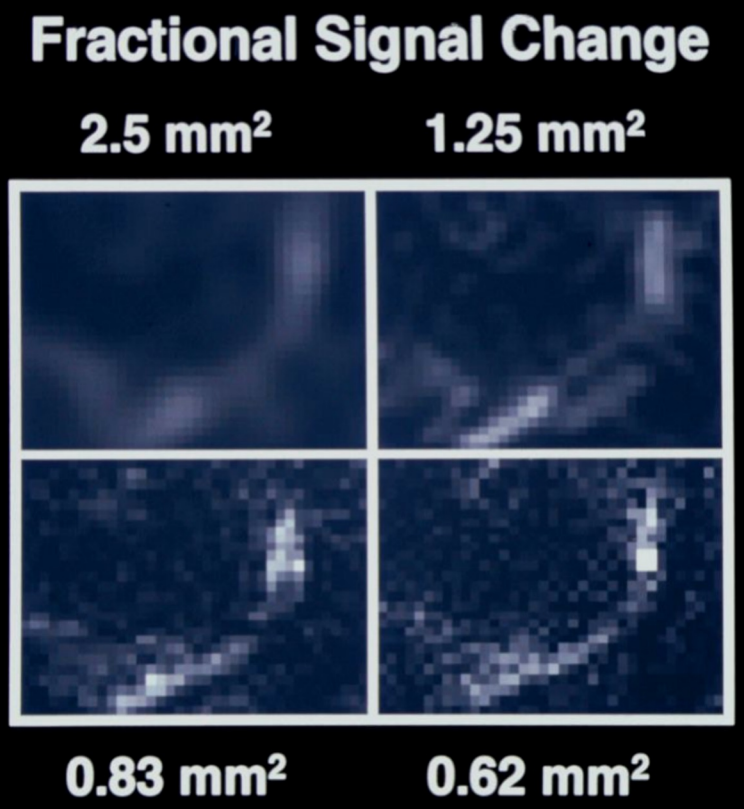


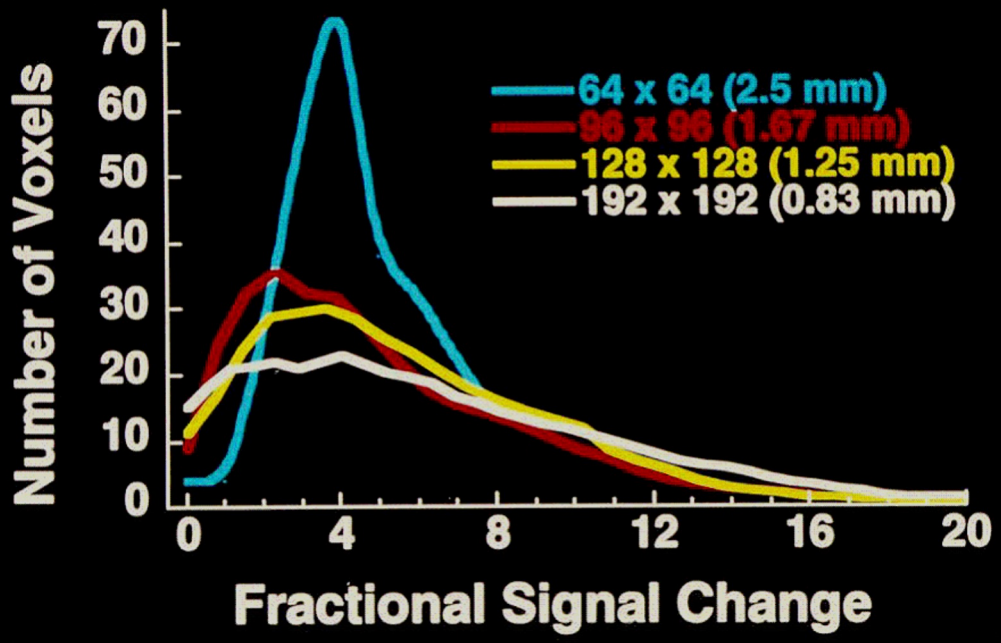
Partial k-space imaging





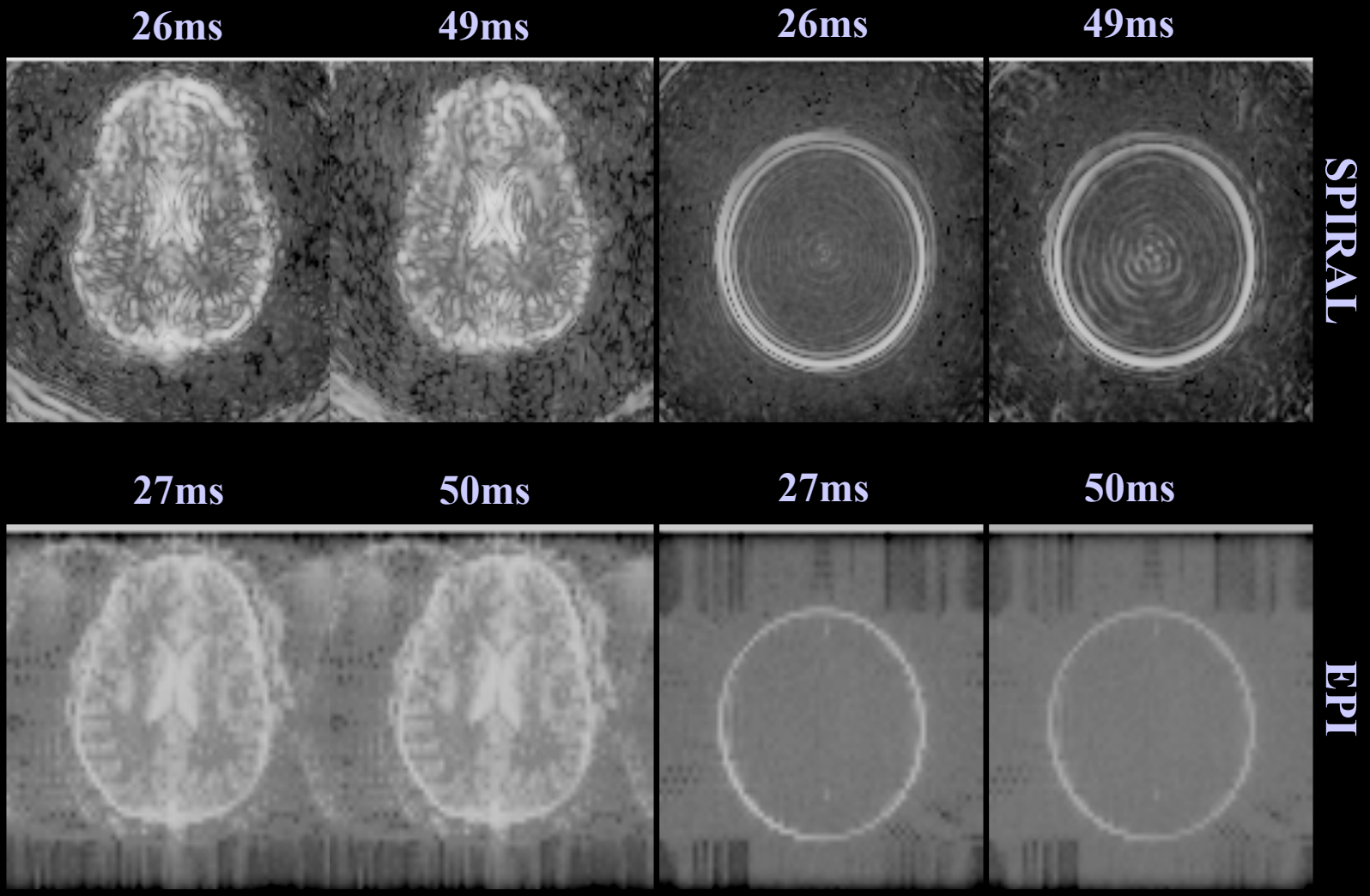
Partial k-space imaging



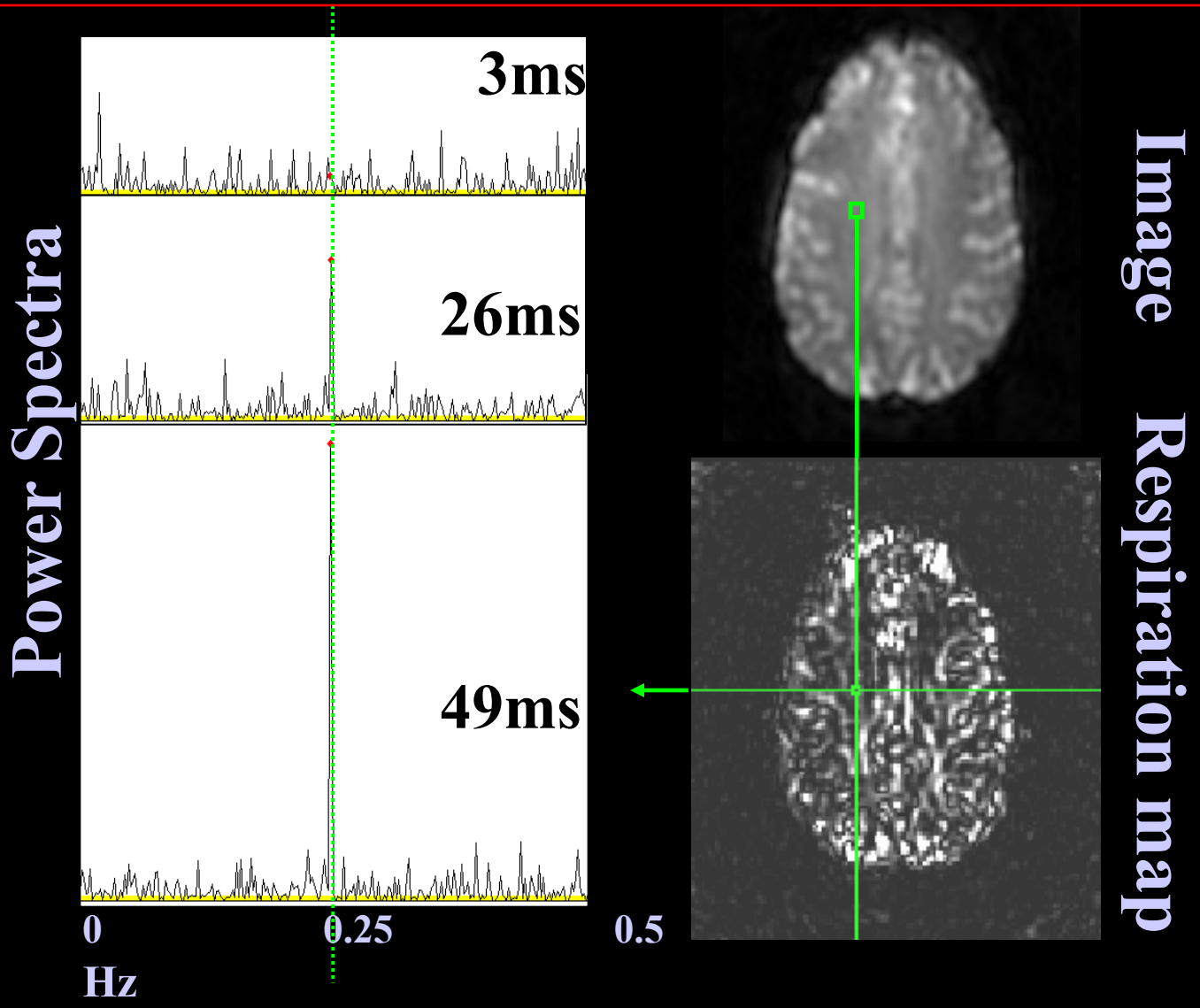


Jesmanowicz, P. A. Bandettini, J. S. Hyde, (1998) "Single shot half k-space high resolution EPI for fMRI at 3T." *Magn. Reson. Med.* 40, 754-762.

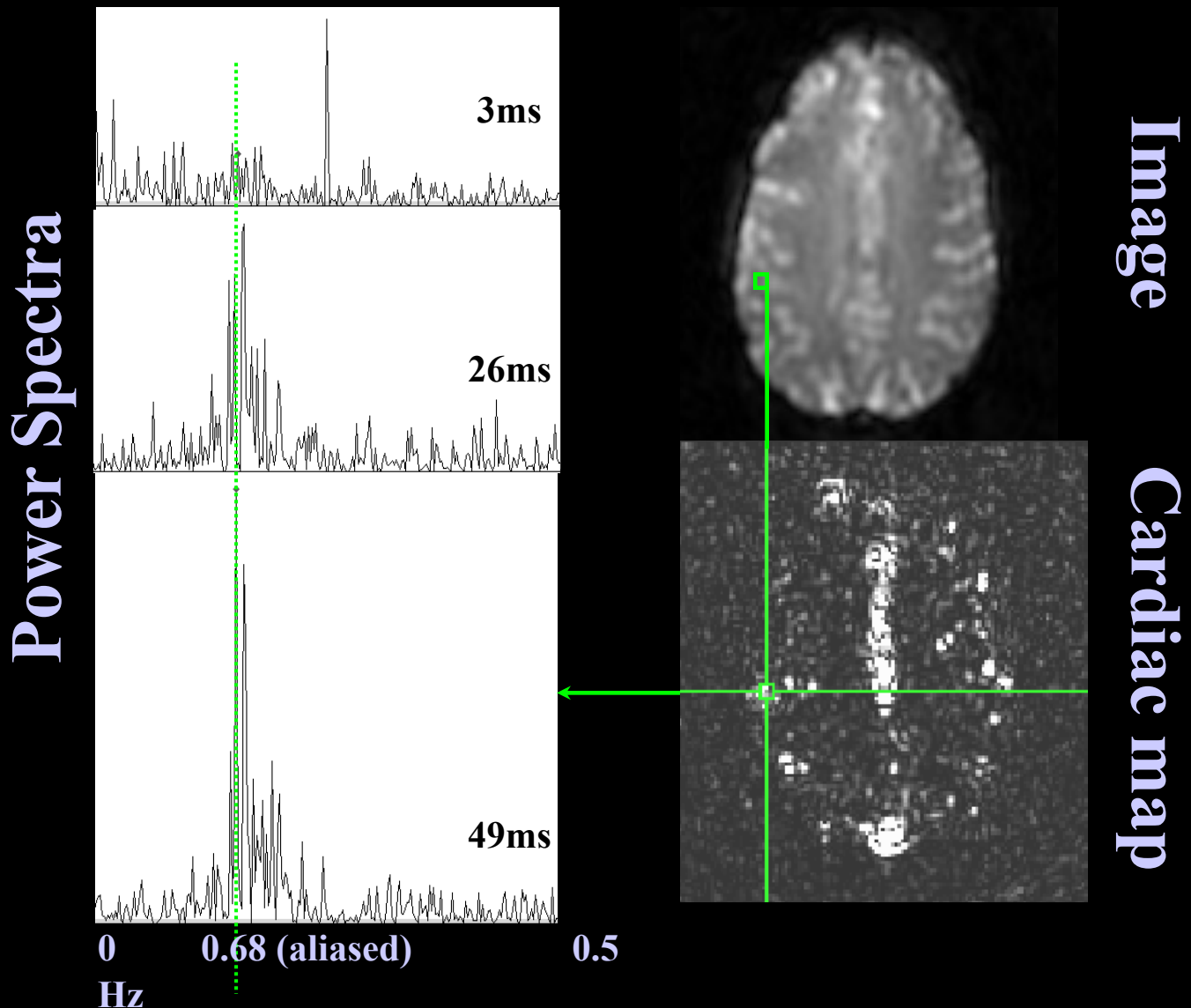
Temporal vs. Spatial SNR- 3T



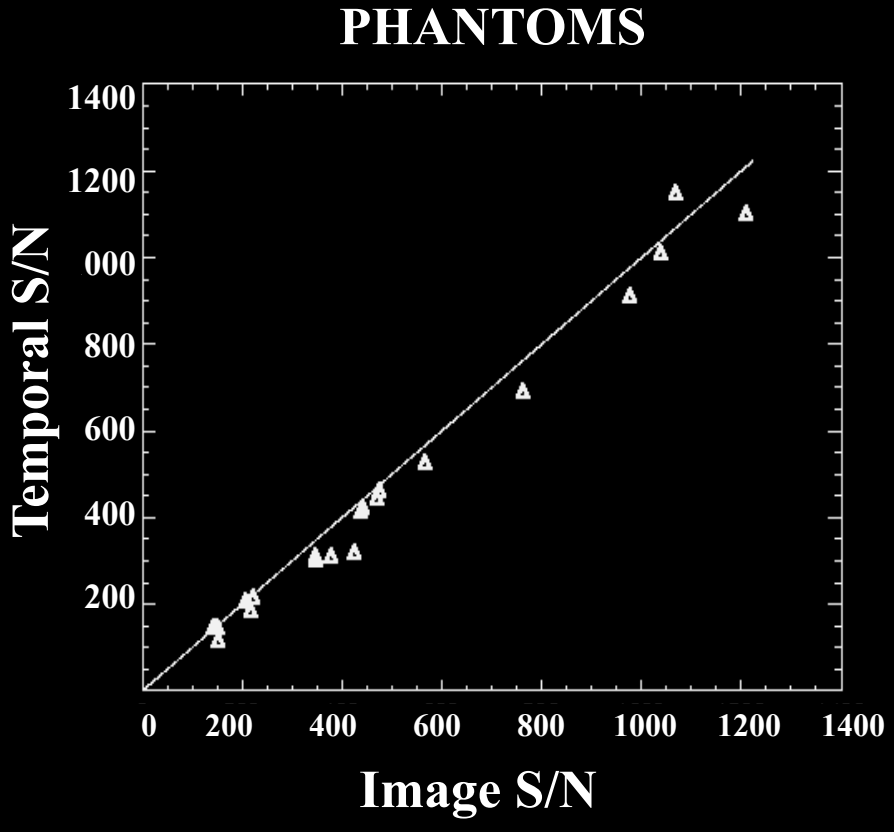
0.25 Hz Breathing at 3T

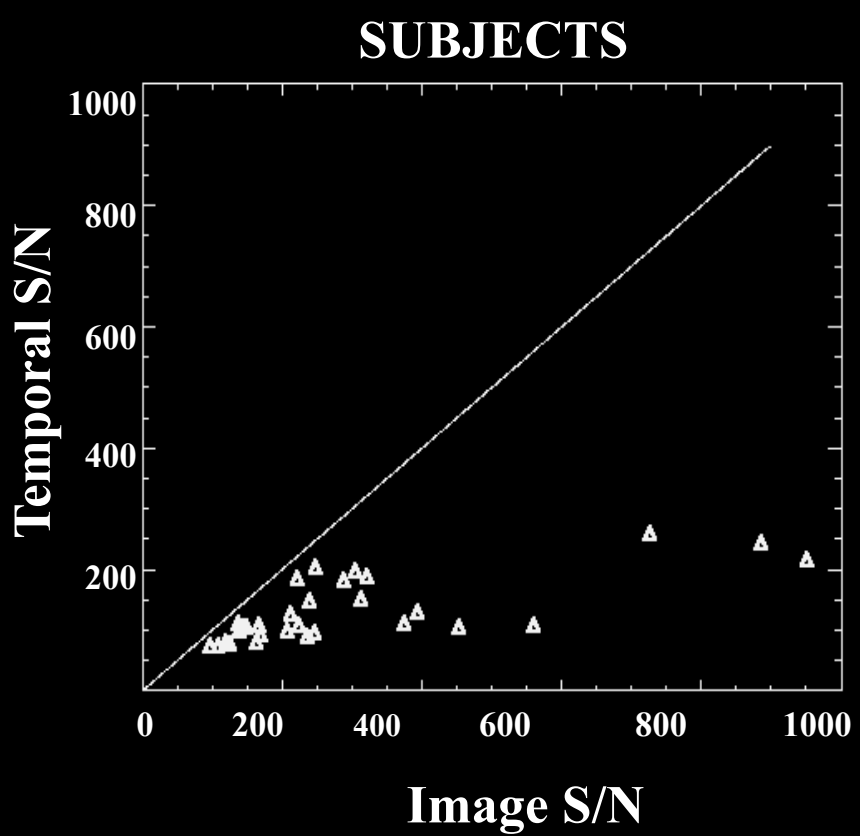


0.68 Hz Cardiac rate at 3T



Temporal S/N vs. Image S/N



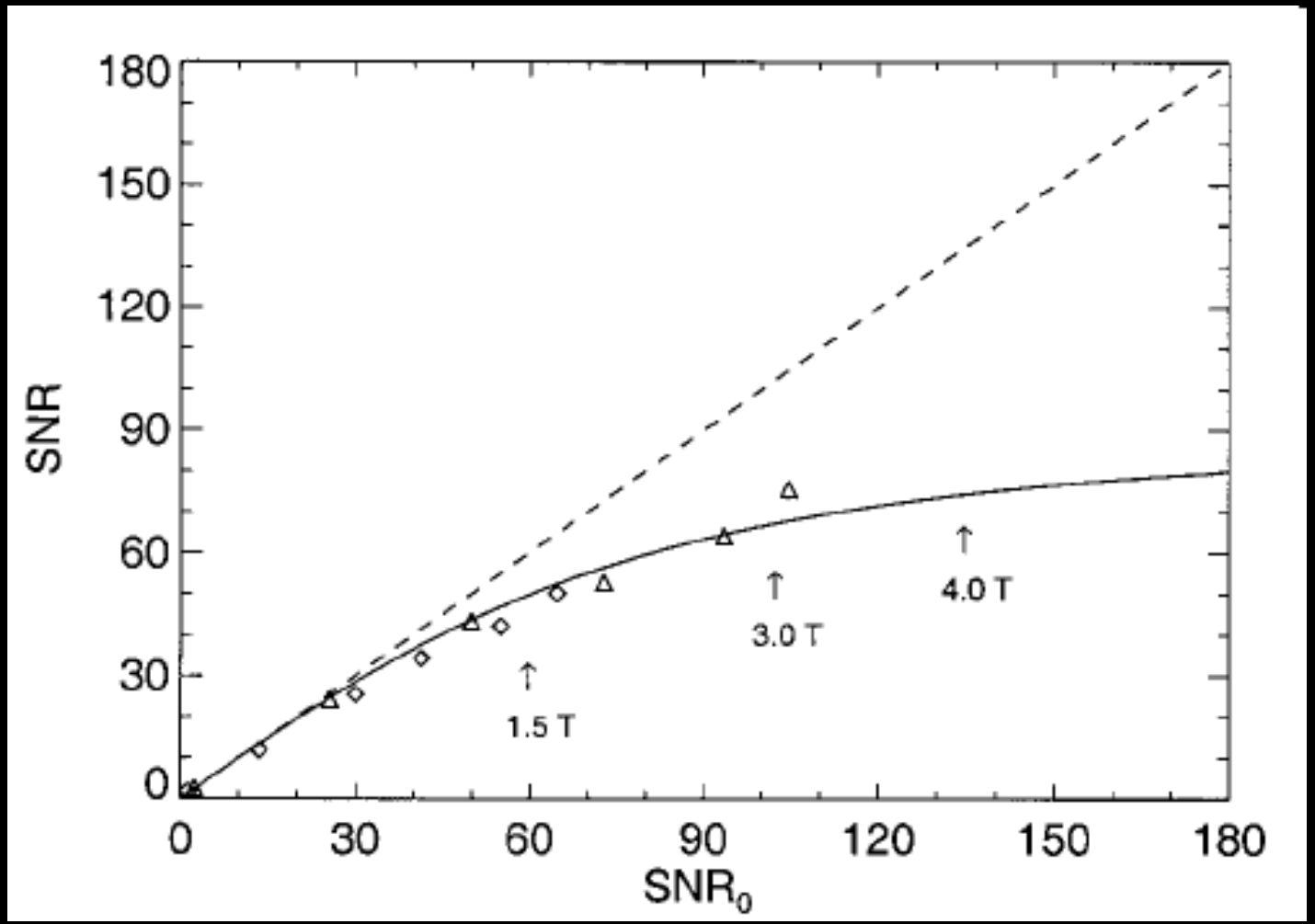


N. Petridou

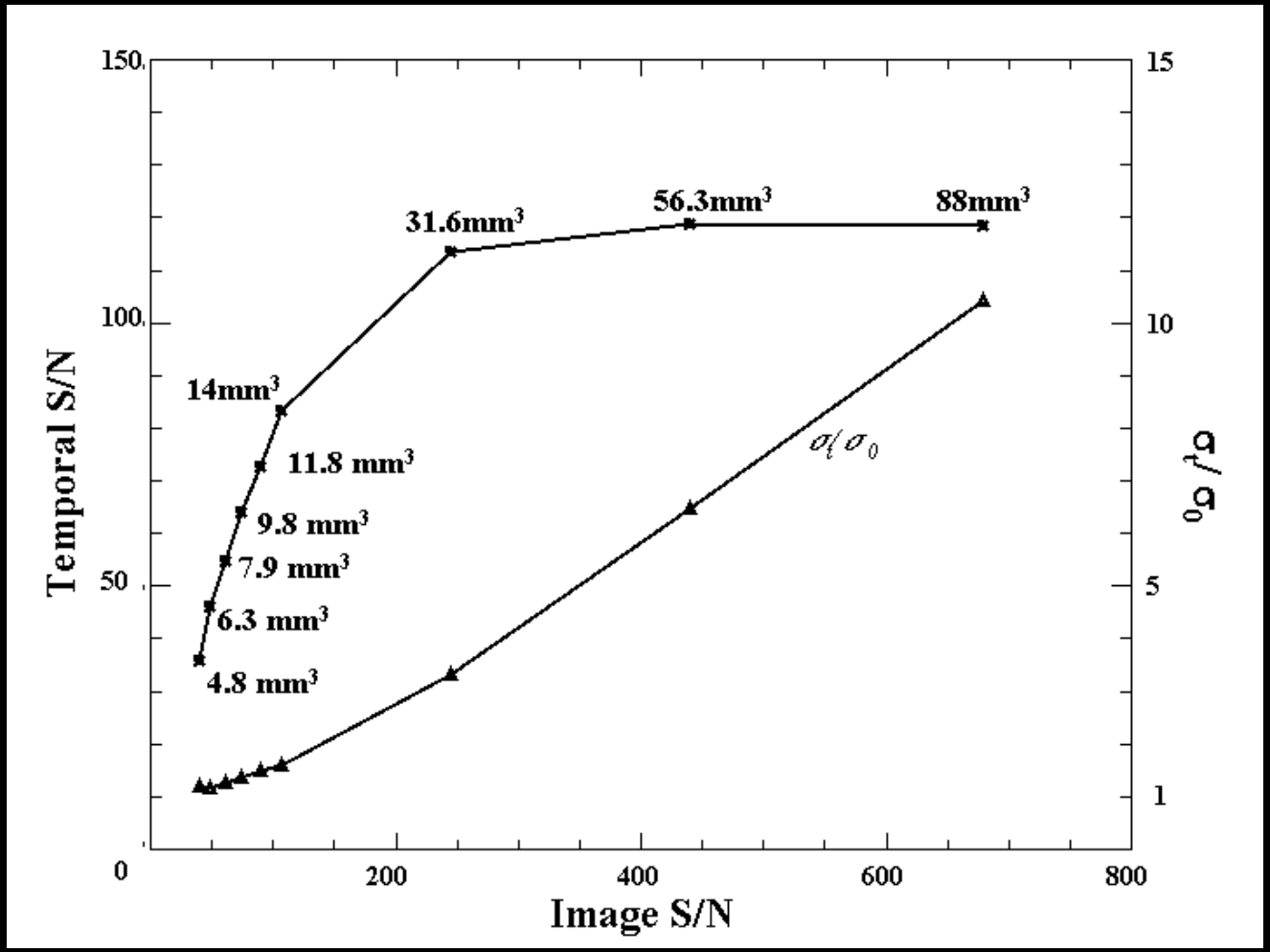
Magnetic Resonance in Medicine 45:595–604 (2001)

Neuroimaging at 1.5 T and 3.0 T: Comparison of Oxygenation-Sensitive Magnetic Resonance Imaging

Gunnar Krüger,* Andreas Kastrup, and Gary H. Glover



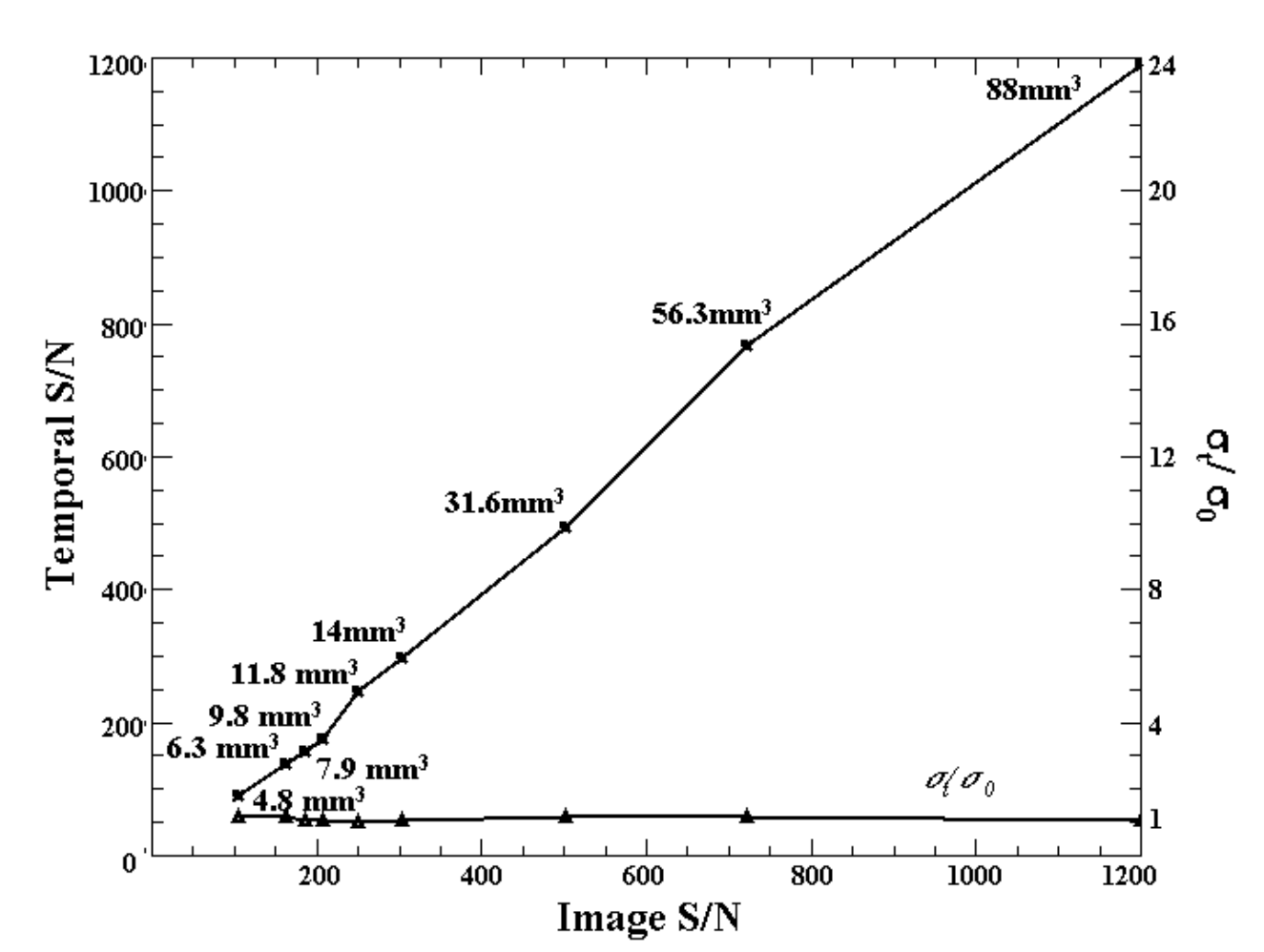
Temporal vs. Image S/N
Optimal Resolution Study



Human data

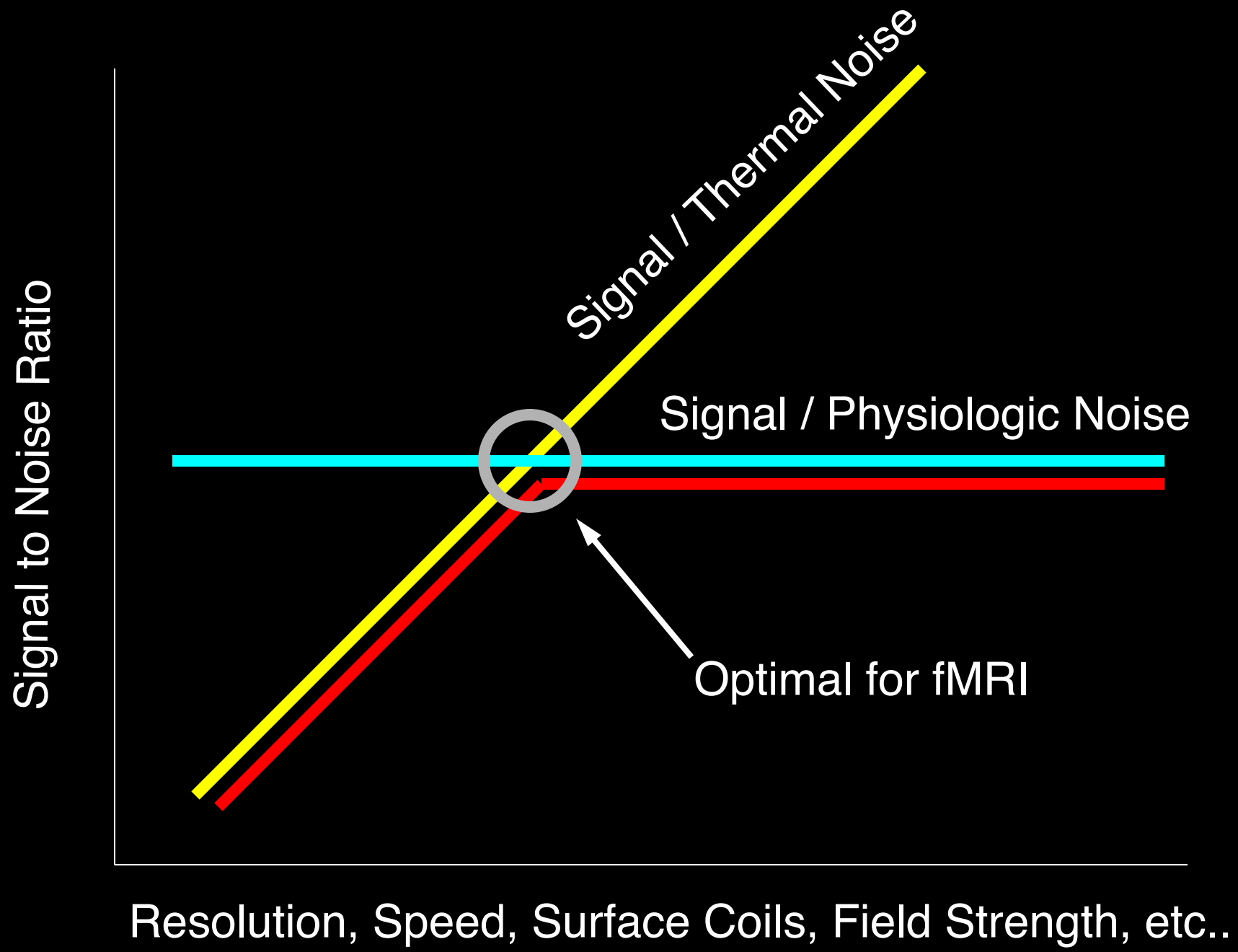
Petridou et al

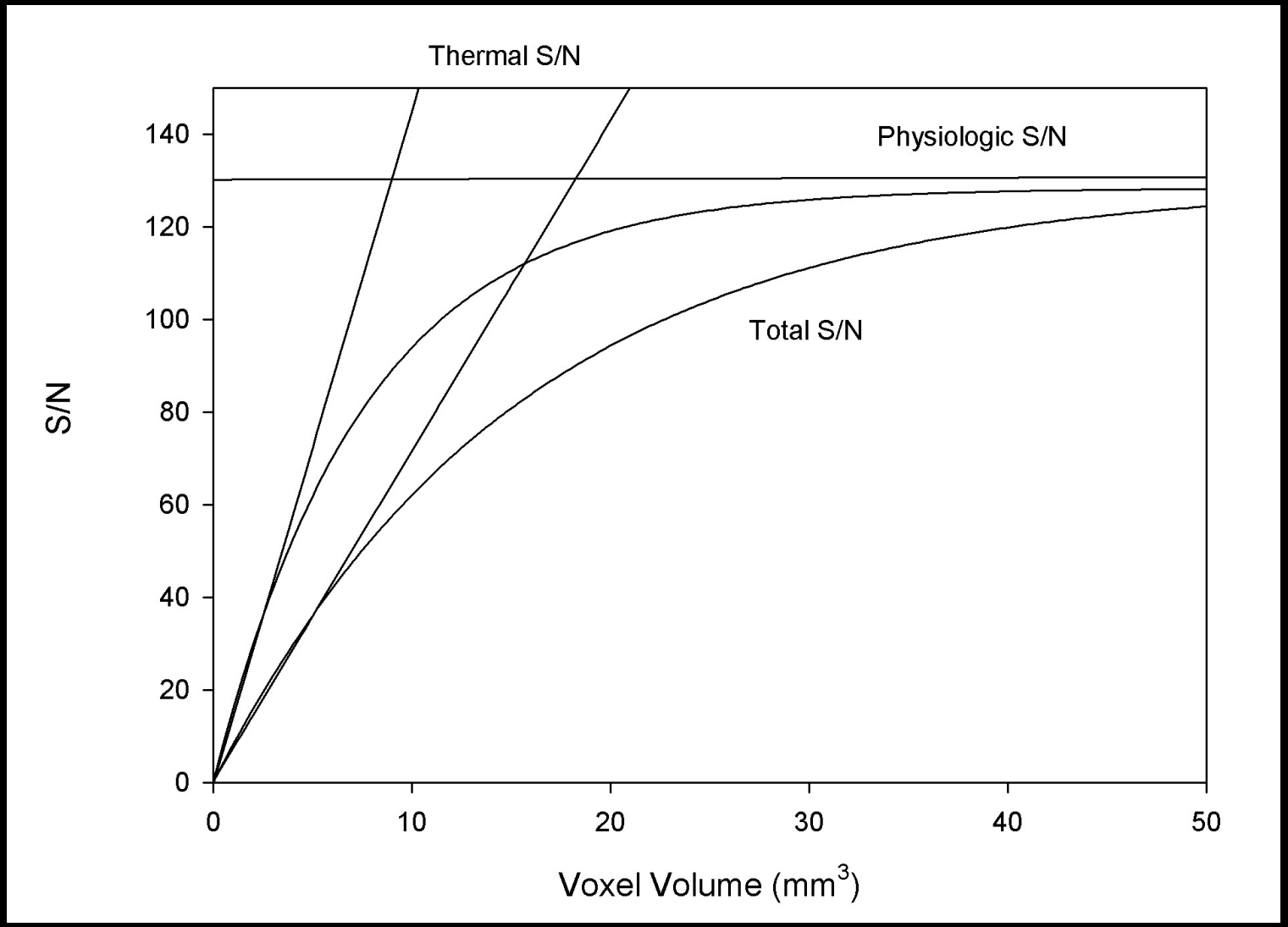
Temporal vs. Image S/N
Optimal Resolution Study



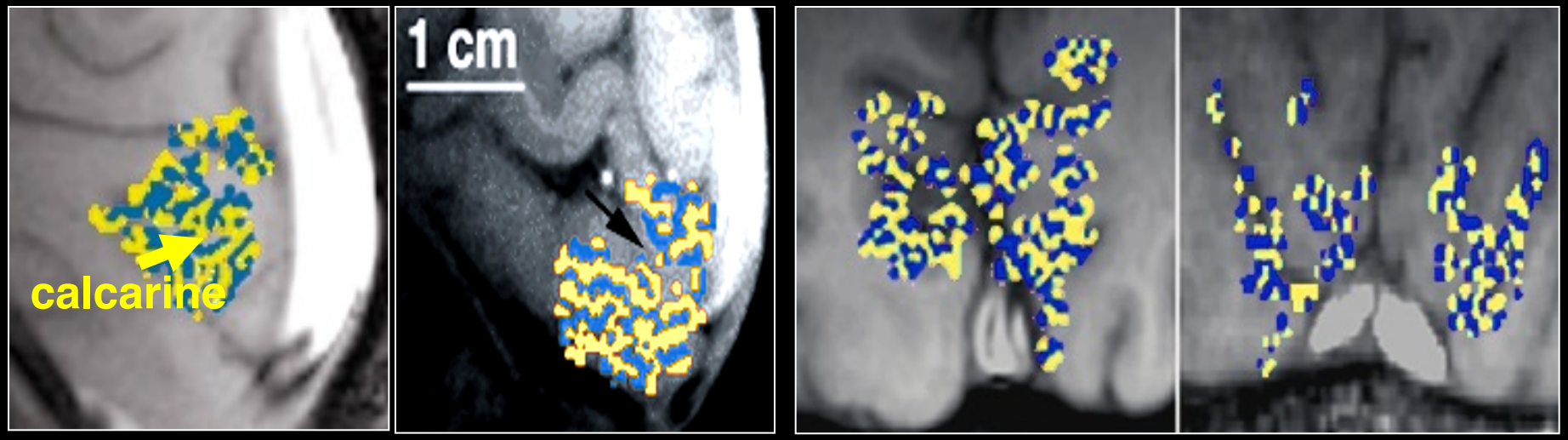
Phantom data

Petridou et al

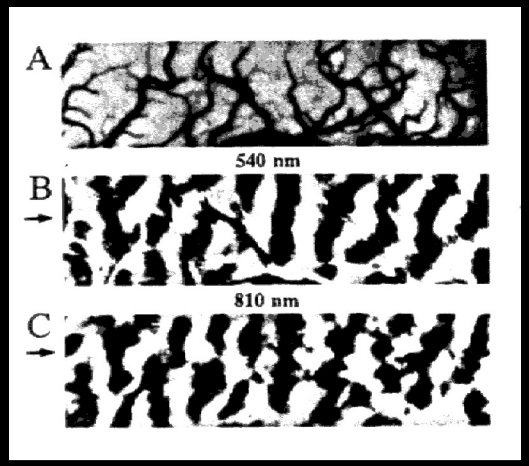

Signal to Noise Ratio
Signal / Thermal Noise
Signal / Physiologic Noise
Optimal for fMRI
Resolution, Speed, Surface Coils, Field Strength, etc..


Thermal S/N
Physiologic S/N
Total S/N
S/N
0
20
40
60
80
100
120
140
0
10
20
30
40
50
Voxel Volume (mm3)

Ocular Dominance Column Mapping using fMRI



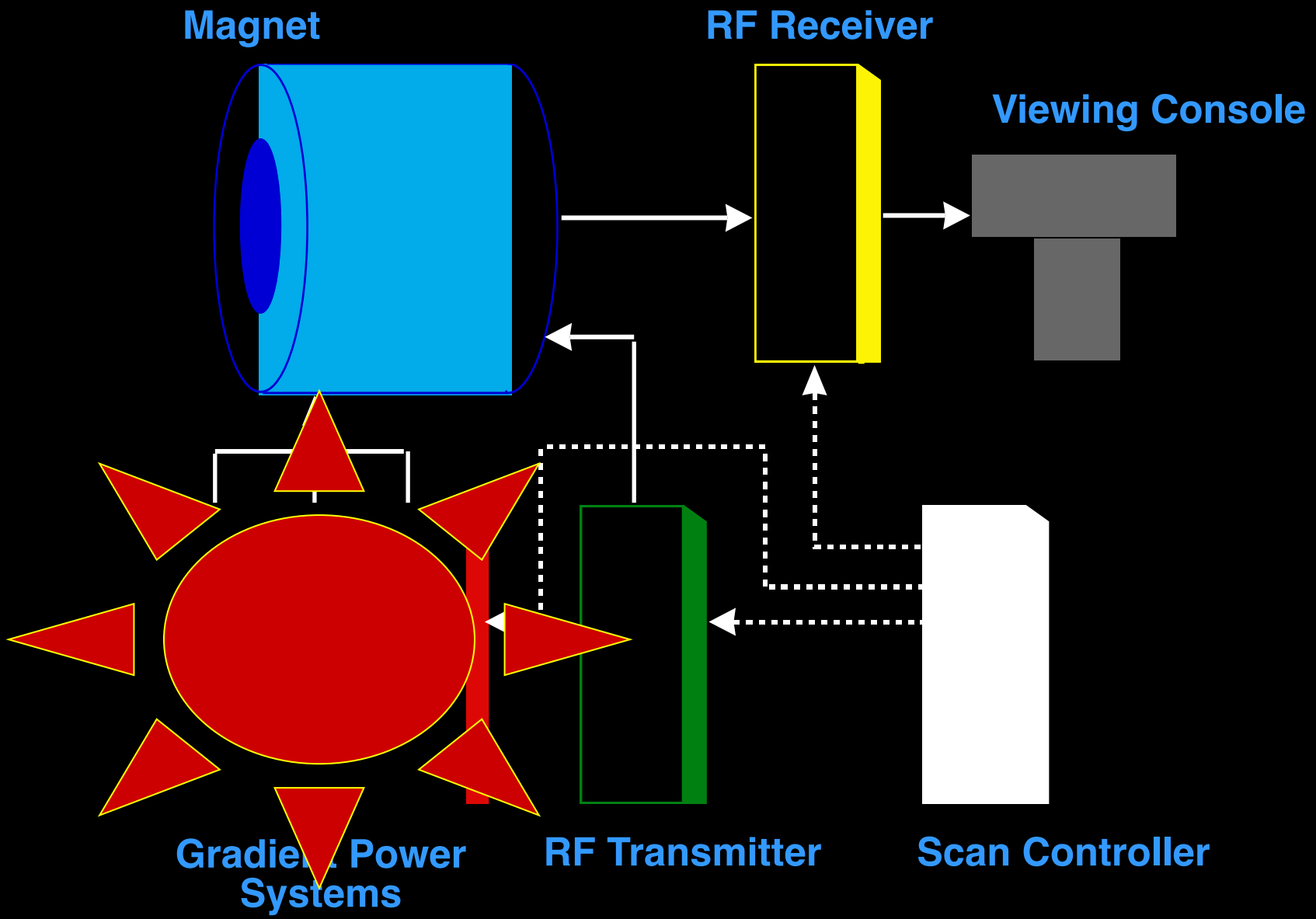
Menon, R. S., S. Ogawa, et al. (1997). "Ocular dominance in human V1 demonstrated by functional magnetic resonance imaging." J Neurophysiol 77(5): 2780-7.



Optical Imaging

R. D. Frostig et. al, PNAS 87: 6082-6086, (1990).

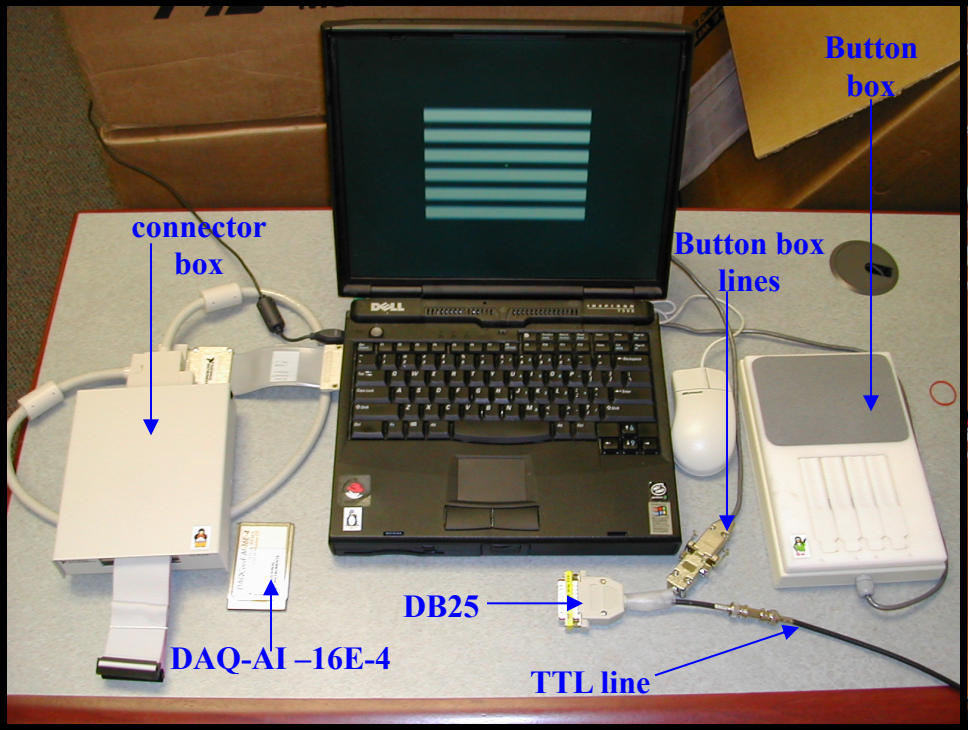
Imaging System Components



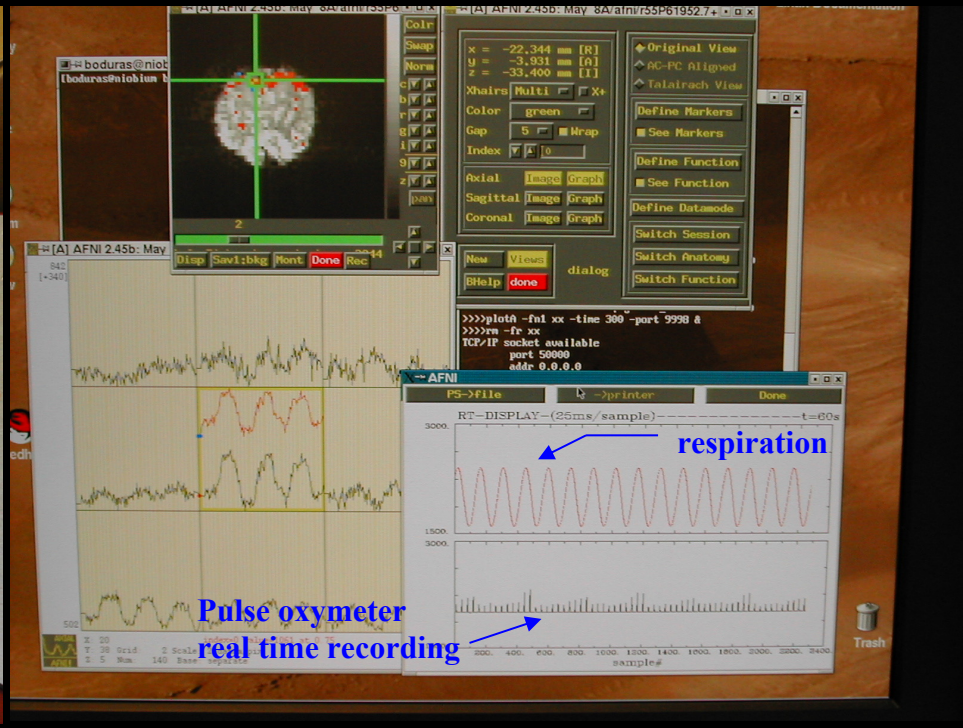
1. Purchasing a scanner
2. Data handling
3. Subject interface devices
4. Data processing
5. Personnel

Data handling

-real time
-pseudo real time
-RAID servers
-reconstruction speed
-reconstruction access

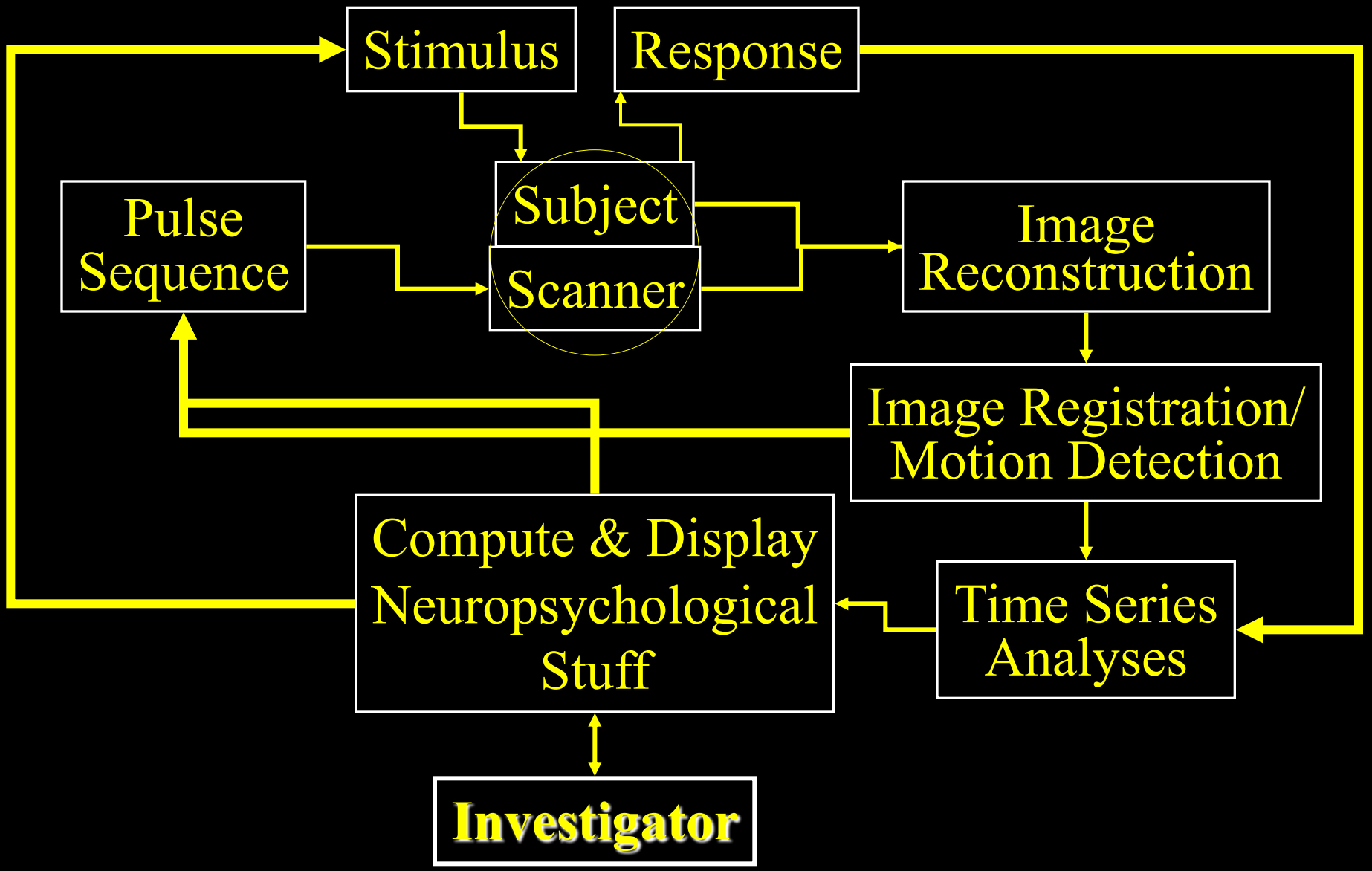


AThe Linux based stimulus delivery system.

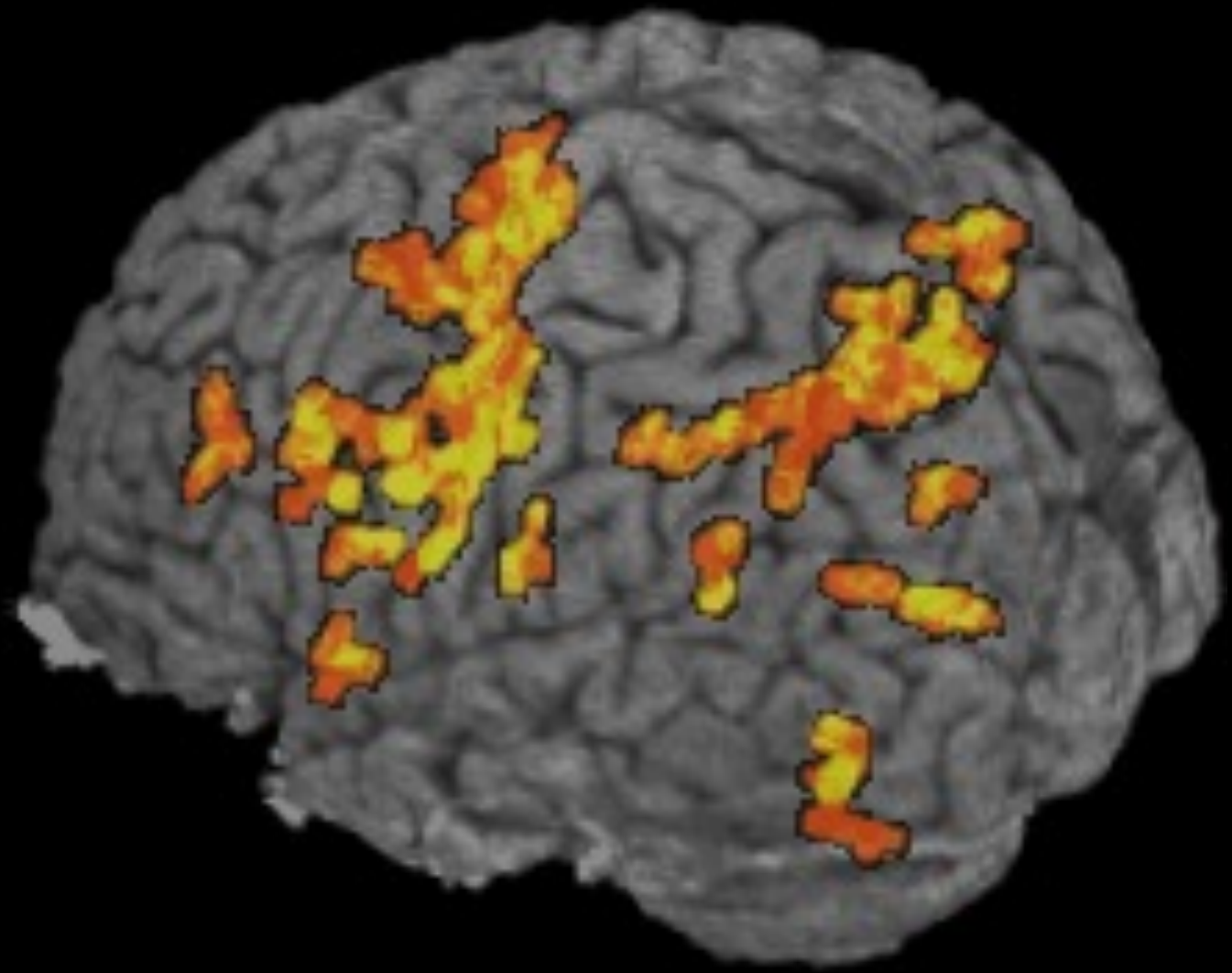


AThe real-time recording and display with AFNI.
delivery system.

Processing Stream with Real Time fMRI



End of Acquisition



< 1 s to render

Blocked trials:
20 s on/20 s off
8 blocks

Blocks: 12345678

Color shows through brain

Correlation > 0.45

The End

1. Purchasing a scanner
2. Data handling
3. Subject interface devices
4. Data processing
5. Personnel

Subject interface devices

-stimulus devices
    >projector, goggles, tactile, smell, sound
-synchronization
-subject feedback
    >button box, SCR, cardiac, respiratory, eye tracking
-subject stability
    >cushions, bite bar

1. Purchasing a scanner
2. Data handling
3. Subject interface devices
4. Data processing
5. Personnel

Data processing

-preprocessing (recon)
-post processing (registration, statistical tests)
-post post processing (subject averaging, display)

1. Purchasing a scanner
2. Data handling
3. Subject interface devices
4. Data processing
5. Personnel

Personnel

-physicist
-engineer
-computer person (processing and stimulus program)
-stimulus/feedback device specialist
-rf coil person
-scanner technologist
-administrator

FIM Unit & FMRI Core Facility

Director:

Peter Bandettini

Staff Scientists:

Sean Marrett

Jerzy Bodurka

Frank Ye

Wen-Ming Luh

Computer Specialist:

Adam Thomas

Post Docs:

Rasmus Birn

Hauke Heekeren

David Knight

Patrick Bellgowan

Ziad Saad

Graduate Student:

Natalia Petridou

Post-Back. IRTA Students:

Elisa Kapler

August Tuan

Dan Kelley

Visiting Fellows:

Sergio Casciaro

Marta Maieron

Guosheng Ding

Clinical Fellow:

James Patterson

Psychologist:

Julie Frost

Summer Students:

Hannah Chang

Courtney Kemps

Douglass Ruff

Carla Wettig

Kang-Xing Jin

Program Assistant:

Kay Kuhns

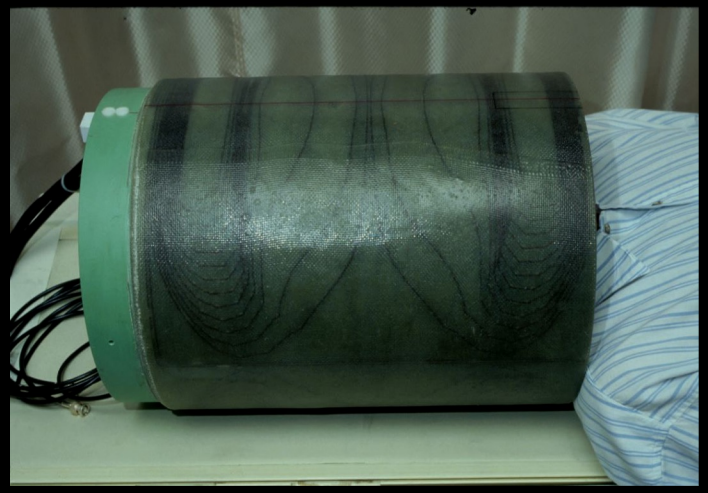
Scanning Technologists:

Karen Bove-Bettis

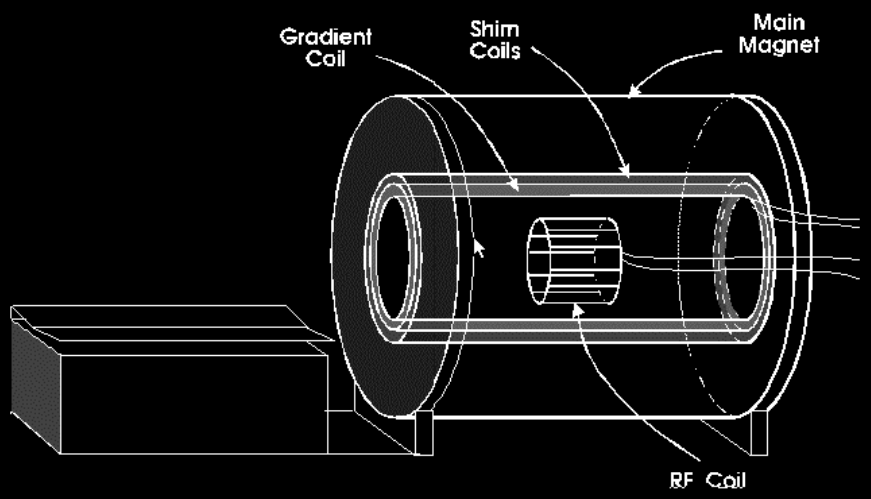
Paula Rowser

- Shimming
- Acoustic Noise
- Multishot Techniques
- Increased Gradient Performance
- Higher Field Strengths
- Surface Coil Arrays
- Calibration / Quantification
- Embedded Functional Contrast
- Noise / Fluctuations
- Direct Neuronal Current Imaging
- Clinical Populations
- Neuronal,Vascular, and Metabolic Informatic

2 G/cm, 350 T/m/s



4 G/cm, 150 T/m/s



10 G/cm, 1000 T/m/s

Diffusion imaging
Faster imaging
Higher resolution