Functional MRI at the NIH

Peter A. Bandettini, Ph.D.

Section on Functional Imaging Methods

http://fim.nimh.nih.gov

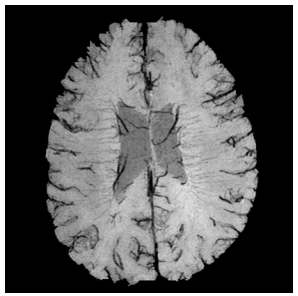
Laboratory of Brain and Cognition

&

Functional MRI Facility

http://fmrif.nimh.nih.gov

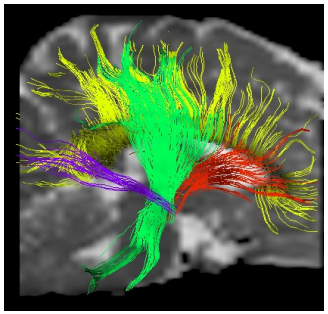
Venography



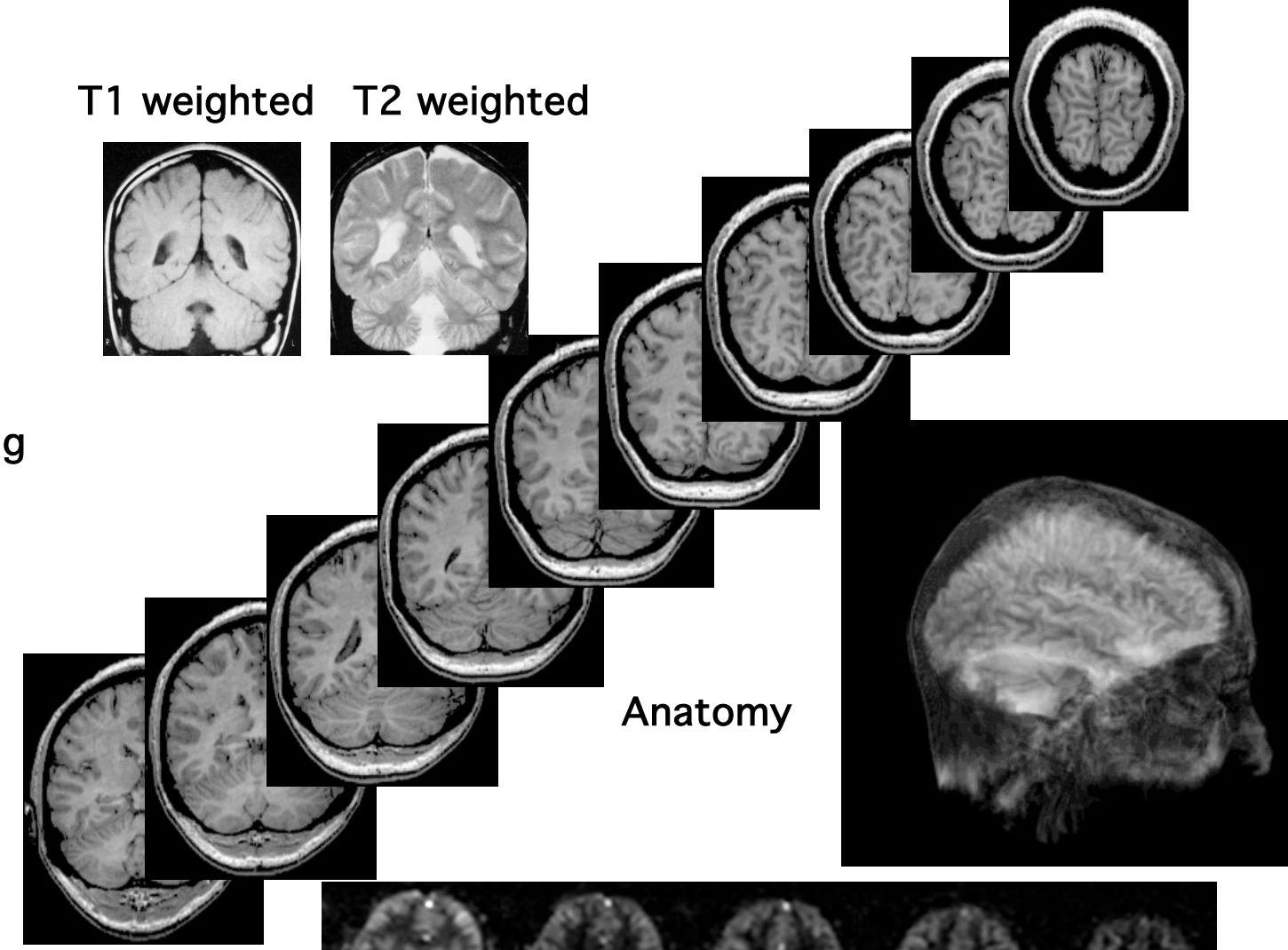
T1 weighted

T2 weighted

Fiber Track Imaging

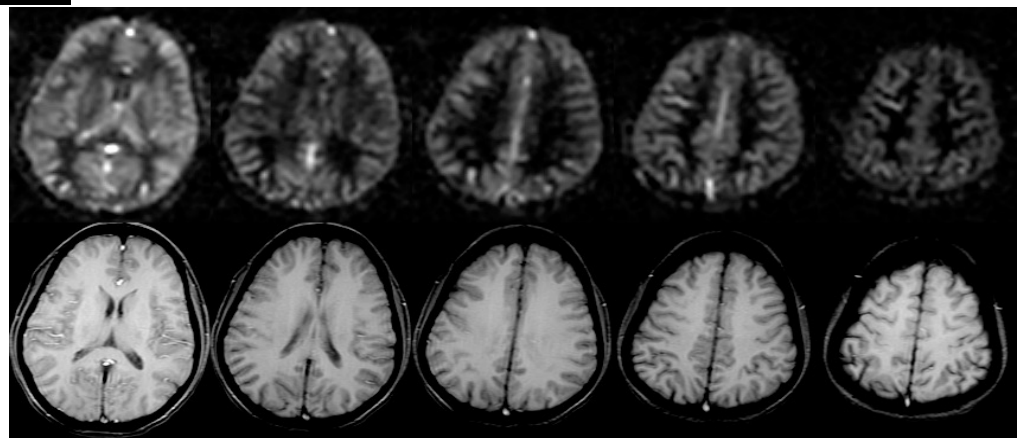


Anatomy



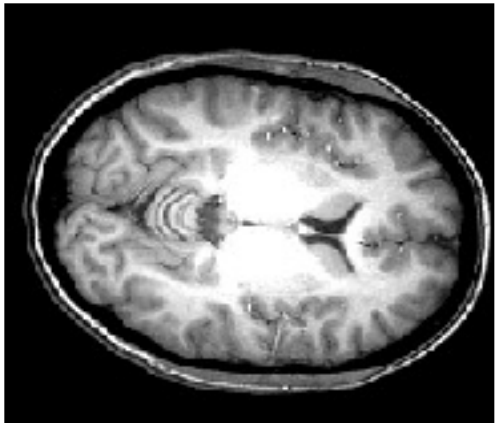
Angiography

Perfusion



MRI vs. fMRI

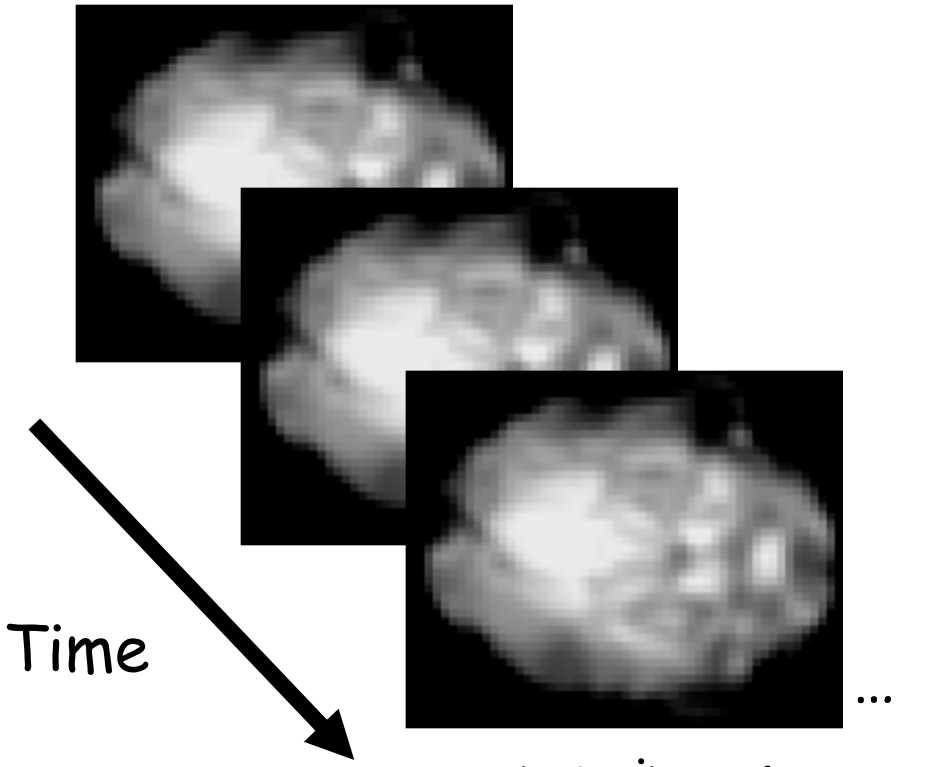
MRI



one image

high resolution
(1 mm or less)

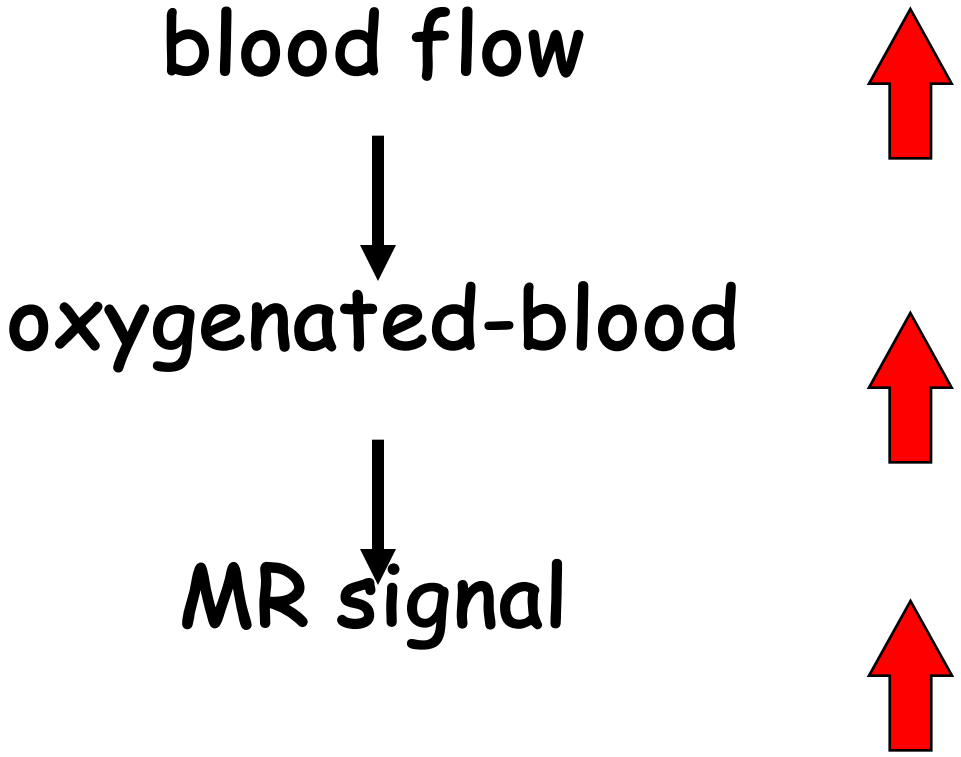
fMRI



many images
(e.g., every 2 sec for 5 mins)

low resolution
(1.5 to 4 mm)

BOLD (Blood Oxygen Level Dependent) Contrast

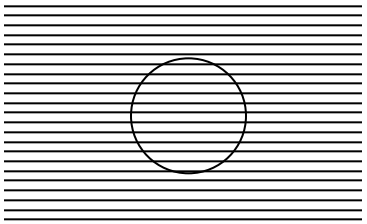


Basis of BOLD Contrast

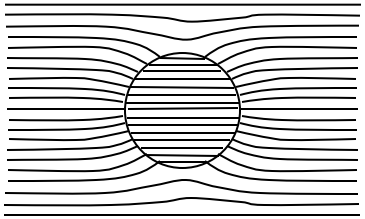
Oxygenated and deoxygenated red blood cells have different magnetic properties

red blood cells

oxygenated



deoxygenated

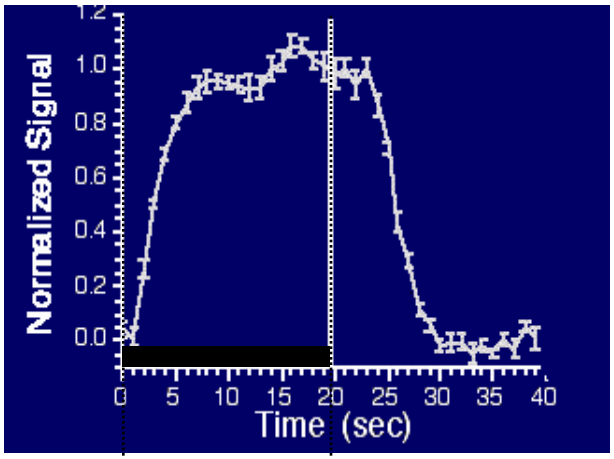


L. Pauling, C. D. Coryell, *Proc.Natl. Acad. Sci. USA 22, 210-216*, **1936**.

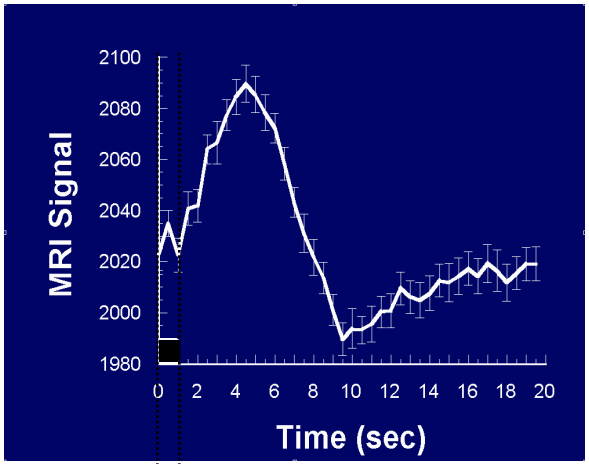
K.R. Thulborn, J. C. Waterton, et al., *Biochim. Biophys. Acta. 714: 265-270*, **1982**.

S. Ogawa, T. M. Lee, A. R. Kay, D. W. Tank, *Proc. Natl. Acad. Sci. USA 87, 9868-9872*, **1990**.

BOLD Contrast Imaging



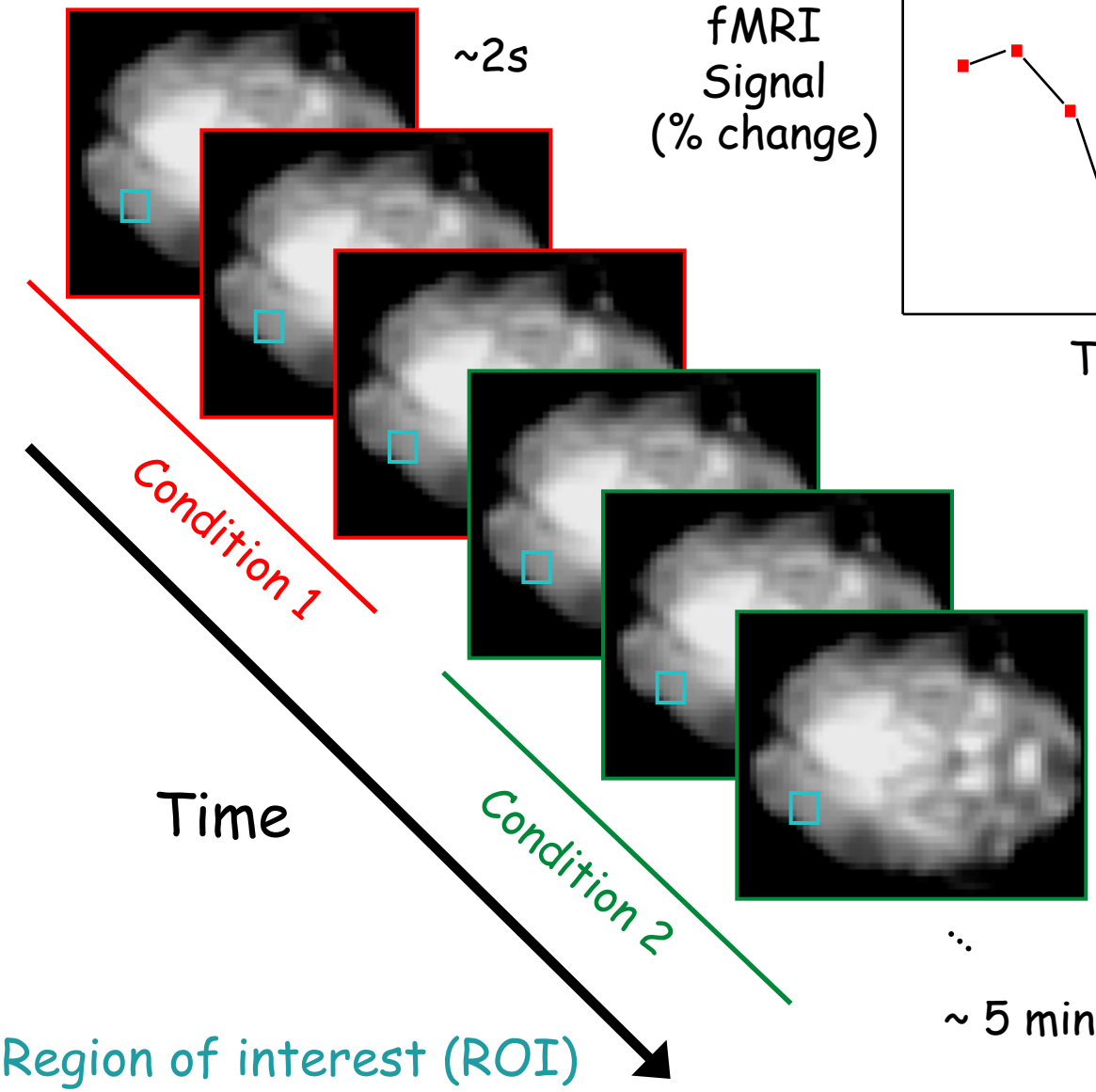
task

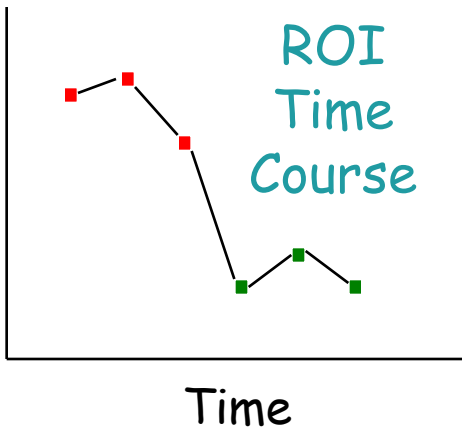


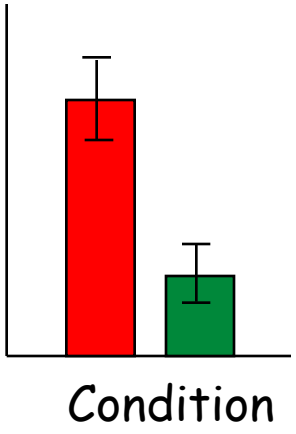
task

Activation Statistics

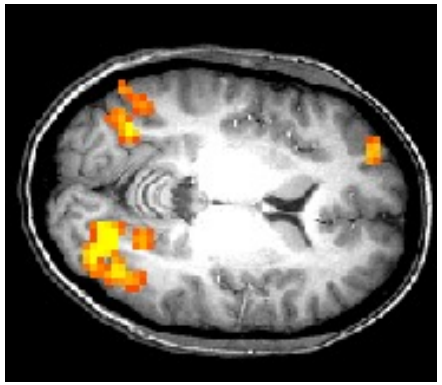
Functional images

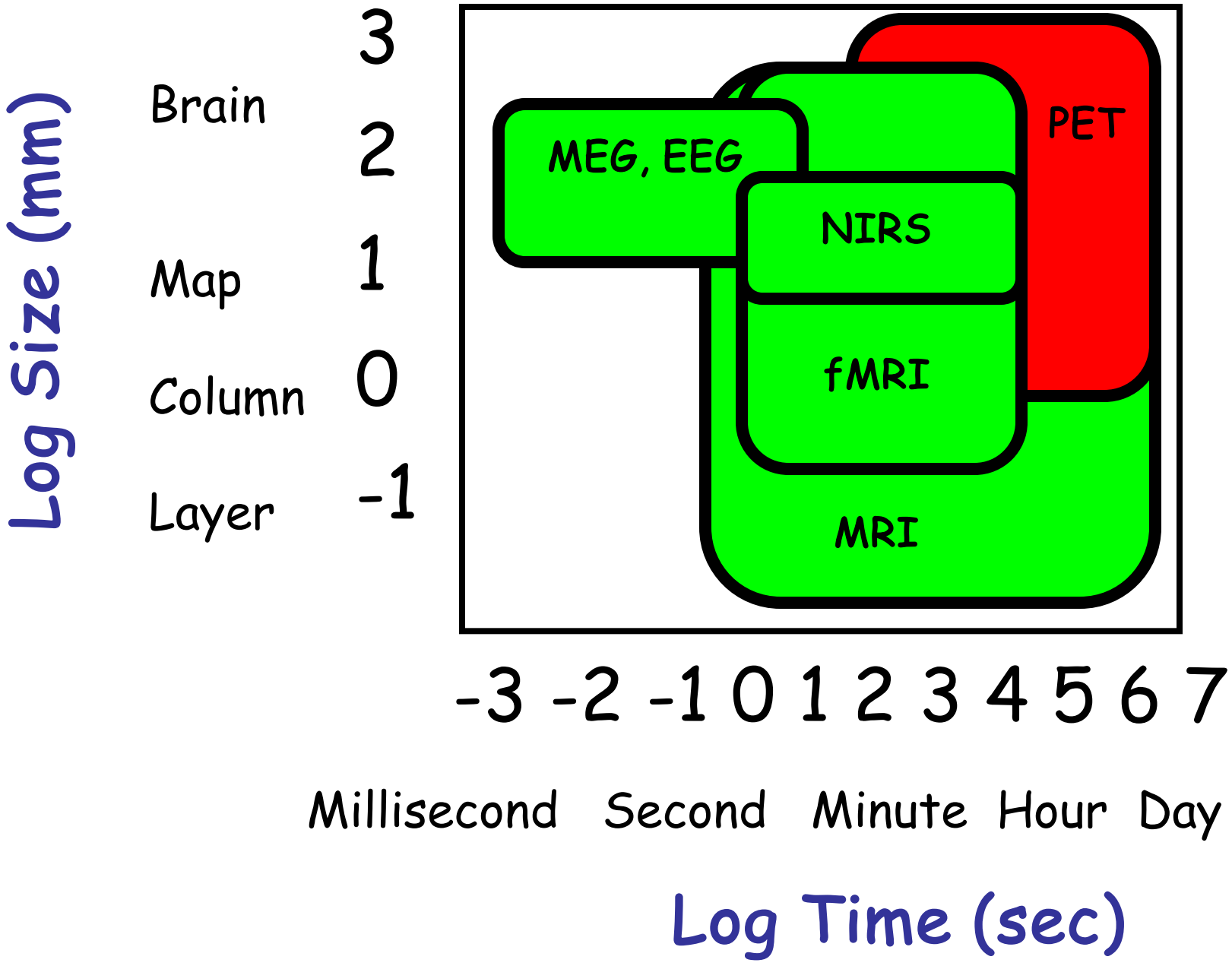




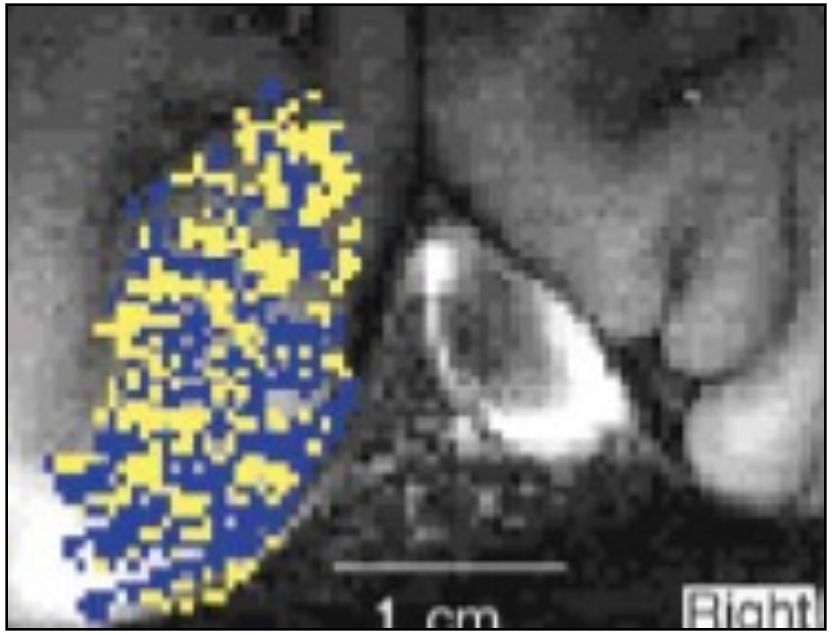


Statistical Map
superimposed on
anatomical MRI image



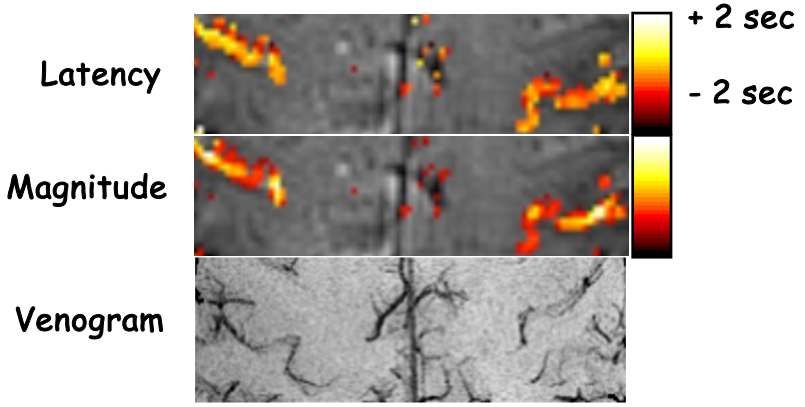

Log Size (mm)
Brain
Map
Column
Layer
3
2
1
0
-1
MEG, EEG
PET
NIRS
fMRI
MRI
-3 -2 -1 0 1 2 3 4 5 6 7
Millisecond
Second
Minute
Hour
Day
Log Time (sec)

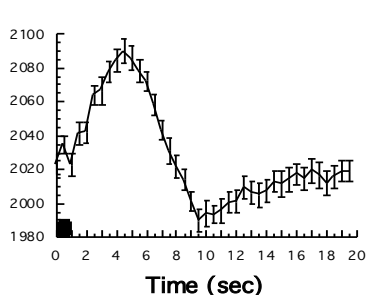
Spatial and Temporal Resolution

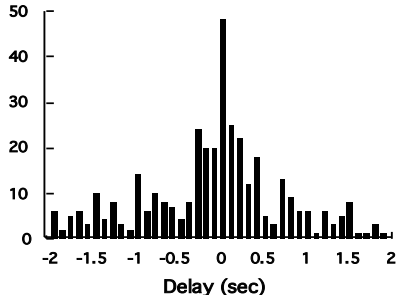


Cheng, et al. (2001) Neuron,32:359-374

Latency Variation…







P. A. Bandettini, (1999) "Functional MRI" 205-220.

Spatial

Temporal

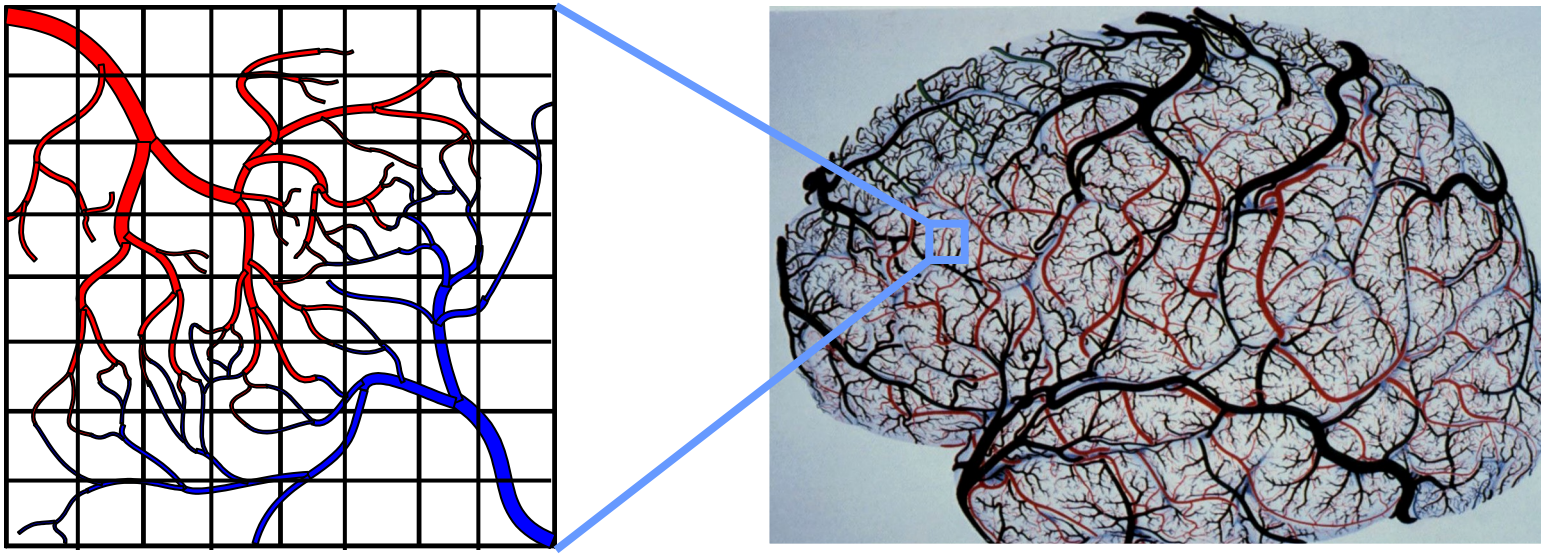
Interpretation

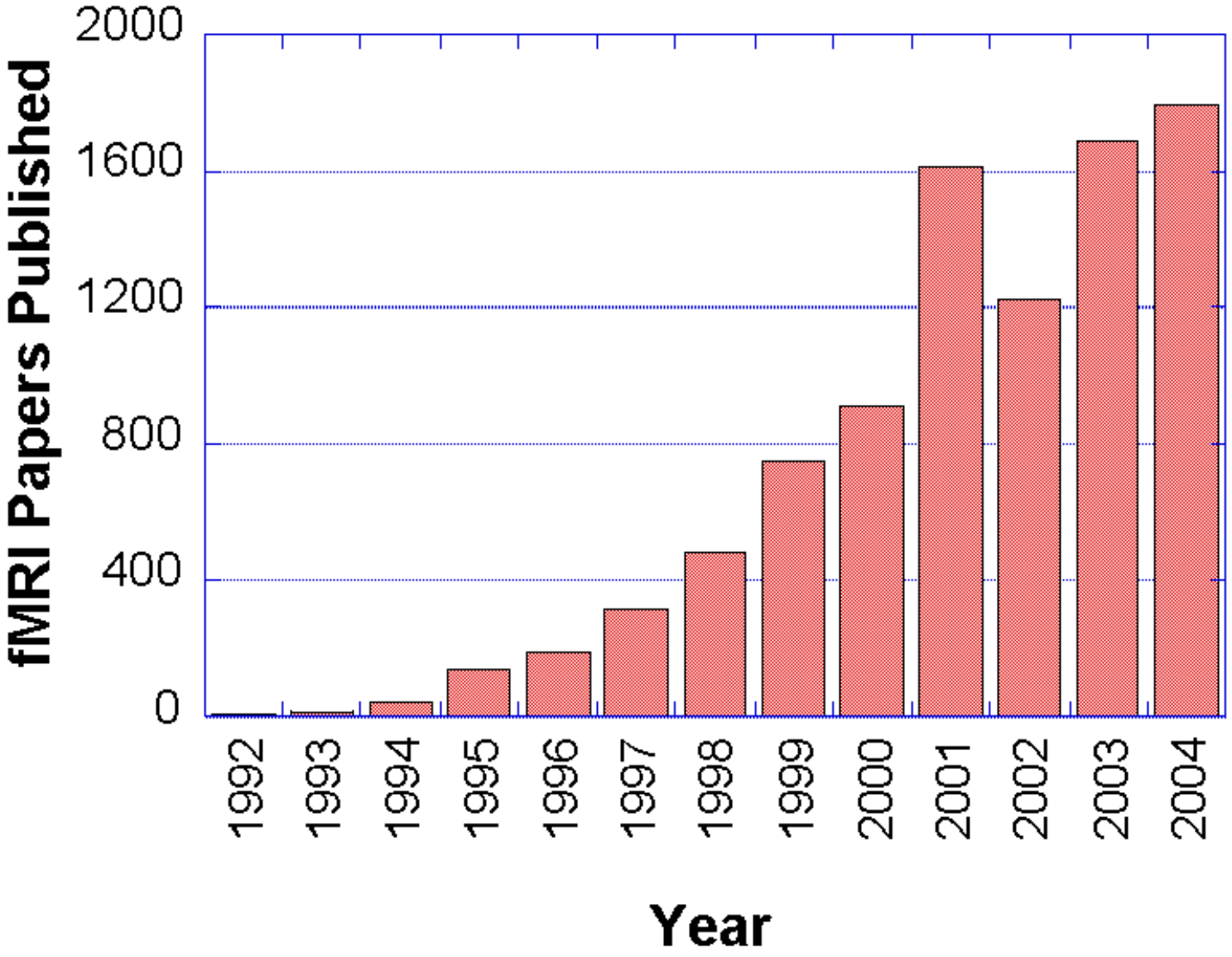
Neuronal Activation ? Measured Signal

? ? ? ?

Hemodynamics

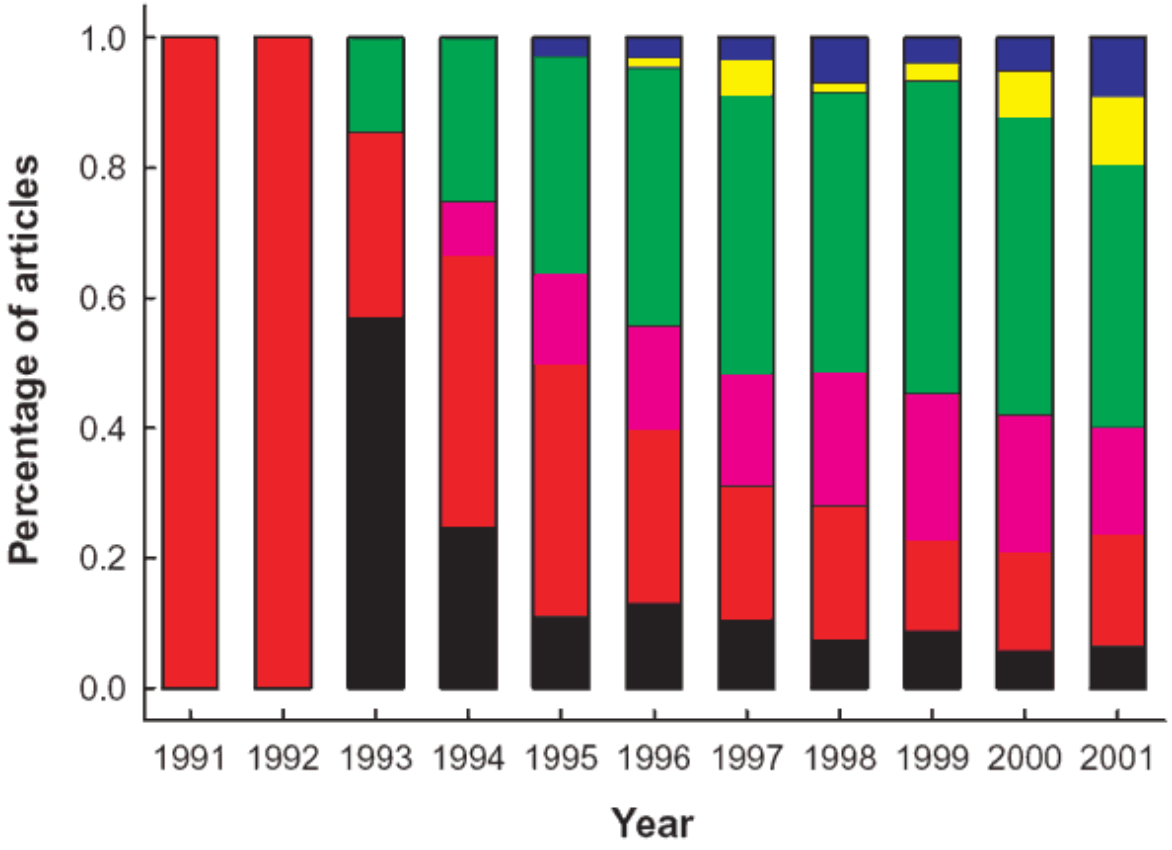
Noise




fMRI Papers Published
2000
1600
1200
800
400
0
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
Year

Type of fMRI research performed

Motor
Primary Sensory
Integrative Sensory
Basic Cognition
High-Order Cognition
Emotion



J. Illes, M. P. Kirschen, J. D. E. Gabrielli,
Nature Neuroscience, 6 (3) p.205, 2001

fMRI Studies at the NIH..

- Epilepsy
- Visual processing
- Mood disorders
- Learning
- Habituation
- Plasticity/Recovery
- Motor Function
- Auditory processing
- Attention
- Language
- Speech
- Stroke
- Social Interaction
- Development
- Aging
- Genetics
- Decision making
- Mood disorders

Principle Investigators doing fMRI:

NIMH:

Peter Bandettini, Ph.D.
Karen Berman, M.D.
James Blair, Ph.D.
Robert Cohen, M.D., Ph.D.
Christian Grillon, Ph.D.
Wayne Drevets, M.D.
Ellen Liebenluft, M.D.
Daniel Pine, M.D.
Jun Shen, Ph.D.
Leslie Ungerleider, Ph.D.
Daniel Weinberger, M.D.

NINDS:

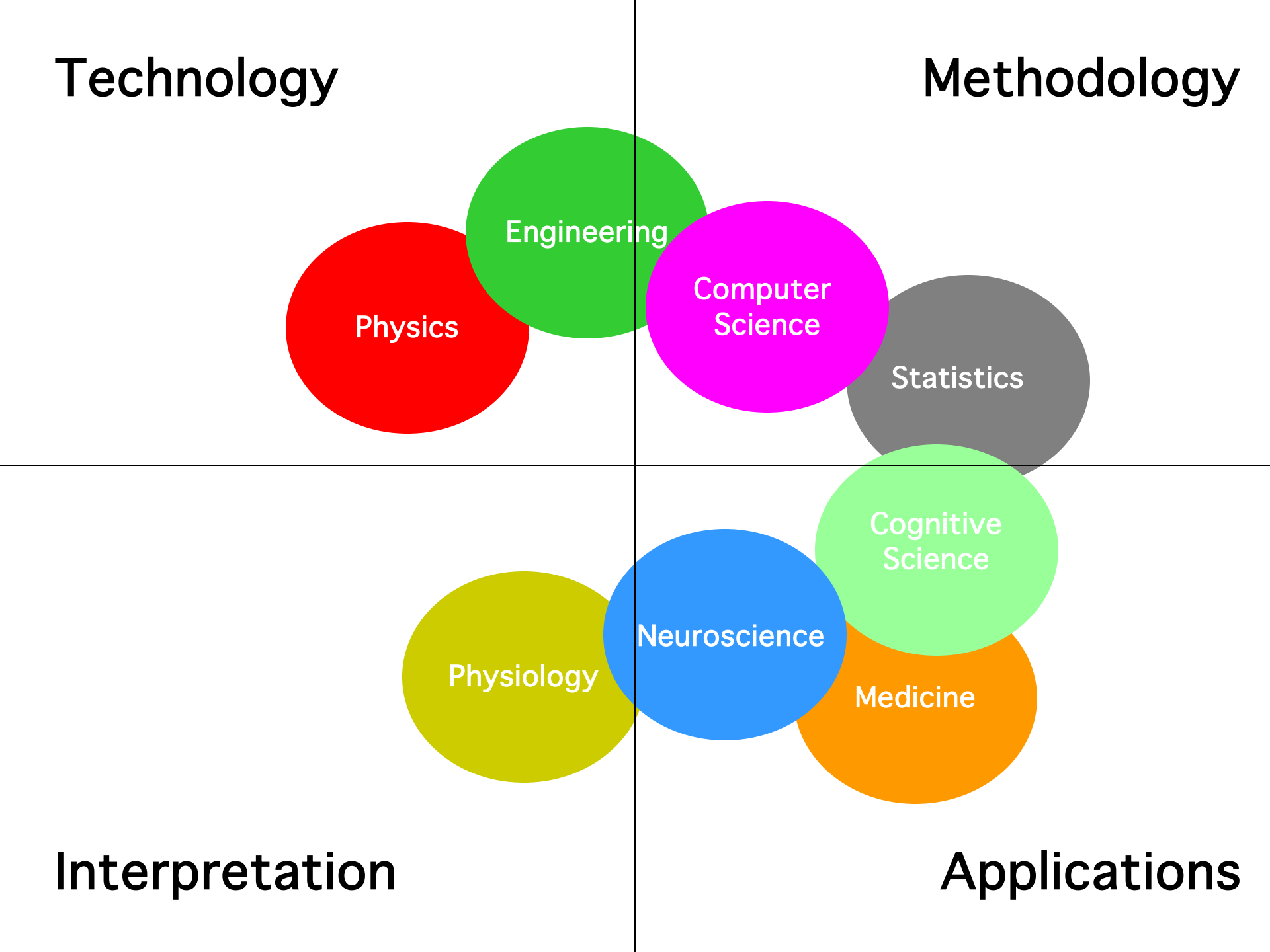
Leonardo Cohen, M.D.
Jeff Duyn, Ph.D.
Jordan Graffman, Ph.D.
Mark Hallet, Ph.D.
Alan Koretsky, Ph.D.
Chrsity Ludlow, Ph.D.

NIAAA:

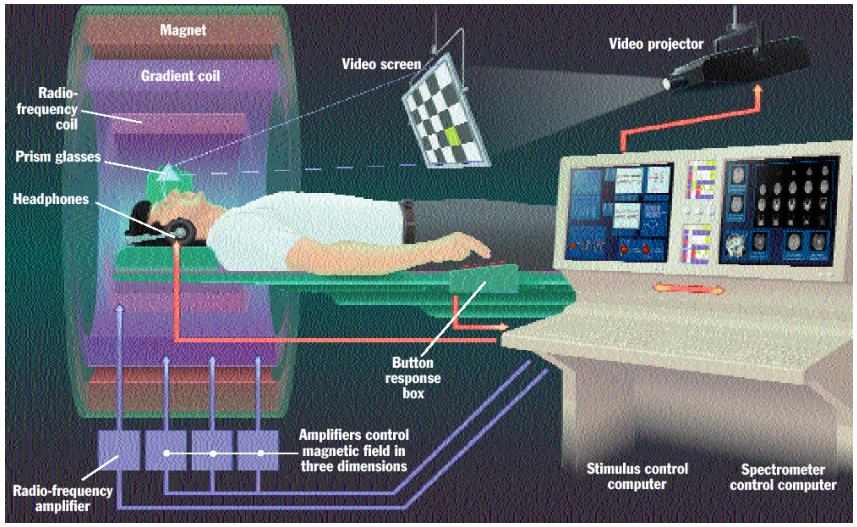
Daniel Hommer, M.D.

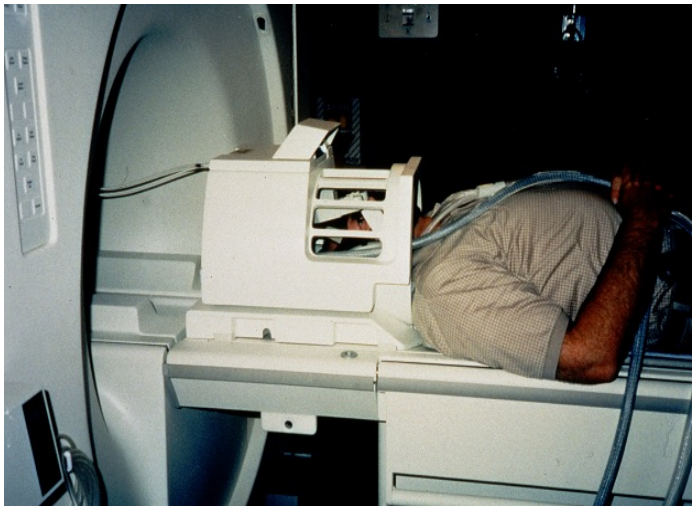
NICHD:

Peter Basser, Ph.D.
Allen Braun, M.D.


Technology
Methodology
Engineering
Physics
Computer Science
Statistics
Cognitive Science
Neuroscience
Physiology
Medicine
Interpretation
Applications

fMRI Setup


Magnet
Gradient coil
Radio-frequency coil
Prism glasses
Headphones
Video screen
Video projector
Button response box
Amplifiers control magnetic field in three dimensions
Radio-frequency amplifier
Stimulus control computer
Spectrometer control computer



Scanners:

“3T-1”	GE 3T	(June 2000)
“3T-2”	GE 3T	(Nov 2002)
“FMRIF 1.5T”	GE 1.5T	(Sept 2004)
Currently being Cited	GE 3T	(Aug 2003)

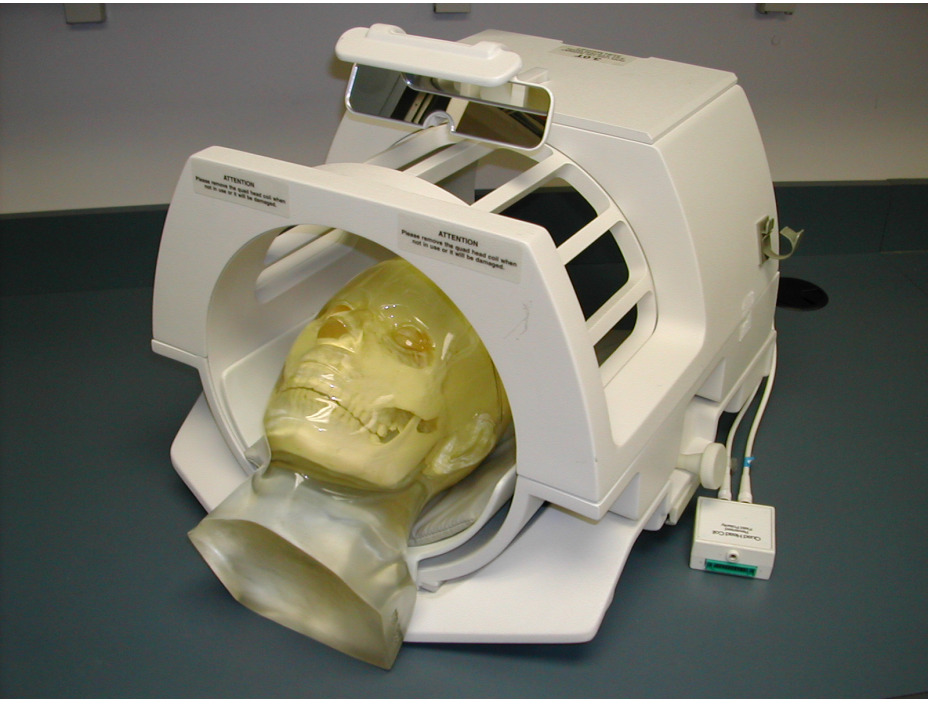
1.5T

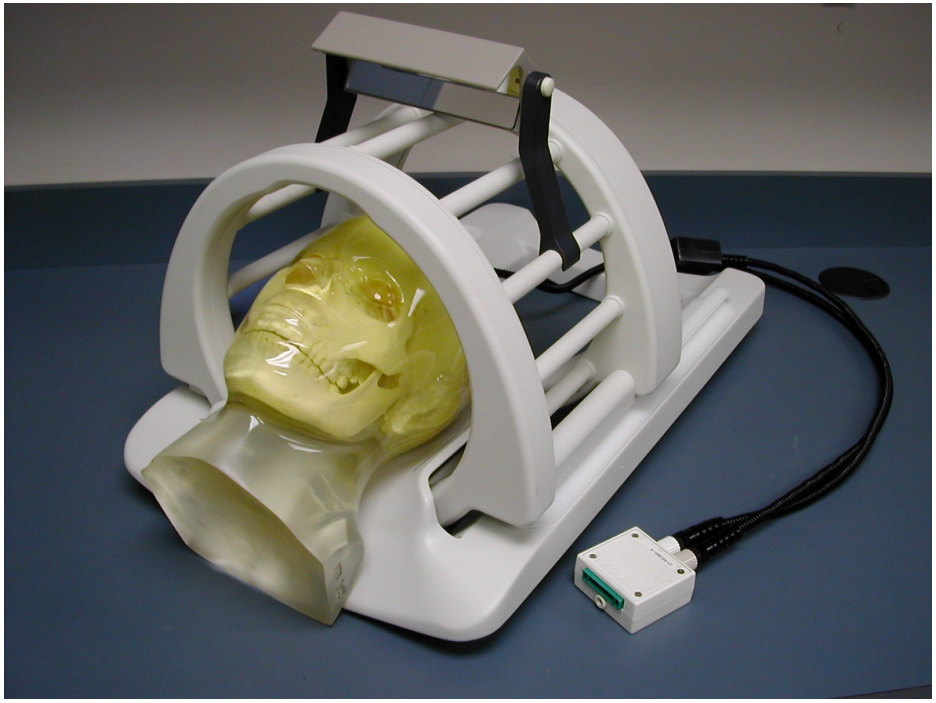
3T-1

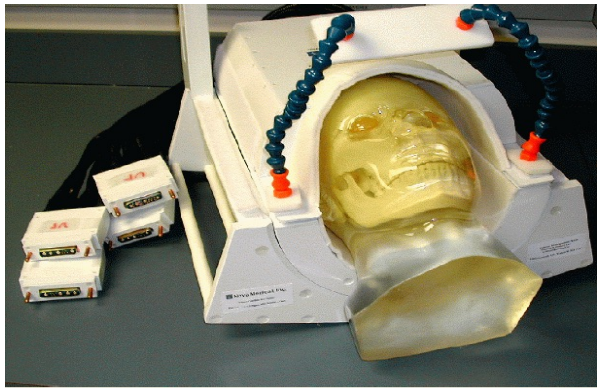
3T-2

Radiofrequency Coils

Head "Bird-cage" coils







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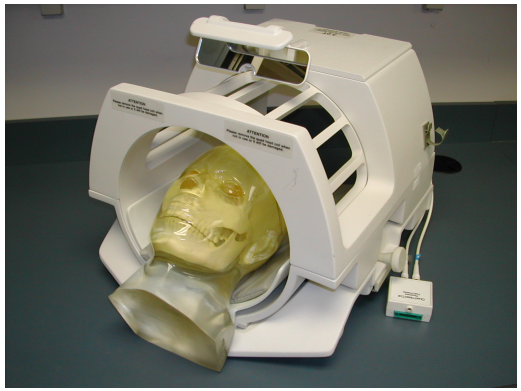
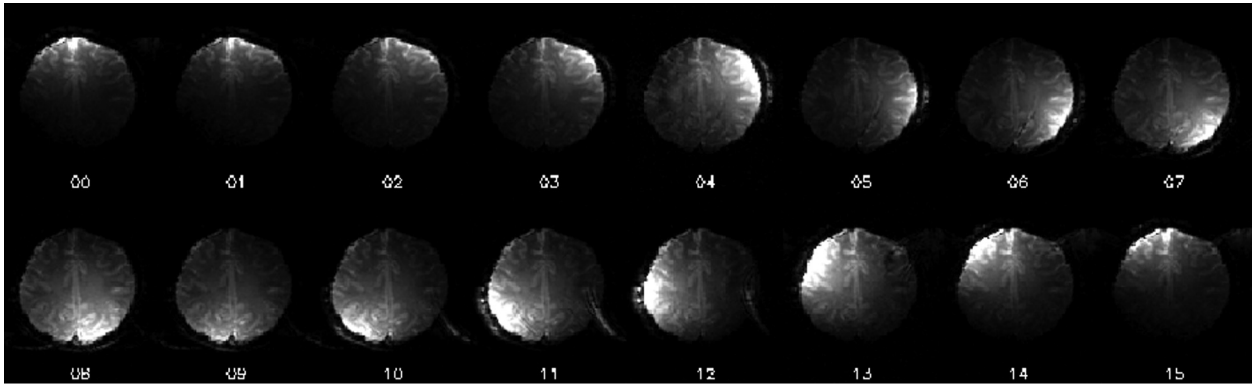


B


00
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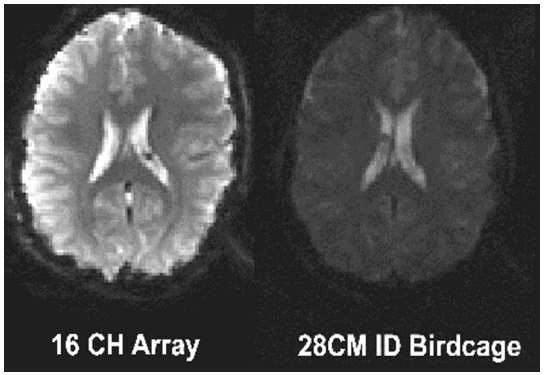
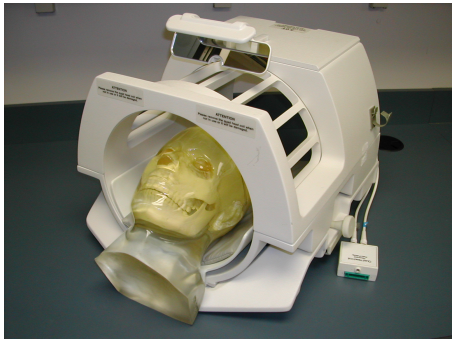
C

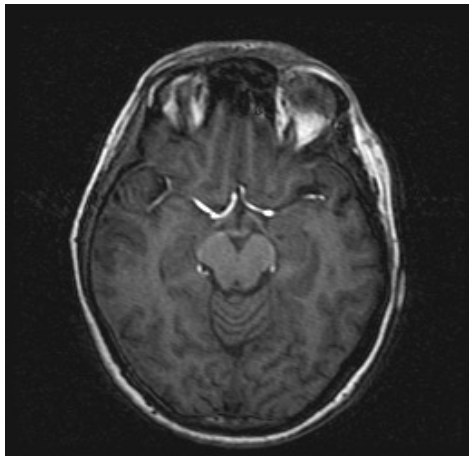

16 CH Array
28CM ID Birdcage

D

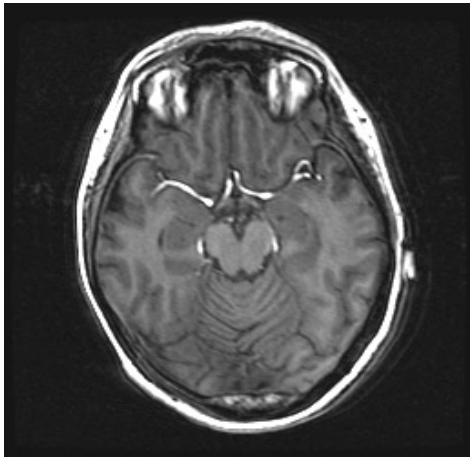
Radiofrequency Coils

8-channel acquisition:

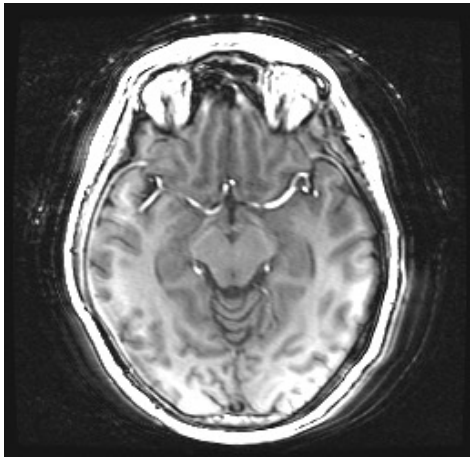




GE birdcage



GE 8 channel coil

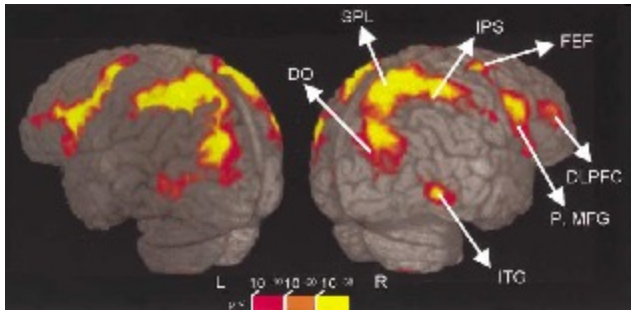


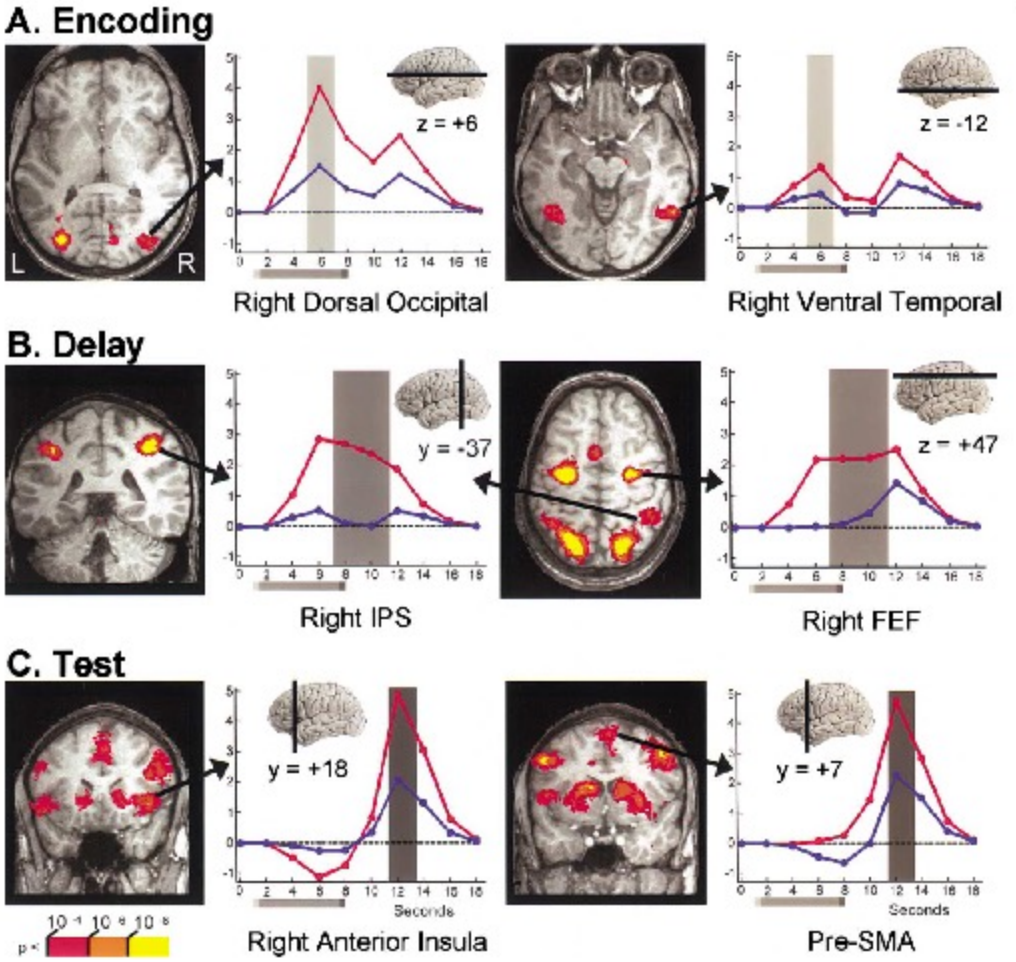
Nova 8 channel coil

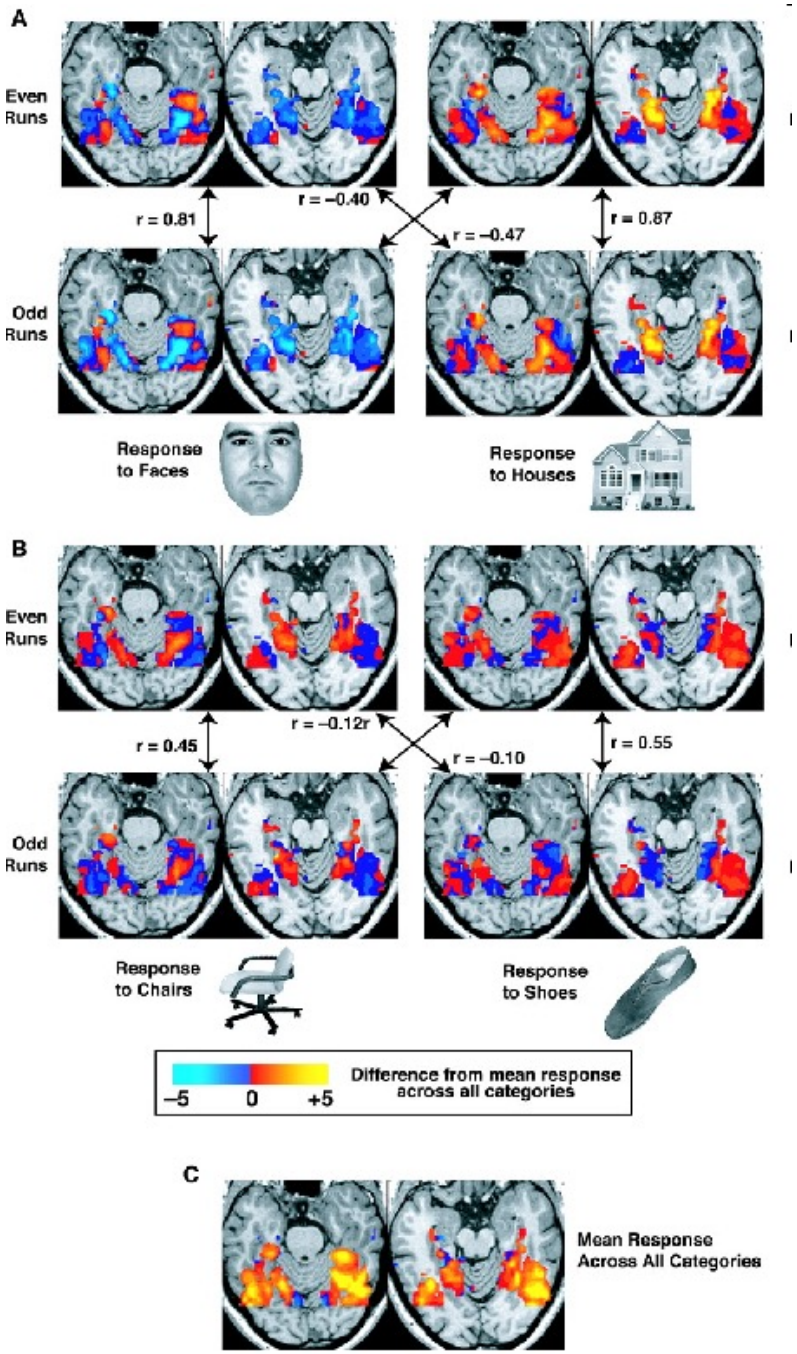
Neuron, Vol. 35, 975–987, August 29, 2002, Copyright ©2002 by Cell Press

Neural Correlates of Visual Working Memory: fMRI Amplitude Predicts Task Performance

Luiz Pessoa,[1] Eva Gutierrez, Peter A. Bandettini, and Leslie G. Ungerleider
Laboratory of Brain and Cognition
National Institute of Mental Health
National Institutes of Health
Bethesda, Maryland 20892







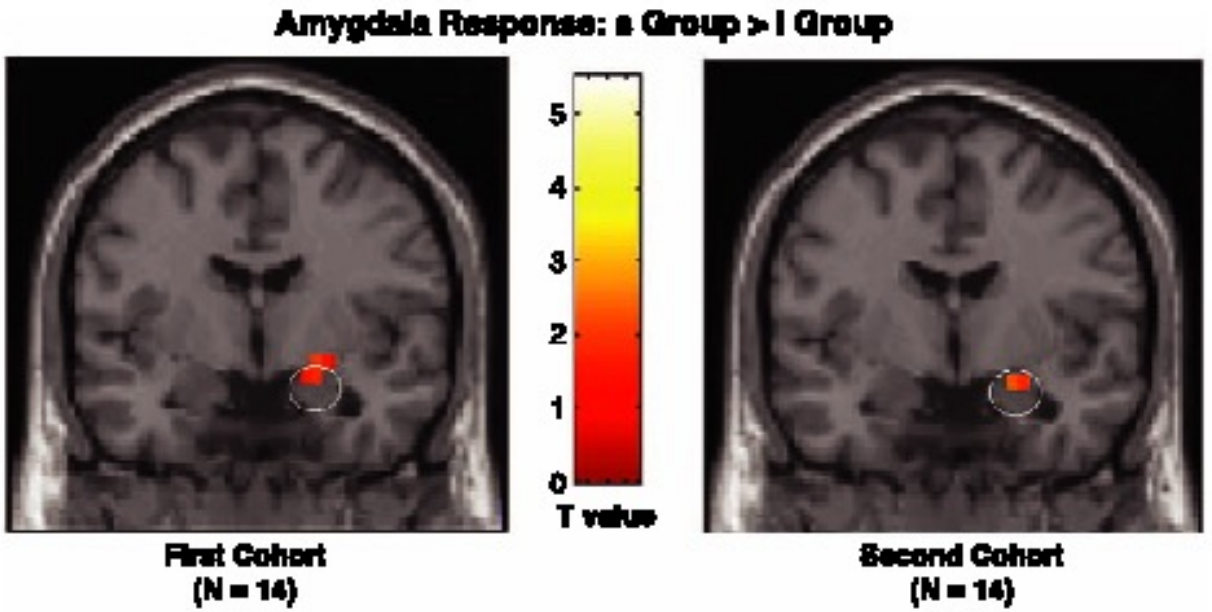
Haxby et al (2001)

Clinical Applications

Comparison of two groups of *normal* individuals with differences in the Serotonin Transporter Gene

Serotonin Transporter Genetic Variation and the Response of the Human Amygdala

Ahmad R. Hariri,[1] Venkata S. Mattay,[1] Alessandro Tessitore,[1]
Bhaskar Kolachana,[1] Francesco Fera,[1] David Goldman,[2]
Michael F. Egan,[1] Daniel R. Weinberger[1]*



SCIENCE VOL 297 19 JULY 2002

Uses

Understanding normal brain organization and changes

- -networks involved with specific tasks (low to high level processing)
- -changes over time (seconds to years)
- -correlates of behavior (response accuracy, performance changes…)

Clinical research

- -correlates of specifically activated networks to clinical populations
- -presurgical mapping

Future Uses

Complementary use for clinical diagnosis

- -utilization of clinical research results
- -prediction of pathology

Clinical treatment and assessment

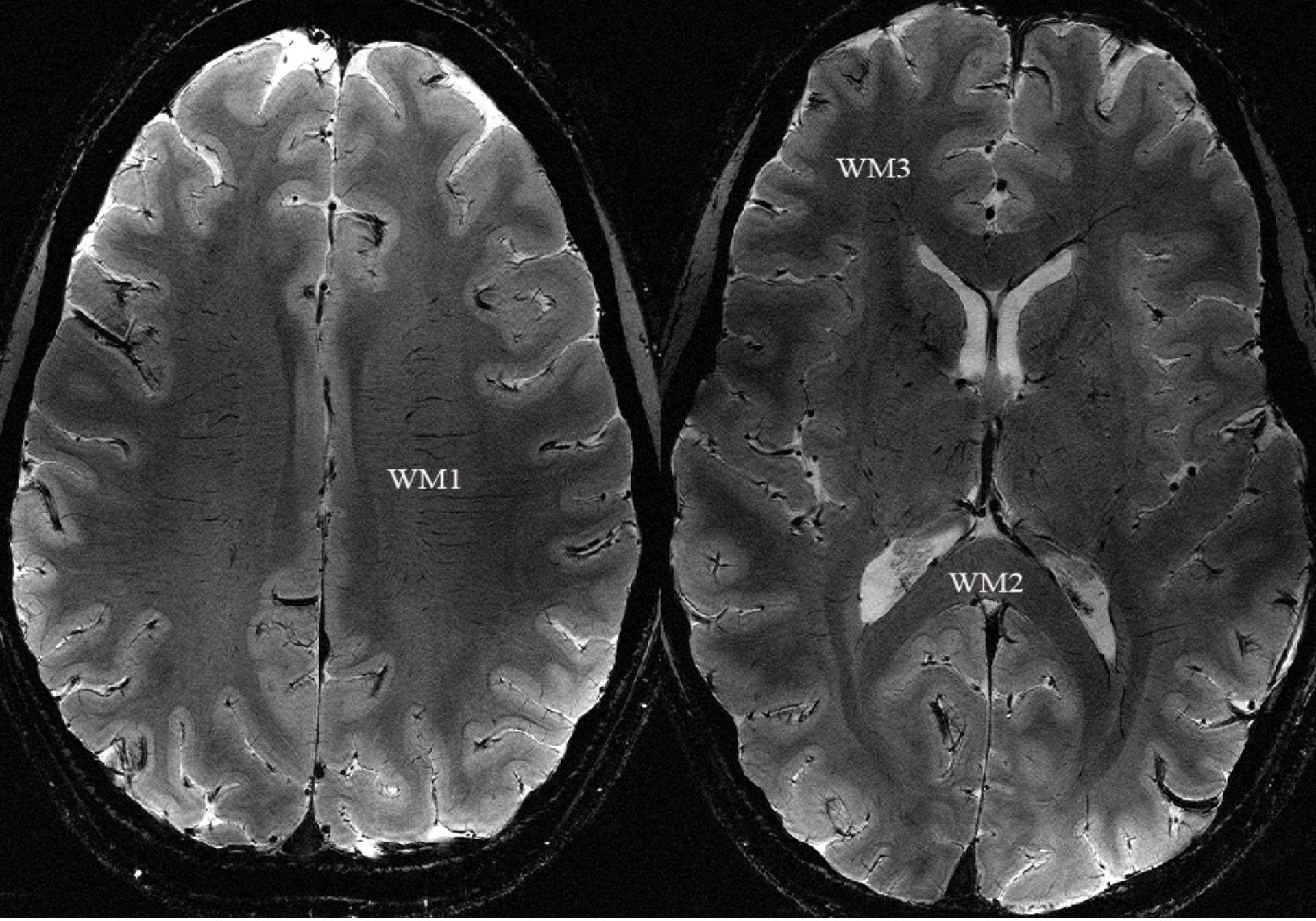
- -drug, therapy, rehabilitation, biofeedback
- -epileptic foci mapping
- -drug effects

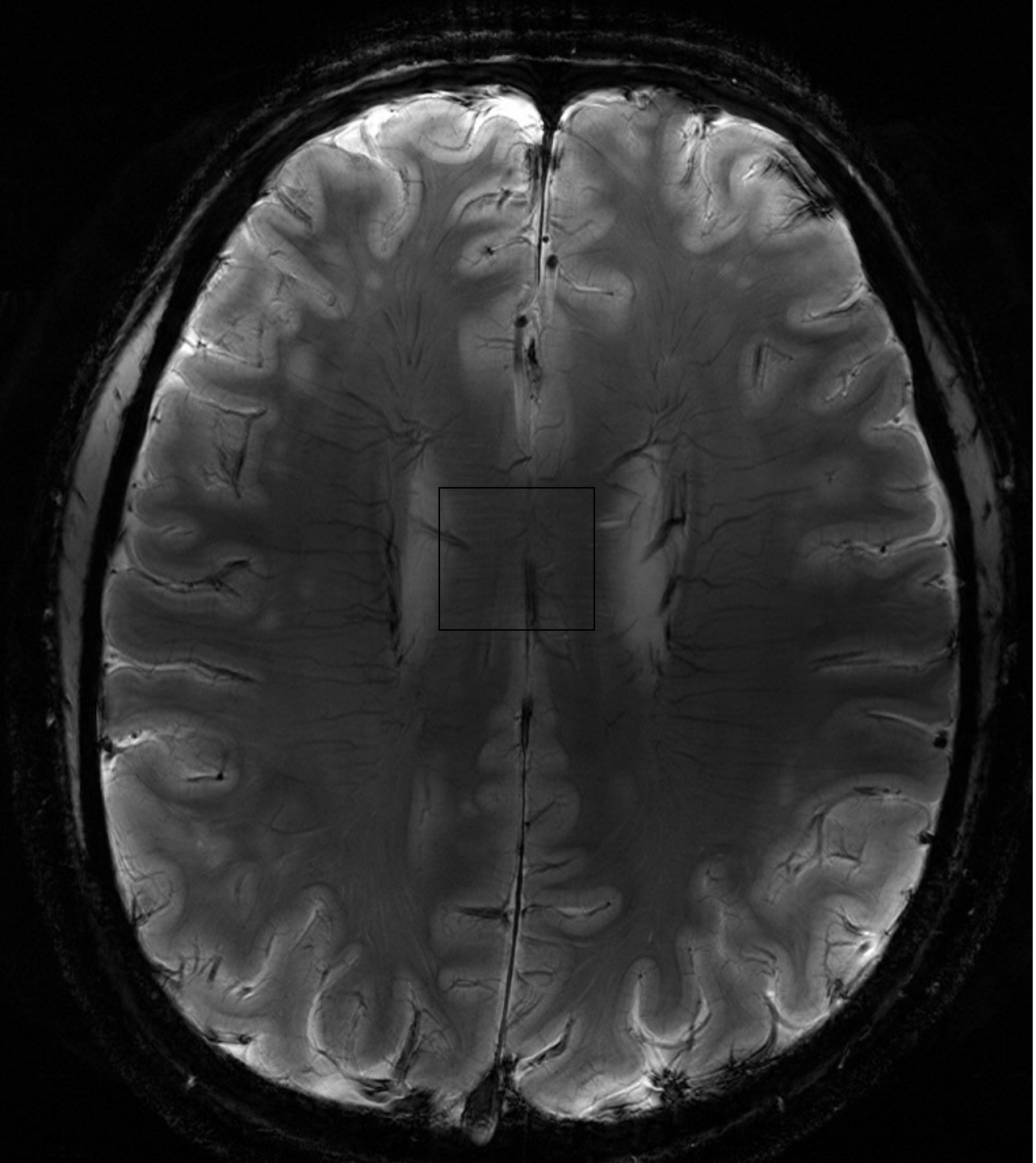
Non clinical uses

- -complementary use with behavioral, anatomical, other modality results
- -lie detection
- -prediction of behavior tendencies
- -brain/computer interface

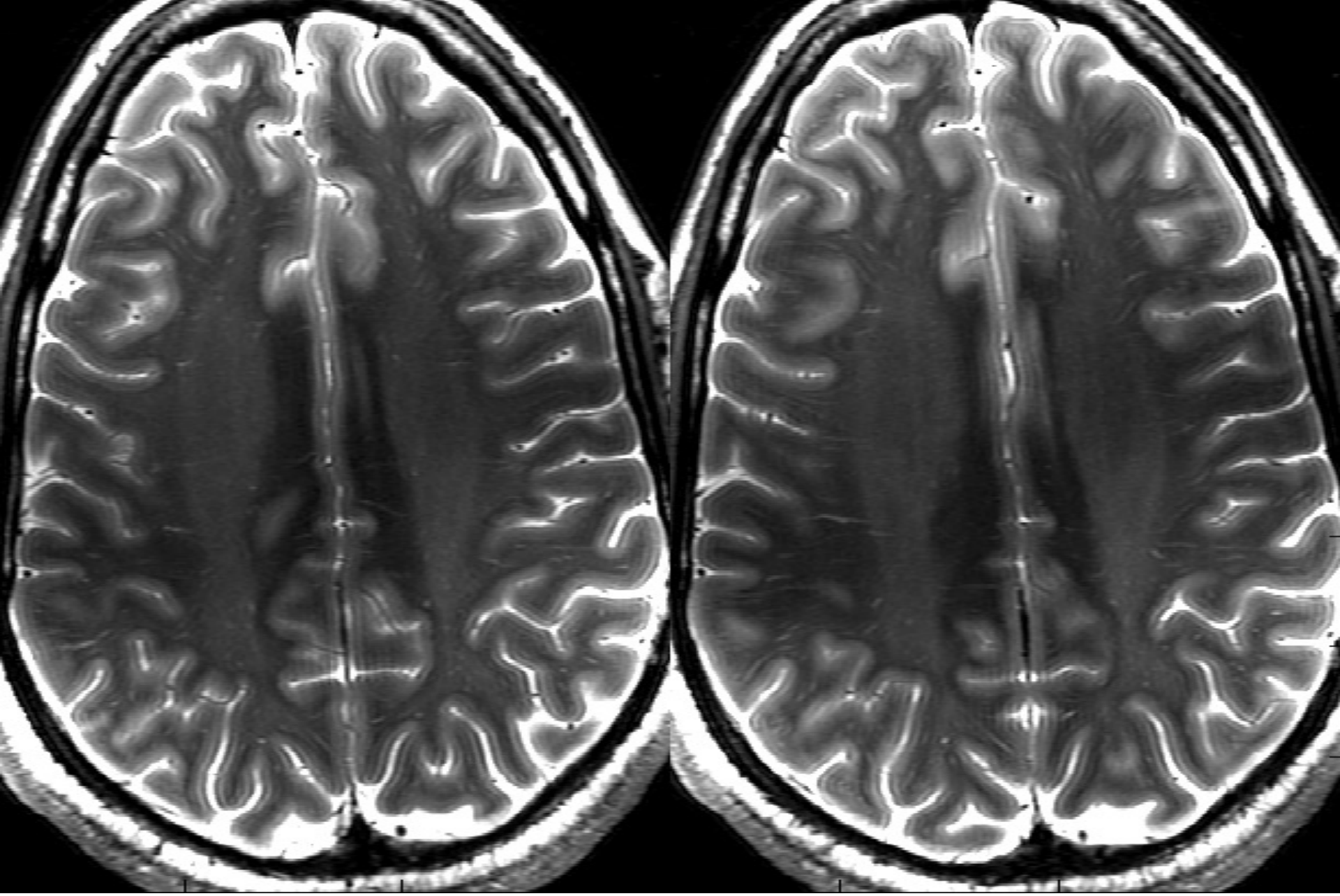
Some Anatomical Images from our Human 7 T Scanner

Alan Koretsky
Tie Qiang Li
Jeff Duyn

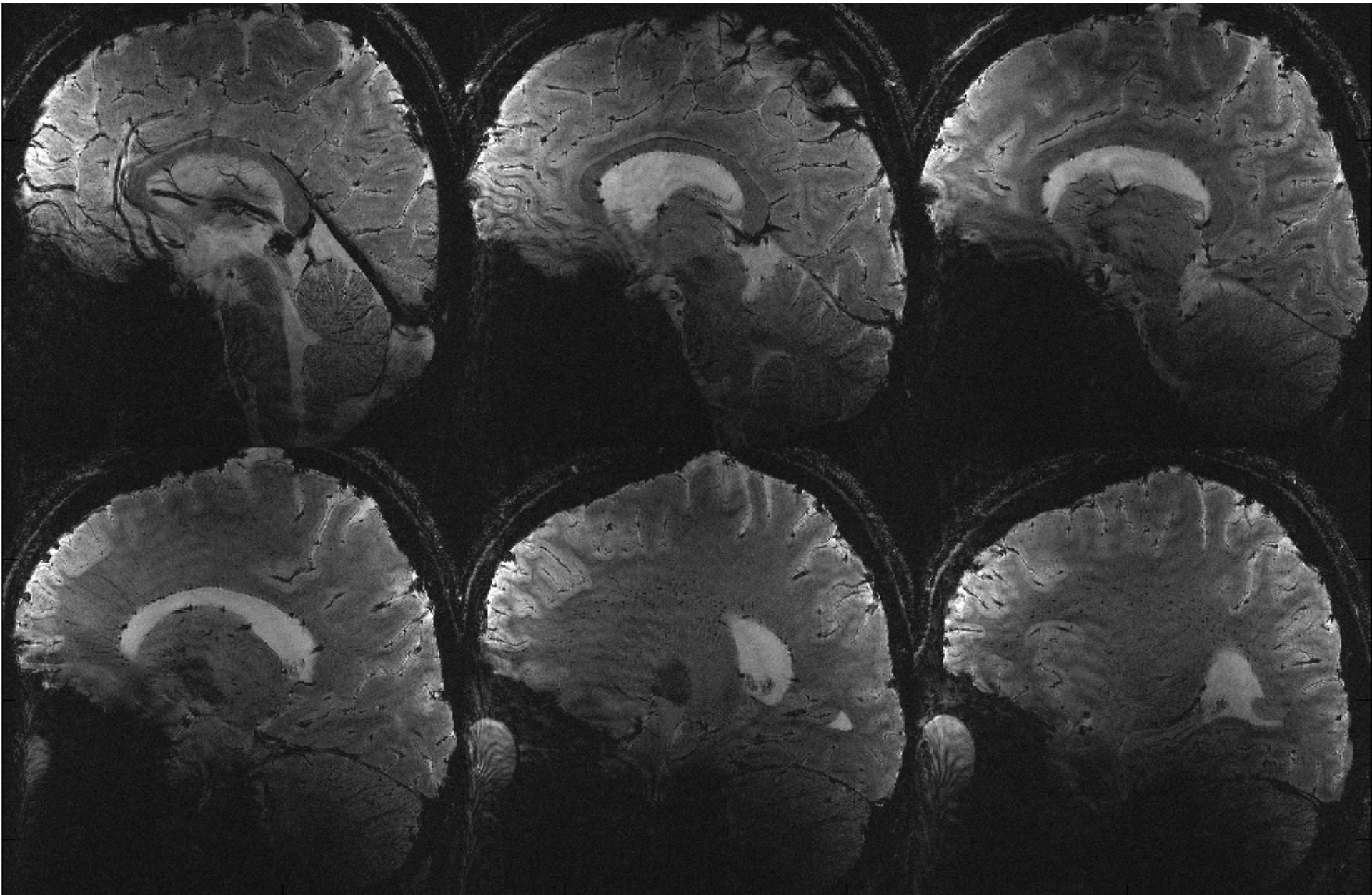

WM1
WM3
WM2

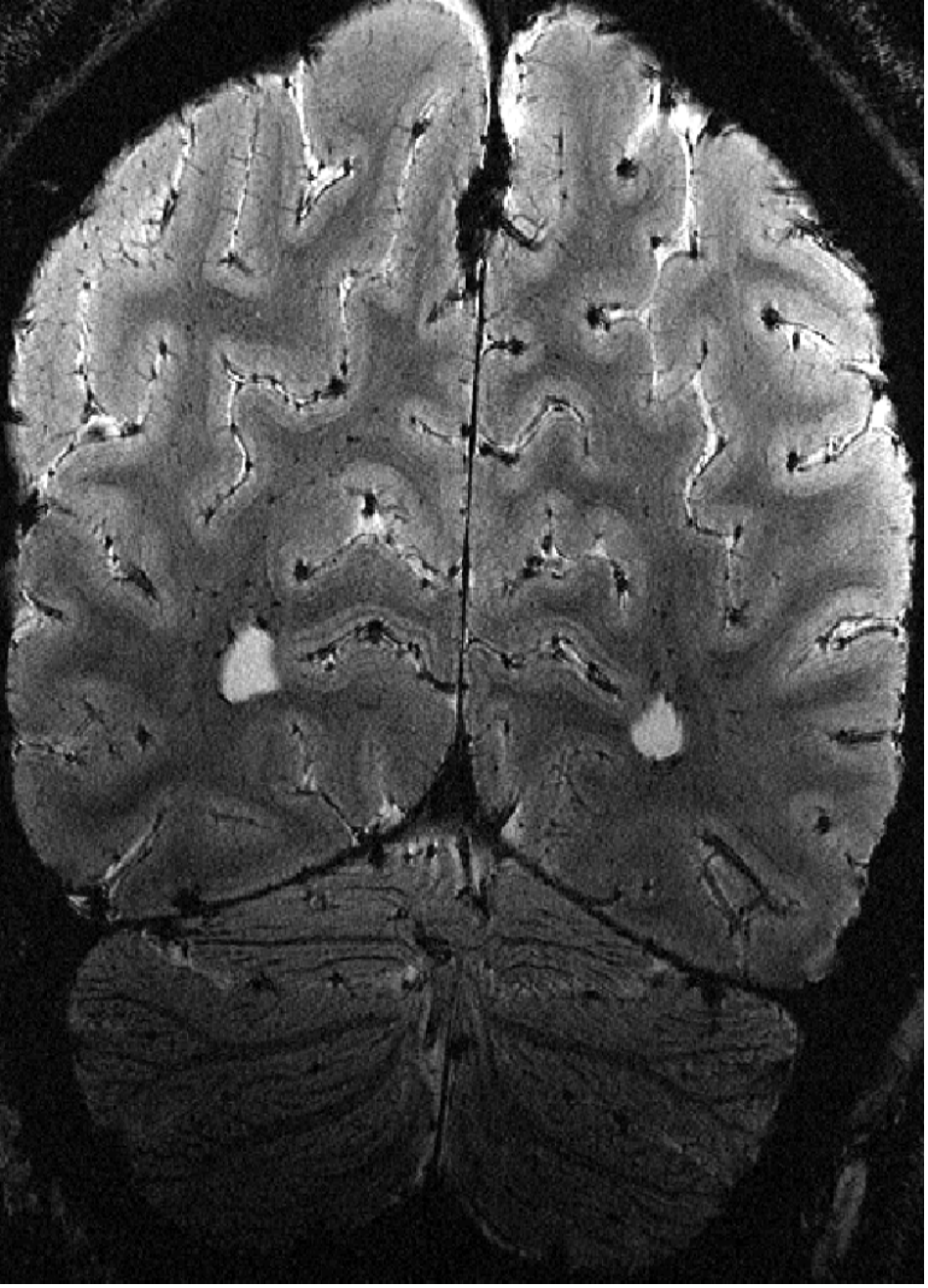


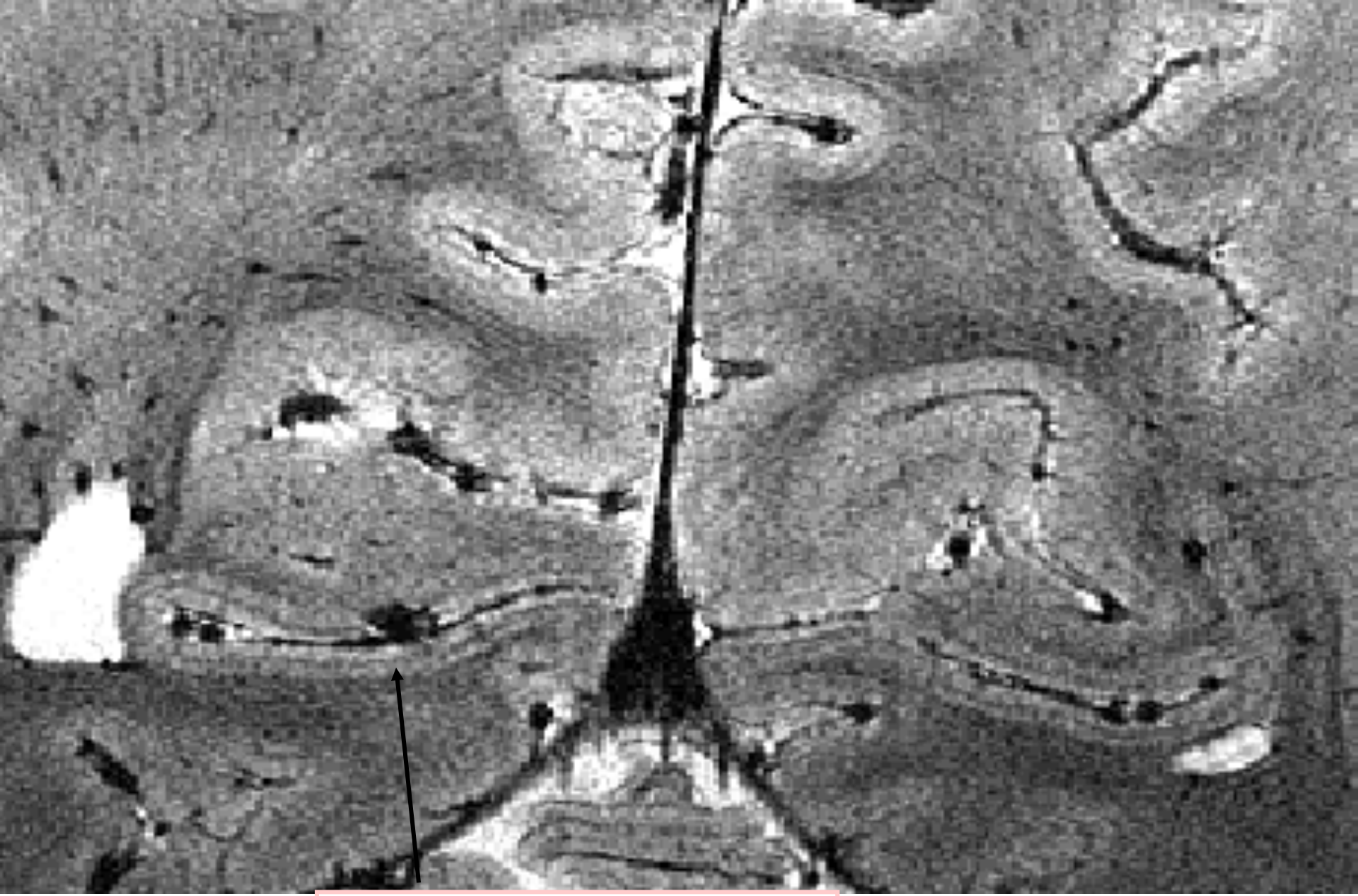
fiber bundles?



FSE **images** at 0.2x.2x1mm^3







Layered structure i
n the visual cortex

Functional MRI Facility

Core Facility Staff:

Peter Bandettini, Ph.D.	– Director
Sean Marrett, Ph.D.	– Staff Scientist
Jerzy Bodurka, Ph.D.	– Staff Scientist
Wen-Ming Luh, Ph.D.	– Staff Scientist
Adam Thomas	– Computer Administrator
Kay Kuhns	– Program Assistant
Karen Bove-Bettis	– Technologist
Janet Ebron	– Technologist
Alda Ottley	– Technologist
Ellen Condon	– Technologist
Sahra Omar	– Technologist

Stimulus presentation equipment

- Back projection screen 48X36in (DaLite Polacoat 100) mounted on an aluminum stand.
- Sharp LCD projectors with Buhl lens
- Avotec Silent Vision fiber-optic glasses for visual stimulus with integrated eye-tracking system
- SMI iView system with long-range lens for video-camera based eye-tracking
- Avotec Silent Scan earphones
- Phone-Or Dual Channel Noise-canceling Microphone

Software and response devices

- Presentation software
- e-prime (biological)
- Psychophysics Toolbox
- SuperLab
- Custom designed button response units and physiological interfaces RSB

New Devices (acquired in the last year)

- EEG
- Custom DLP projection (higher temporal resolution)
- DLP Backprojection
- Fiber-optic response systems
- MRI compatible power-injector
- Drug infusion pump

Pulse Sequences

BOLD imaging:

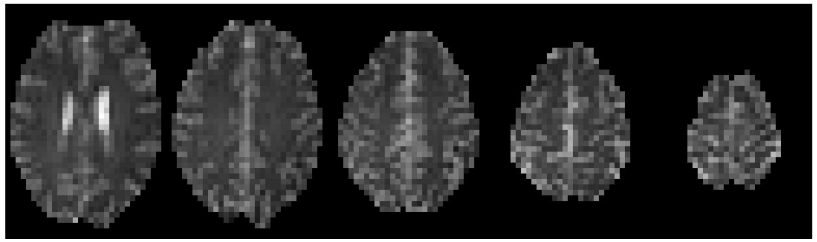
•***EPI-RT :*** General purpose BOLD imaging with real time display

•***epi3, epi4*** **:** NIH EPI sequences, epi4 for use with 16 channel system

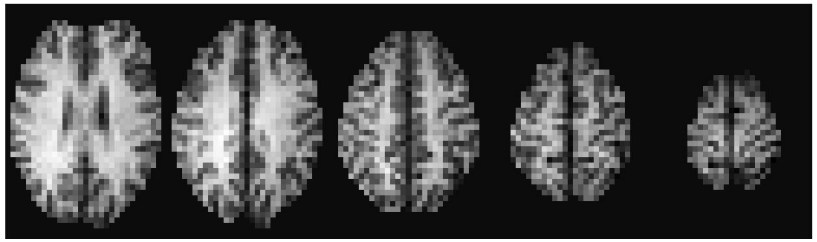
•***SPEP:*** Simultaneous perfusion and BOLD -spiral/EPI sequence with perfusion and diffusion modules and multi-echo and combined SE and GE capability

•***Clustered volume EPI-RT:*** (for auditory studies)

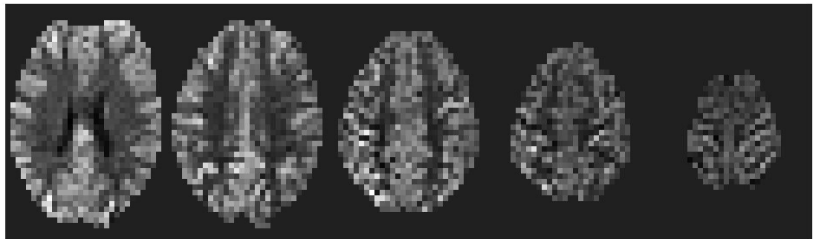
•***NIH-EPI*** (for use with 16 channel receiver system)



EPI



IR-EPI

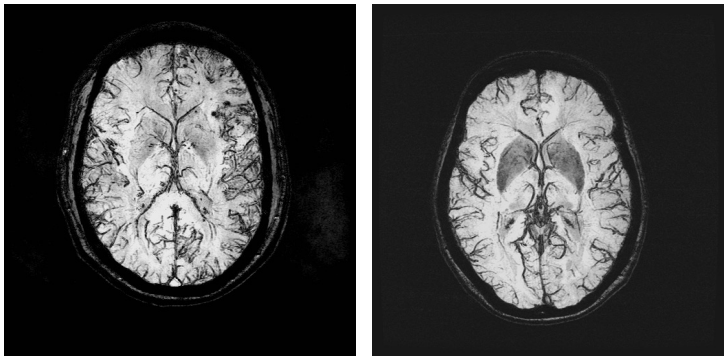


Pulsed ASL (QUIPSS II)

Anatomical Imaging:

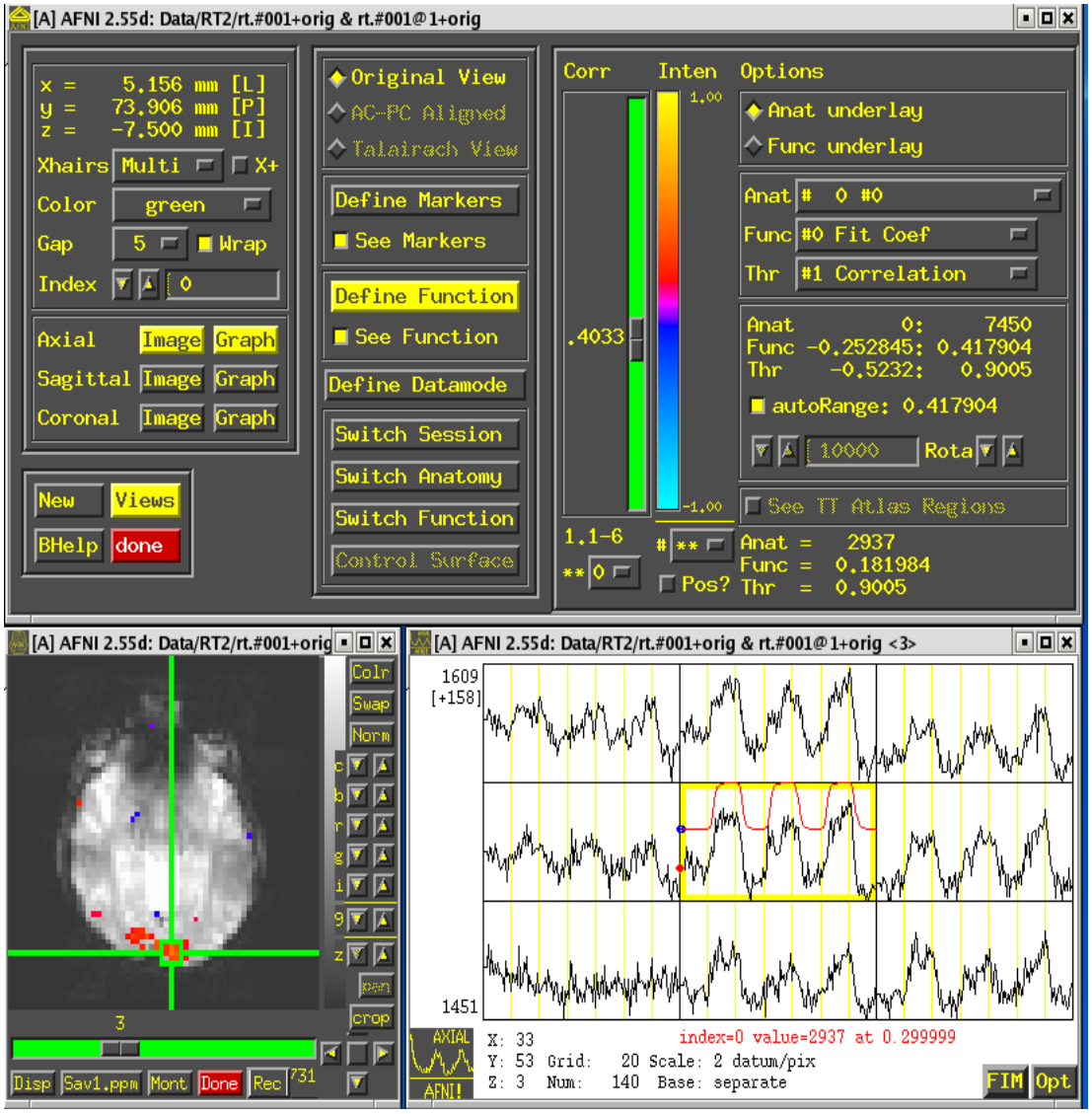
• **MP-RAGE:** T1 weighted sequence with excellent Gray/White matter contrast

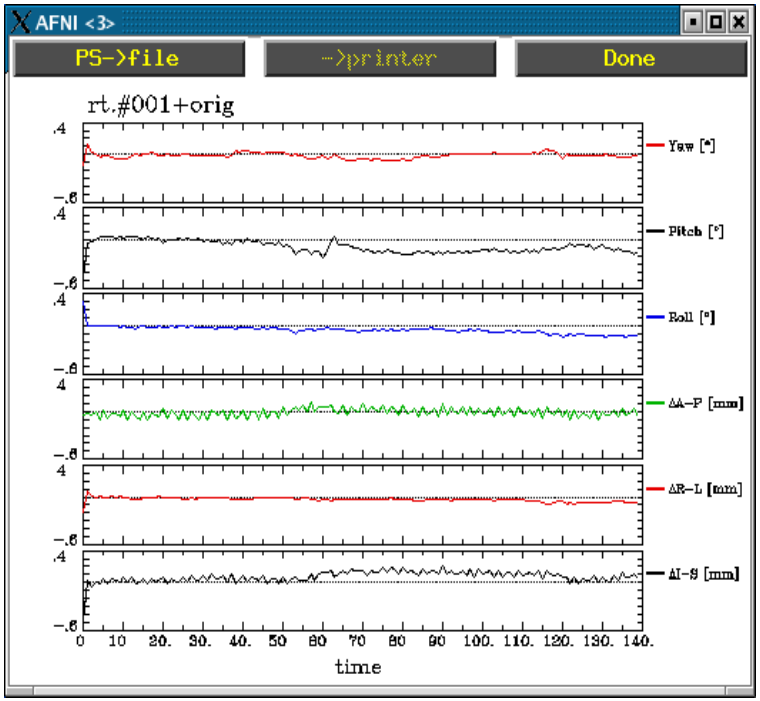
• standard product multi-shot sequences like: SPGR, SE, FSE etc.



High-resolution venogram

“Real – Time” fMRI

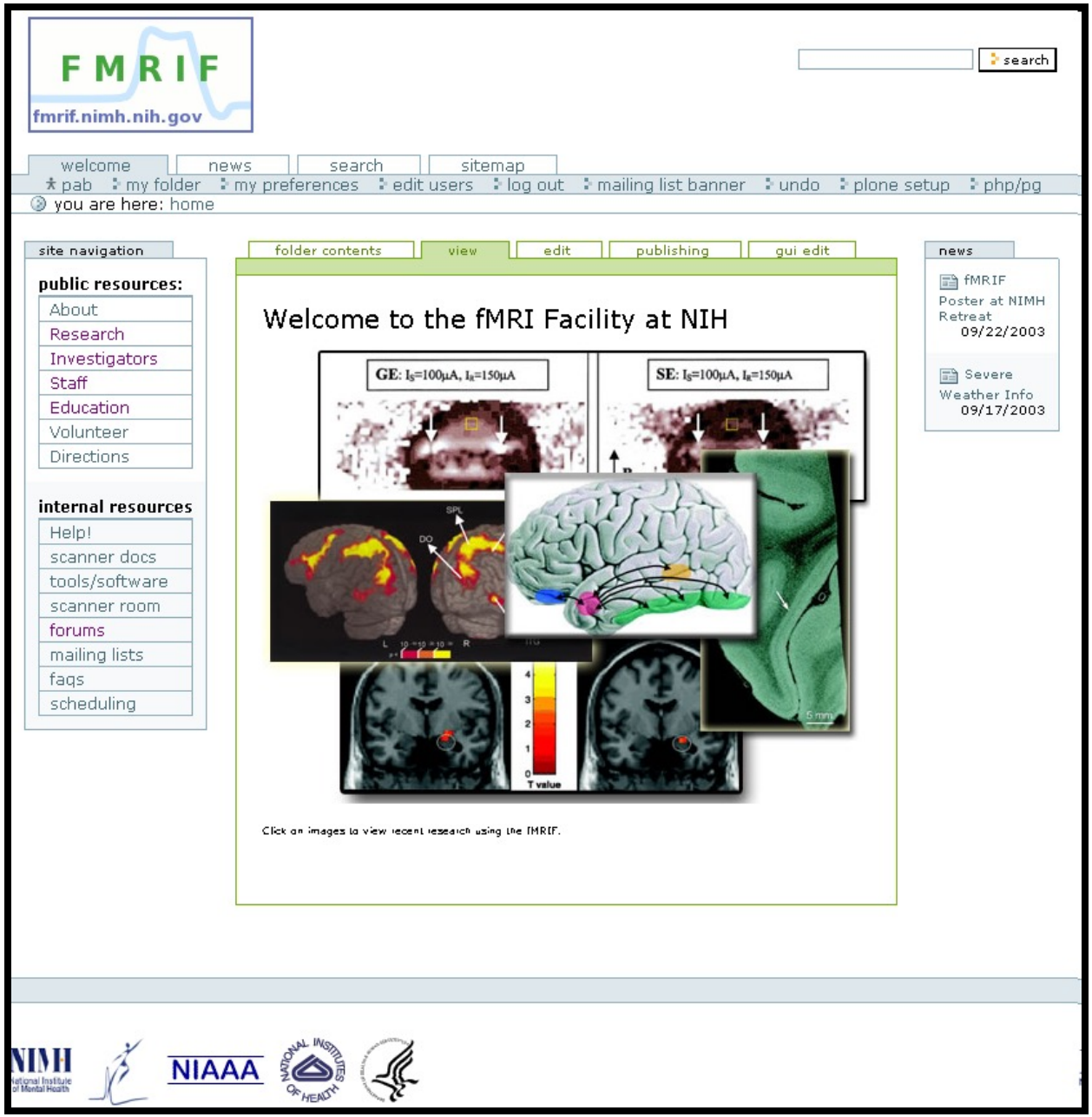




motion tracking

Website:

FMRIF.NIMH.NIH.GOV



3T-1

	Wednesday 03/09/05	Thursday 03/10/05	Friday 03/11/05	Saturday 03/12/05	Sunday 03/13/05	Monday 03/14/05	Tuesday 03/15/05
8am	CBDB (smarenco)	CBDB (Berman)	LBC (sfriedman-hill)	NMRF	CBDB (Berman)	training	CBDB (vmattay)
9am	CBDB (jcallicott)	CBDB (Berman)	LBC (sfriedman-hill)	NMRF	CBDB (Berman)	training	CBDB (vmattay)
10am	CBDB (jcallicott)	CBDB (Berman)	LBC (sfriedman-hill)	NMRF	CBDB (Berman)	CBDB (vmattay)	CBDB (smarenco)
11am	CBDB (jcallicott)	CBDB (vmattay)	LBC (sfriedman-hill)	NMRF	LBC	CBDB (vmattay)	NINDS
Noon	NMRF	CBDB (vmattay)	LBC (sfriedman-hill)	NINDS	LBC	CBDB (vmattay)	NINDS
1pm	NMRF	CBDB (jcallicott)	LBC (sfriedman-hill)	NINDS	LBC	CBDB (vmattay)	NINDS
2pm	NMRF	CBDB (jcallicott)	CBDB (Berman)	NINDS	LBC	NINDS	NINDS
3pm	NMRF	FIM (dknight)	CBDB (Berman)	NINDS	LBC	NINDS	NINDS
4pm	NIAA	FIM (dknight)	CBDB	NINDS	LBC	NINDS	NINDS
5pm	NIAA	FIM (dknight)	CBDB (smarenco)	NINDS	LBC	NINDS	NINDS
6pm	NIAA	FIM (dknight)	CBDB (vmattay)	NINDS	LBC	NINDS	NINDS
7pm	NIAA	FIM (rbirn)	CBDB (vmattay)	NINDS	LBC	NINDS	NINDS
8pm	DEV	FIM (rbirn)	CBDB (vmattay)	NINDS	LBC	GE	DEV
9pm	DEV	FIM (rbirn)	CBDB (vmattay)	NINDS	LBC	GE	DEV
10pm	DEV	FIM (rbirn)	CBDB (vmattay)	NINDS	LBC	GE	DEV

	Weekday		Weekend	
Department	Day	Eve	Day	Eve
Geriatric Psychiatric Branch				
training				
NIAA - National Inst. of Alcohol and Alcoholism				
DEV - Scanner Development				
FIM - Functional Imaging Methods				
GE Maintenance Time				
MAP - Mood and Anxieties Program				
NINDS - Neurological Disorders and Stroke				
CBDB - Clinical Brain Disorders Branch				
LBC - Laboratory of Brain and Cognition				
NMRF - NIH Magnetic Resonance Facility				
David Rubinow				
Posted				

3T-2

	Wednesday 03/09/05	Thursday 03/10/05	Friday 03/11/05	Saturday 03/12/05	Sunday 03/13/05	Monday 03/14/05	Tuesday 03/15/05
8am	MAP	NINDS	NINDS	MAP	DR	DR	DR
9am	MAP	NINDS	NINDS	MAP	LBC	training	CBDB
10am	MAP	NINDS	NINDS	MAP	LBC	training	CBDB
11am	MAP	NINDS	NINDS	MAP	LBC	MAP	CBDB
Noon	MAP	NINDS	NINDS	MAP	LBC	MAP	GPB
1pm	MAP	NINDS	NINDS	MAP	FIM	LBC (imukai)	GPB
2pm	MAP	NMRF	NINDS	MAP	FIM	LBC (imukai)	GPB
3pm	MAP	NMRF	NINDS	MAP	NINDS	LBC (imukai)	GPB
4pm	MAP	NMRF	NINDS	MAP	NINDS	LBC (imukai)	MAP
5pm	MAP	NMRF	NINDS	MAP	NINDS	LBC (imukai)	MAP
6pm	MAP	NMRF	NINDS	MAP	NINDS	LBC (imukai)	MAP
7pm	MAP	NMRF	NINDS	MAP	NINDS	NMRF	MAP
8pm	DEV	DEV	NINDS	GPB	NINDS	NMRF	GE
9pm	DEV	DEV	NINDS	GPB	NINDS	NMRF	GE
10pm	DEV	DEV	NINDS	GPB	NINDS	NMRF	GE

	Weekday		Weekend	
Department	Day	Eve	Day	Eve
Geriatric Psychiatric Branch				
training				
NIAA - National Inst. of Alcohol and Alcoholism				
DEV - Scanner Development				
FIM - Functional Imaging Methods				
GE Maintenance Time				
MAP - Mood and Anxieties Program				
NINDS - Neurological Disorders and Stroke				
CBDB - Clinical Brain Disorders Branch				
LBC - Laboratory of Brain and Cognition				
NMRF - NIH Magnetic Resonance Facility				
David Rubinow				
Posted				

Education / Support:

- Weekly fMRI discussions (Fridays, 1pm, 10/4N230)
- Bi-Monthly user meetings (First Monday every other month, 3pm, 10/4N230)
- Bi-Monthly steering committee meetings (First Monday every other month, 3pm, 10/4N230)
- Meetings with each PI to address needs and concerns & guide purchases
- Training in scanner operation and use of subject interface devices
- Consulting on paradigm design

PI Research:

NIMH:
Peter Bandettini, Ph.D.
Karen Berman, M.D.
James Blair, Ph.D.
Robert Cohen, M.D., Ph.D.
Christian Grillon, Ph.D.
Wayne Drevets, M.D.
Ellen Liebenluft, M.D.
Daniel Pine, M.D.
Jun Shen, Ph.D.
Leslie Ungerleider, Ph.D.
Daniel Weinberger, M.D.

NINDS:
Leonardo Cohen, M.D.
Jeff Duyn, Ph.D.
Jordan Graffman, Ph.D.
Mark Hallet, Ph.D.
Alan Koretsky, Ph.D.
Chrsity Ludlow, Ph.D.

NIAAA:
Daniel Hommer, M.D.

NICHD:
Peter Basser, Ph.D.
Allen Braun, M.D.

Research Protocols on FMRIF Scanners

Current Protocols in Use on 1.5T			
Protocol Numbe	*Institute*	*Lab(s)*	*PI*
76-N-0021	NINDS	NIB	McFarland, Henry
89-M-0006	NIMH	MAP	Geidd, Jay
90-M-0014	NIMH	CBDB	Berman, Karen
91-M-0124	NIMH	CBDB	Mattay, Venkata S.
93-M-0170	NIMH	LBC	Ungerleider, Leslie
98-N-0047	NINDS	NIB	Jacobson, Steve
00-M-0085	NIMH	CBDB	Mattay, Venkata S.
01-M-0192	NIMH	MAP	Pine, Daniel
02-M-0021	NIMH	MAP	Leibenluft, Ellen
03-M-0093	NIMH	MAP	Lissek, Shmuel
03-M-0185	NIMH	MAP	Blair, James
03-N-0196	NINDS	CNS	Grafman, Jordan
03-M-0292	NIMH	MAP	Vythilingam, Meena
03-M-0297	NIMH	MAP	Vythilingam, Meena
04-N-0019	NINDS	NIB	Martin, Roland
05-N-0039	NINDS	NIB	Bagnato, Francesca
05-M-0105	NIMH	MAP	Blair, James

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Current Protocols in Use on 3T1			
Protocol Nur	*Institute*	*Lab(s)*	*PI*
92-DC-0178	NIDCD	LS	Braun, Allen R.
93-M-0170	NIMH	LBC/FIM	Ungerleider, Leslie G.
94-AR-0066	NIAMS	CCTBR	Illei, Gabor G.
98-AA-0056	NIAAA	SBEI	Hommer, Daniel W.
99-CC-0163	CC	LDRR/FIM	Frank, Joseph A.
00-N-0082	NINDS	LFMI	Koretsky, Alan P.
00-M-0085	NIMH	CBDB	Mattay, Venkata S.
01-N-0139	NINDS	CES	Theodore, William
02-M-0018	NIMH	MAP	Zarate, Carlos A.
02-N-0082	NINDS	HCPS	Cohen, Leonardo G.
02-N-0216	NINDS	HMCS	Hallett, Mark
02-M-0231	NIMH	MAP	Zarate, Carlos A.
02-AR-0267	NIAMS	CCTBR	Illei, Gabor G.
03-M-0001	NIMH	MAP	Cannon, Dara M.
03-N-0195	NINDS	CNS	Grafman, Jordan H.
03-N-0230	NINDS	HMCS	Hallett, Mark
03-N-0260	NINDS	LSS	Ludlow, Christy L.
04-N-0110	NINDS	HCPS	Cohen, Leonardo G.
04-N-0192	NINDS	CNS	Grafman, Jordan H.
05-N-0032	NINDS	MNB	Hallett, Mark

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Current Protocols in Use on 3T2			
Protocol Nur	*Institute*	*Lab(s)*	*PI*
92-DC-0178	NIDCD	LS	Braun, Allen
93-M-0170	NIMH	LBC/FIM	Ungerlieder, Leslie
97-H-0026	NHLBI	cardiac	Arai, Andrew
00-N-0082	NINDS	HMCS	Hallet, Mark
00-M-0085	NIMH	CBDB	Mattay, Venkata S.
01-M-0192	NIMH	MAP	Pine, Daniel
00-M-0198	NIMH	MAP	Leinbenluft,Ellen
01-M-0254	NIMH	MAP	Denicoff, Kirk
02-M-0018	NIMH	MAP	Zarate, Carlos
02-M-0021	NIMH	MAP	Pine, Daniel
02-M-0047	NIMH	MAP	Drevets, Wayne
02-N-0082	NINDS	MNB	Cohen,Leonardo
02-M-0092	NIMH	MAP	Ernst,Monique
02-M-0095	NIMH	GPB	Cohen, Robert
02-N-0128	NINDS	HMCS	Hallet, Mark
02-M-0162	NIMH	MAP	Neumeister,Alex
02-N-0216	NINDS	HMCS	Hallet, Mark
02-M-0317	NIMH	MAP	Bonne,Omar
02-M-0321	NIMH	MAP	Grillon, Christian
03-M-0001	NIMH	MAP	Cannon, Dara
03-M-0014	NIMH	MAP	Pine, Daniel
03-M-0102	NIMH	MAP	Drevets, Wayne
03-M-0149	NIMH	MAP	Duan, Yu-Fe
03-M-0186	NIMH	MAP	Ernst,Monique
03-M-0292	NIMH	MAP	Vythilingam, Meena
04-N-0047	NINDS	MNB	Shibasaki, Hiroshi
04-AA-0058	NIAAA	LMBB	Salem, Norman
04-N-0113	NIMH	CNS	Grafman,Jordan
04-M-0136	NIMH	MAP	Bain, Earl
04-N-0146	NINDS	HMCS	Hallet, Mark
04-M-0180	NIMH	MIB	Innis, Robert
04-N-0192	NINDS	CNS	Grafman, Jordan

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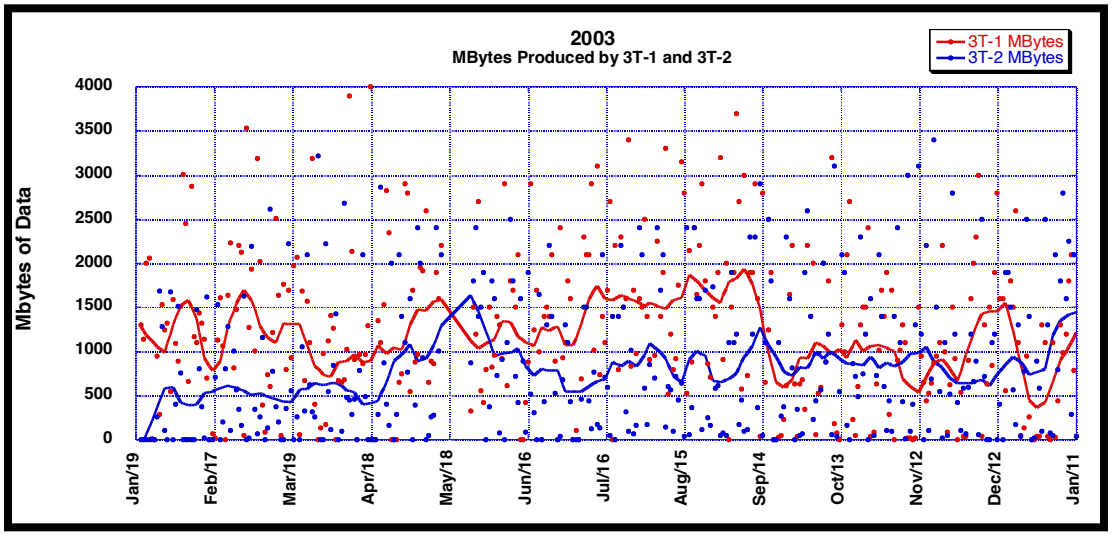

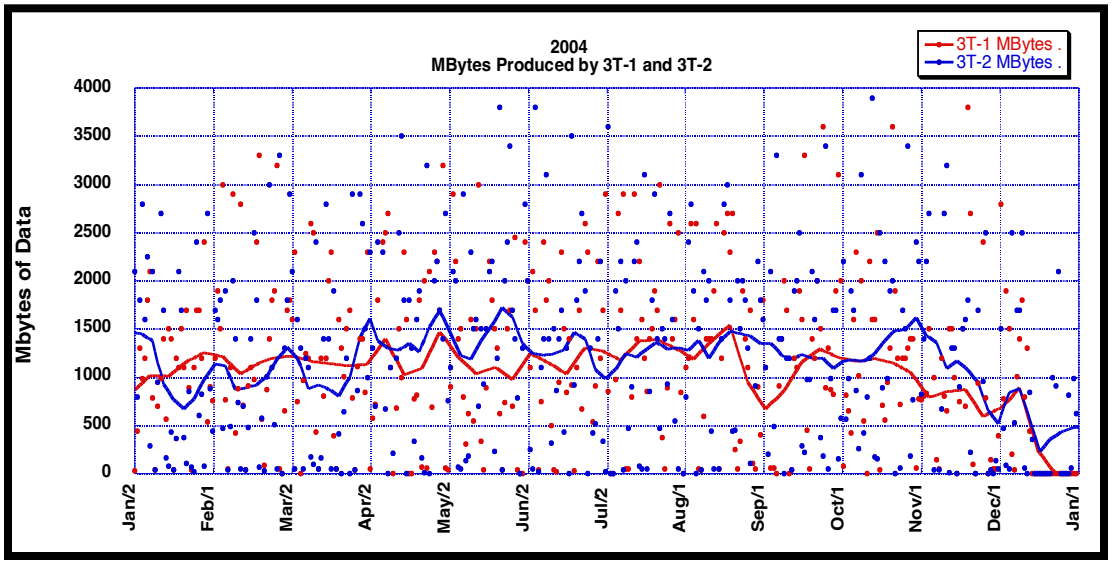

2003:

Up days:
3T-1: 303
3T-2: 280

Total budget (including salaries): $1,746 000.00

Cost per usage hour (only counting up days x 10 hrs day): $309

Cost per Gigabyte: $2.35

Functional MRI
Papers Published at the NIH:

2000: **20**
2001: **11**
2002: **24**
2003: **26**
2004: **31**
2005: **5**

Ongoing Projects and Directions

- More routine access to advanced subject interface devices (eye tracking, skin conductance).
- Better dissemination of methods information to and across groups.
- Simultaneous EEG/fMRI.
- Higher resolution single shot fMRI (1.5 mm^3).
- More routine access to perfusion imaging methods and processing.
- Better shimming techniques (to image base of brain more effectively).