Functional MRI at the NIH

Peter A. Bandettini, Ph.D.

Section on Functional Imaging Methods

http://fim.nimh.nih.gov

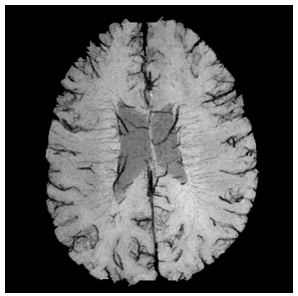
Laboratory of Brain and Cognition

&

Functional MRI Facility

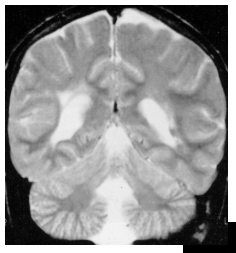
http://fmrif.nimh.nih.gov

Venography

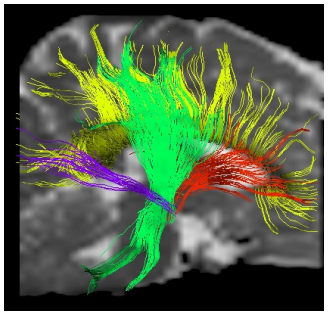


T1 weighted

T2 weighted



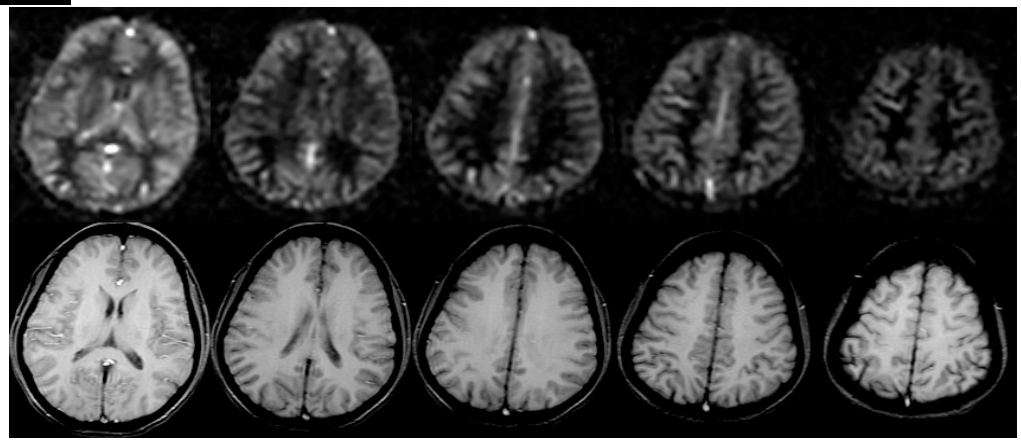
Fiber Track Imaging



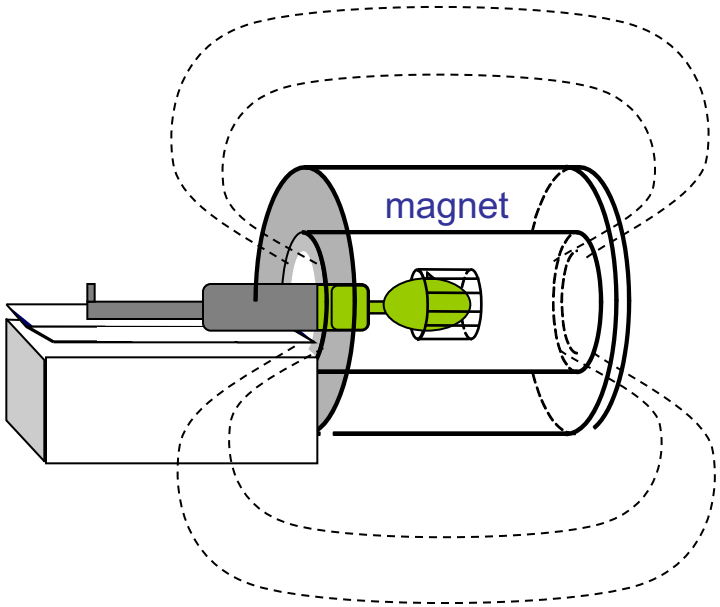
Anatomy

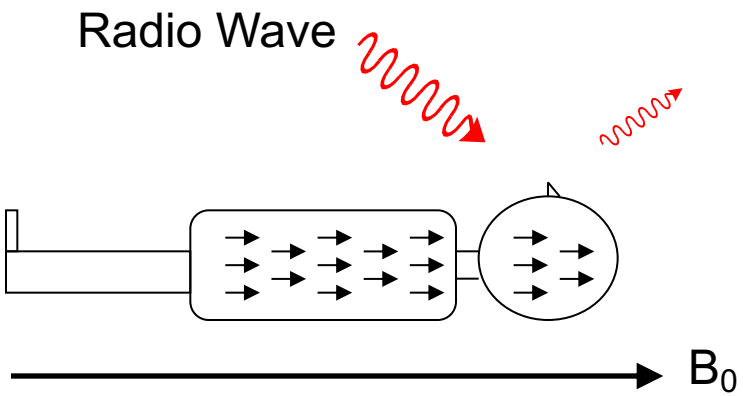
Angiography

Perfusion



Magnetic Resonance Imaging (MRI)



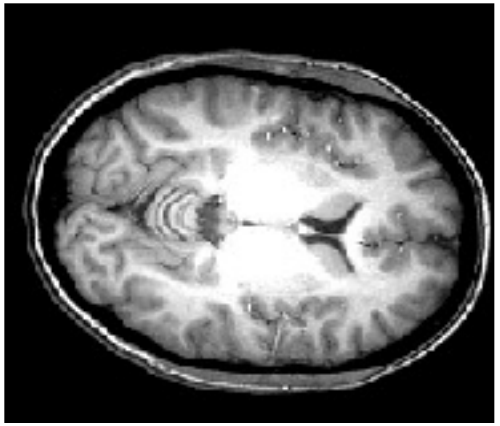


Sensitive to:

- # of protons (H_2O)
- Magnetic environment
  - Tissue structure

MRI vs. fMRI

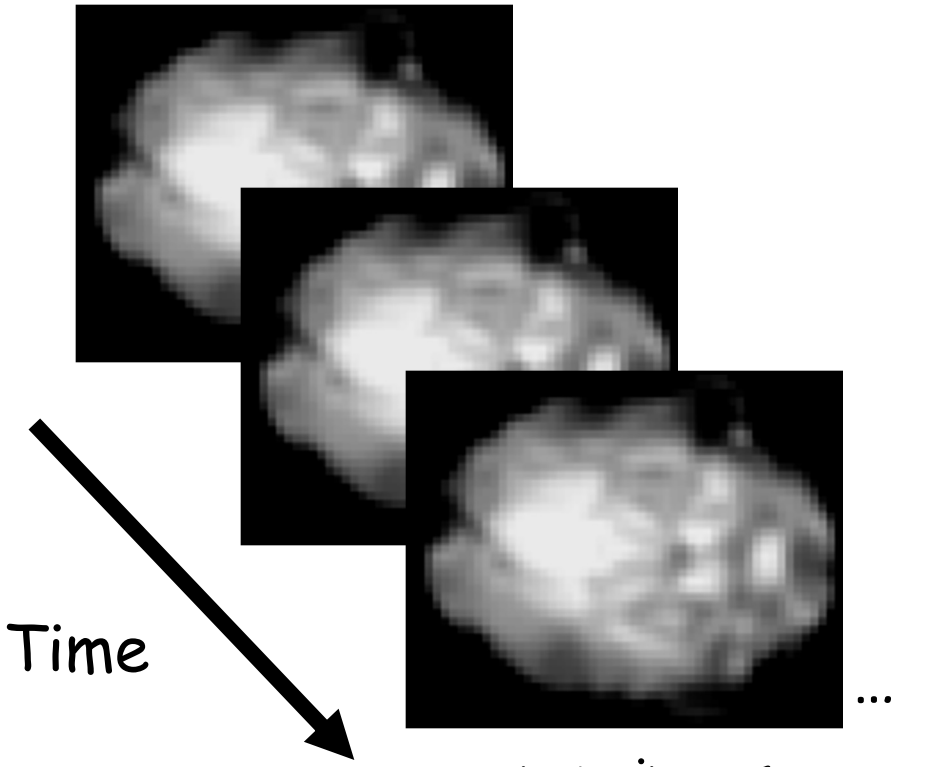
MRI



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)

Measuring Brain function with MRI

Functional MRI (fMRI)

↑ Task

↓

↑ neuronal activity

↓

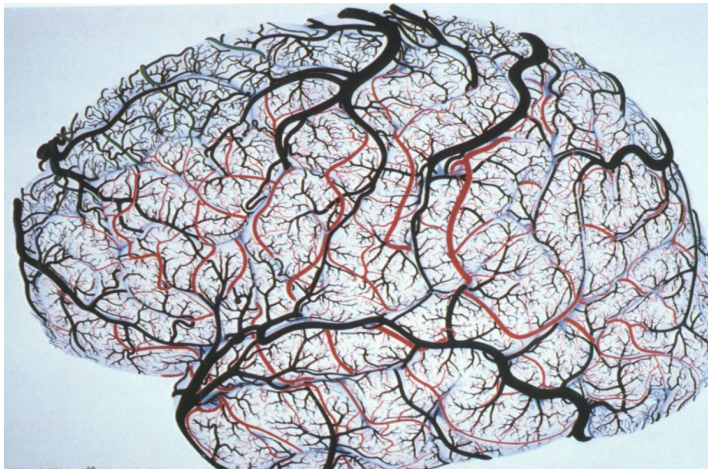
↑ Blood Flow

↓

↑ Oxygenation of blood

↓

↑ MRI signal



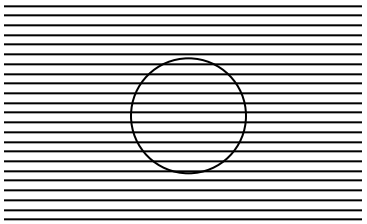
Red Blood Cells

Basis of BOLD Contrast

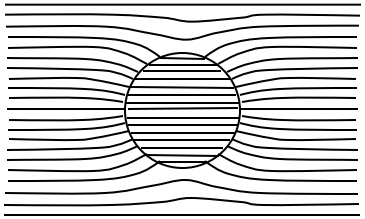
Oxygenated and deoxygenated red blood cells have different magnetic properties

red blood cells

oxygenated



deoxygenated

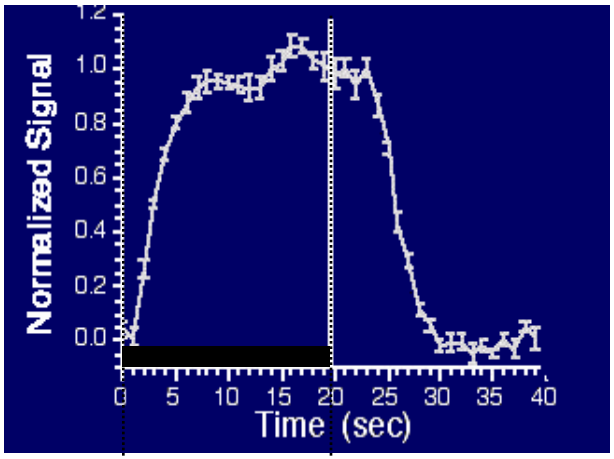


L. Pauling, C. D. Coryell, *Proc.Natl. Acad. Sci. USA 22, 210-216*, **1936**.

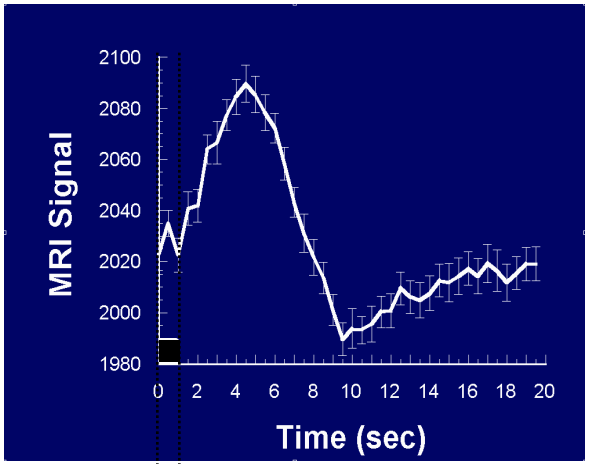
K.R. Thulborn, J. C. Waterton, et al., *Biochim. Biophys. Acta. 714: 265-270*, **1982**.

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

BOLD Contrast Imaging



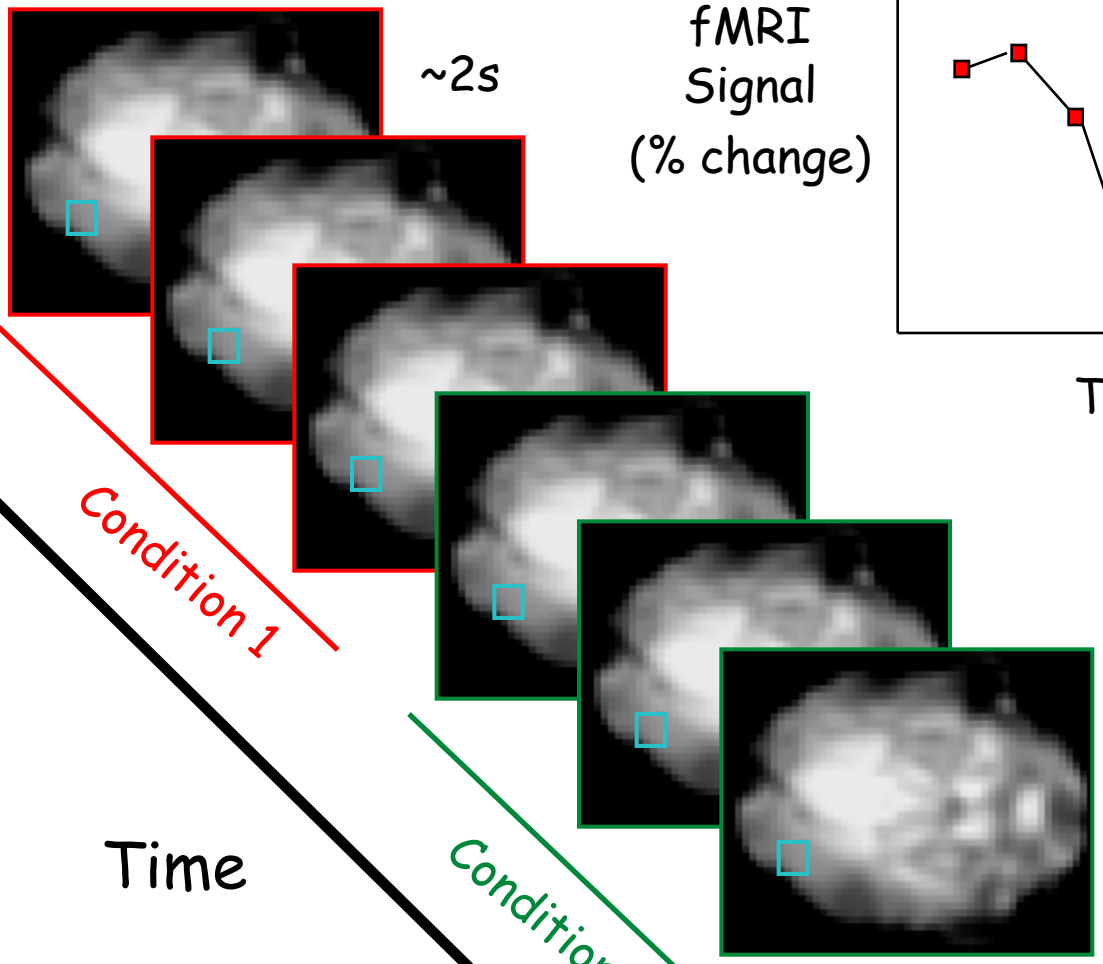
task



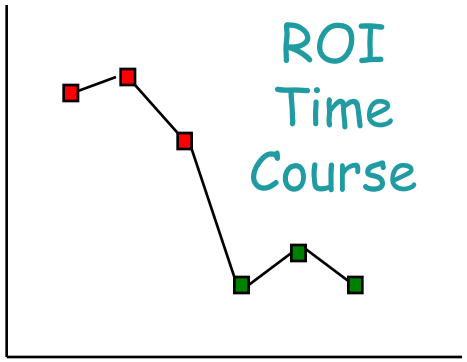
task

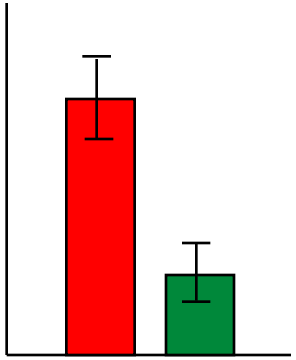
Activation Statistics

Functional images

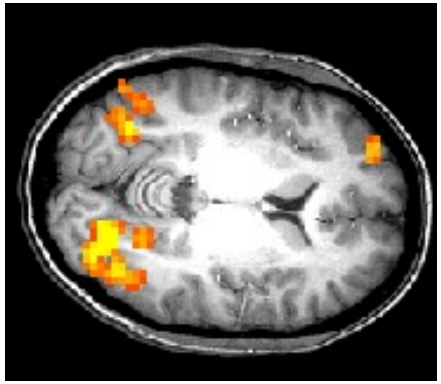


fMRI Signal (% change)



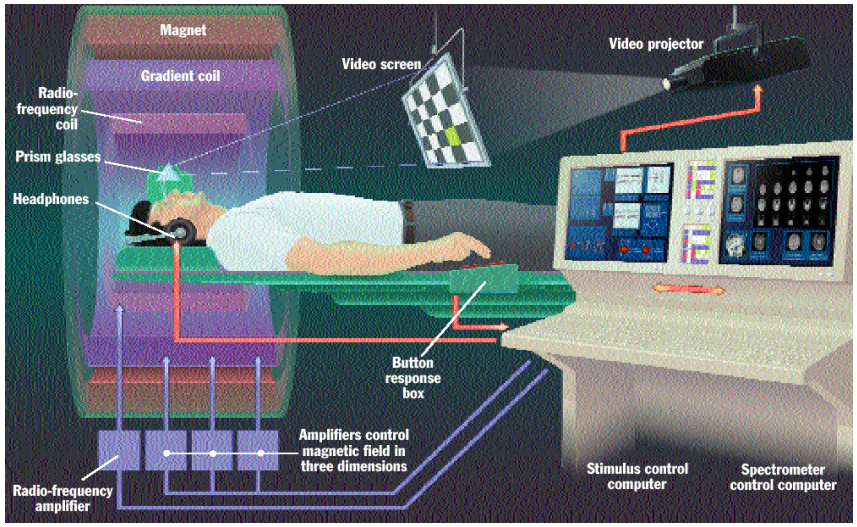


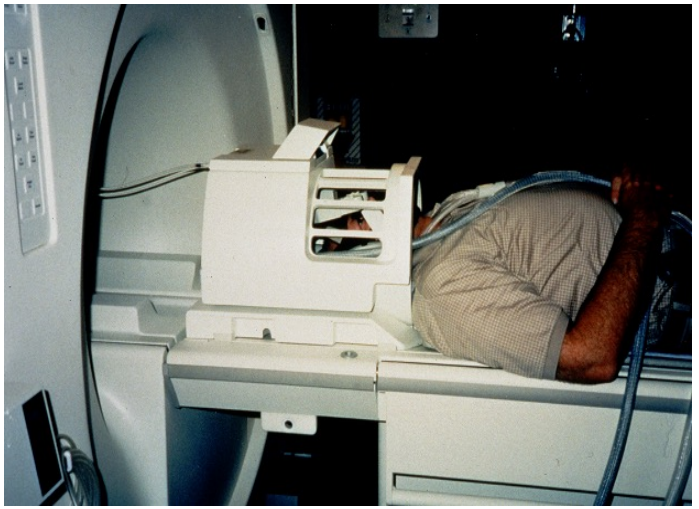
Statistical Map
superimposed on anatomical MRI image



Magnetic Resonance Imaging

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



Users

NIMH:
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Jay Giedd, M.D.
Christian Grillon, Ph.D.
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Ellen Liebenluft, M.D.
Alex Martin, Ph.D
Husseini Manji, M.D.
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Elizabeth Murray, Ph.D
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Mark Hallet, Ph.D.
John Hallenbeck, M.D.
Alan Koretsky, Ph.D.
Christy Ludlow, Ph.D.
Henry F. McFarland, M.D.
Edward Oldfield, M.D.
William Theodore, M.D.

NIAAA:
Daniel Hommer, M.D.

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

NCI:
Kathy Warren, M.D.

fMRI research + resources at the NIH

Studies focusing on:

- Normal Brain Function
- Mental disorders
  - Anxiety disorders
  - Bipolar disorder
  - Depression
  - Autism
  - Schizophrenia
  - …

7 human MRI scanners (1 - **1.5T**, 5 - **3T**, 1 - **7T**)

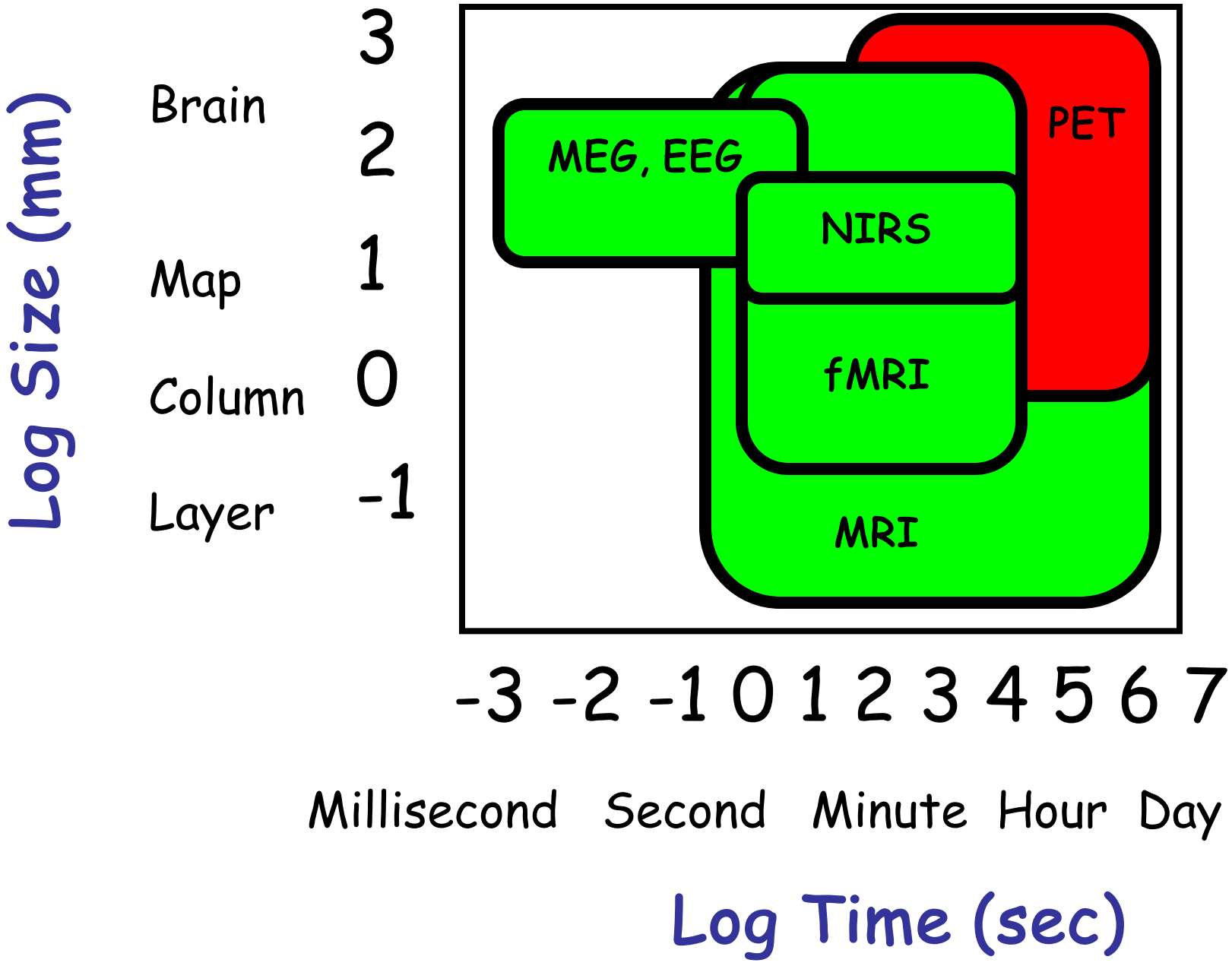
MEG, EEG

3 dedicated animal MRI scanners

Micro CT, Ultrasound, Bioluminescence

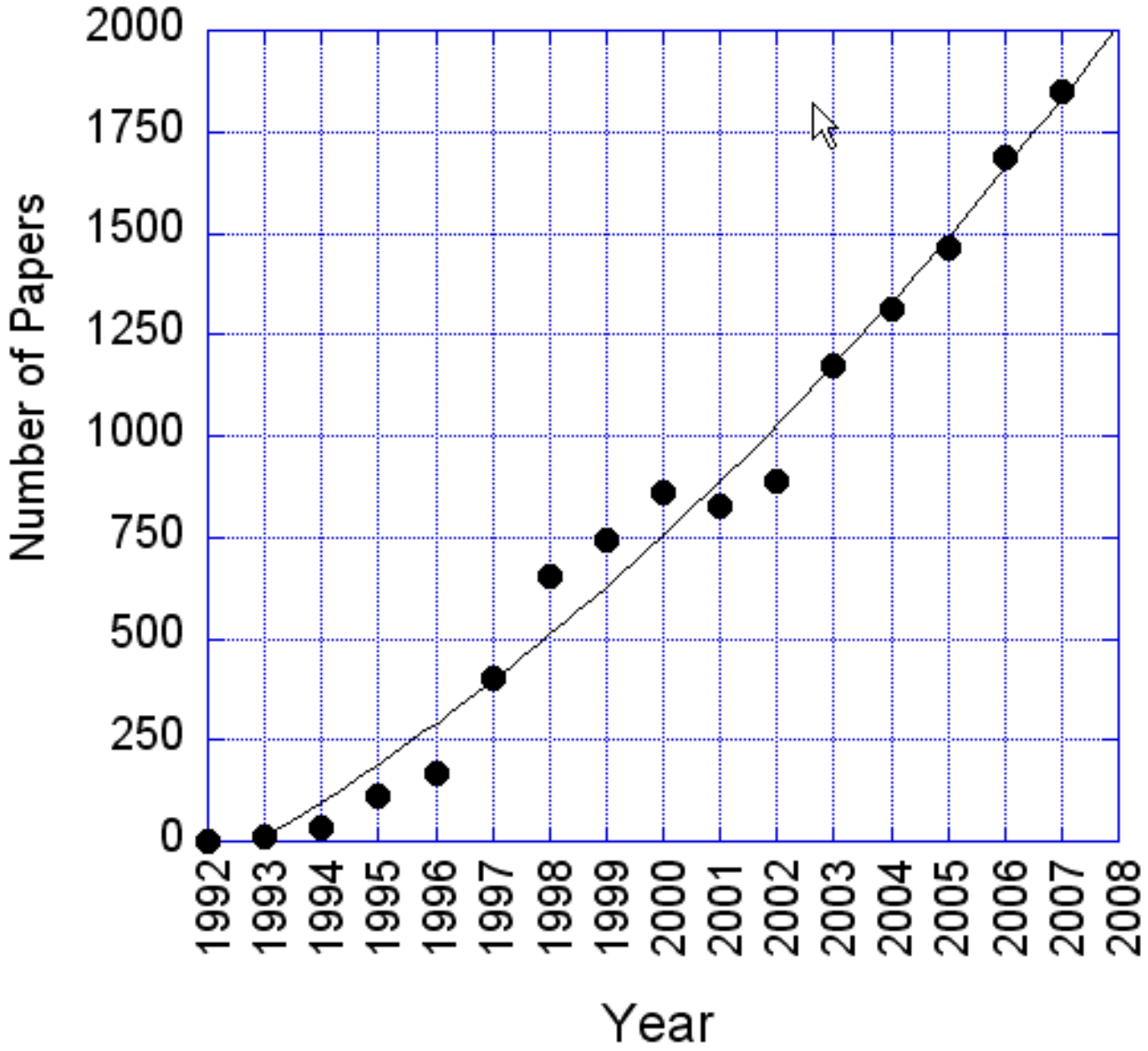
fMRI Studies at the NIH..

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


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)

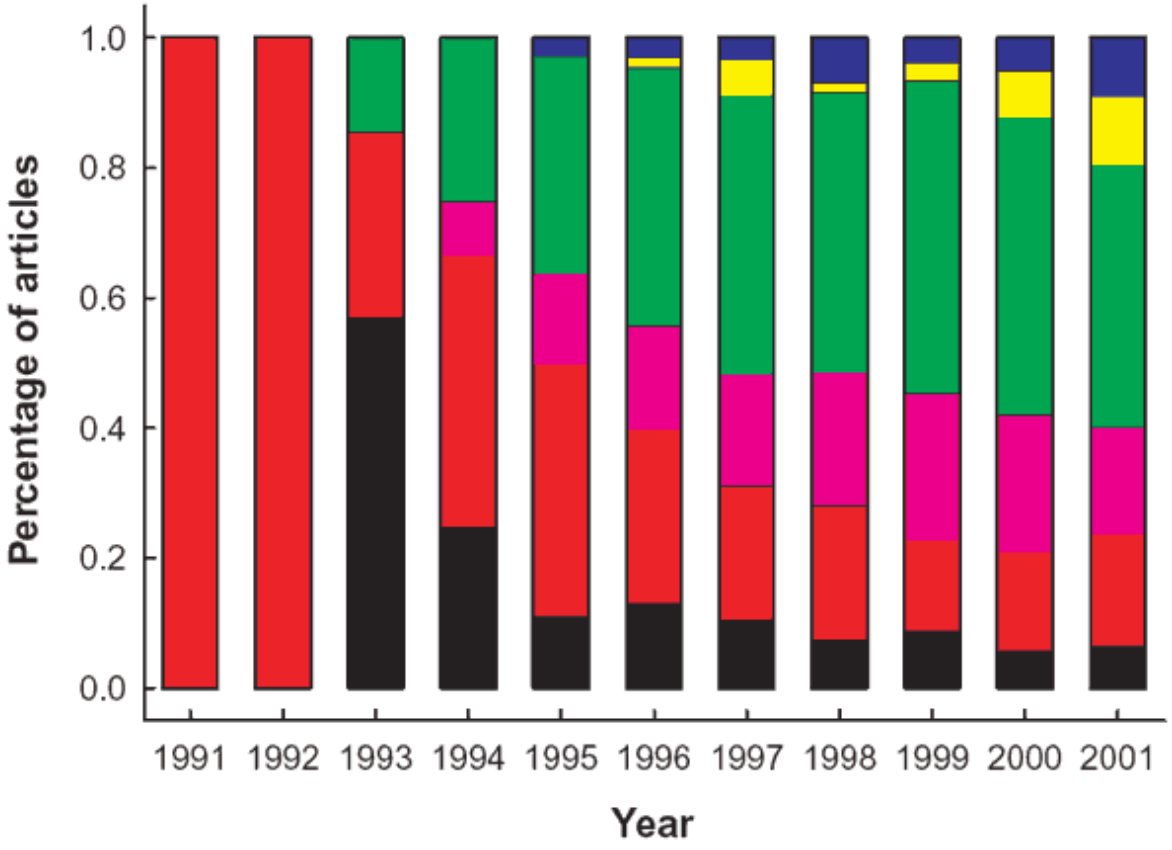
Scopus: Articles or Reviews Published per Year

"fMRI" or "functional MRI"



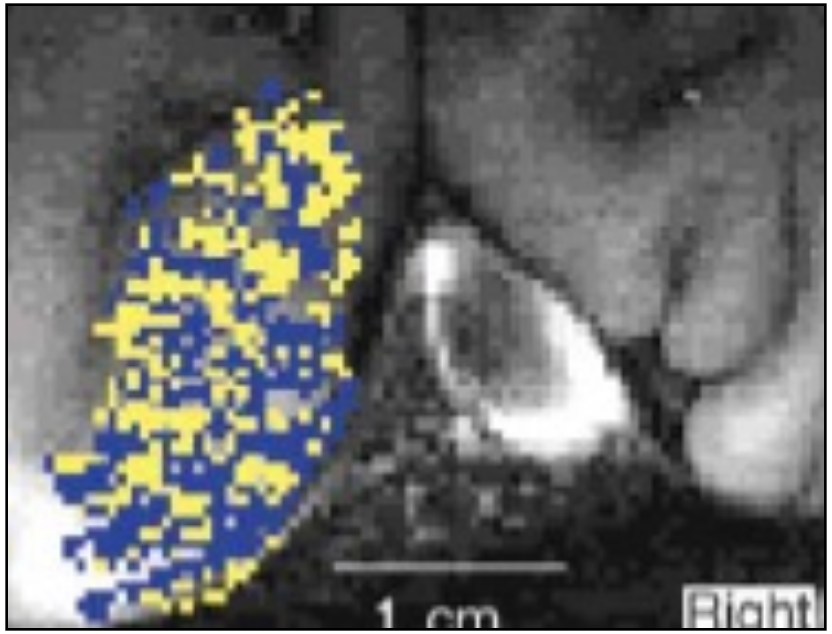
Type of fMRI research performed

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



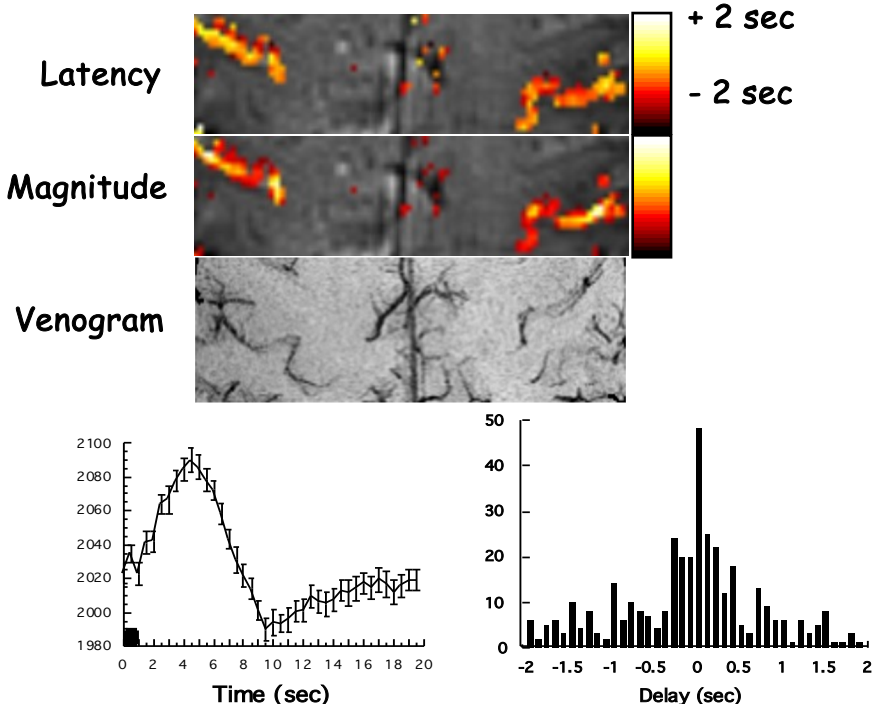
J. Illes, M. P. Kirschen, J. D. E. Gabrielli,
Nature Neuroscience, 6 (3) p.205, 2001

Spatial and Temporal Resolution



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

Latency Variation…



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

Spatial

Temporal

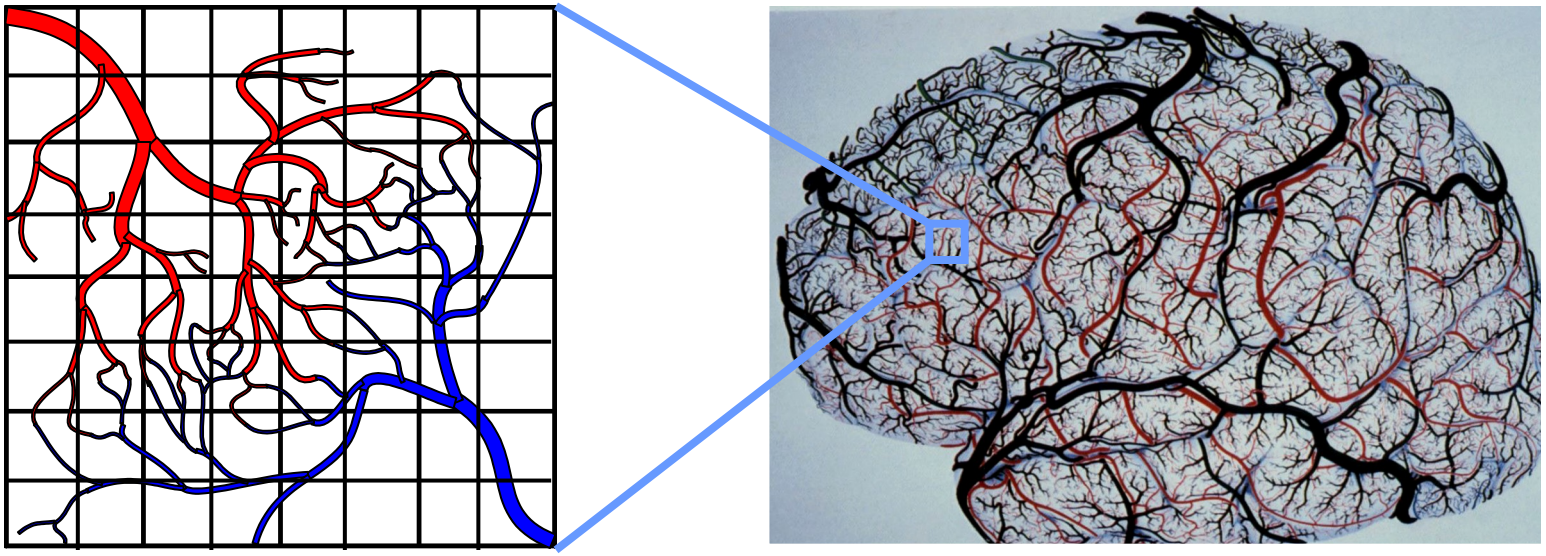
Interpretation

Neuronal Activation ? Measured Signal

? ? ? ?

Hemodynamics

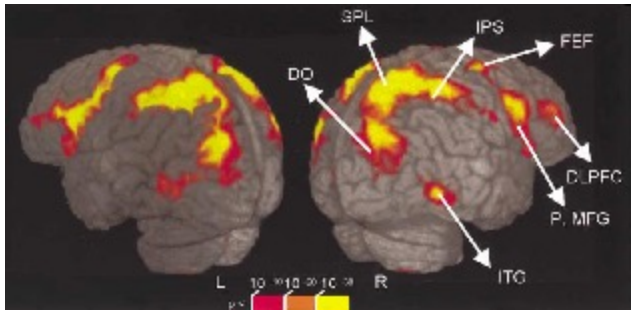
Noise

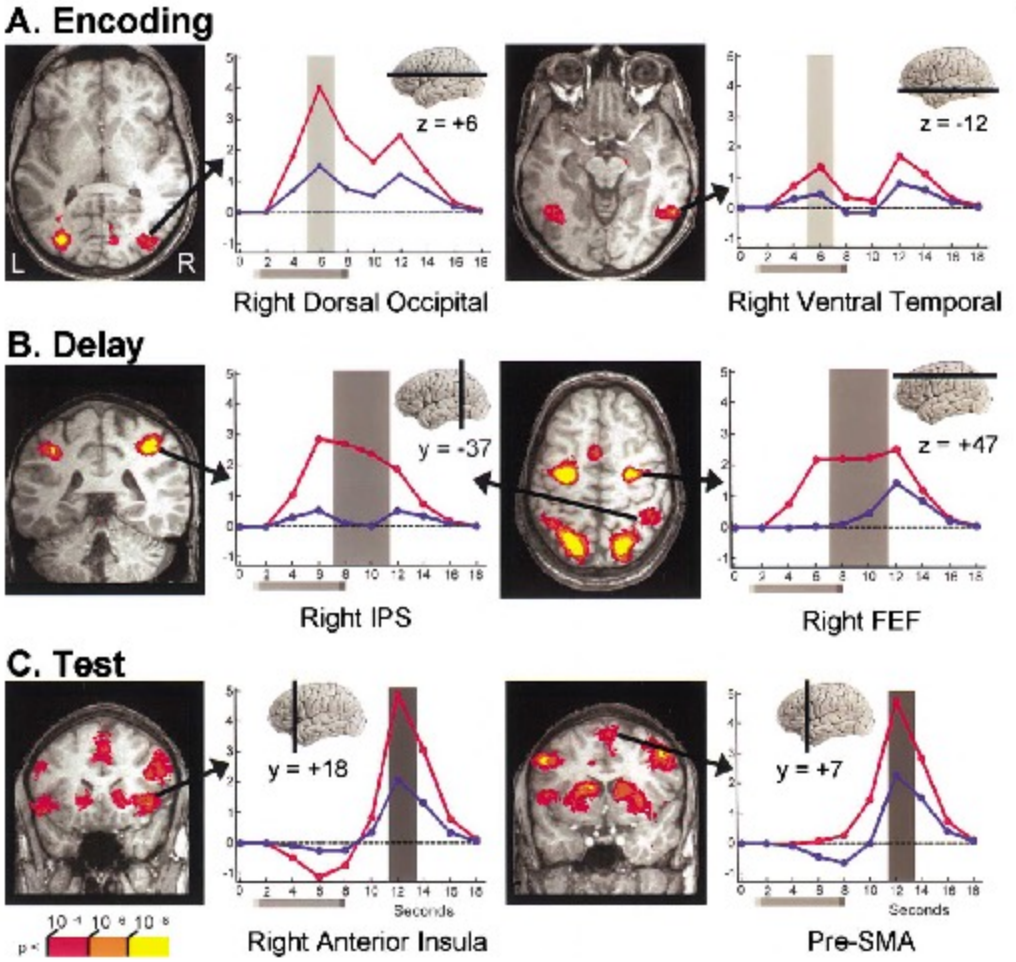


Neuron, Vol. 35, 975–987, August 29, 2002, Copyright ©2002 by Cell Press

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

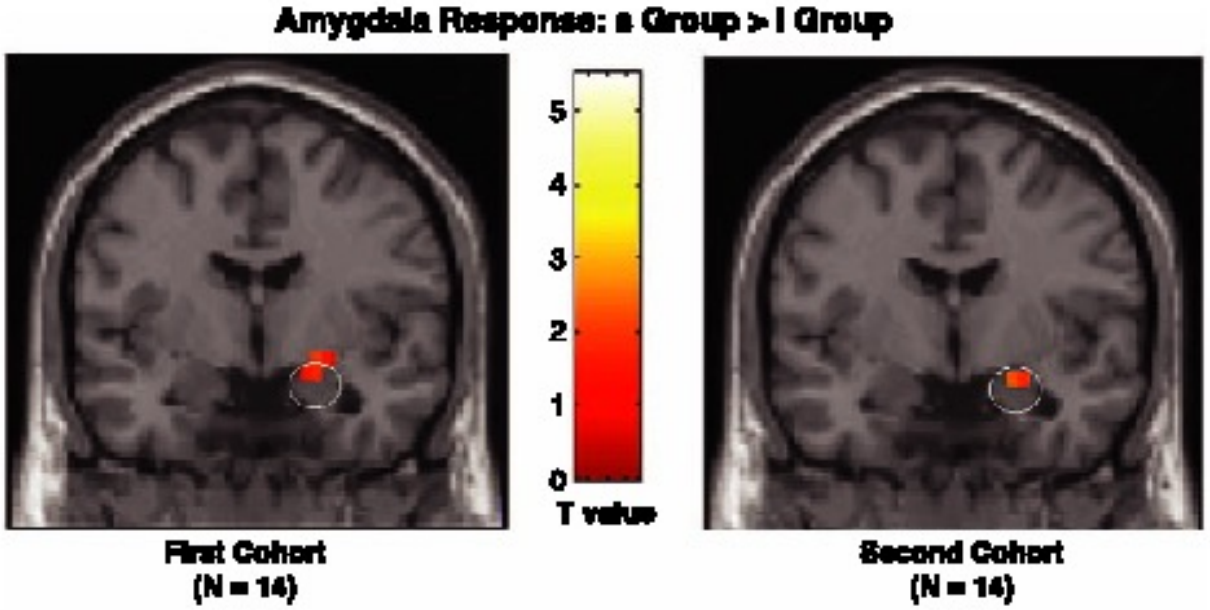




Comparison of two groups of *normal* individuals with differences in the Serotonin Transporter Gene

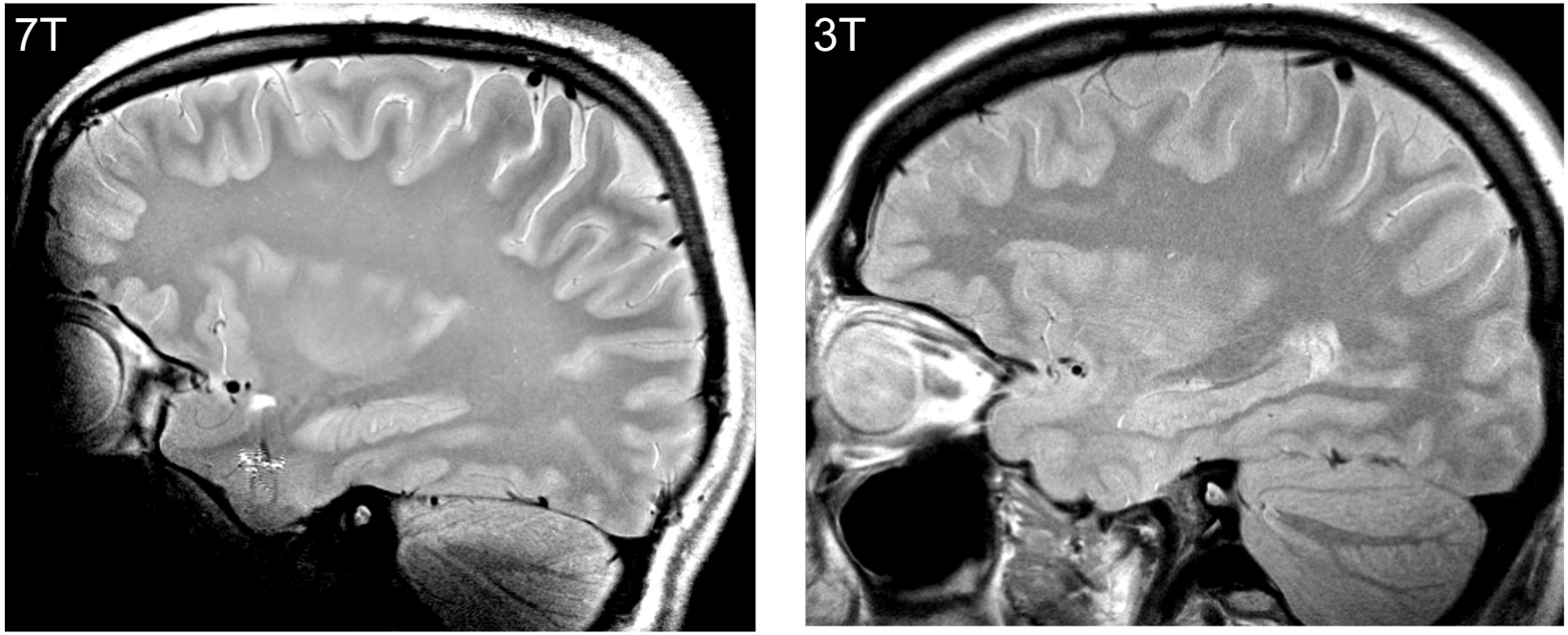
Serotonin Transporter Genetic Variation and the Response of the Human Amygdala

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]*



Current Developments –
Technology

- Higher magnetic fields



TSE, 11 echoes, 7 min exam, 20cm FOV, 512x512 (0.4mm x 0.4mm), 3mm thick slices.

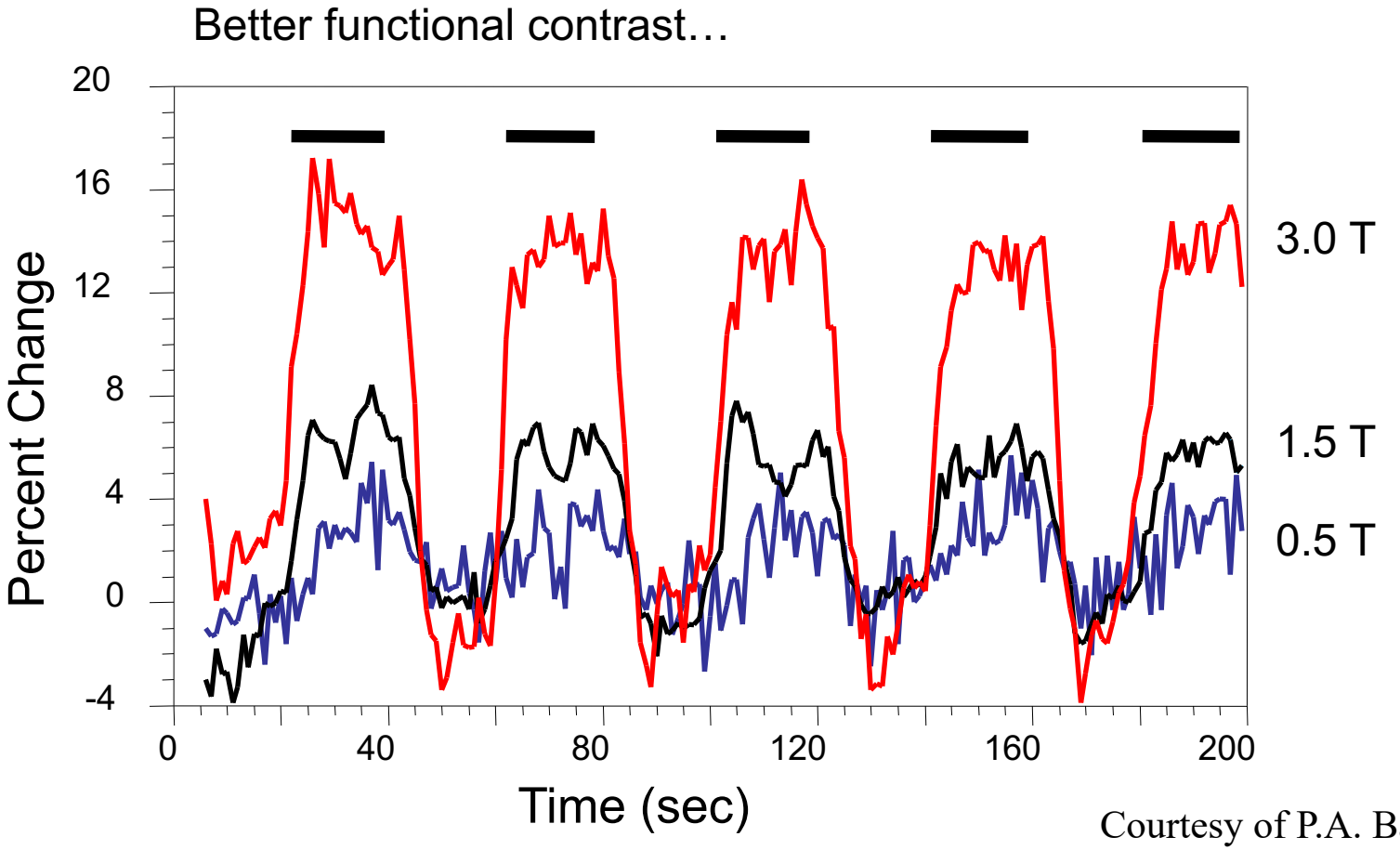
white matter SNR = 65
Gray matter SNR = 76

white matter SNR = 26
Gray matter SNR = 34

Courtesy of L. Wald, MGH, Boston

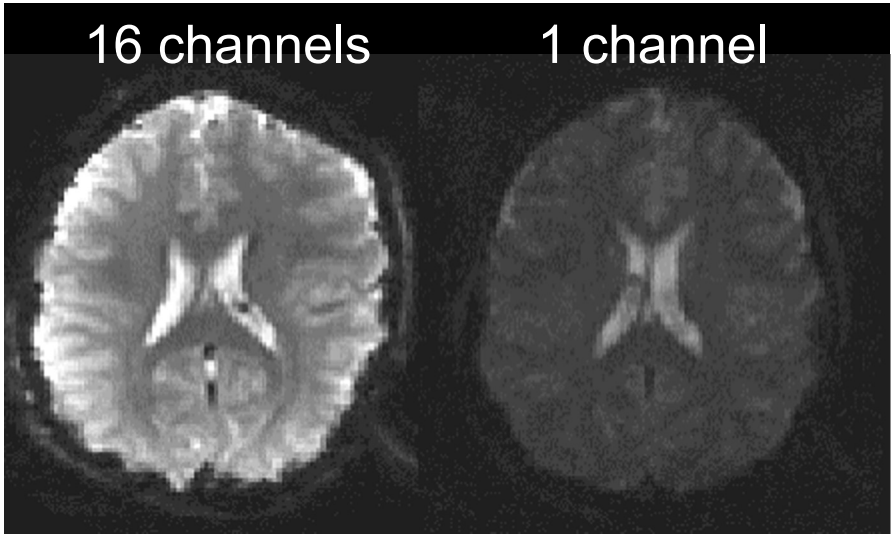
Current Developments –
Technology

- Higher magnetic fields



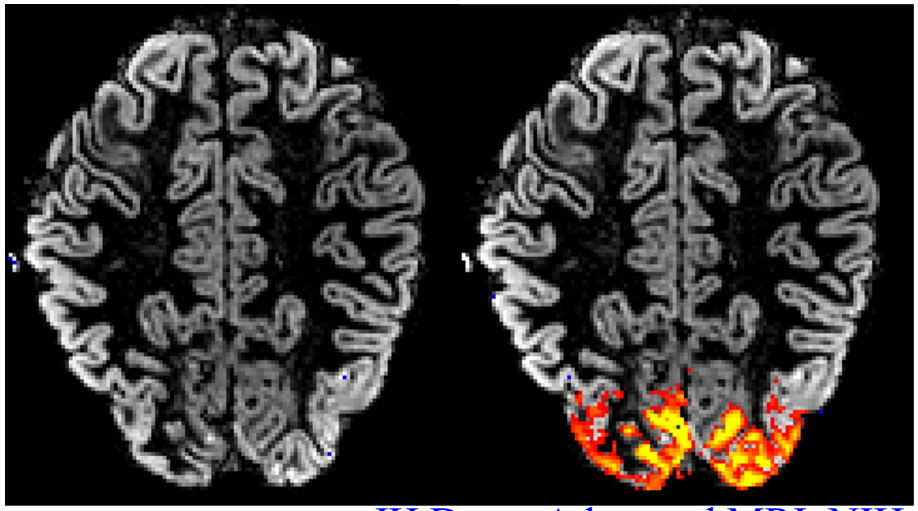
Courtesy of P.A. Bandettini

Current Developments – *Technology: Parallel Imaging*



J. Bodurka, FMRIF, NIH

More signal



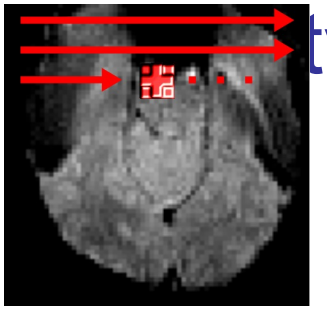
JH Duyn, Advanced MRI, NIH

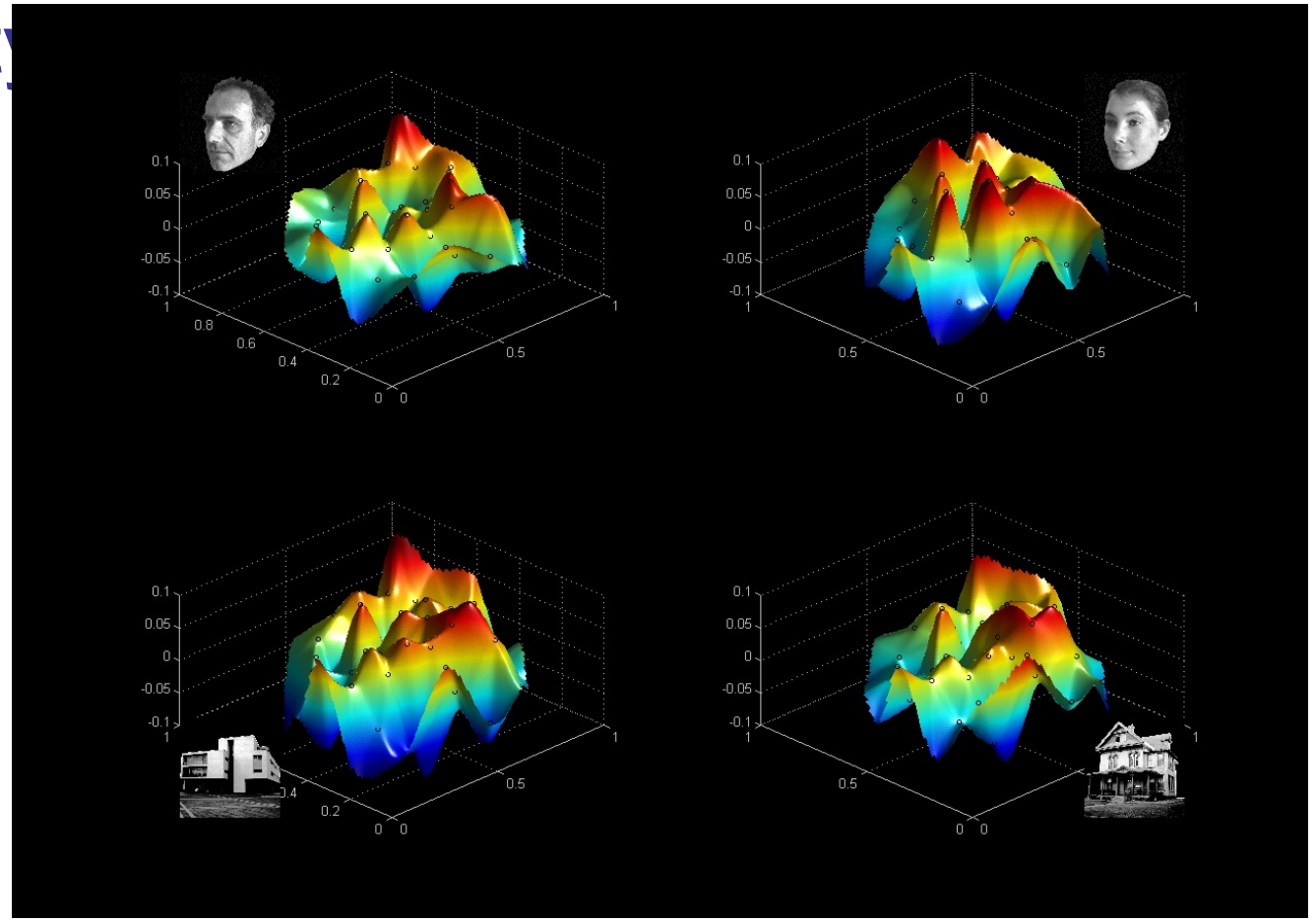
Higher resolution

voxel size = 1.1 x 1.1 mm

Current Developments – Analysis

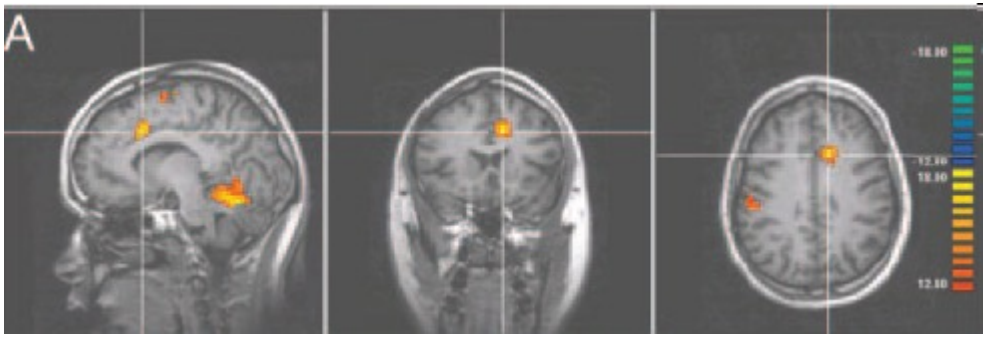
- Identifying patterns and networks of

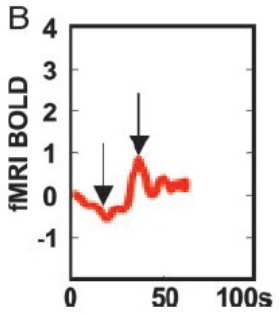


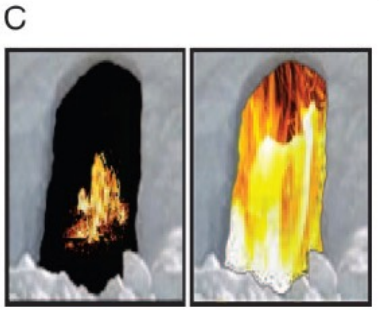


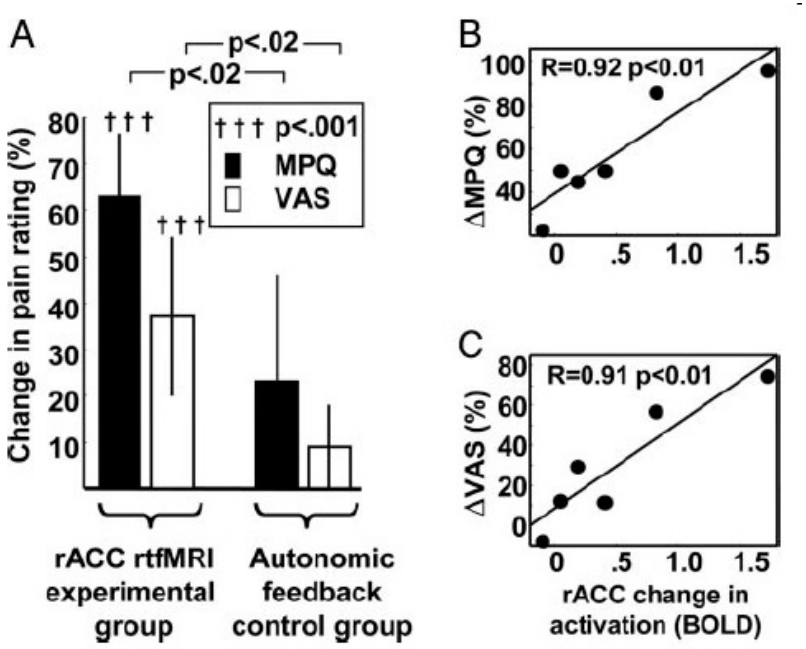
Niko Kriegeskorte

Real time fMRI feedback to reduce chronic pain



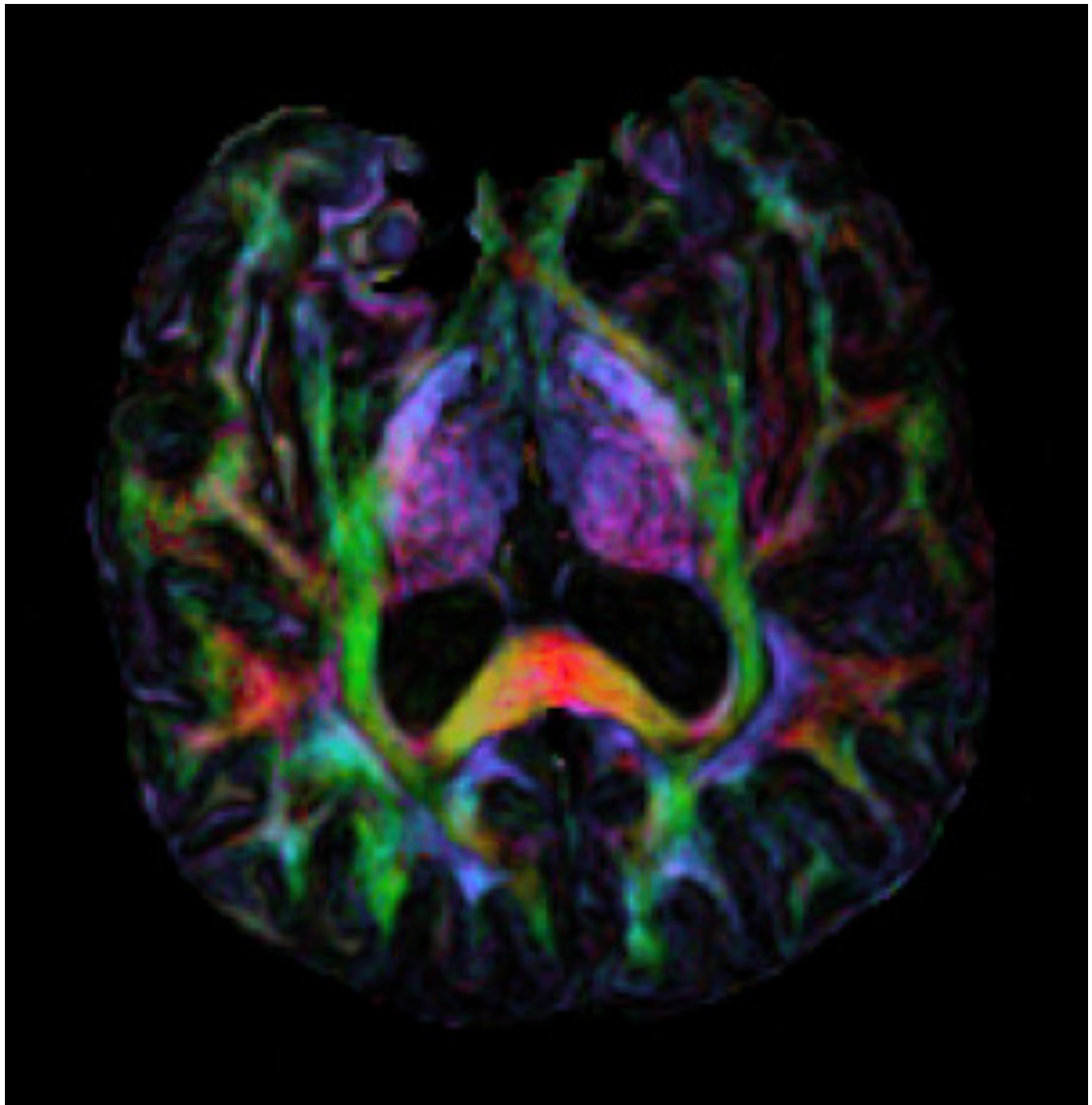






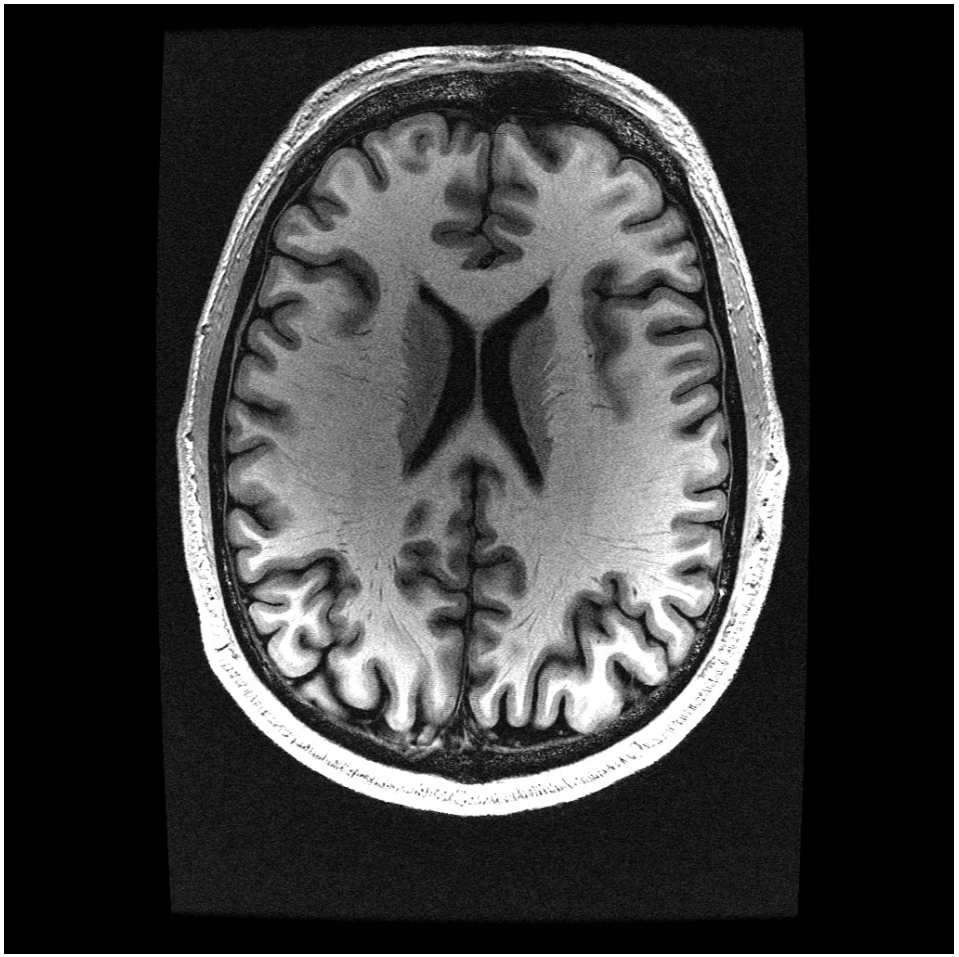
Control over brain activation and pain learned by using real-time functional MRI, R. C. deCharms, et al. PNAS, 102; 18626-18631 (2005)

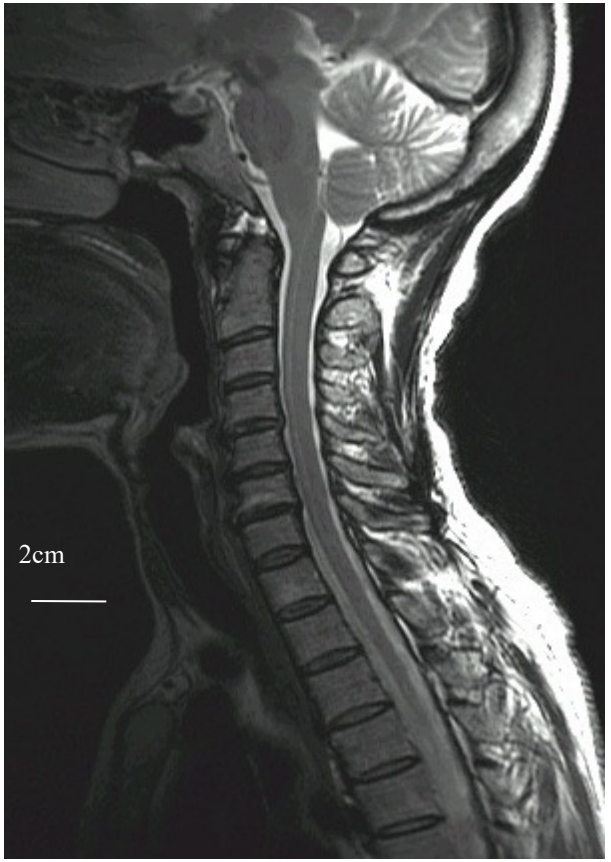
Diffusion Tensor Imaging



Sub-millimeter resolution DTI map of microstructure. (J. Sarlls, C. Pierpaoli, & P. Basser, NICHD)

High resolution





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

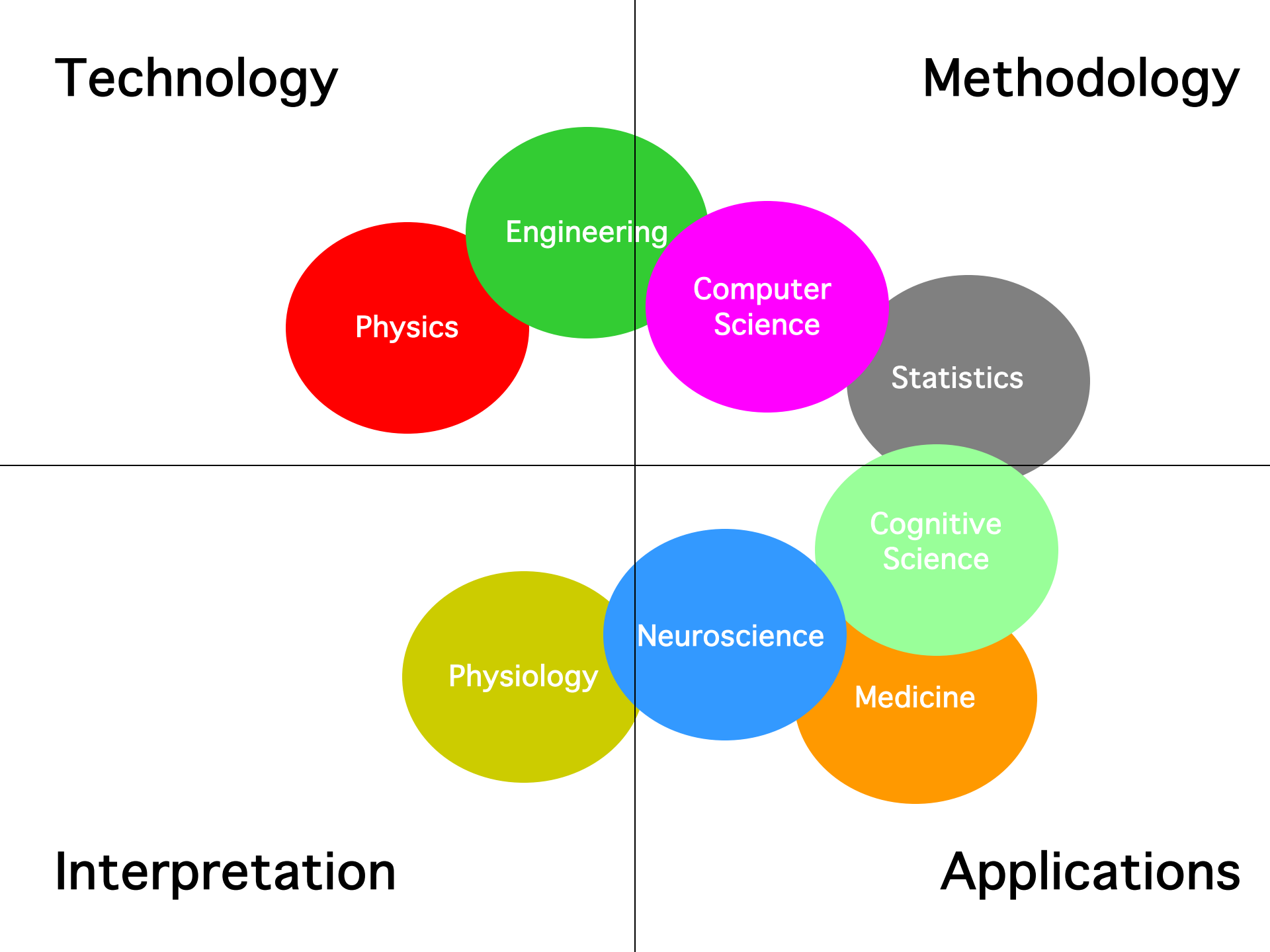
- -utilization of clinical research results
- -prediction of pathology

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


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