fMRI and MRI at NIH

Sean Marrett / FMRIF / NIMH

Functional MRI Summer Course 2015

Outline

1. The NIH has probably the largest concentration of resources for MRI method development and application to neuroscience in the world
   - Functional MRI Facility
   - In-vivo NMR Facility/Mouse Imaging Facility
   - Scientific Statistical Computing Core
   - Neurophysiological Imaging Facilty
   - MEG
   - Scientific Instrumentation Branch
   - etc

2. Because of the scale, it is not easy to understand all the resources that are available or the range of MRI studies that get carried out at the NIH
3. Some examples of some of the advanced/interesting MR methods and studies that are or have been carried out at NIH from 20 investigators (a work in progress)

fMRI Studies at the NIH..

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

Methods – FMRI, MRS, DTI
Hardware – Coils, receivers
Pulse sequences
Pre and Post-processing
Contrast agents/particles etc

All papers involving MRI from Bethesda

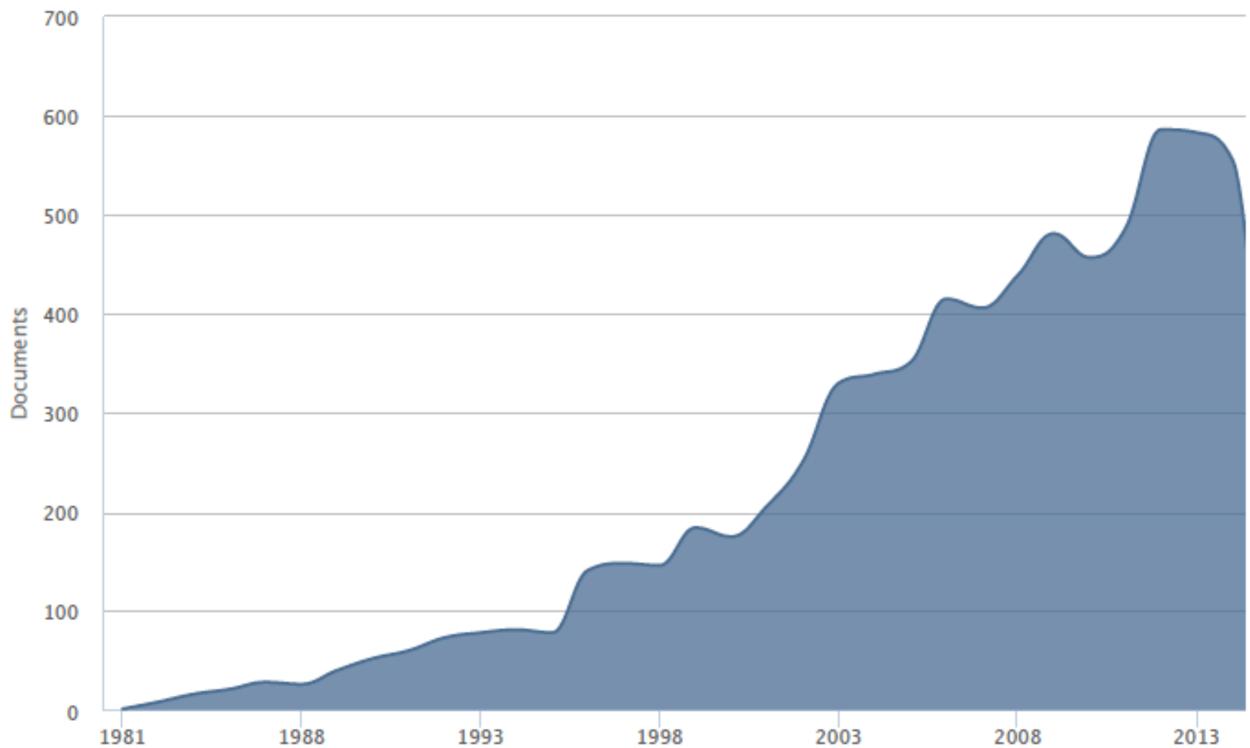
(TITLE-ABS-KEY (**mri** OR **"magnetic resonance imaging"**) AND AFFIL (**bethesda**)) Back to your search results

7454 document results Choose date range to analyze: 1981 to 2015 Analyze

Year | Source | Author | Affiliation | Country/Territory | Document type | Subject area

Year	Documents
2015	213
2014	555
2013	583
2012	586
2011	486
2010	457
2009	481
2008	439
2007	406
2006	415
2005	351
2004	339
2003	330
2002	251
2001	206

Documents by year



Somewhat more manageable

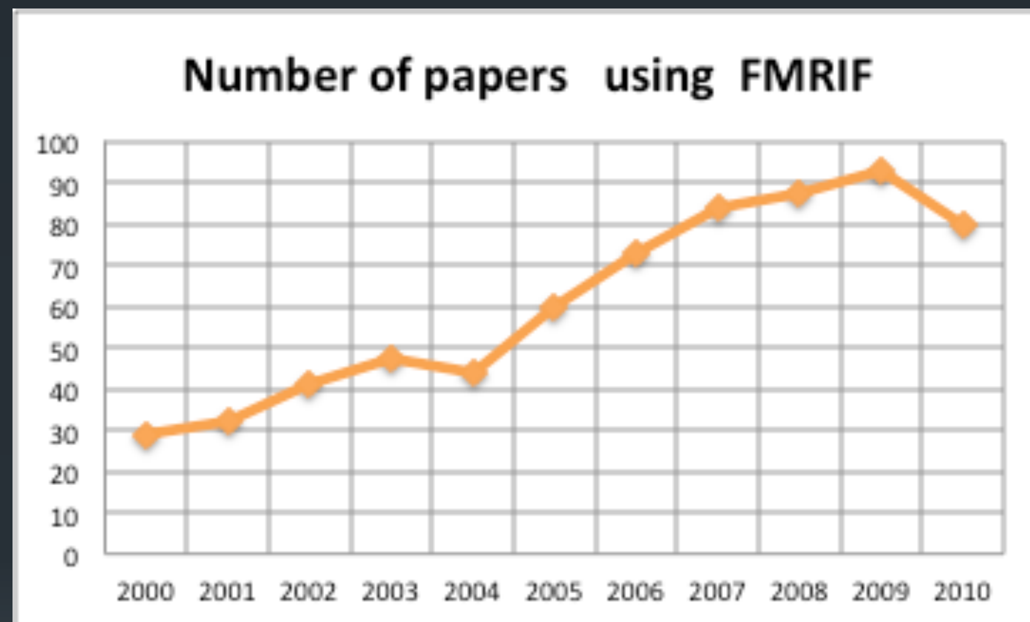
Papers produced through FMRIF

Since 2000:

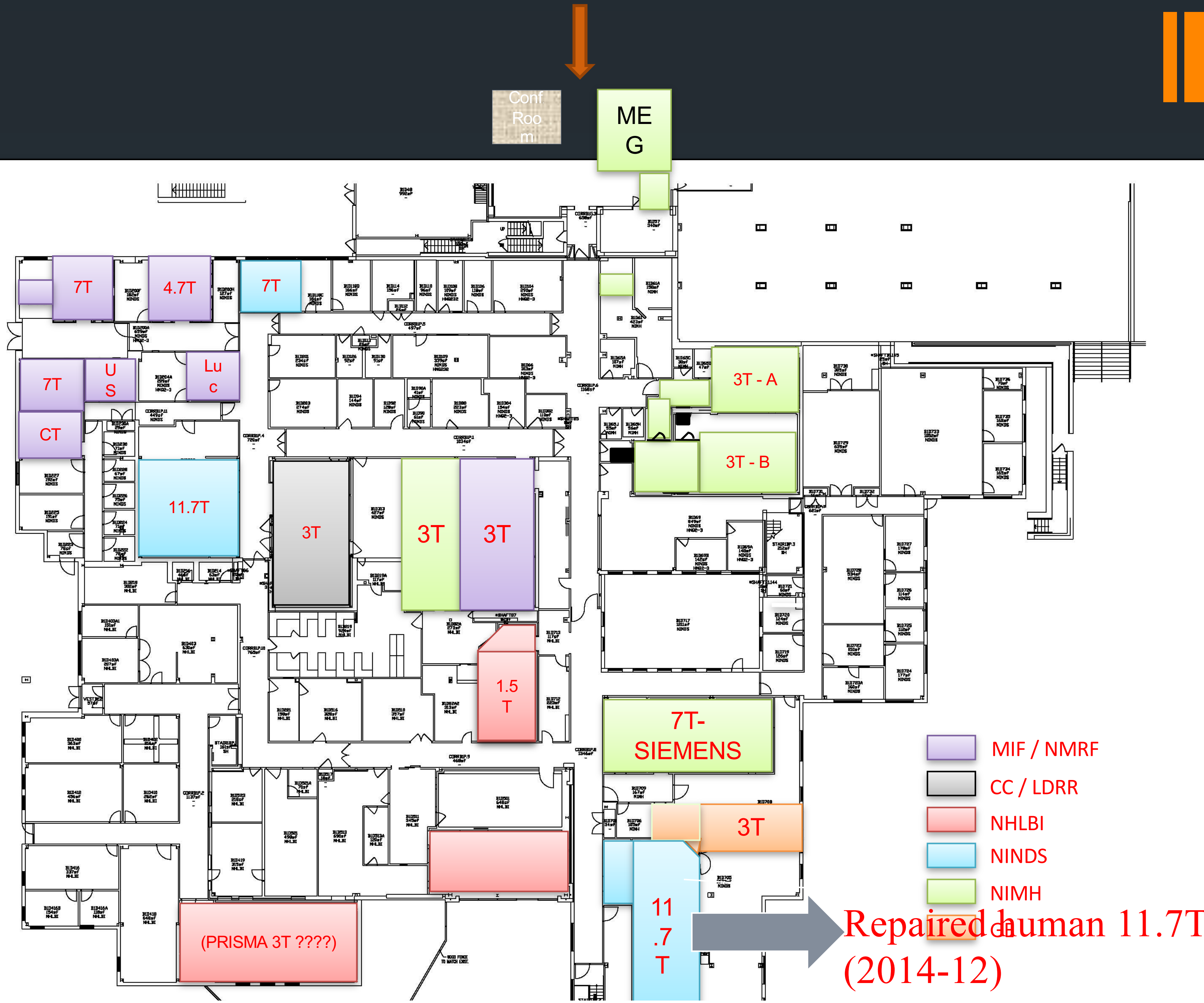
750+ Papers

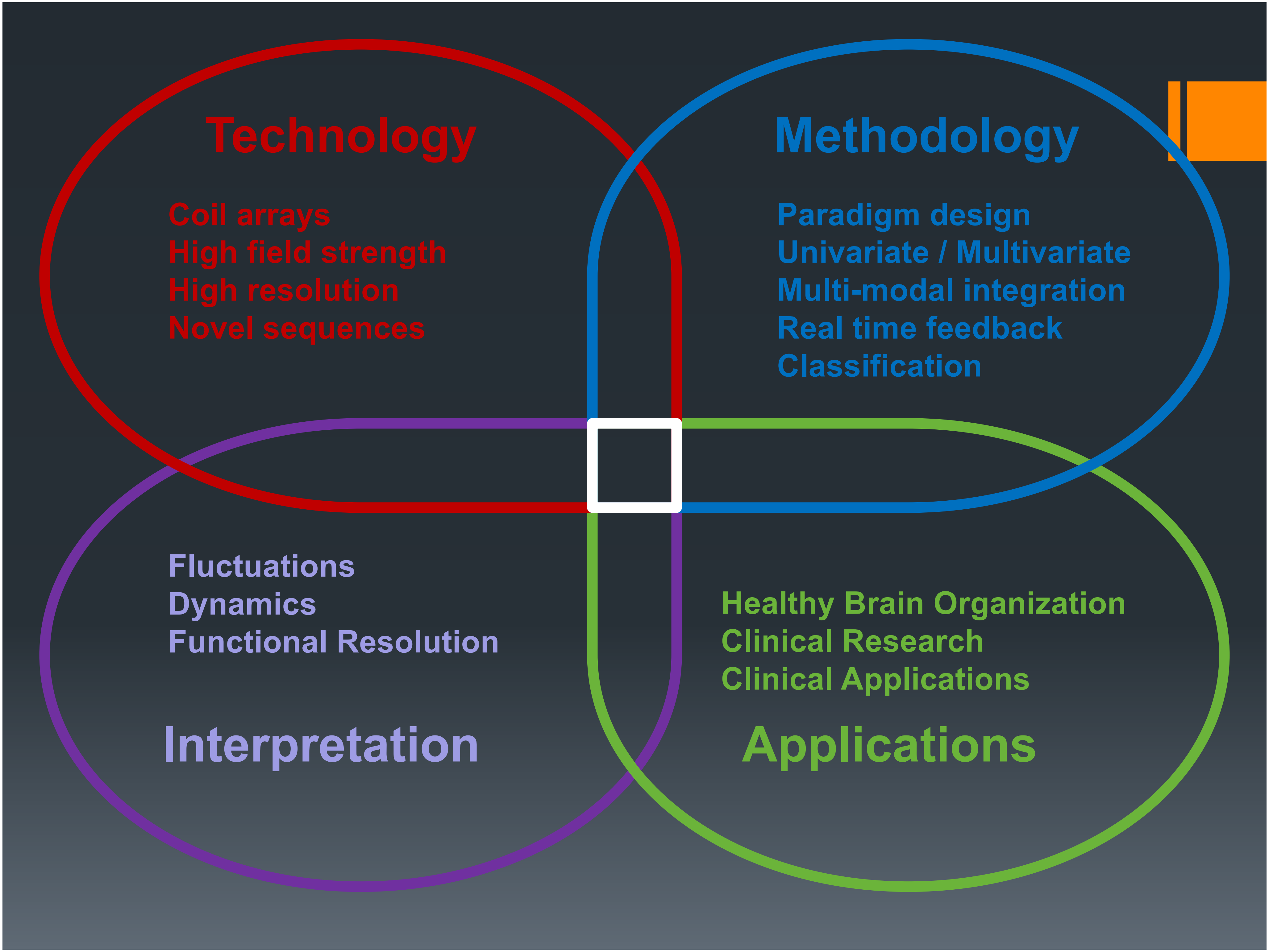
h-index = 100+

total citations = 40,000+



In-Vivo NMR Center Magnets




Technology
Coil arrays
High field strength
High resolution
Novel sequences
Methodology
Paradigm design
Univariate / Multivariate
Multi-modal integration
Real time feedback
Classification
Fluctuations
Dynamics
Functional Resolution
Interpretation
Healthy Brain Organization
Clinical Research
Clinical Applications
Applications

7T MRI (FMRIF) – Arrive 2010/ 2011 scanning begins

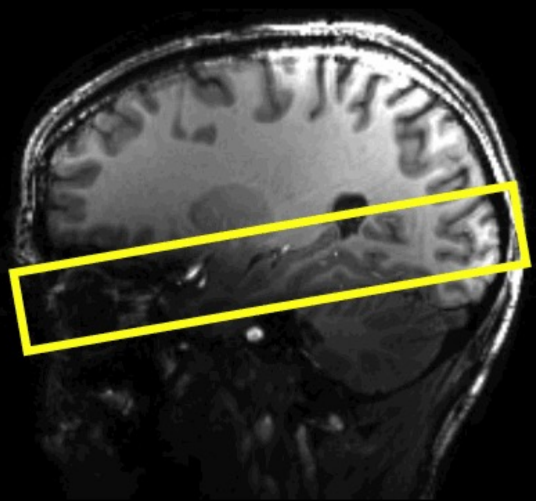
- Actively shielded, body gradient
- Sub-mm anatomical (T1, T2)
- EPI (0.8 – 1.6mm^3)

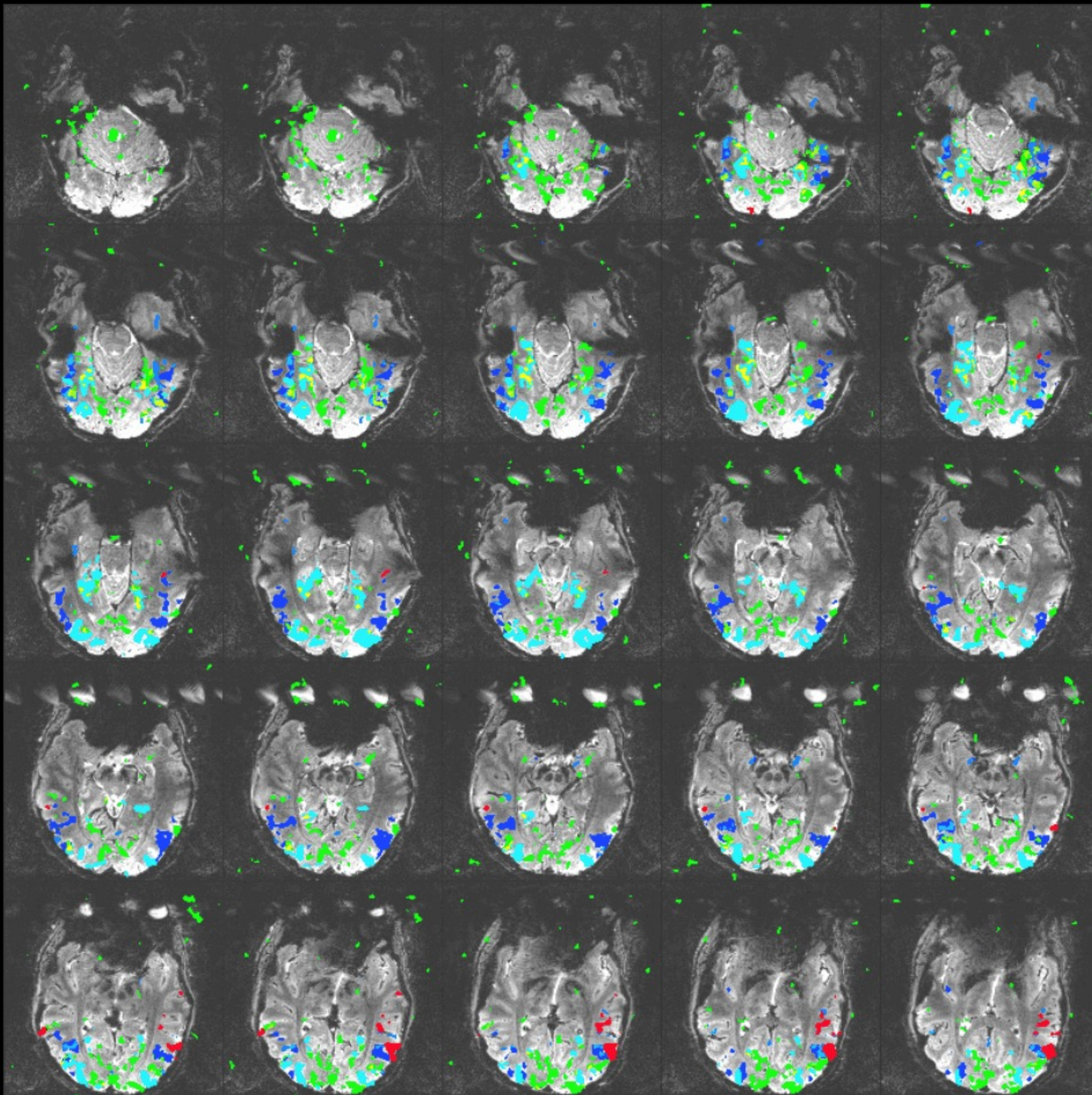
Actively-shielded 7T MRI

32-channel head coil

High Resolution FMRI

Smooth 3mm p>1e-4





1.2 mm iso, TR=2s
1-back, Block
Faces/Scenes
Objects/Scrambled
Bodies/Objects
English/Chinese

DK, SM, CB

1985-1990

- 1987 – NMRF Center Opens (Instigator: Ted Becker /Director:David Hoult)
- 1988 – David Hoult hires Bob Turner
- 1989 – Bob Balaban publishes magnetization transfer paper
- 1989 - Bob Turner & LeBihan implements DW-EPI on 1.5T
- 1989 – Harold McFarland – first longitudinal MS protocol (Original protocol still recruiting subjects for Neuroimmunology (Reich))

The NIH Record
November 17, 1987
Vol. XXXIX No. 23
U.S. Department of Health and Human Services
National Institutes of Health

New NMR Center Opens

By Blair Gately

The NIH In Vivo NMR Research Center has opened in a one-story building adjacent to the Clinical Center's "D" wing.

The new facility, which was dedicated late last month, is the first centralized NMR facility on campus and will be the focus of biomedical NMR research, according to Dr. Cherie Fisk, Office of Research Services. It houses three nuclear magnetic resonance imaging and spectroscopy instruments, two for animal studies and one for patients.

Nuclear magnetic resonance is used to study anatomical and physiological processes in living systems. The new center has a 1.5 Tesla whole-body instrument and two wide-bore animal NMR machines, one with a 2 Tesla field and the other with a 4.7 Tesla field, and associated data stations and computer facilities. In addition, a 7 Tesla 10-cm spectrometer is there for special applications in NMR spectroscopy.

By having machines for both animal and human images in the center, researchers will be able to conduct directly analogous experiments.

The center also has a small patient care area with waiting, dressing and preparation rooms.

"This is a day many of us have been looking

(See NMR, Page 8)

NMR

(Continued from Page 1)

forward to for a long time," Dr. Edwin D. Becker, NIH associate director for research services, said at the dedication ceremony in the ACRF Amphitheater. "This facility is a cooperative and collegial effort by NIH's institutes."

The keynote speaker at the ceremony, Dr. E. Raymond Andrew, professor of physics and radiology, University of Florida, spoke about the impact of "NMR in Biomedicine."

"Nuclear magnetic resonance has become more important in biology and medicine over the last 10 years," he said. "Initially it was the province of the physicist, then the chemist, and

Dr. E. Raymond Andrew, professor of physics and radiology at the University of Florida, gave the keynote address at the opening of the NMR Center.

it has moved across the disciplines."

Andrew showed a series of slides of his own head and abdomen to illustrate the results of NMR imaging.

Dr. S. Morry Blumenfeld of General Electric Medical Systems, the prime contractor for establishment of the center, told the audience, "Our goal is the creation of a new diagnostic modality to bring to the clinician not only the physical attributes of a patient, but also information on the chemistry and biochemistry of abnormal tissues." GE designed, built, and equipped the new center.

Both imaging and spectroscopy make use of the magnetic quality of certain atomic nuclei.

The NMR phenomenon occurs when nuclei containing an odd number of protons and/or neutrons are introduced into a strong magnetic field. These nuclei behave as if they were spinning charges, and precess (gyrate like a top) in a preferred orientation in a strong magnetic field.

When a radio frequency (RF) pulse is introduced by a transmitter—often for only millionths of a second—the nuclear spins will reorient in the field and, as a whole, will absorb energy. Following the pulse, the nuclei "relax" to their original state. The time it takes the stimulated nuclei to relax after a burst of RF energy is a measurable quantity, charac-

Blending in evenly with the brick exterior of the Clinical Center is the one-story In Vivo NMR Research Center, adjacent to the CC's D wing.

teristic of a particular molecular environment.

The relaxation times of these nuclei and the RF frequency for resonance are of use in physics, chemistry, and biochemistry. The distribution in space of these nuclei can be used to obtain images.

While imaging of human anatomy is perhaps the most widely known aspect of NMR, the procedure has been used at NIH for more than 30 years for basic research in organic and physical chemistry, and, more recently, for biochemistry and physiology. NMR can provide information on the structure of molecules.

"I was introduced to NMR 30 years ago by Dr. Becker and I was impressed then and have been ever since with the power of this technique," said Dr. Joseph Rall, NIH deputy director for intramural research. "NIH is a good community for a center because of both the expertise and the clinical need that we have."

NMR was discovered in 1946 by two American scientists, Felix Bloch and Edward Purcell, who were awarded the Nobel prize in physics in 1952 for their work.

Inspecting the facilities in the recently opened In Vivo NMR Research Center are (from l) Dr. David Hoult and Dr. Ching-Nien Chen, BEIB; Judie Ireland, ORS; Dr. Andrew Dwyer and Dr. Joseph Frank, CC-Diagnostic Radiology Department.

1991-1995

1991 – Judy Rapoport and Jay Giedde begin longitudinal pediatric study of normal brain development.

1992 – 4T installed in NHLBI in NMRF (Turner hired by Bob Balaban)

1992 – First successful FMRI @ NIH

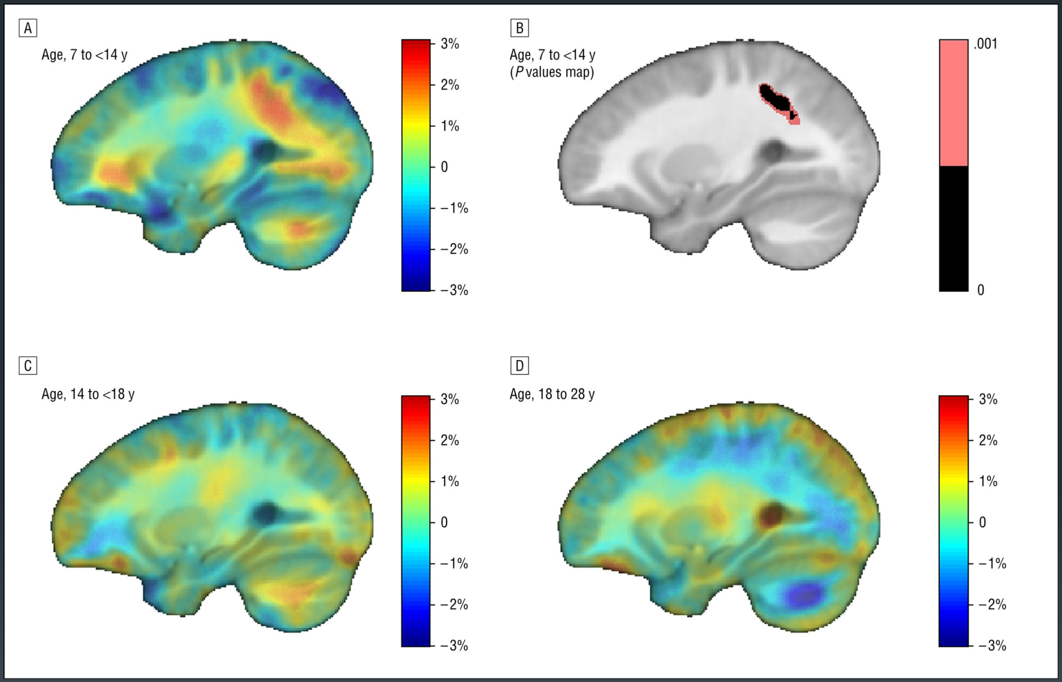
1992 – Peter Basser publishes first DTI paper

1992 – Bandettini and Wong et al publish BOLD-EPI finger-tapping experiment (same year as Kwong et al and Ogawa et al)

1995 – Plasticity/Motor learning FMRI (Ungerleider/Turner)

Judy Rapoport/Childhood Psychiatry

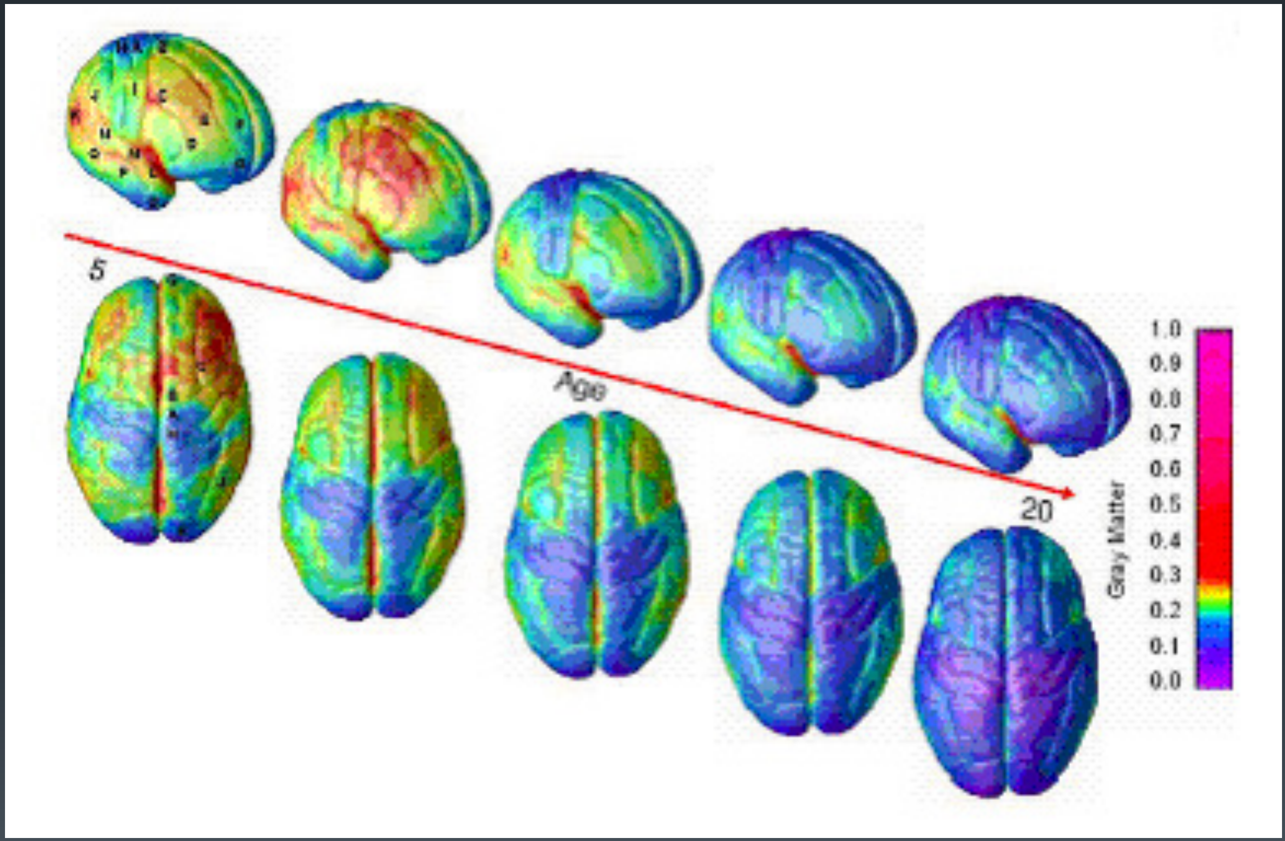
- Early studies of brain development
- Longitudinal studies of childhood onset schizophrenia



Longitudinal MRI, genomi

Jay Giedde (working with Judy Rapoport)

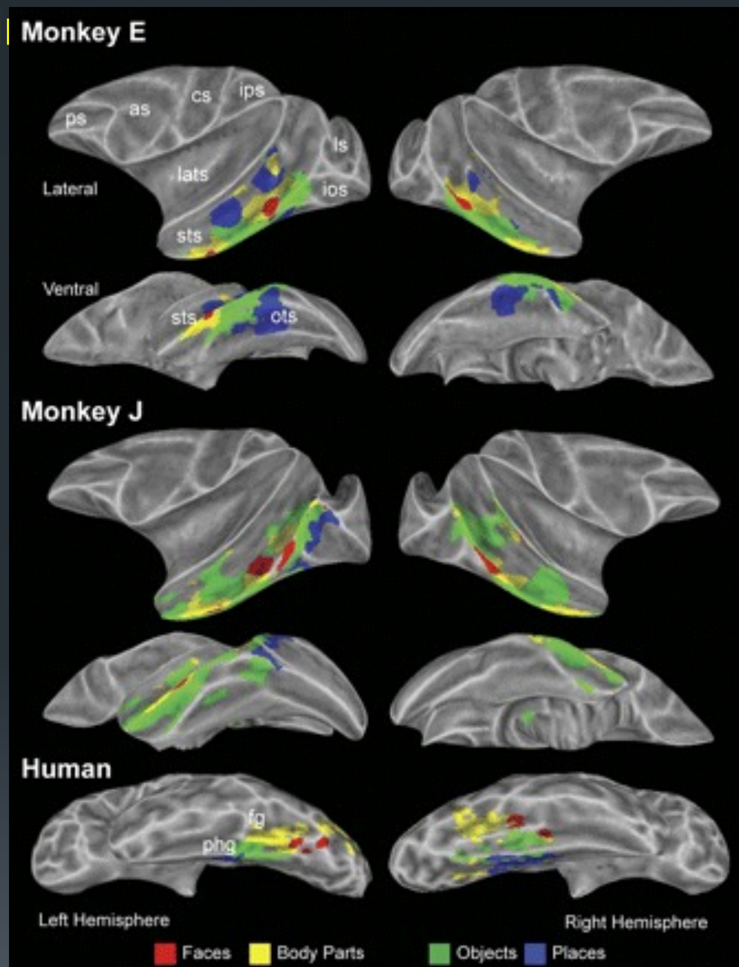
- Longitudinal MRI studies of normal brain development in children



PROMO, longitudinal

Leslie Ungerleider/Neurocircuity Section

Early FMRI adopter
Functional architecture of perceptual and attentional systems
Functional anatomy of face processing
Primate imaging/anatomical studies
Combi



Use: eye tracking, TMS
Primate FMRI

- H

1996-2000

1997 – Ungerleider, Haxby, Martin – Vision, attention, FFA etc

1999 – Koretsky hired to run NMRF

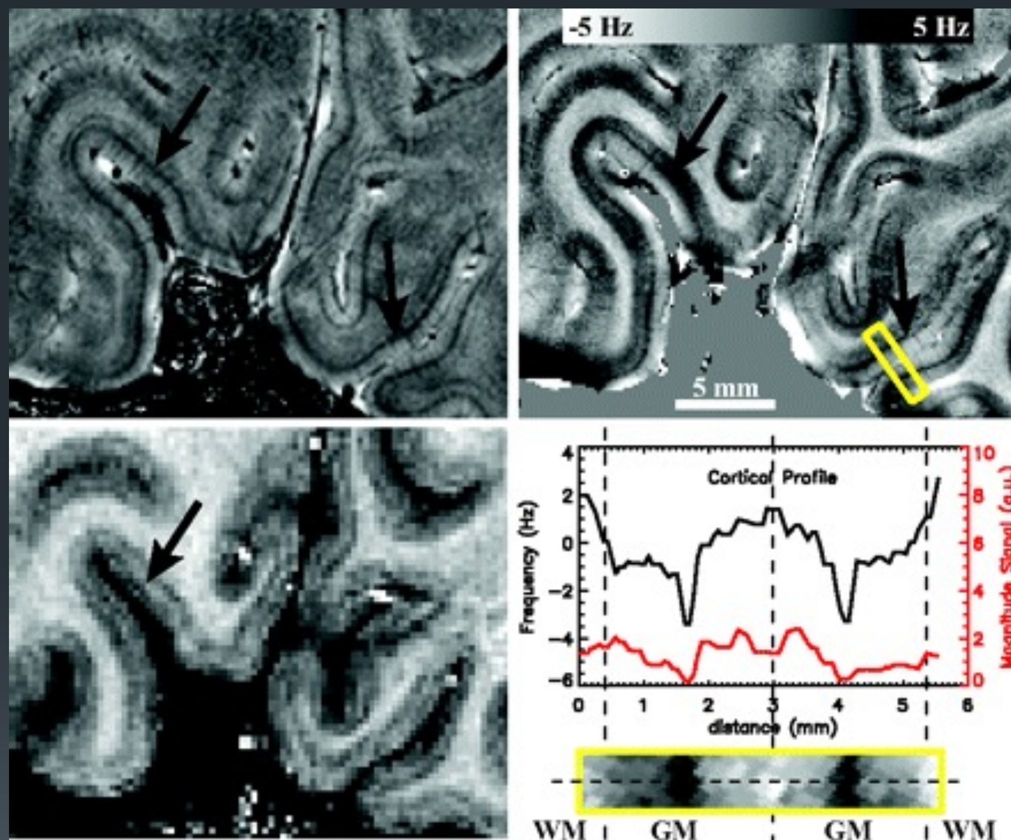
1999 – Peter Bandettini hired to run newly established Functional MRI Facility (NIMH/NINDS)

1999 – Delivery of first commercial 3T (GE/VHi) MRI system to FMRIF

2000 – Routine scanning begins on FMRIF 3T

Jeff Duyn/Advanced MRI (Methods development)

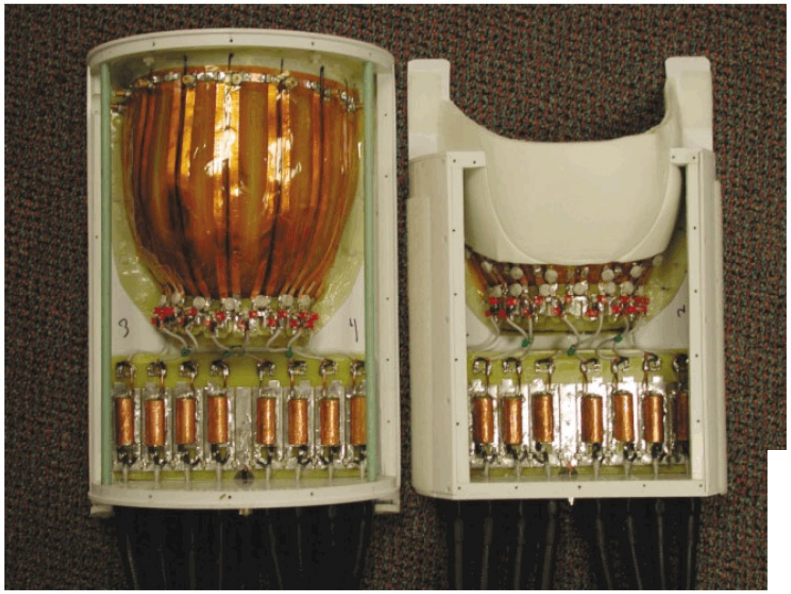
- Imaging methods/technology especially parallel imaging
- Magnetic susceptibility contrast imaging – mechanisms & applications
- Physiological basis of spontaneous brain activity
- pulse sequences and techniques esp for UHF imaging (7T & 11.7T)



Use: EEG/MRI,
eye tracking (7T),
custom pulse seq&recon

- High-field MRI of brain cortical substructure based on signal phase, Duyn, J.H. et al (2007) PNAS
- Low-frequency fluctuations … as a source of variance in the resting-state fMRI BOLD signal Shmueli, K. etal (2007) NeuroImage
- Susceptibility contrast in high field MRI of human brain as a function of tissue iron content Yao, B. et al (2009) NeuroImage, 44 (4)
- Layer-specific variation of iron content in cerebral cortex as a source of MRI contrast, Fukunaga, M et al (2010) PNAS

Parallel imaging -16 channel coil for 3T



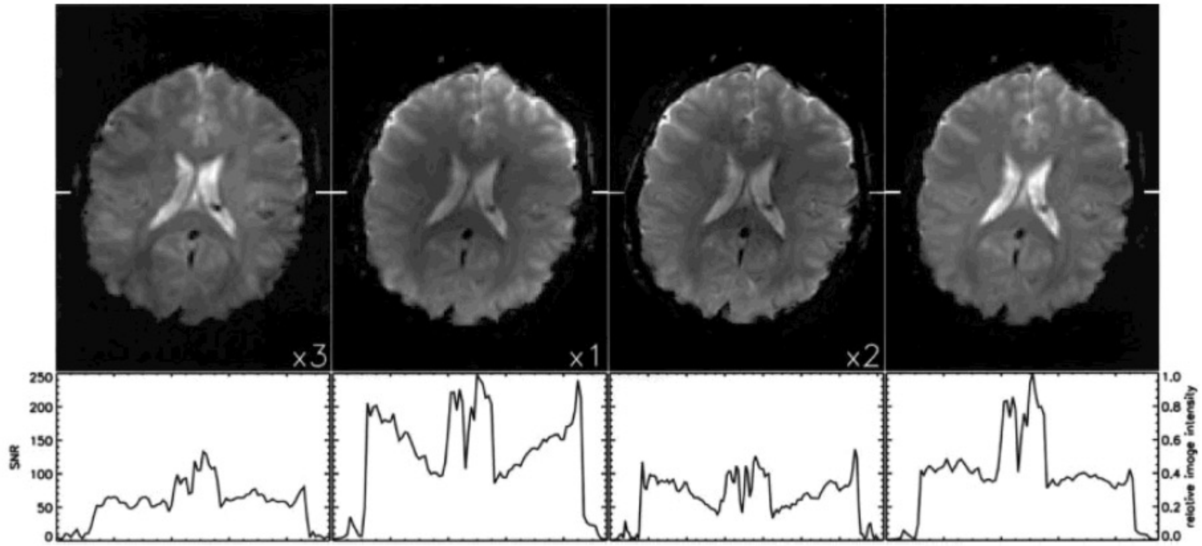
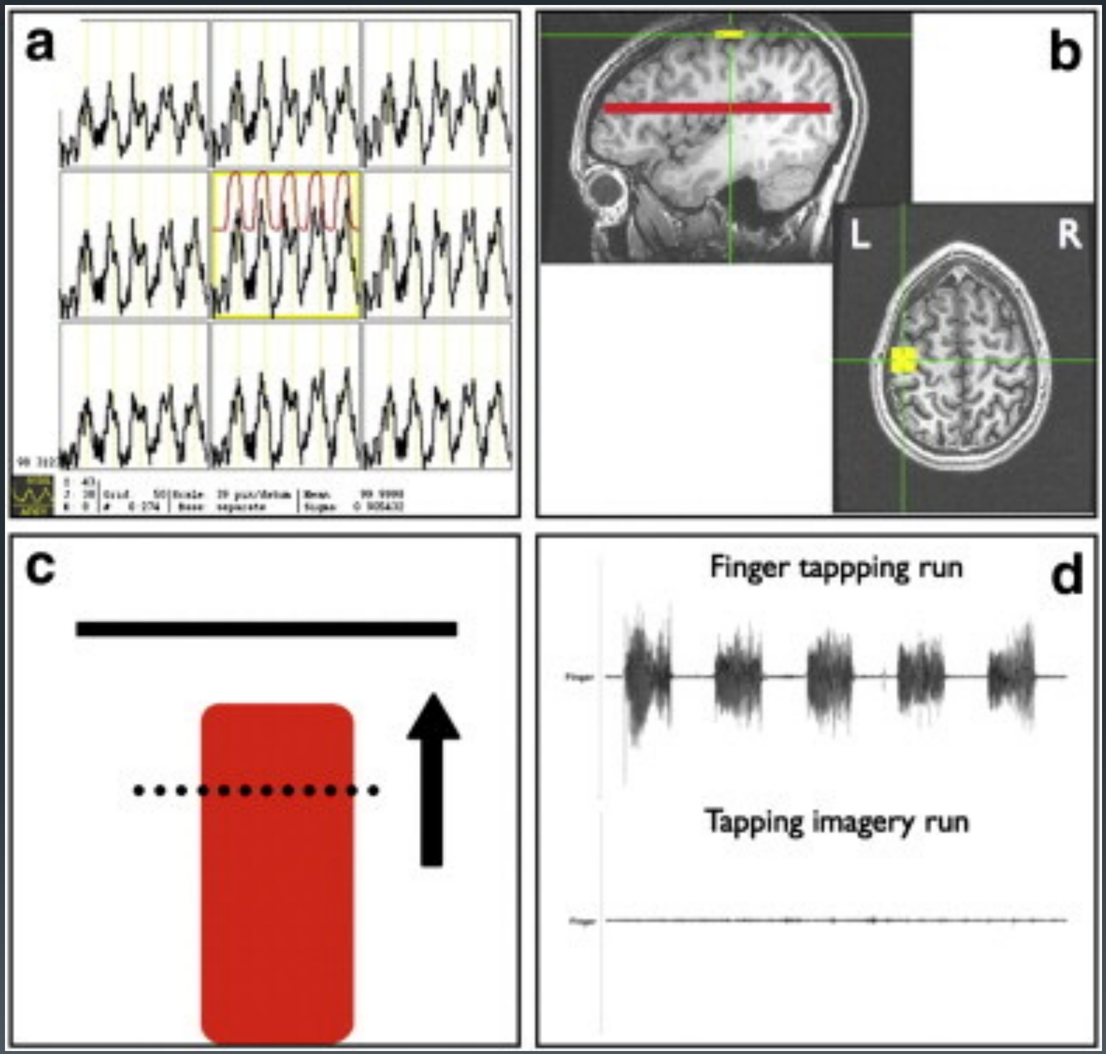


FIG. 2. Performance of the 16-channel coil compared to the standard 28-cm GE birdcage head coil. The top row shows a single slice of the acquired EPI data. The three leftmost images are SNR maps. Their relative scaling factor is indicated in the lower right corner of the image. The rightmost image shows the same data as in the second image, after intensity correction. Tick marks left and right in each image indicate the location of the profile shown below it. The first column shows single-shot EPI data from the birdcage head coil (128 × 96 resolution). Data in all other columns were acquired with the 16-channel coil. Data in the second and third columns were acquired at respectively the same (128 × 96) and higher (192 × 144, rate-2 SENSE) spatial resolution. Note that the scaling of the rightmost column is arbitrary. See text for more details.

Mark Hallett/Human Motor Control Section

- Evaluating motor disorders with FMRI, rsMRI, MRS
- FMRI neurofeedback / treating movement disorders
- Motor learning in dystonia and healthy controls

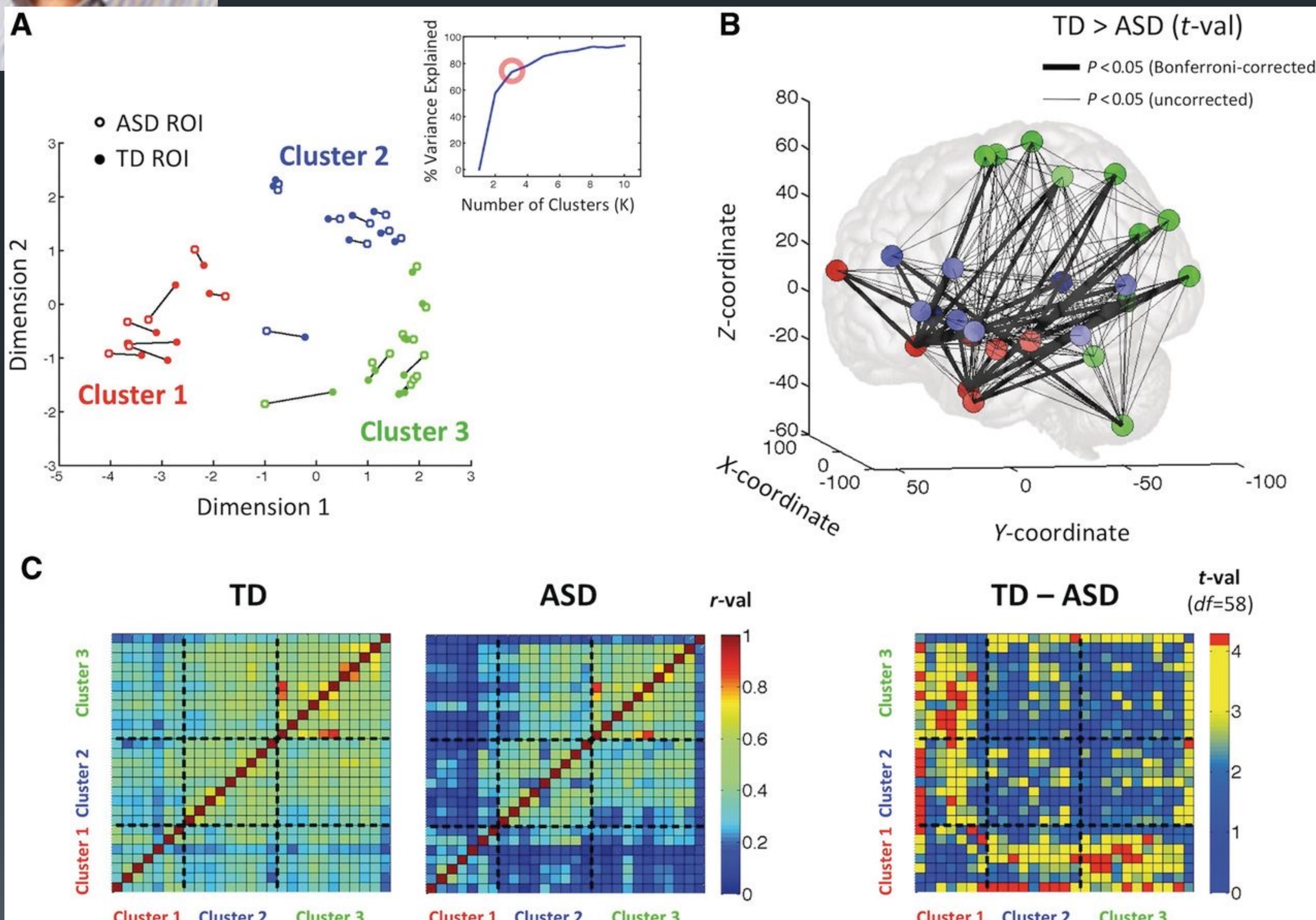


- Voon et al, Dopamine and impulse control

Use: eeg/fmri, RT-feedback stimulators, force-measurement

Alex Martin/**Section on Cognitive Neuropsychology**

- Object and category semantic representation in cortex
- Representation of social network information in normals & autistics



- **Gotts S J et al. Brain 2012;135:2711-2725**

Use: gustatatory input, speech output (noise cancelling microphone, etc)

Unraveling multisensory integration: patchy organization within human STS multisensory cortex

Michael S Beauchamp[1], Brenna D Argall[1], Jerzy Bodurka[2], Jeff H Duyn[3] & Alex Martin[1]

Although early sensory cortex is organized along dimensions encoded by receptor organs, little is known about the organization of higher areas in which different modalities are integrated. We investigated multisensory integration in human superior temporal sulcus using recent advances in parallel imaging to perform functional magnetic resonance imaging (fMRI) at very high resolution. These studies suggest a functional architecture in which information from different modalities is brought into close proximity via a patchy distribution of inputs, followed by integration in the intervening cortex.

The human superior temporal sulcus multisensory area (STS-MS) is important for integrating auditory and visual information about objects, speech, letters and other behaviorally relevant stimuli[1–4]. Electrophysiological recording studies from macaque monkeys demonstrate that individual neurons in monkey STS may respond only to auditory stimuli, only to visual stimuli, or both to auditory and to visual stimuli[5,6]. Although it is reasonable to assume that similar neuronal response properties exist in human STS-MS, there has been no direct evidence for this. Additionally, electrophysiological and functional neuroimaging studies to date have provided no information on the topographic organization of these different types of neurons.

One possibility is that the STS-MS is organized as a homogeneous mixture of auditory, visual and auditory-visual neurons. Arguing against this idea is the observation from tracer injection studies that auditory and visual projections to monkey STS lie in non-overlapping domains[7]. This patchy organization is on a scale of 1–2 mm (ref. 8). Owing to technical limitations, standard-resolution fMRI uses voxels that are too large (40–70 mm^3) to observe fine structure within cortical areas. Recent advances in multichannel MRI receivers[9] and whole-brain surface coil phased arrays[10] provide improved signal-to-noise ratio and permit the acquisition of high-resolution fMRI data with significantly more flexibility than single surface coils[11,12], making them ideally suited to study the STS-MS.

We mapped the STS-MS in human subjects using standard-resolution fMRI and either videos of tools (for example, a hammer making a hammering motion), recordings of

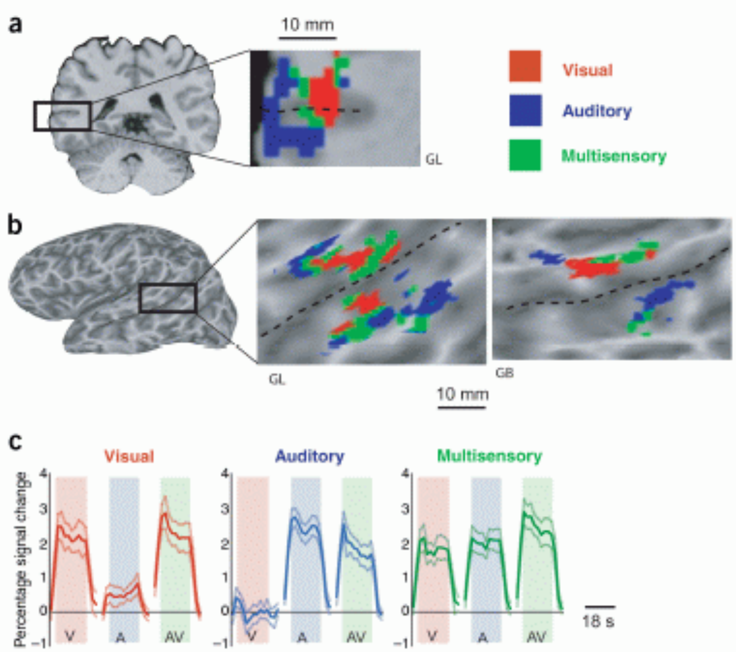


Figure 1 Patchy organization within the STS-MS. (a) Coronal section with enlargement of the left STS (dashed line). Colors show relative response to unisensory visual (V) and auditory (A) tools. Orange (visual patches): V > A, $P < 0.05$. Blue (auditory patches): A > V, $P < 0.05$. Green (multisensory patches): A = V, $P < 0.05$. Two-letter code (GL) indicates subject identity. (b) Lateral view of the left hemisphere of an inflated cortical surface model, with enlargement showing the STS-MS in two subjects. Same color scale as in a. (c) Average MR time series across subjects ($n = 8$). Three graphs showing the response in visual (left), auditory (middle) and multisensory (right) patches to the three stimulus types (pink shaded region, V, response to visual tools; blue shaded region, A, response to auditory tools; green shaded region, AV, response to multisensory tools) and fixation baseline (non-shaded regions). Thick line, mean response; thin line, s.e.m.

[1]Laboratory of Brain and Cognition and [2]Functional MRI Facility, National Institute of Mental Health, and [3] Section on Advanced MRI, Laboratory of Functional and Molecular Imaging, National Institute of Neurological Disorders and Stroke, National Institutes of Health, Bethesda, Maryland, USA. Correspondence should be addressed to M.S.B. (mbeauchamp@nih.gov).

Published online 10 October 2004; doi:10.1038/nn1333

Peter Bandettini/Functional Imaging Methods

- Maximizing information that can be extracted from FMRI time series
- Multi-echo EPI for improved fMRI & rs-fMRI clustering
- Mass averaging reveals widespread BOLD activation
- Understanding rsFMRI mechanisms and confounds
- Information mapping/decoding FMRI

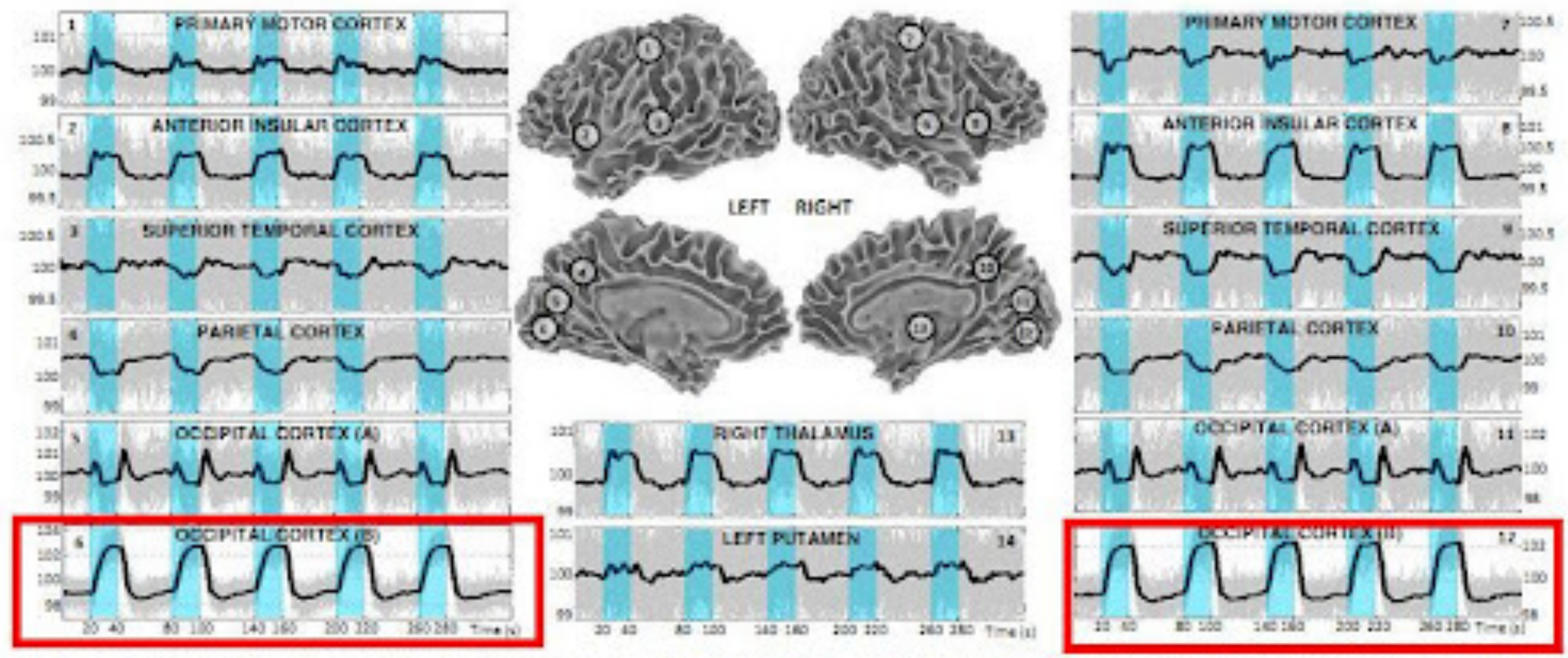
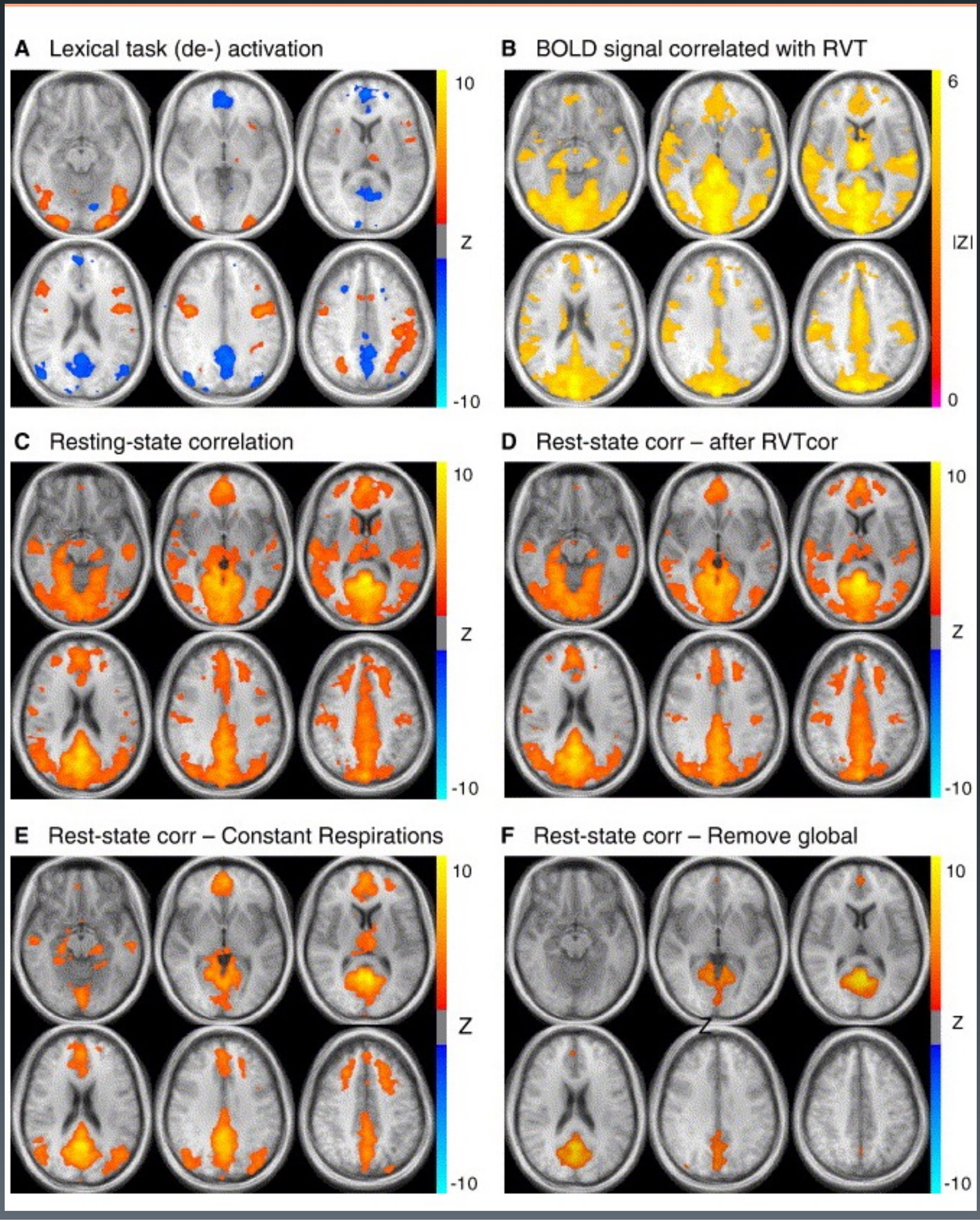


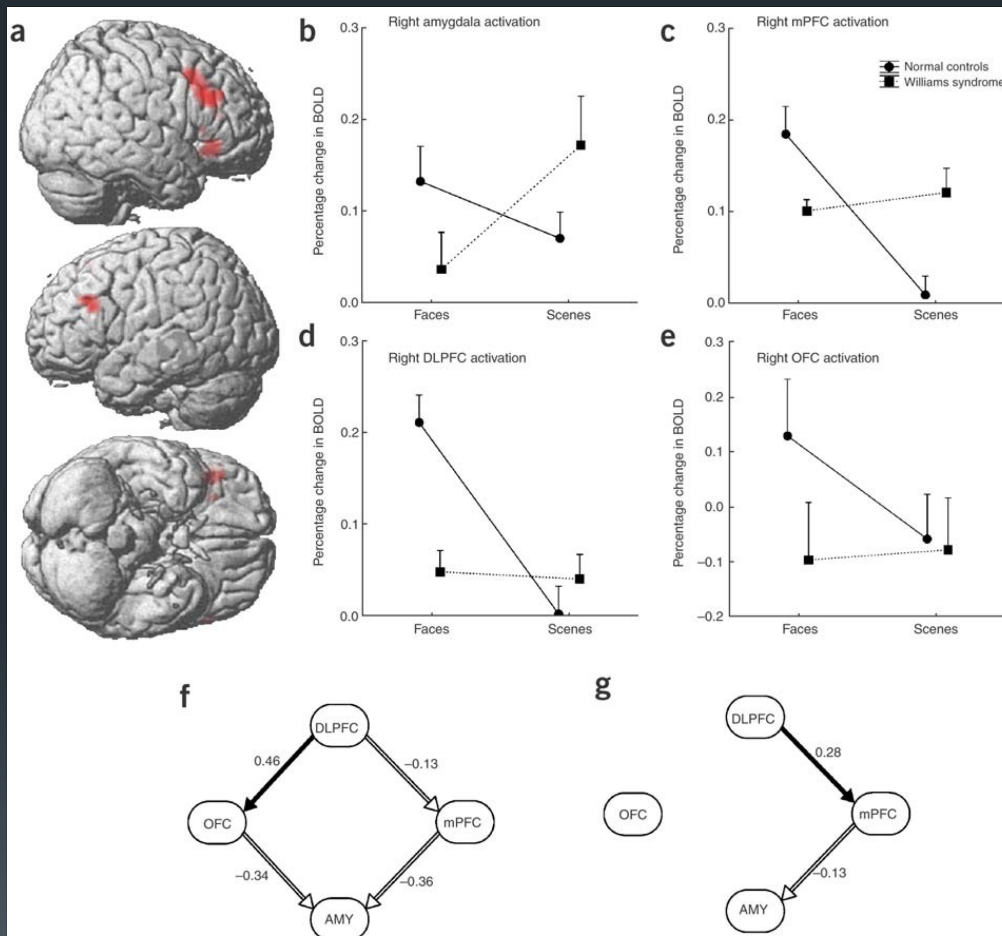
Fig. 2. Time-series for a subset of statistically significant voxels. For each voxel the 100 individual measures are plotted in gray and their average in black.

Separating respiratory-variation-related fluctuations from neuronal-activity-related fluctuations in fMRI (Birn et al)



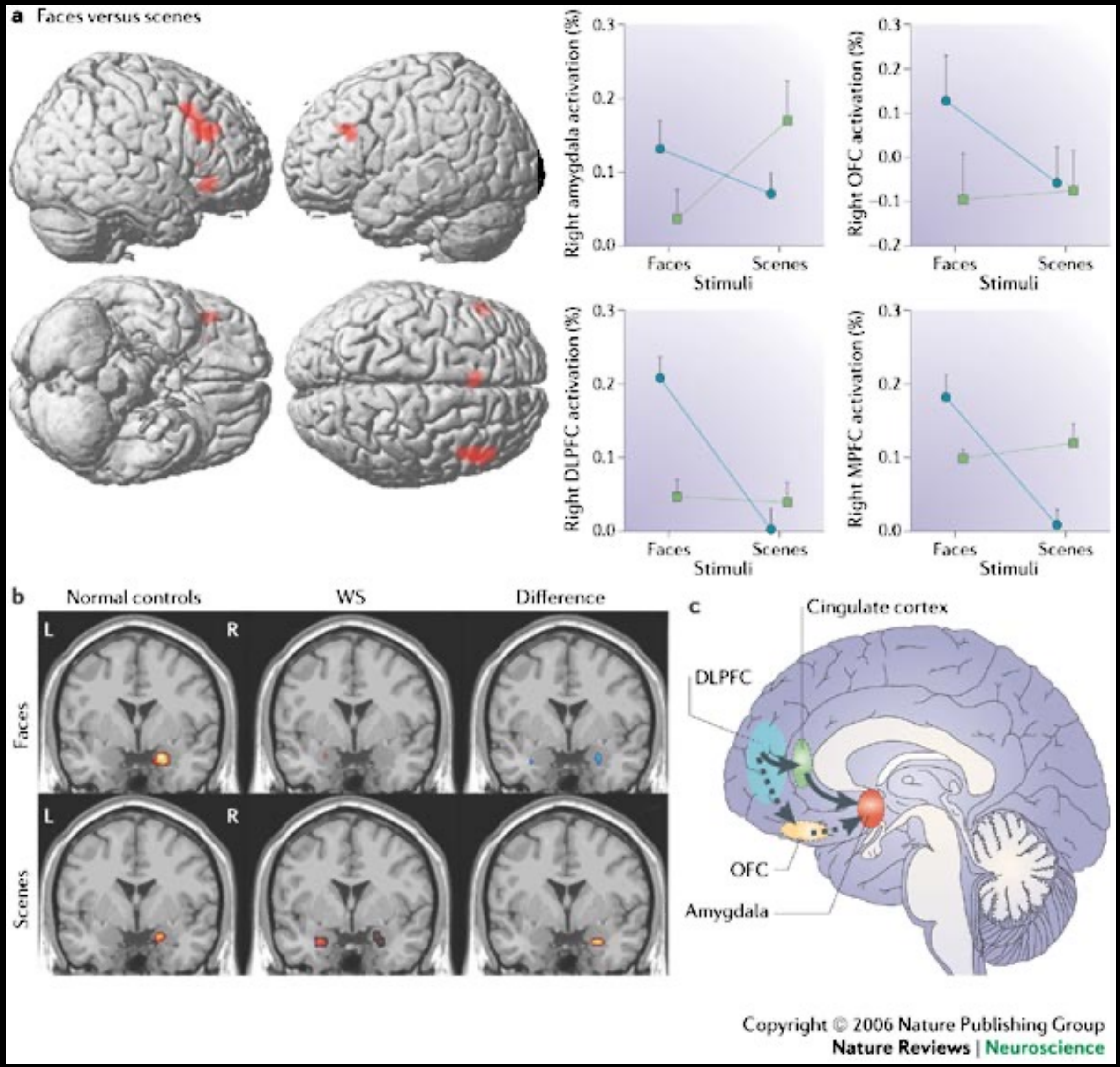
Karen F. Berman / Section Integrative Neuroimaging

- Developmental neuropsychiatric disorders
- Genetics of social cognition(esp. Williams Syndrome)
- Multi-modality imaging



Use: eye-tracking, auditory
In young children

Williams syndrome chromosome ...hypersocial, anxious personality… altered insula structure….. Jabbi M, Kippenhan JS et al, . Proc Natl Acad Sci U S A. 2012
Variation in dopamine genes influences responsivity of the human reward system. Dreher JC et al,. Proc Natl Acad Sci U S A. 2009
Neural correlates of genetically abnormal social cognition in Williams syndrome. Meyer-Lindenberg A et al Nat Neurosci. 2005
Human dorsal and ventral auditory streams subserve rehearsal-based and echoic processes during verbal working memory. Buchsbaum et al, Neuron. 2005



From Berman Group:. *Nature Reviews Neuroscience* **7,** 380–393 (May 2006)

nature REVIEWS NEUROSCIENCE

2001-2005

2001-2003 – Mood and Disorder PI's (Pine, Leibenluft, Grillon, Shen Zarate/Drevets)

2002-2003 – Expansion of FMRIF (3T-2)
2003-2004 – Purchase/installation of unshielded 7T

2002-2004 – Custom-built 16 channel coil and receiver project (Duyn, Bandettini) demonstrating utility of multi-channel coil at 3T for FMRI

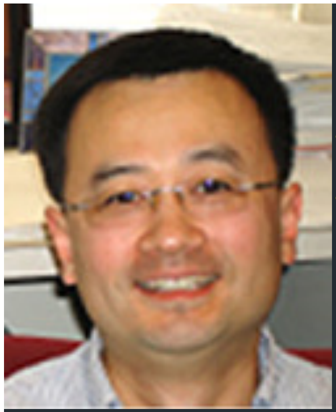
(Short) History of fMRI and Brain MRI at NIH

1. Development of MRI at NIH
   - In-Vivo NMR Center (established 1988)
2. Early FMRI studies in animals (Bob Turner, 1987)
3. Initial human functional studies (4T 1993)
4. Key developments from NIH MRI researchers
   - DTI
   - High-field imaging (4 Tesla, 7 Tesla and now 11.7T)
   - Magnetization Transfer
   - Perfusion imaging (ASL)
   - Large scale longitudinal studies of brain development
   - Imaging genomics
   - FMRI/BOLD
   - Decoding/Multivoxel Pattern Analysis
   - High resolution anatomical imaging
   - Real-time FMRI / analysis Software

Resources for MRI - Human

1. NIH MRI Research Facility (NMRF)
    - 3T-Siemens-Skyra (Sep 2011)
2. FMRIF (NIMH & NINDS – 470 hrs/week of scan time)
    - 2 x 3T GE HDx
    - 1 x 3T-GE-mr750 (June 2011)
    - 1 x 3T-Siemens-Skyra (Sep 2011)
    - 7T Siemens/Magnex (Jan 2011)
3. NINDS/NIMH
    - 11.7T Siemens/Magnex (world's first 2011-2012)
4. Clinical Center (Radiology & Imaging Sciences, TBI)
    - 2 x 3T & 1.5T Philips & 3T Siemens
    - 3T-Siemens Biograph (MR/PET)
5. NHLBI (Cardiac)
    - Multiple 3T Siemens Scanners NCI
    - 3T Phillips

- Etc



Jun Shen/ MRS Section

- MRS methods development, especially 13C
- 13C / GABA / Glu quantification

(use: everything MRS)

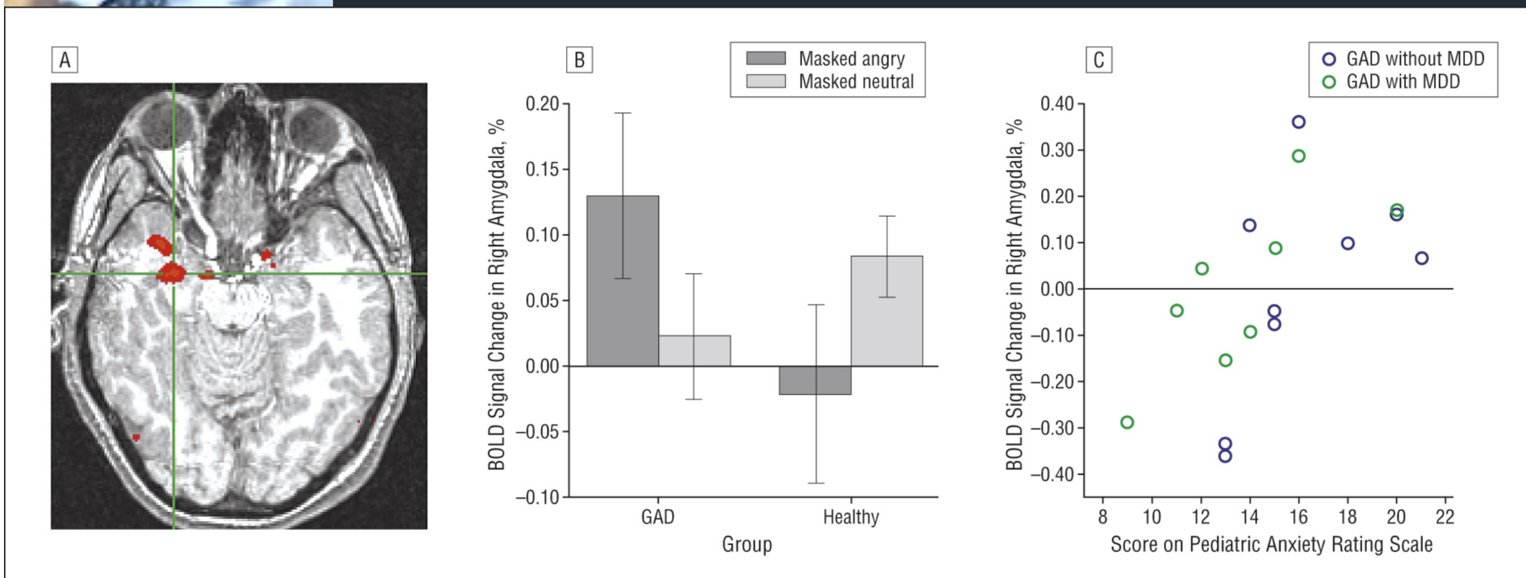
Sue Swedo/Developmental Pediatrics

- Phenotyping autism and related disorders using MRI
- Longitudinal MRI of infants at risk for autism

Use: everything infant, T1 mapping

Daniel Pine/ Developmental &Affective Neuroscience

- fMRI studies pediatric & adolescent anxiety
- Fear and threat processing in adolescent patient groups

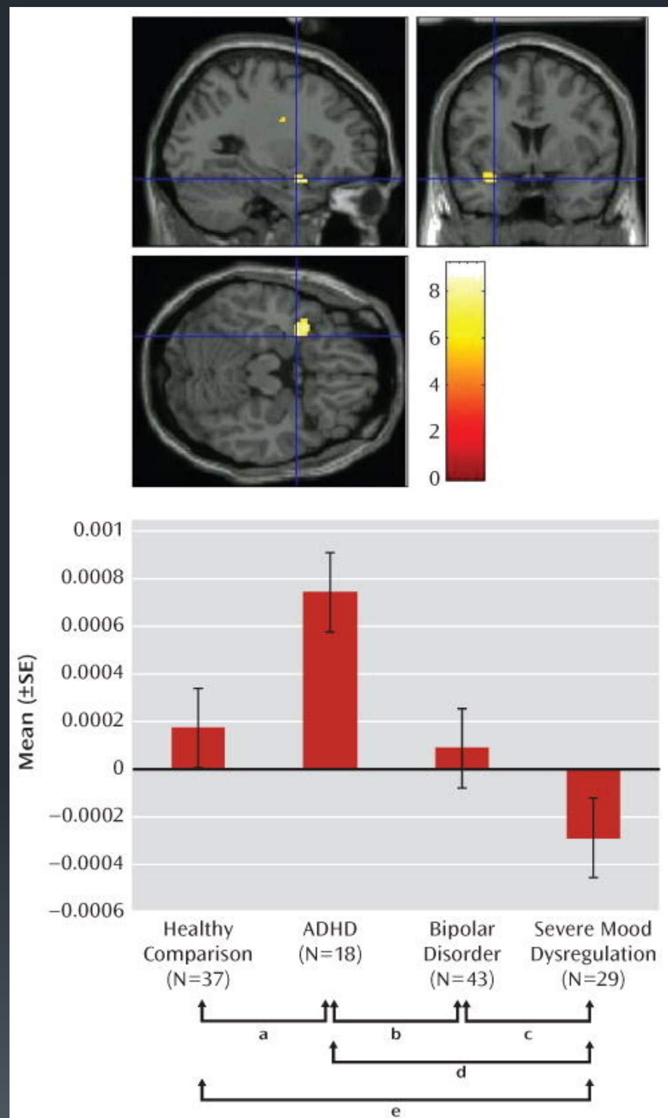


Use: eye tracking, skin conductance

- High-field MRI of brain cortical substructure based on signal phase, Duyn, J.H. et al (2007) PNAS
- Low-frequency fluctuations … as a source of variance in the resting-state fMRI BOLD signal Shmueli, K. etal (2007) NeuroImage
- Susceptibility contrast in high field MRI of human brain as a function of tissue iron content Yao, B. et al (2009) NeuroImage, 44 (4)
- Layer-specific variation of iron content in cerebral cortex as a source of MRI contrast, Fukunaga, M et al (2010) PNAS

Ellen Leibenluft/Bipolar Disorders

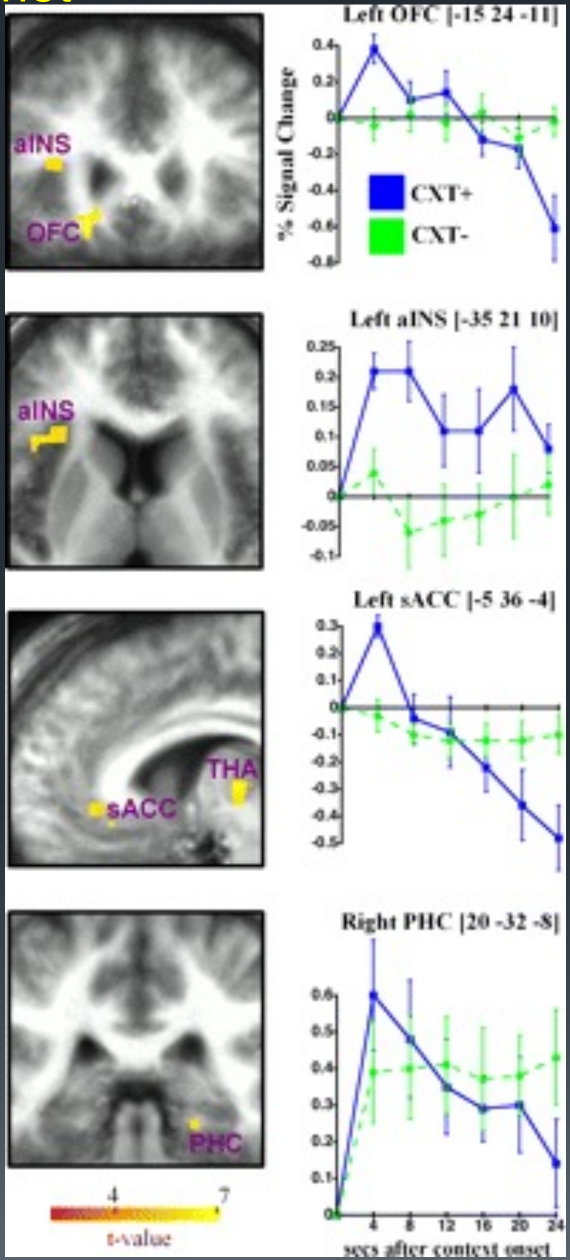
- Brain mechanisms in childhood bipolar
- FMRI of adolescents with severe irritability



- **Cross-sectional & longitudinal abnormalities in brain structure in children with SMD or BD (Adelman et al, 2012)**
- **Amygdala activation during emotion processing of neutral faces in children with severe mood dysregulation versus ADHD or bipolar disorder (Brotman et al, AM. J Psychiatry, 2010)**

Christian Grillion/**Neurobiology of Fear and Anxiety**

- Phasic and sustained threat
- Electric shock in the magnet
- Virtual reality and FMRI



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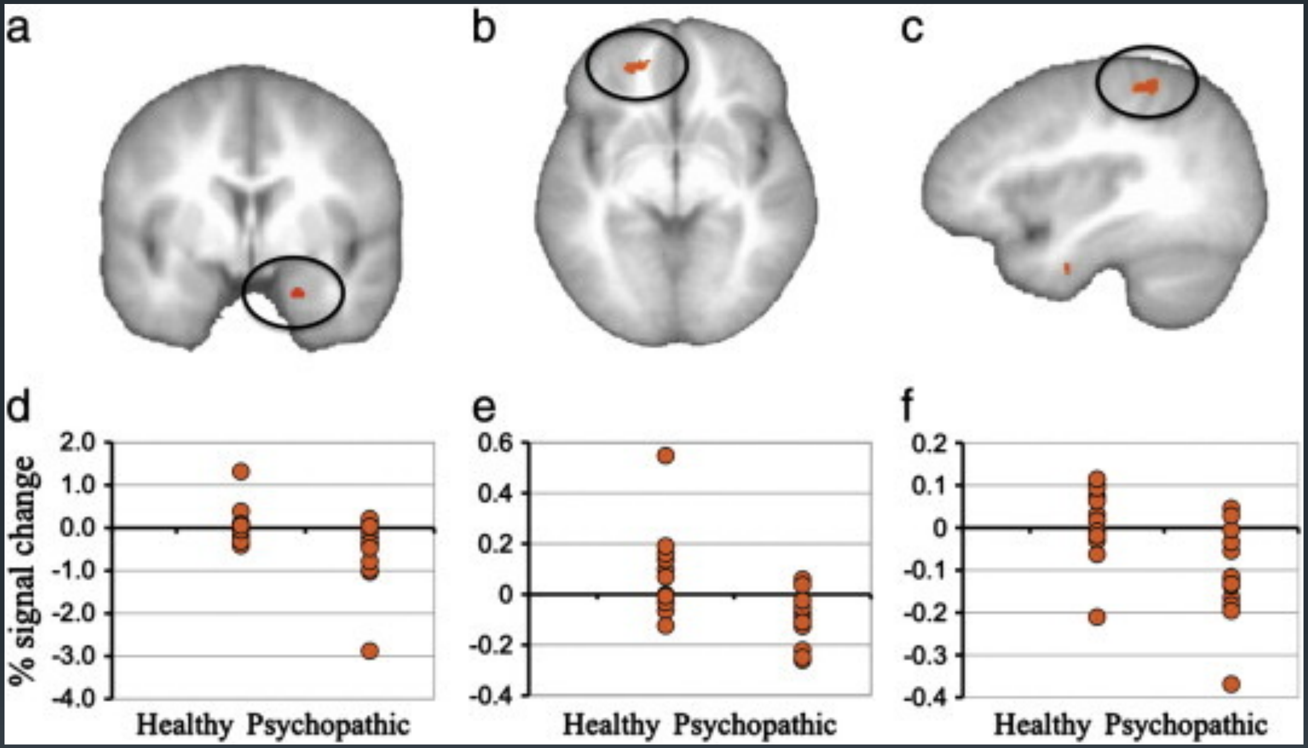
James Blair/Affective Cognitive Neuroscience

- FMRI studies of children with conduct disorders
- Emotional dysfunction and childhood behavioral disturbance
- Decision making in psychpathological

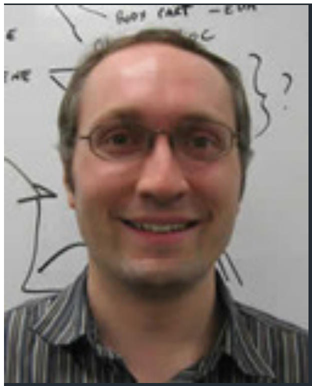


- Reduced amygdala–orbitofrontal connectivity during moral judgments in youths with disruptive behavior disorders and psychopathic traits (

2006-2010

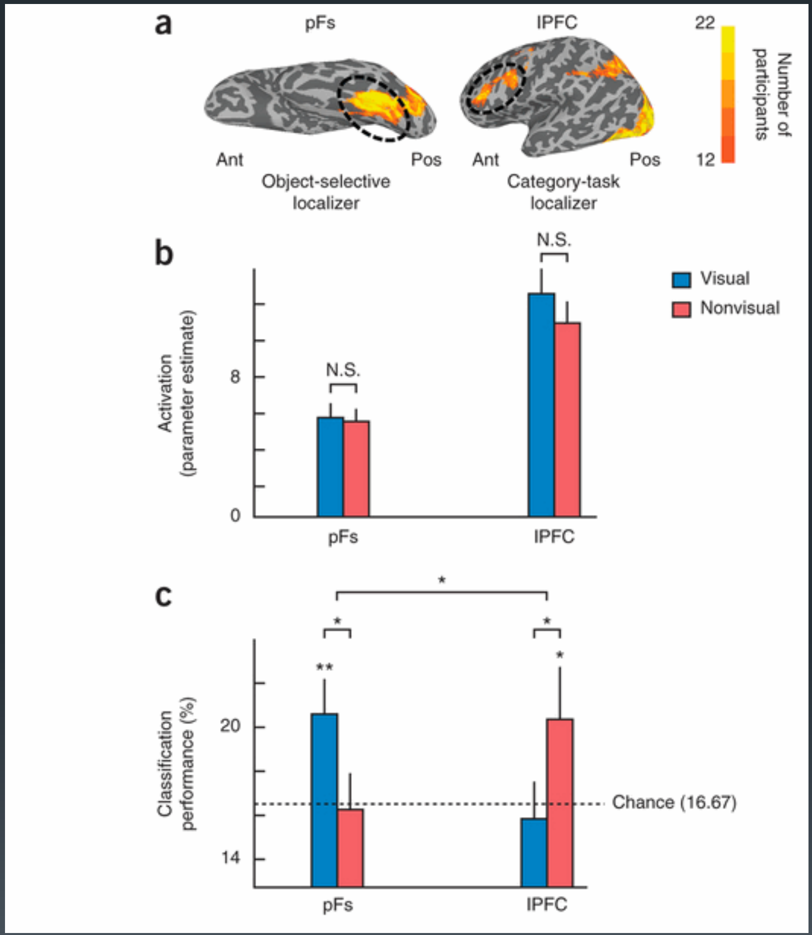
2006-2007 – 3T-1 replaced by 3T-A & 3T-B

2010 – Upgrade of 3T-C to mr750 platform



Chris Baker/Unit on Learning and Plasticity

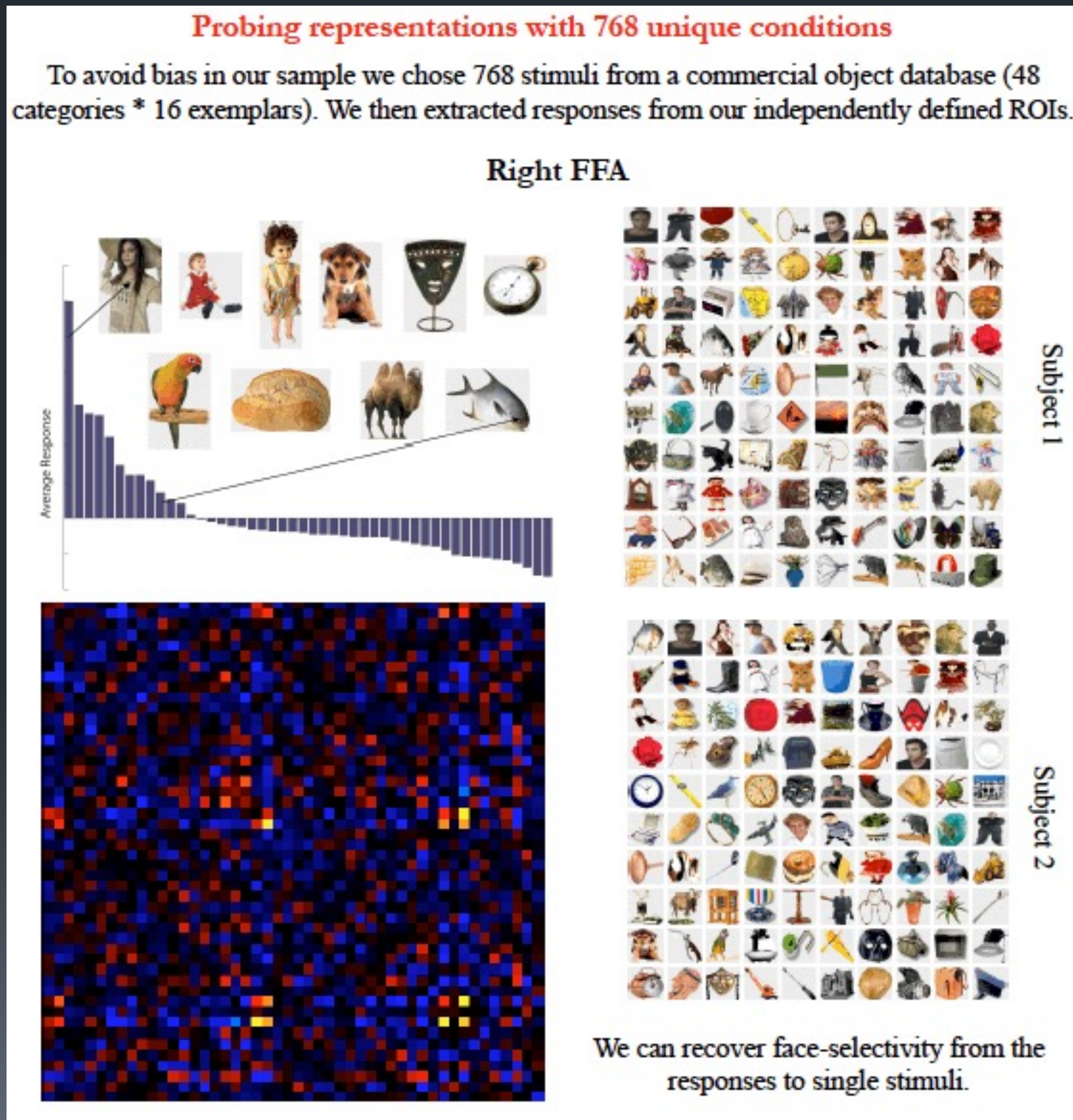
- Object, face and body representations in the human brain/task effects
- Neural basis of visual object learning/
- Interaction between bottom-up & top-down processing
- Engaged in debate on circularity artifacts / 7T methods



Use: 7T, decoding
Auditory/7T,
Lower limb response

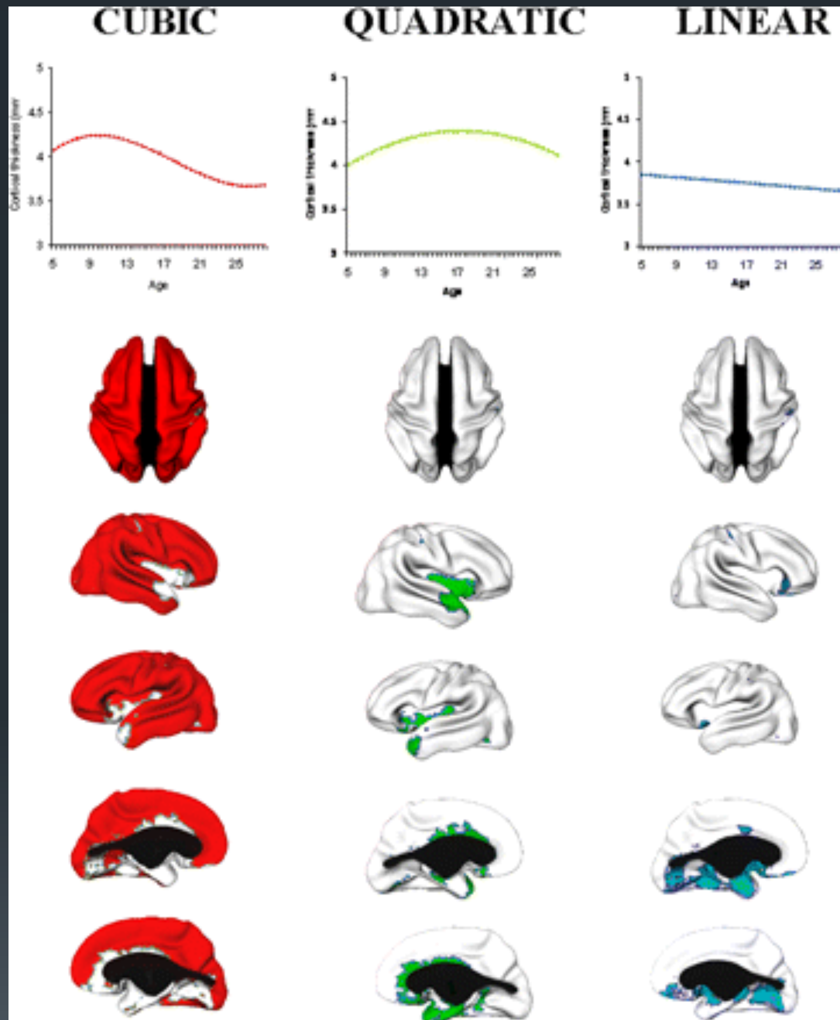
- Circular analysis in systems neuroscience: the dangers of double dipping. Kriegeskorte, N., et al (2009) Nature neuroscience,
- A new neural framework for visuospatial processing Kravitz, D.J., et al (2011) Nature Reviews Neuroscience,
- Real-world scene representations in high-level visual cortex: It's the spaces more than the places Kravitz, D.J., et al (2011) Journal of Neuroscience,
- Goal-dependent dissociation of visual and prefrontal cortices during working memory Lee, S.-H., Kravitz, D.J., Baker, C.I. (2013) Nature Neuroscience, .

Single-item Single-event



Phil Shaw/NHGRI Neurobehavioral Unit

- Longitudinal studies of brain development in youths with ADHD
- CPB Alumnus / Well known studies of brain development & IQ etc
- Cortical development trajectories



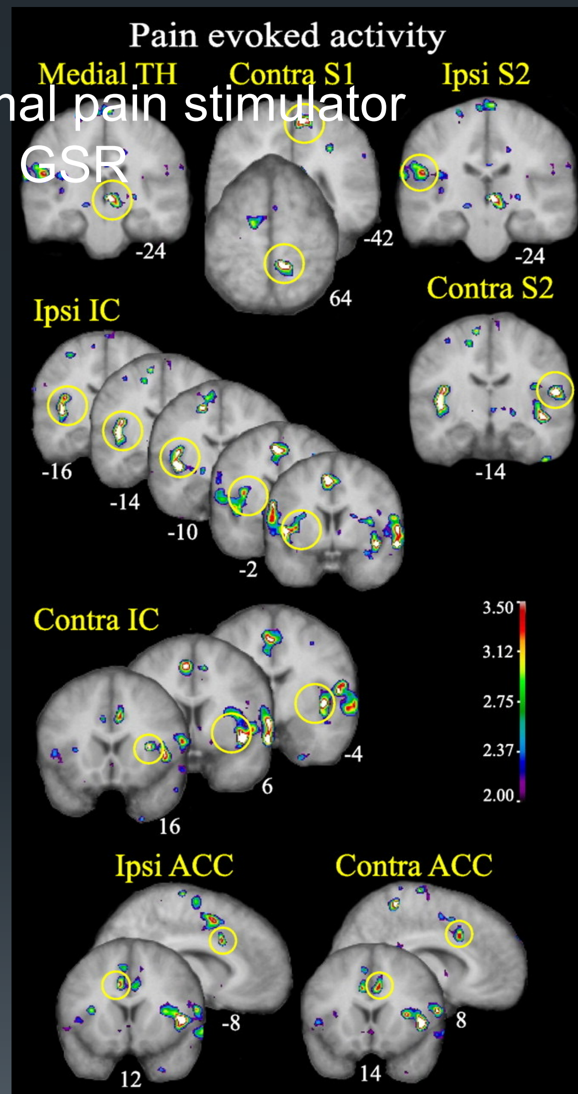
- Intellectual ability and cortical development in children and adolescents , Shaw, P., et al (2006) Nature, 440 (7084), pp. 676-679.
- Attention-deficit/hyperactivity disorder is characterized by a delay in cortical maturation Shaw, P., et al (2007) PNAS
- Neurodevelopmental trajectories of the human cerebral cortex Shaw, P., et al, (2008) Journal of Neuroscience
- Longitudinal mapping .. children and adolescents with ADHD, Shaw, P., et al, (2006) Archives of General Psychiatry, 63 (5), pp. 54

Catherine Bushnell/NCCAM

- Recruited from McGill in 2013
- Pioneer in imaging studies of pain perception and cognition

Uses: thermal pain stimulator
Analgesics, GSR

Thalamic and cortical activity evoked by heat pain in the alternating warm/pain task.

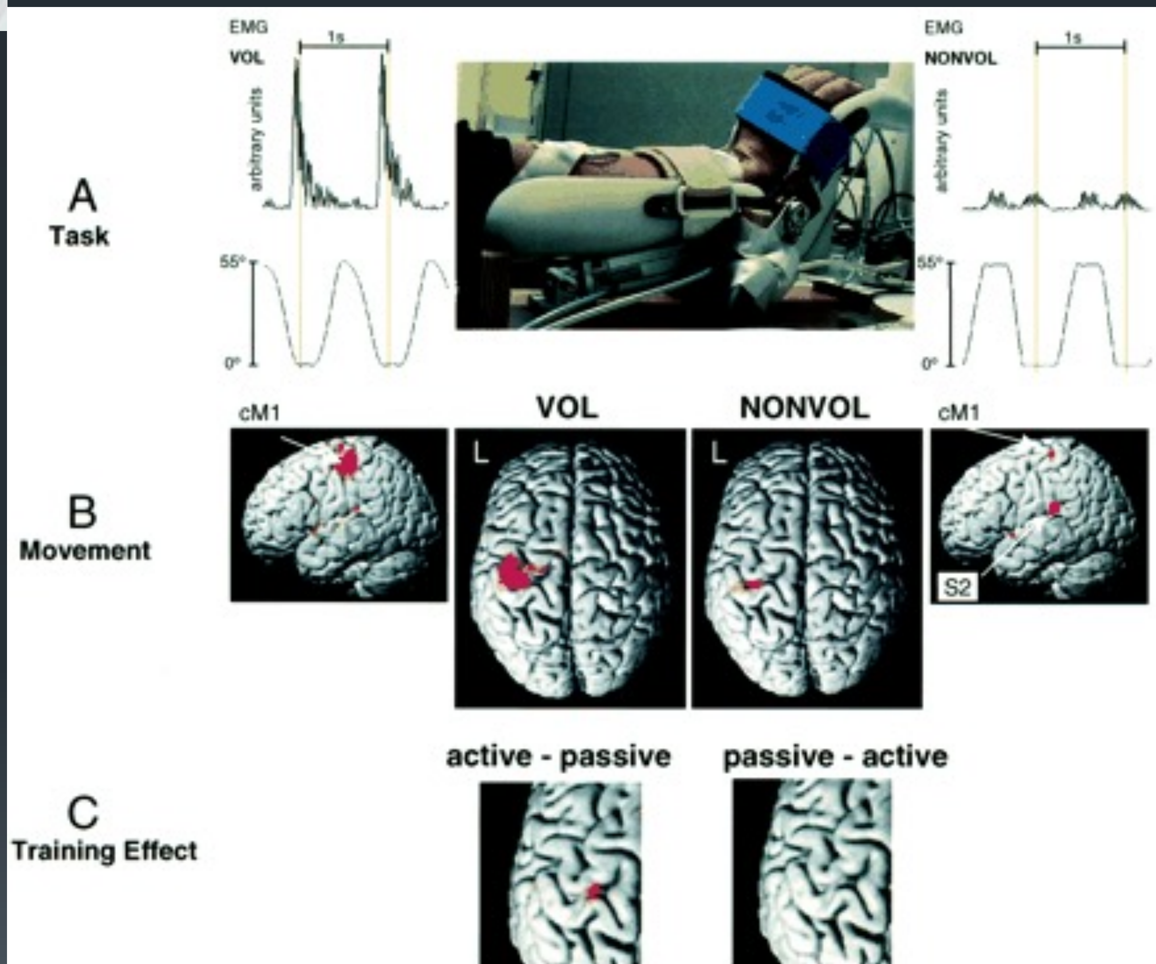


Chantal Villemure, and M. Catherine Bushnell J. Neurosci. 2009;29:705-715

The Journal of Neuroscience

Leonardo Cohen/Human Cortical Physiology Section

- Brain Plasticity/Stroke Recovery / Cortical reorganization (using MRS)
- Therapy using brain stimulation (TMS, tDCS)
- Effects of reward on motor learning

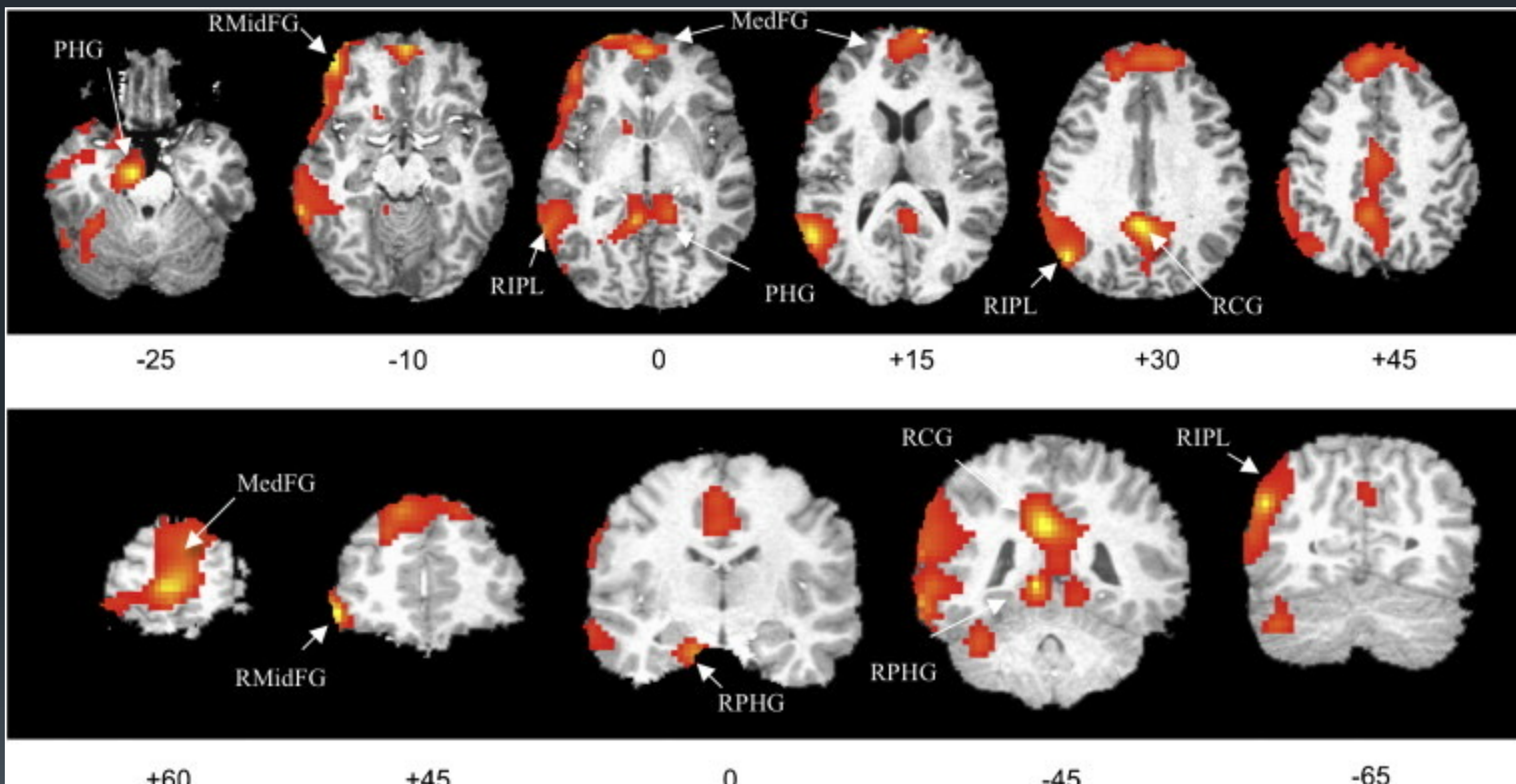


Use:TMS, MRS

- Neural Substrates of Intermanual Transfer of a Newly Acquired Motor Skill Perez, M.A., et al, (2007) Current Biology, 17 (21), pp. 1
- Effects of different viewing perspectives on somatosensory activations during observation of touch Schafer, Mi(2009) Human Brain
- Functional neuroanatomy of mirroring during a unimanual force generation task Sehm, B., et al(2010) Cerebral Cortex, 20 (1), pp. 3

Eric Wasserman/Behavioral Neurology Unit

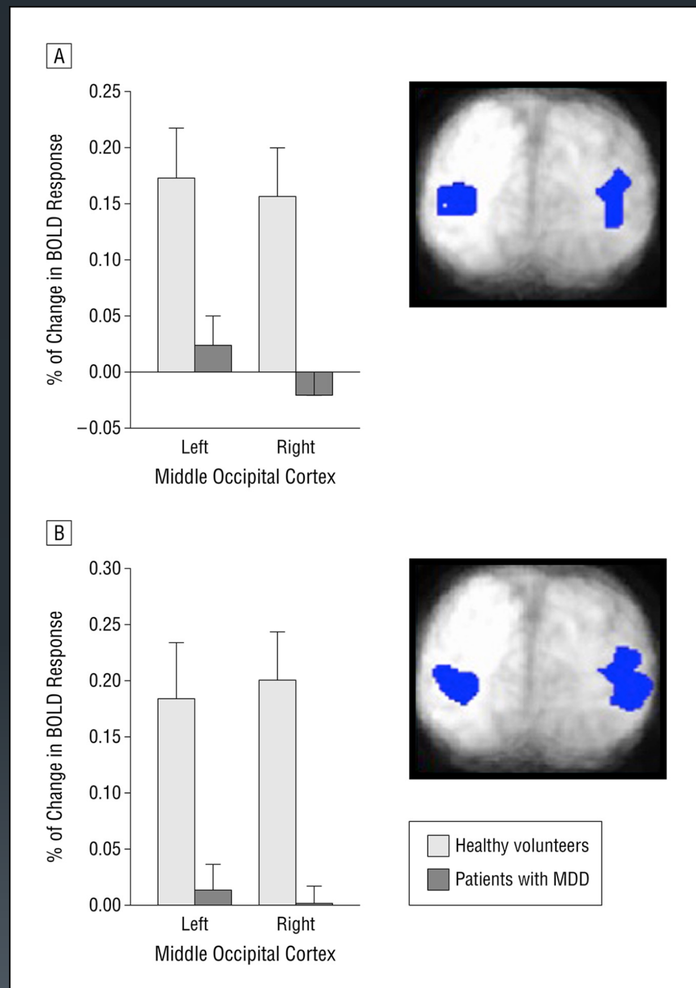
- FMRI Studies of brain stimulation (TMS / tcDCS)
- Validating NIRS with FMRI
- Interventional studies of neural plasticity with tcDCS



Use: TMS, tDCS, NIRS

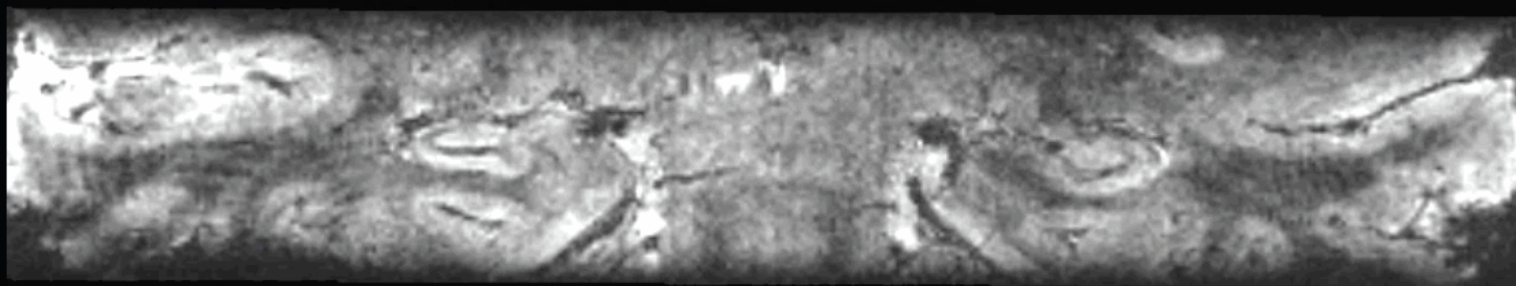
Carlos Zarate/Experimental Therapeutics

- Multimodal studies of fast-acting glutamatergic antidepressants
- Functional MRS
- High resolution studies of hippocampal structures linked to MDD



Use: High-res 7T anatomy fMRS,

High Resolution Anatomy



GRE imaging of the hippocampus
0.4mm iso, 512x448x60
TE=30ms, TR=50ms, FA=10°
TA=8min

AN

2011-2015

2011 – Self-shielded semi-clinical Siemens 7T-830/AS Magnetom instaled and becomes operational

2011 – 1.5T GE replaced by Siemens Skyra 3T

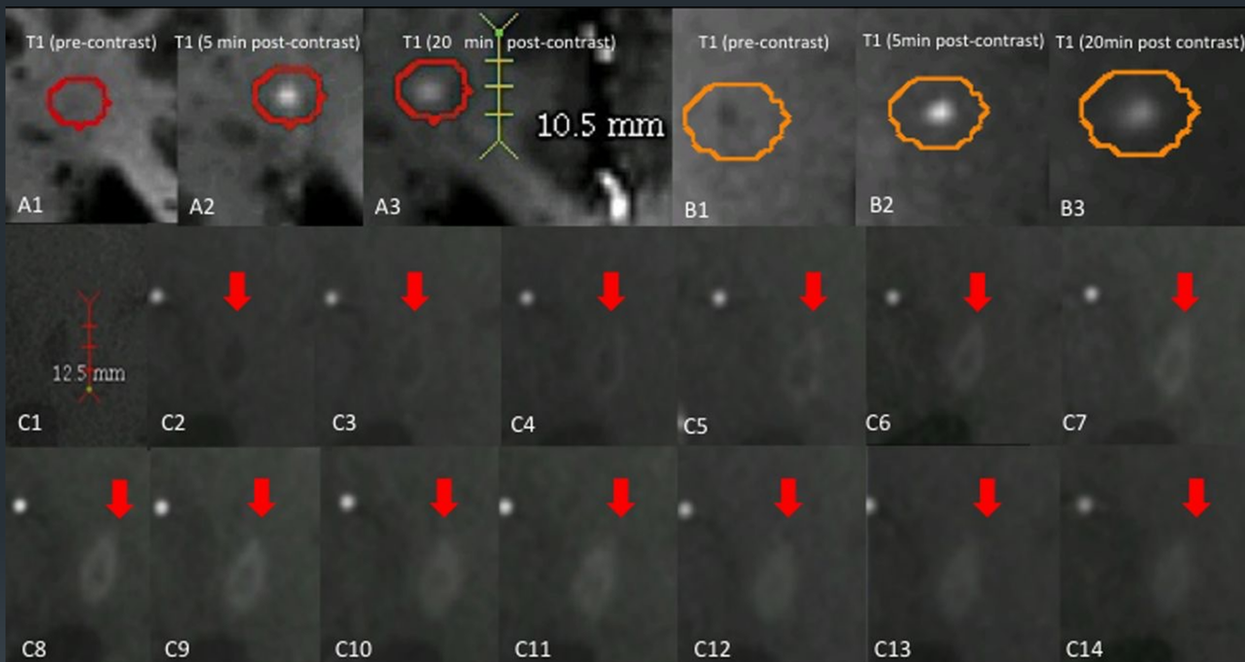
2012 – 11.7T gets to field (& quenches)

2015 – NIAAA Siemens Magnetom Prisma (NIMH & NINDS 25% time each)

2015 – upgrade of 3T-A/3T-B (!)

Danny S Reich/Translational Neuroradiology Unit

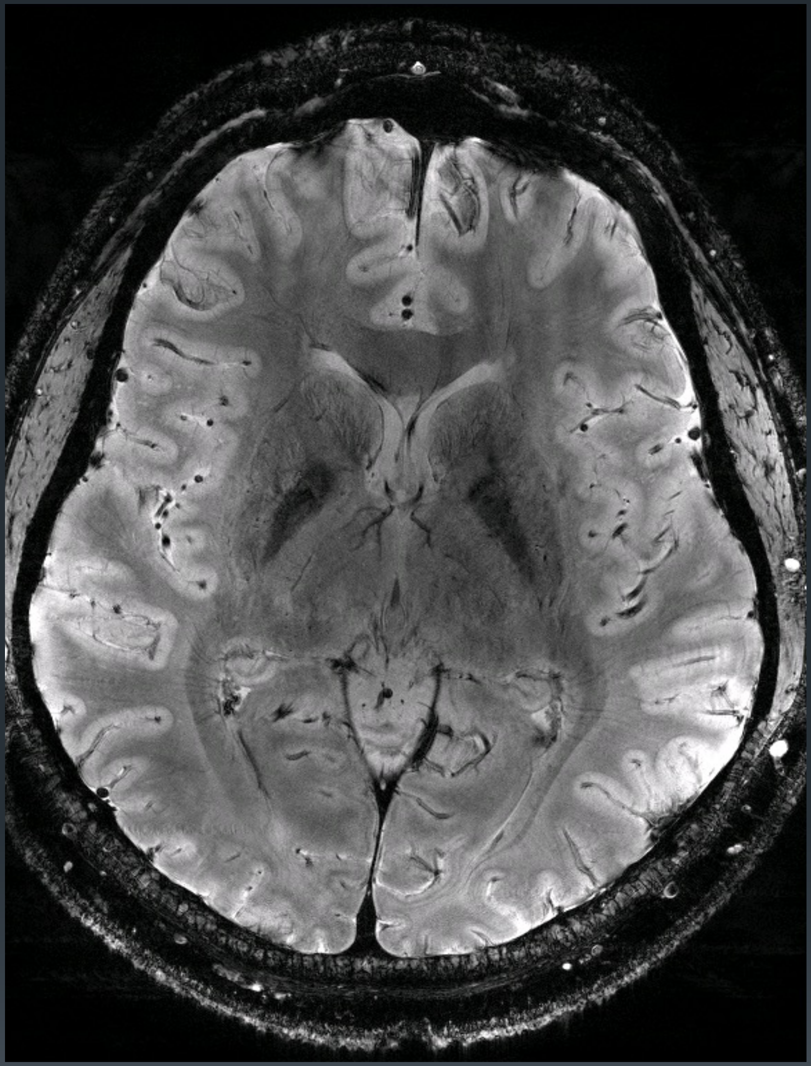
- Imaging parechymal venules and their relationship to MS lesions
- Novel methods for quantitative imaging of myelin with T2*susceptibility
- Using DTS to image axonal damage in patients with MS
- High resolution studies of MS at 7T

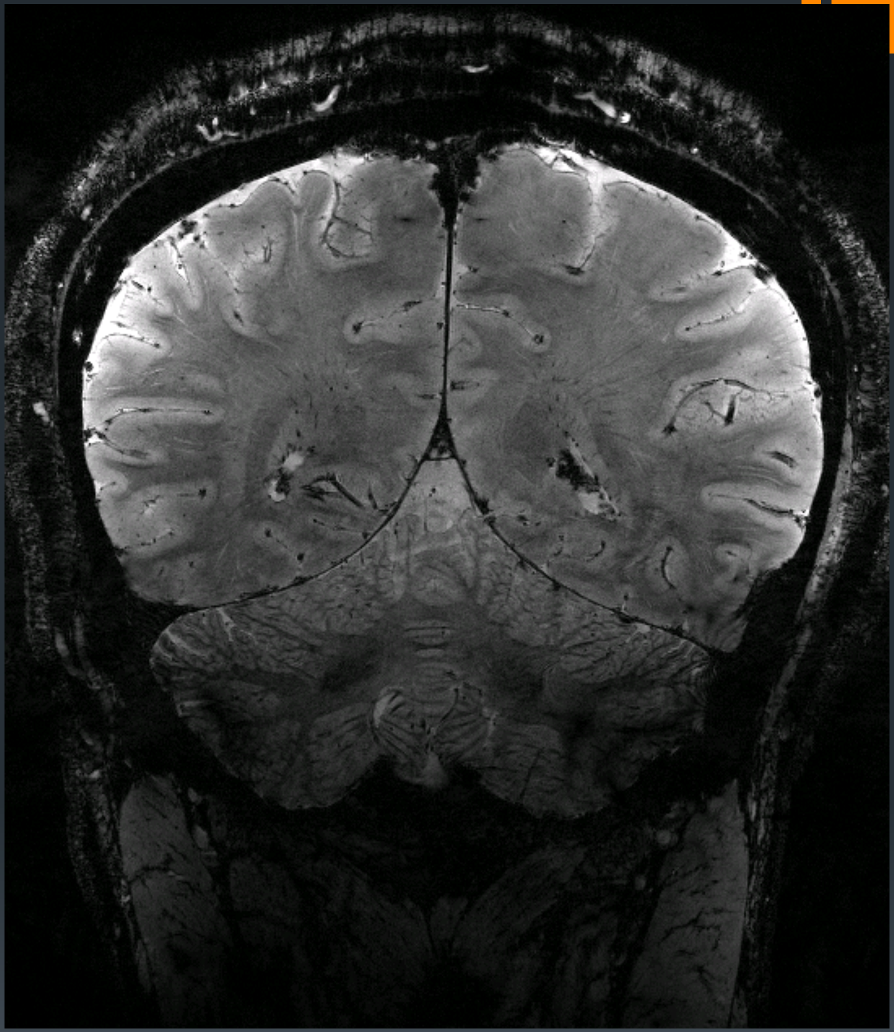


Use: custom pulse sequences, contrast injection, ex-vivo tissue

- **Dynamics of lesion enhancement measured at 7T / Gaitán M I et al Mult Scler 2012;19:1068-1073**

Benefits of 7T MRI

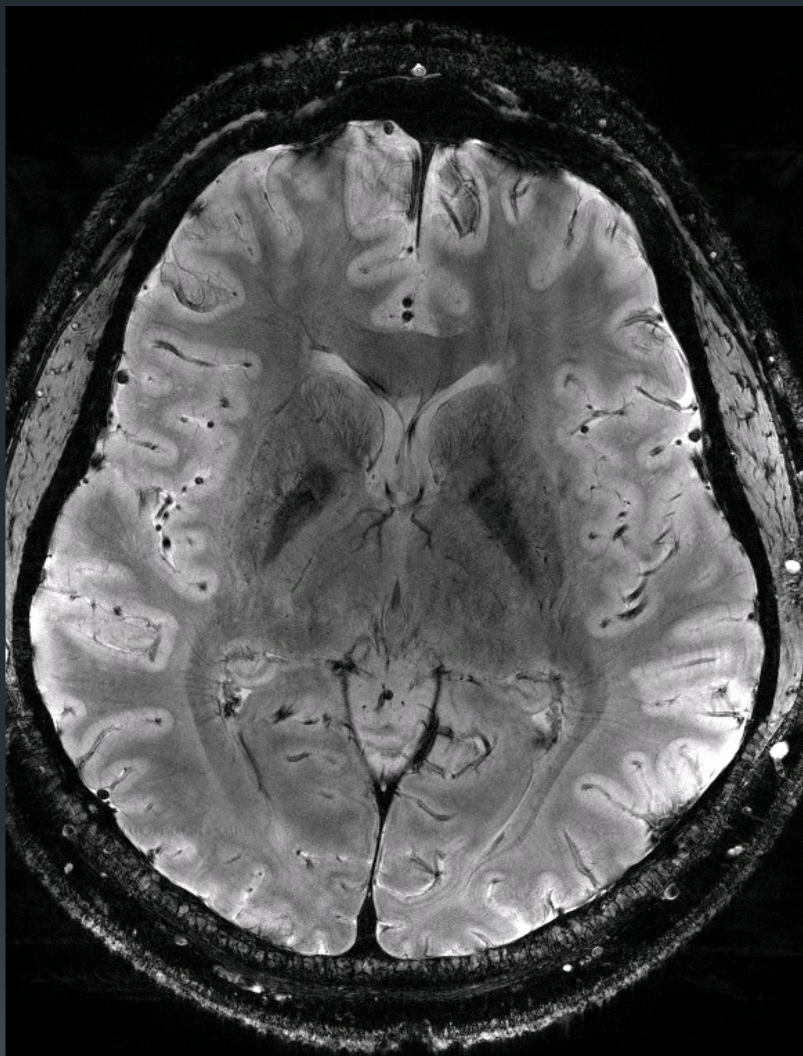




Healthy, T2*w, 0.2 x 0.2 x 1mm

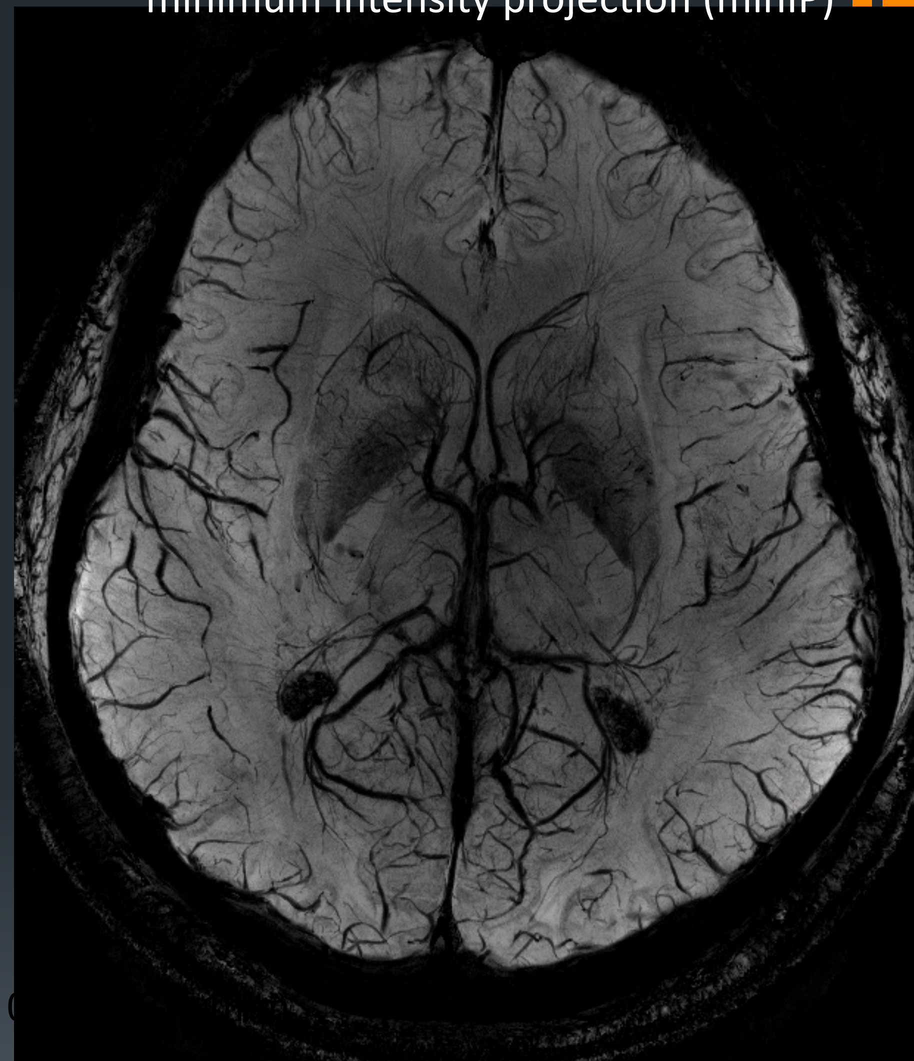
increase in image resolution and contrast

Benefits of 7T MRI



2*w,

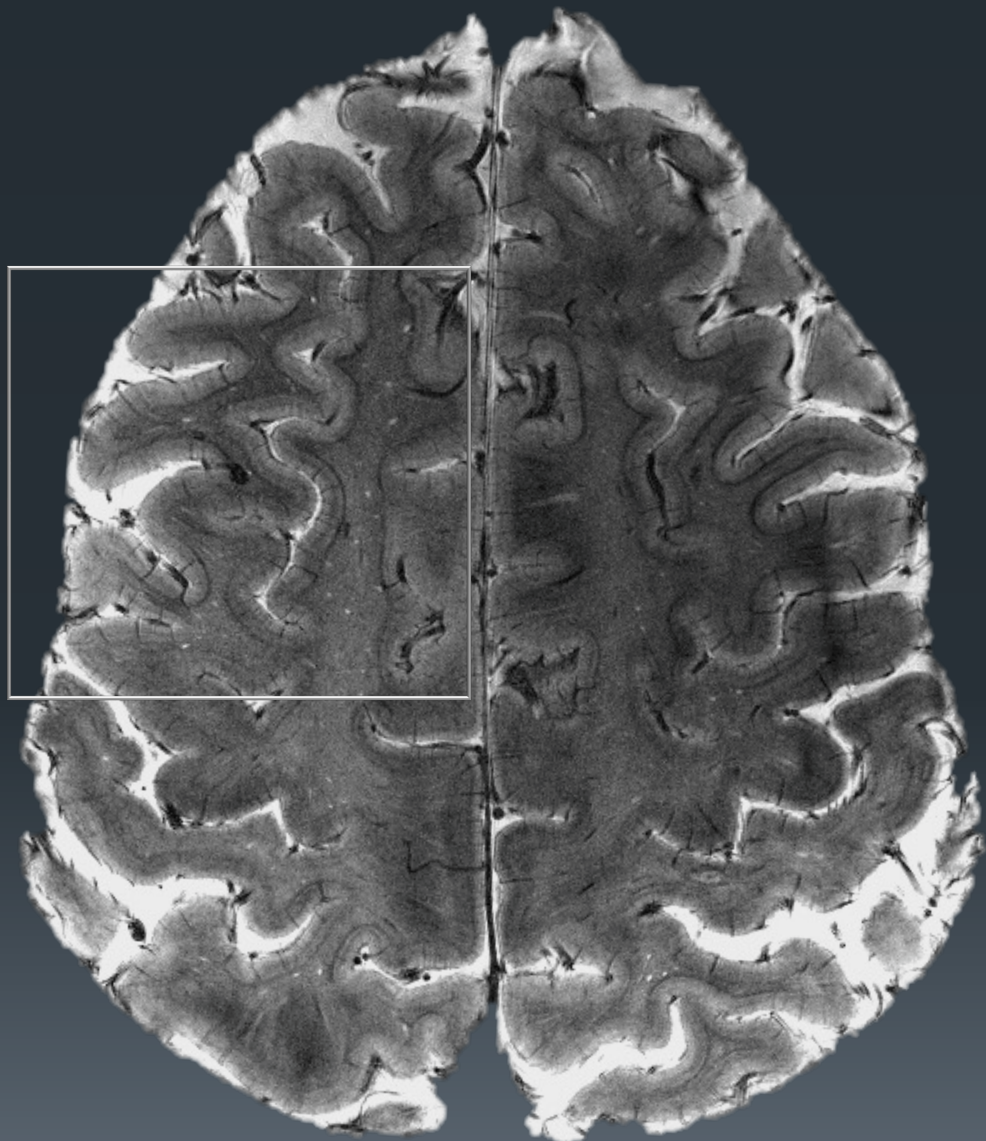
minimum intensity projection (minIP)

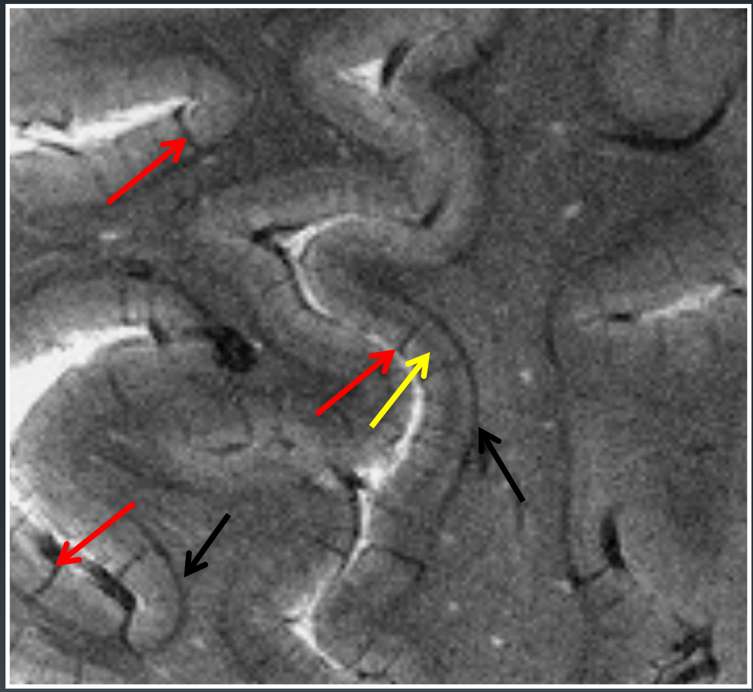


high level of details (ex: study of cerebral vasculature) (Sati)

Cortex imaging with 7T MRI

MS patient, T2*w, 0.2 x 0.2 x 1mm

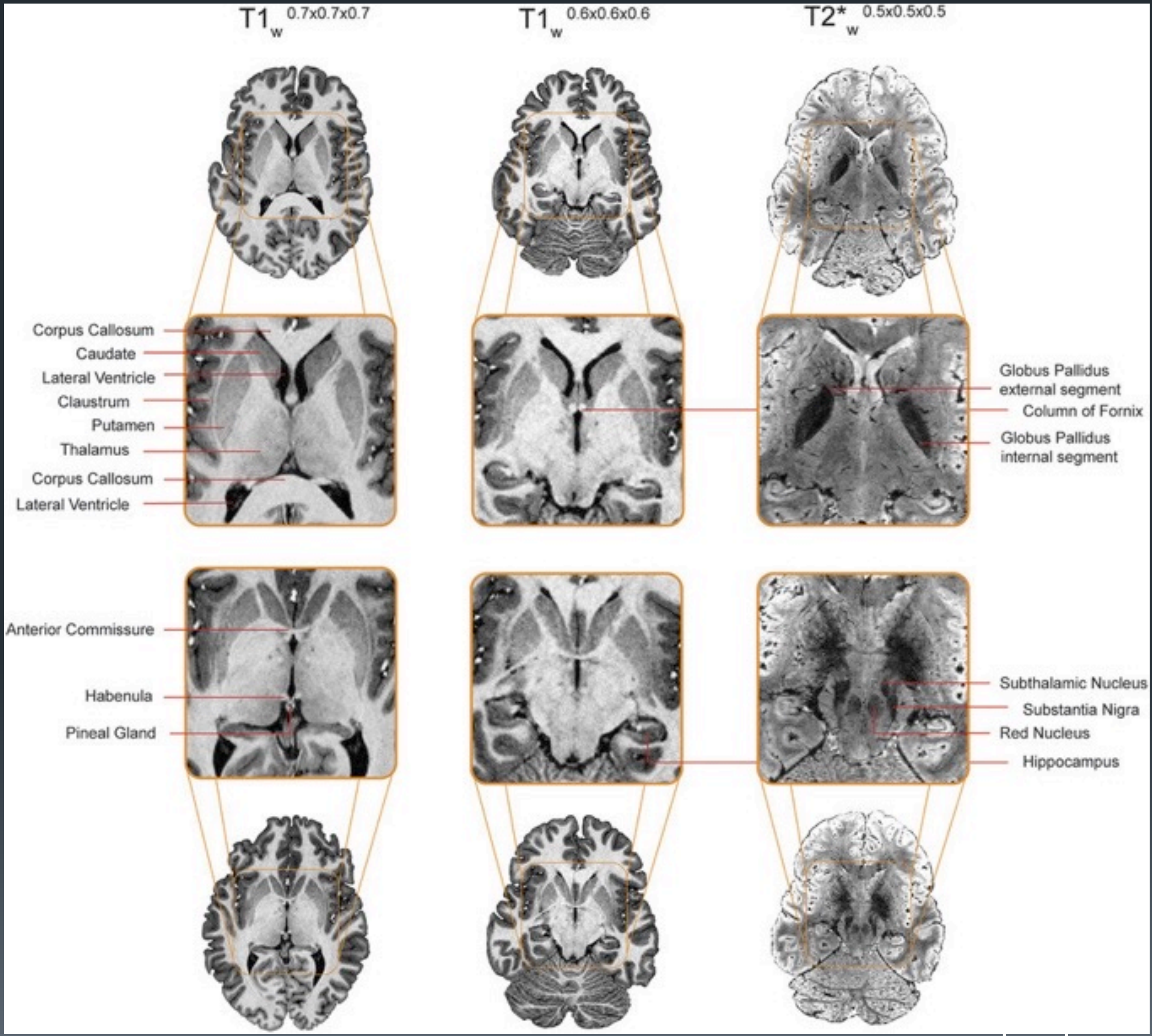




in-plane resolution = 200 μm x 200 μm

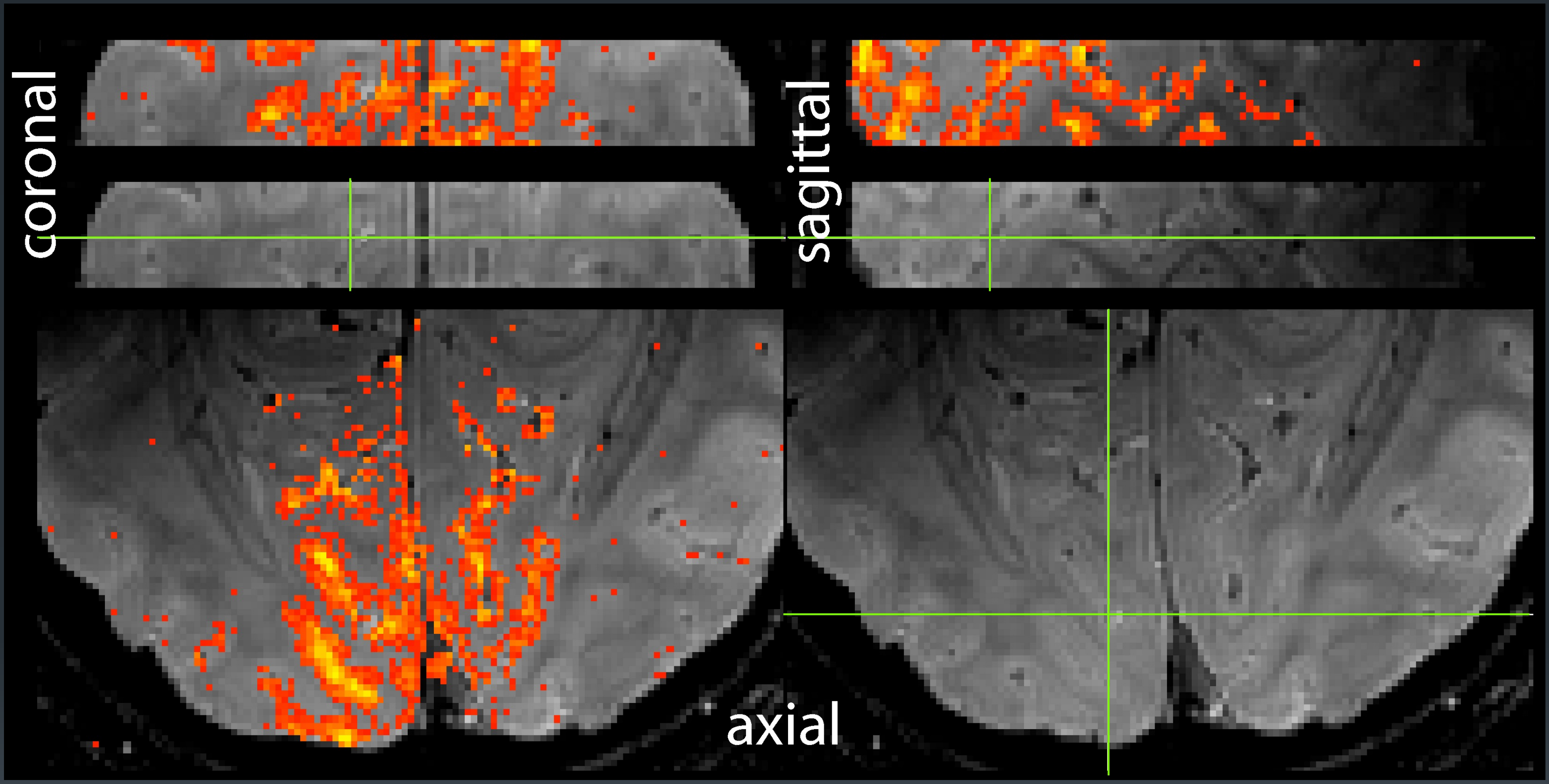
7T @NIH

MP2RAGE AT 7T



Forstmann et al, Scientific Data

7T FMRI



High-res 7T: 0.58 x 0.58 x 0.58 mm^3 = 0.2 mm^3
High-res 3T: 1 x 1 x 1 mm^3 = 1 mm^3
Conventional 3T: 3 x 3 x 3 mm^3 = 27 mm^3
(FMRIB/Karla Miller)


SIEMENS
MAGNETOM Terra

Conclusion:

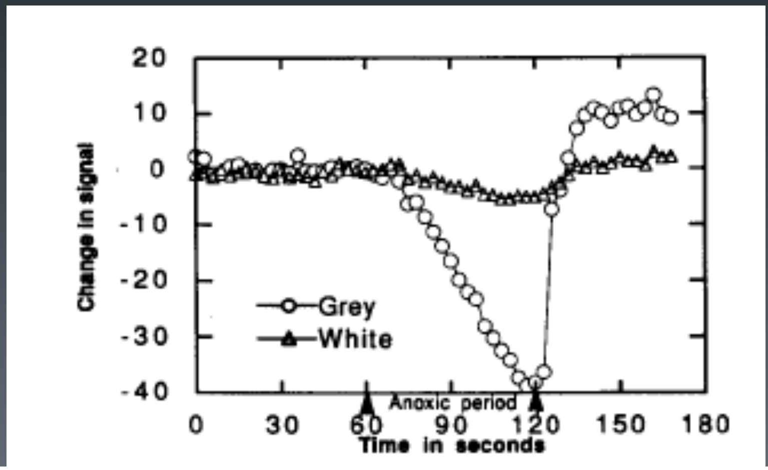
Other MRI facilities at NIH (dedicated animal)

1. NIH MRI Research Facility (NMRF) & Mouse Imaging Facility
   - Multiple small animal magnets (4.7T, 7T Bruker, pharmascan)
2. Neurophysiology Imaging Facility (NIMH/NINDS/NEI)
   - dedicated 4.7T vertical bore primate
3. LFMI/NINDS
   - 7T Bruker (marmoset, rodent)
   - 11.7T Bruker (rodent, small animal)

Dynamic BOLD MR Measurements in Cats

Turner R, Le Bihan D, Moonen CT, Despres D, Frank J "Echo-planar time course MRI of cat brain oxygenation changes" Magn Reson Med. 1991 Nov;22(1):159-66

Abstract: When deoxygenated, blood behaves as an effective susceptibility contrast agent. Changes in brain oxygenation can be monitored using gradient-echo echo-planar imaging. With this technique, difference images also demonstrate that blood oxygenation is increased during periods of recovery from respiratory challenge.



Biophysical Journal Volume 66 January 1994 259–267

MR Diffusion *Tensor* Spectroscopy and Imaging

Peter J. Basser,* James Mattiello,* and Denis LeBihan‡

*Biomedical Engineering and Instrumentation Program, National Center for Research Resources, and ‡Diagnostic Radiology Department, The Warren G. Magnuson Clinical Center, National Institutes of Health, Bethesda, Maryland 20892 USA

ABSTRACT This paper describes a new NMR imaging modality—MR diffusion *tensor* imaging. It consists of estimating an effective diffusion tensor, $\mathbf{D}_{eff}$, within a voxel, and then displaying useful quantities derived from it. We show how the phenomenon of anisotropic diffusion of water (or metabolites) in anisotropic tissues, measured noninvasively by these NMR methods, is exploited to determine fiber tract orientation and mean particle displacements. Once $\mathbf{D}_{eff}$ is estimated from a series of NMR pulsed-gradient, spin-echo experiments, a tissue's three orthotropic axes can be determined. They coincide with the eigenvectors of $\mathbf{D}_{eff}$, while the effective diffusivities along these orthotropic directions are the eigenvalues of $\mathbf{D}_{eff}$. Diffusion ellipsoids, constructed in each voxel from $\mathbf{D}_{eff}$, depict both these orthotropic axes and the mean diffusion distances in these directions. Moreover, the three scalar invariants of $\mathbf{D}_{eff}$, which are independent of the tissue's orientation in the laboratory frame of reference, reveal useful information about molecular mobility reflective of local microstructure and anatomy. Inherently, tensors (like $\mathbf{D}_{eff}$) describing transport processes in anisotropic media contain new information *within a macroscopic voxel* that scalars (such as the apparent diffusivity, proton density, T_1, and T_2) do not.

Nature Neuroscience **2**, 861 - 863 (1999)
doi:10.1038/13158

Brain development during childhood and adolescence: a longitudinal MRI study

Jay N. Giedd, Jonathan Blumenthal, Neal O. Jeffries, F. X. Castellanos, Hong Liu, Alex Zijdenbos, Tomáš Paus, Alan C. Evans & Judith L. Rapoport

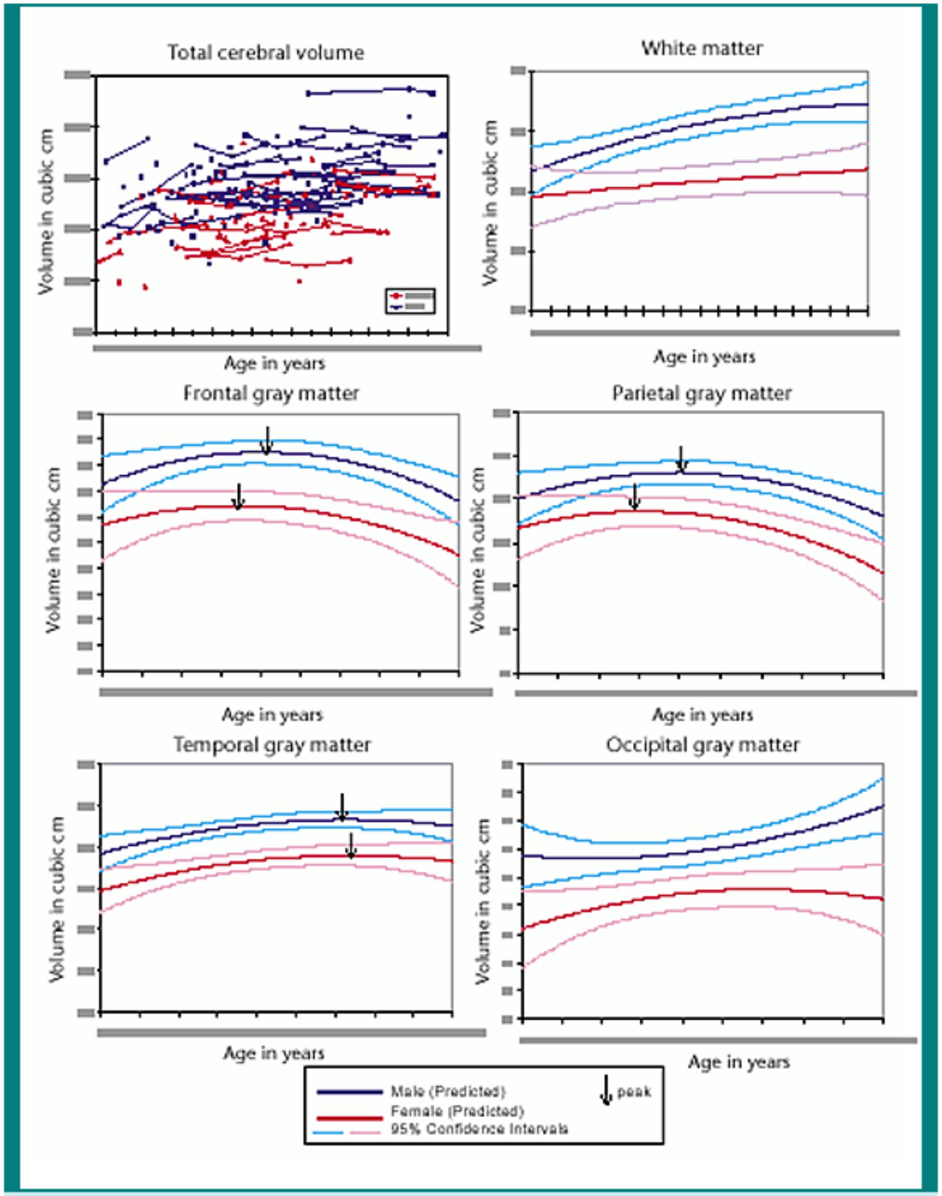
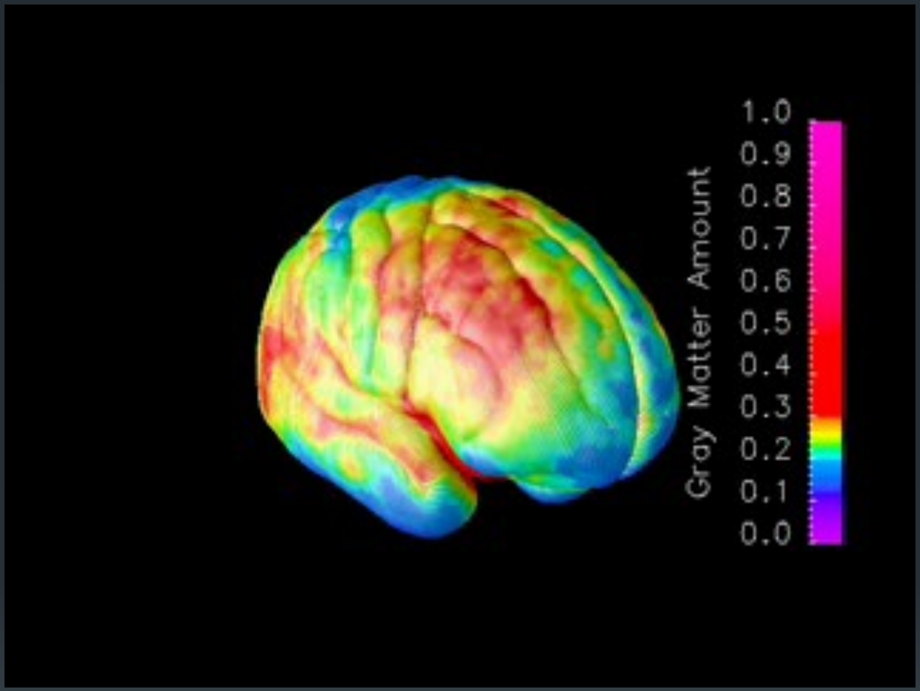


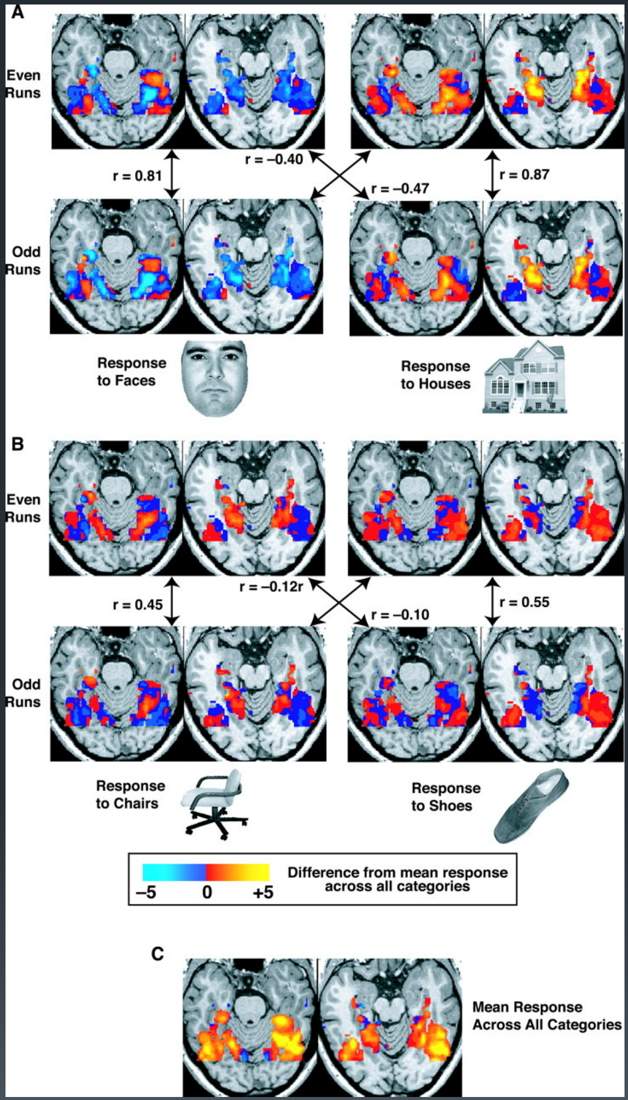
Figure 1. Predicted size with 95% confidence intervals for cortical gray matter in frontal, parietal, temporal and occipital lobes for 243 scans from 89 males and 56 females, ages 4 to 22 years. The arrows indicate peaks of the curves.

Dynamic mapping of human cortical development during childhood through early adulthood (Gogtay et al. PNAS 2004)



J. V. Haxby et al., Science 293, 2425 -2430 (2001)

Published by AAAS



J. V. Haxby et al., Science 293, 2425 -2430 (2001)

Published by AAAS

Functional Mapping of the Human Visual Cortex at 4 and 1.5 Tesla Using Deoxygenation Contrast EPI

R. Turner, P. Jezzard, H. Wen, K. K. Kwong, D. Le Bihan, T. Zeffiro, R. S. Balaban

The effects of photic stimulation on the visual cortex of human brain were studied by means of gradient-echo echo-planar imaging (EPI). Whole-body 4 and 1.5 T MRI systems, equipped with a small *z* axis head gradient coil, were used. Variations of image intensity of up to 28% at 4 T, and up to 7% at 1.5 T, were observed in primary visual cortex, corresponding to an increase of blood oxygenation in regions of increased neural activity. The larger effects at 4 T are due to the increased importance of the susceptibility difference between deoxygenated and oxygenated blood at high fields.

blood flow than in oxygen utilization during somatosensory stimulation. Similar results were reported in cat brain during electrical stimulation by Lübbers and Leniger-Follert (9).

Given that for higher magnetic fields the effect of susceptibility variations is heightened, it was of interest to determine whether large changes due to photic stimulation would be observable using our 4 T whole-body MR system. To make a fair comparison, EPI experiments at 4

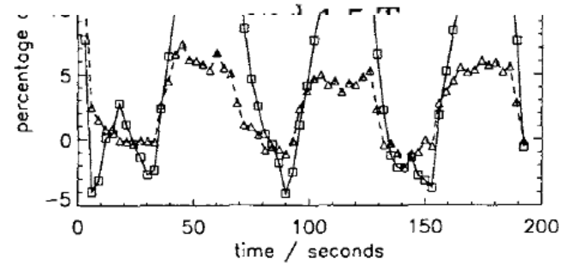
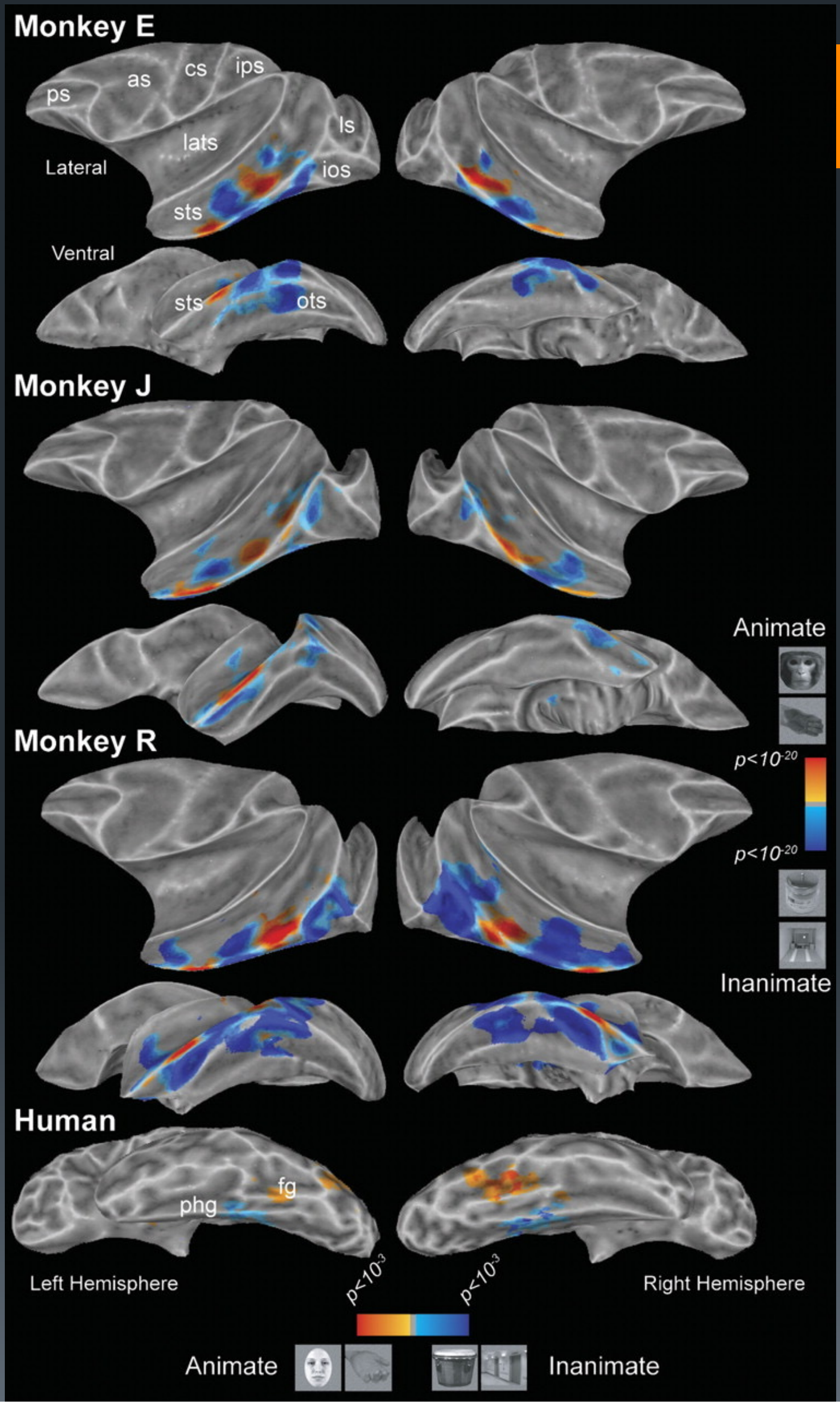


FIG. 2. Plot of fractional change in 4 T (squares) and 1.5 T (triangles) EPI image intensity versus time in the eight-voxel regions of interest in the visual cortex shown in Fig. 1, for a volunteer experiencing alternate 30-s periods of rest and photic stimulation. Details of acquisition for the 4 and 1.5 T data are described in the caption for Fig. 1.

Representation of animate vs. inanimate stimuli in the brain.



Bell A H et al. J Neurophysiol 2009;101:688-700

Journal of Neurophysiology

November 17, 1987
Vol. XXXIX No. 23
U.S. Department of Health and Human Services
National Institutes of Health

The NIH Record

The Countdown Has Begun

Special Centennial Clock Will Mark Off the Next 100 Years

By Anne Barber

The seconds tick off, one by one, marking the time until the next 100 years will around—the year 2087. The clock, a blue metal box containing 10 glowing red digits that measure about one inch high, has been programmed to count down until the second NIH 100 year mark has been reached. Dr. James B. Wyngaarden, NIH director, started the clock at the Centennial Commemorative ceremony, Oct. 16, officially opening NIH's second century.

The clock was designed by the Biomedical Engineering and Instrumentation Branch, part of the Division of Research Services. According to Dr. Henry Eden, deputy chief, BEIB, "It is a very simple, straightforward circuit. We chose to count down seconds—rather than display years, months, and days—because it was easier to implement within the short deadline for the project.

"We took leap years into account to come up with the right number of seconds—3,155,760,000," he continued. "It was a project within BEIB and my role was simply to coordinate it. Allen Markowitz, an electronic engineer, and Bart Chidakel, electronic technician, designed and built the electronics; and Thomas Tedder, biomedical instrument maker, built the cabinet enclosure. Purchasing agents Maxine Anders, Patricia Hales and Chris Hansen procured all the parts."

Explained Eden, "We were given some latitude with the design—and we considered producing an hourglass or a spiraled tube filled with liquid and a ball marking the years—but, because of the short turnaround time required, we chose to go with a design that we knew would work."

According to Markowitz, design was not the problem; getting the parts was. The main chip for the clock came from California and the sockets for the light-emitting diodes came from New Jersey.

"If you don't have the parts, you can't have a design," he said.

Glued to an inside wall of the clock is a slogan borrowed from a DRS brochure; it reads "Proud to serve."

The clock, along with a Centennial time capsule (yet to be fabricated) will eventually be located in Bldg. 10, along with other Centennial memorabilia.

Dr. Samuel Kasper, chairman of the NIH Centennial subcommittee that has responsibility for the time capsule and other aspects of the celebration, says it will probably be December or later before all time capsule contents

(See CLOCK, Page 2)

The BEIB clock team: front row (l to r) Allen Markowitz, Maxine Anders, Patricia Hales, Bart Chidakel; back row (l to r) Thomas Tedder and Chris Hansen.

Seminars Focus on Lab Safety

By Blair Gately

The recent laboratory-acquired infection of two people working with the AIDS virus, HIV, has prompted the Division of Safety to sponsor several programs to acquaint employees with preventive measures.

Dr. Joseph E. Rall, NIH deputy director for intramural research, told the audience at a recent Clinical Center Grand Rounds, "Working in a lab has never been a particularly safe profession. Worker-acquired infections are not new."

He said studies have analyzed how the two workers became infected with HIV and what measures should be taken to avoid additional cases of infection.

The Grand Rounds session not only focused on HIV, but also on hepatitis B and Rocky Mountain spotted fever.

Dr. Robert McKinney, director, Division of Safety, related a case involving two laboratory support service workers who died after becoming afflicted with Rocky Mountain spotted fever.

"It was not possible to establish the source of their infection," he said. "Their duties were

(See SAFETY, Page 6)

New NMR Center Opens

By Blair Gately

The NIH In Vivo NMR Research Center has opened in a one-story building adjacent to the Clinical Center's "D" wing.

The new facility, which was dedicated late last month, is the first centralized NMR facility on campus and will be the focus of biomedical NMR research, according to Dr. Cherie Fisk, Office of Research Services. It houses three nuclear magnetic resonance imaging and spectroscopy instruments, two for animal studies and one for patients.

Nuclear magnetic resonance is used to study anatomical and physiological processes in living systems. The new center has a 1.5 Tesla whole-body instrument and two wide-bore animal NMR machines, one with a 2 Tesla field and the other with a 4.7 Tesla field, and associated data stations and computer facilities. In addition, a 7 Tesla 30-cm spectrometer is there for special applications in NMR spectroscopy.

By having machines for both animal and human images in the center, researchers will be able to conduct directly analogous experiments.

The center also has a small patient care area with waiting, dressing and preparation rooms.

"This is a day many of us have been looking

(See NMR, Page 8)

NMR

(Continued from Page 1)

forward to for a long time," Dr. Edwin D. Becker, NIH associate director for research services, said at the dedication ceremony in the ACRF Amphitheater. "This facility is a cooperative and collegial effort by NIH's institutes."

The keynote speaker at the ceremony, Dr. E. Raymond Andrew, professor of physics and radiology, University of Florida, spoke about the impact of "NMR in Biomedicine."

"Nuclear magnetic resonance has become more important in biology and medicine over the last 10 years," he said. "Initially it was the province of the physicist, then the chemist, and it has moved across the disciplines."

Dr. E. Raymond Andrew, professor of physics and radiology at the University of Florida, gave the keynote address at the opening of the NMR Center.

Andrew showed a series of slides of his own head and abdomen to illustrate the results of NMR imaging.

Dr. S. Morry Blumenfeld of General Electric Medical Systems, the prime contractor for establishment of the center, told the audience, "Our goal is the creation of a new diagnostic modality to bring to the clinician not only the physical attributes of a patient, but also information on the chemistry and biochemistry of abnormal tissues." GE designed, built, and equipped the new center.

Both imaging and spectroscopy make use of the magnetic quality of certain atomic nuclei.

The NMR phenomenon occurs when nuclei containing an odd number of protons and/or neutrons are introduced into a strong magnetic field. These nuclei behave as if they were spinning charges, and precess (gyrate like a top) in a preferred orientation in a strong magnetic field.

When a radio frequency (RF) pulse is introduced by a transmitter—often for only millionths of a second—the nuclear spins will reorient in the field and, as a whole, will absorb energy. Following the pulse, the nuclei "relax" to their original state. The time it takes the stimulated nuclei to relax after a burst of RF energy is a measurable quantity, characteristic of a particular molecular environment.

Blending in nicely with the brick exterior of the Clinical Center is the one-story In Vivo NMR Research Center, adjacent to the CC's D wing.

The relaxation times of these nuclei and the RF frequency for resonance are of use in physics, chemistry, and biochemistry. The distribution in space of these nuclei can be used to obtain images.

While imaging of human anatomy is perhaps the most widely known aspect of NMR, the procedure has been used at NIH for more than 30 years for basic research in organic and physical chemistry, and, more recently, for biochemistry and physiology. NMR can provide information on the structure of molecules.

"I was introduced to NMR 30 years ago by Dr. Becker and I was impressed then and have been ever since with the power of this technique," said Dr. Joseph Rall, NIH deputy director for intramural research. "NIH is a good community for a center because of both the expertise and the clinical need that we have."

NMR was discovered in 1946 by two American scientists, Felix Bloch and Edward Purcell, who were awarded the Nobel prize in physics in 1952 for their work.

Inspecting the facilities in the recently opened In Vivo NMR Research Center are (from l) Dr. David Hoult and Dr. Chang-Nien Chen, BEIB; Judie Ireland, ORS; Dr. Andrew Dwyer and Dr. Joseph Frank, CC-Diagnostic Radiology Department.

A portrait bust of the late Vice President Hubert H. Humphrey was unveiled at DHHS headquarters in Washington recently. Secretary Otis R. Bowen accepted the sculpture, which will remain on permanent display in the Humphrey Bldg. A gift of Humphrey's sister, Frances Humphrey Howard (an NLM employee), and Joseph John Jova, former U.S. ambassador to the Organization of American States, the bust is by Mexican sculptor Gabriel Ponzanelli.

Preschool Holds Book Sale

The NIH Preschool Developmental Program will hold a book fair in time for the holiday season. The sale will be held outside the cafeteria in Bldg. 35 on Dec. 2 from 11 a.m. to 3 p.m.

Orders will be taken from a large display of sample books. Books will arrive in plenty of time for Chanukah and Christmas giving. Money is due when the order is placed. All proceeds will be used to benefit the program. ☐

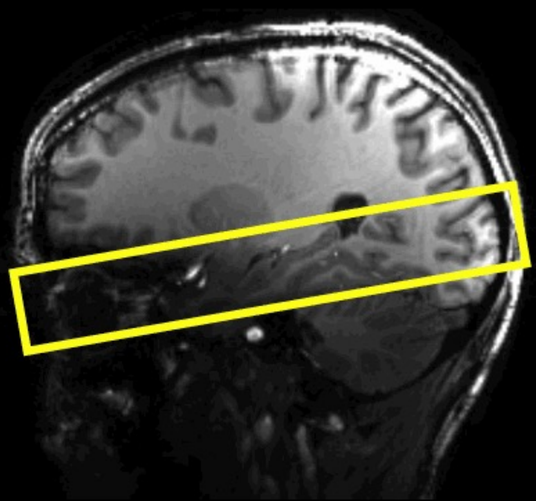
NIMH Seeks Male Twins

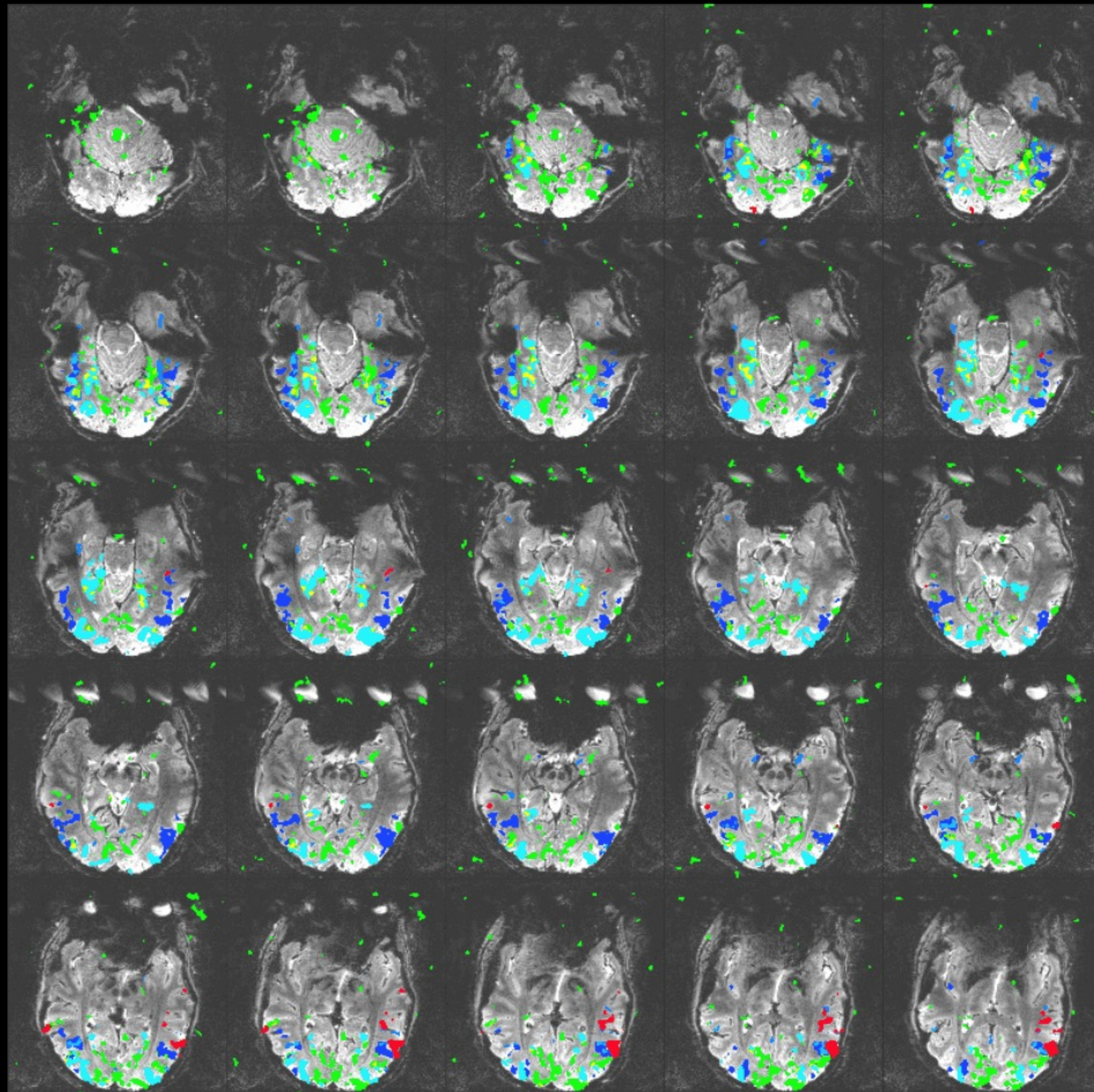
The National Institute of Mental Health is seeking male twins over age 20 to participate in research. Participants will be paid.

For further information call, Dr. Gabbay, 496-7672. ☐

High Resolution FMRI

Smooth 3mm p>1e-4





1.2 mm iso, TR=2s
1-back, Block
Faces/Scenes
Objects/Scrambled
Bodies/Objects
English/Chinese

DK, SM, CB

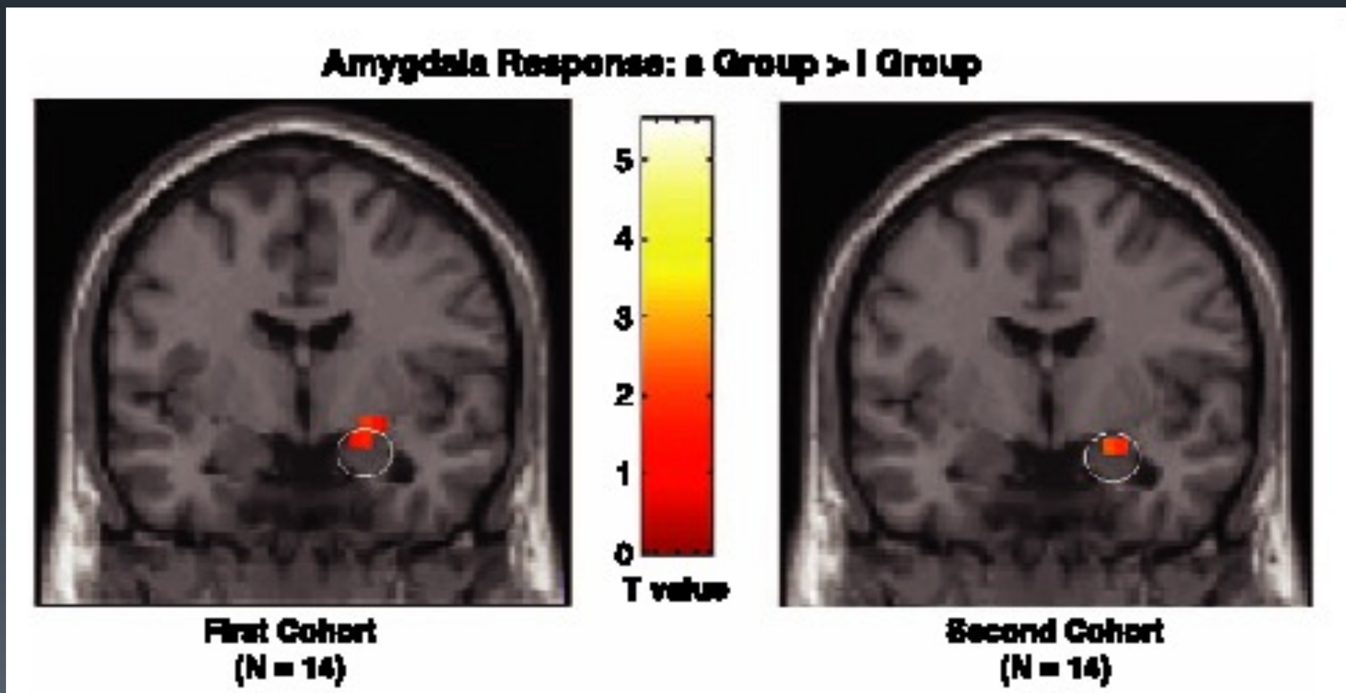
Helpful people

- FMRIF staff (Mostly data acquisition)
  - Souheil Inati, Sean Marrett, Adam Thomas, Vinai Roopchansingh
- NMRF staff
  - Lalith Talagala, Joelle Sarlis
- SSSC (Design and analysis)
  - Bob Cox, Ziad Saad, Gang Chen, Rick Reynolds, Daniel Glen
- Scientific Instrumentation Branch (George Dold, Daryl Bandy)

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

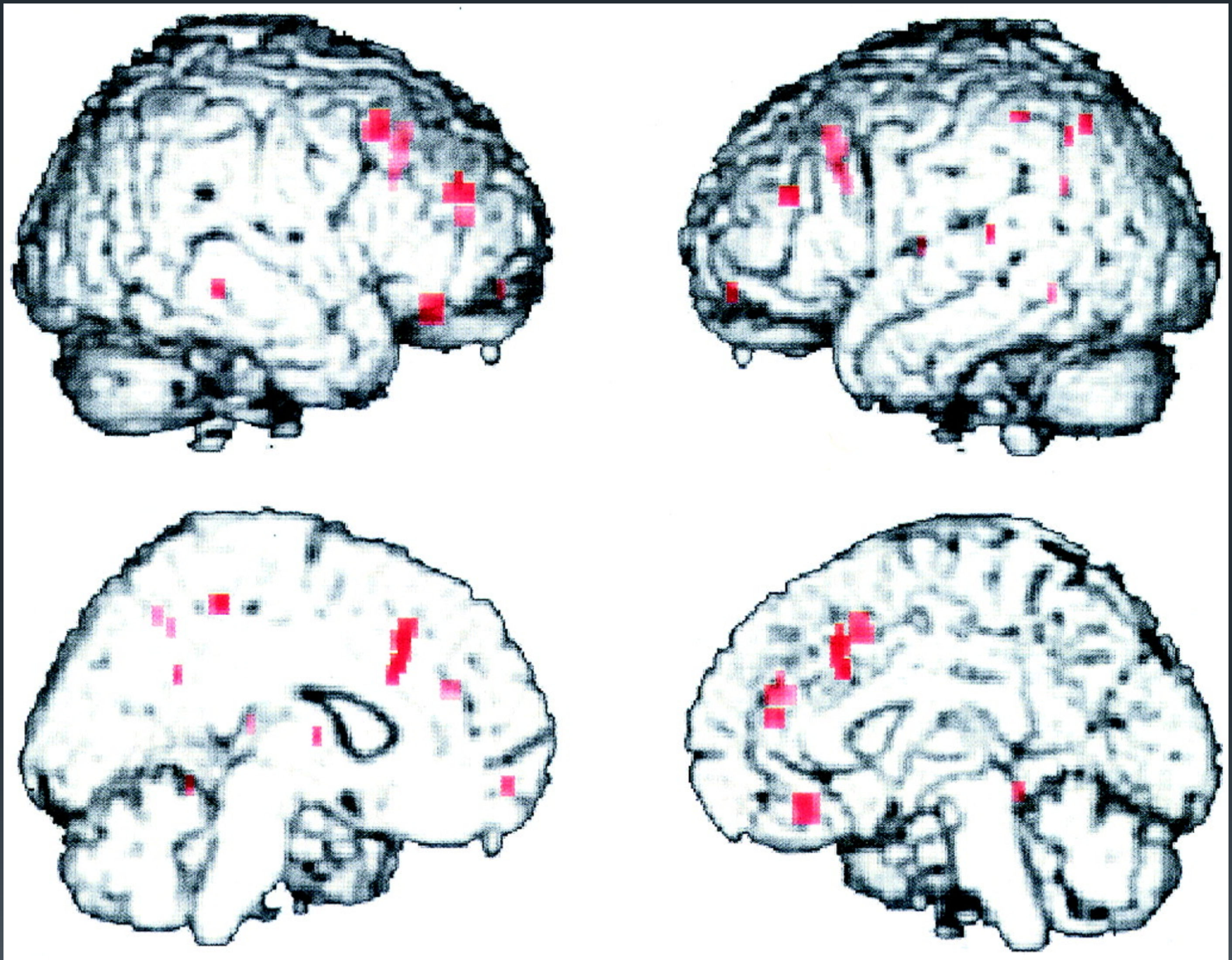
Serotonin Transporter Genetic Variation and the Response of the Human Amygdala

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

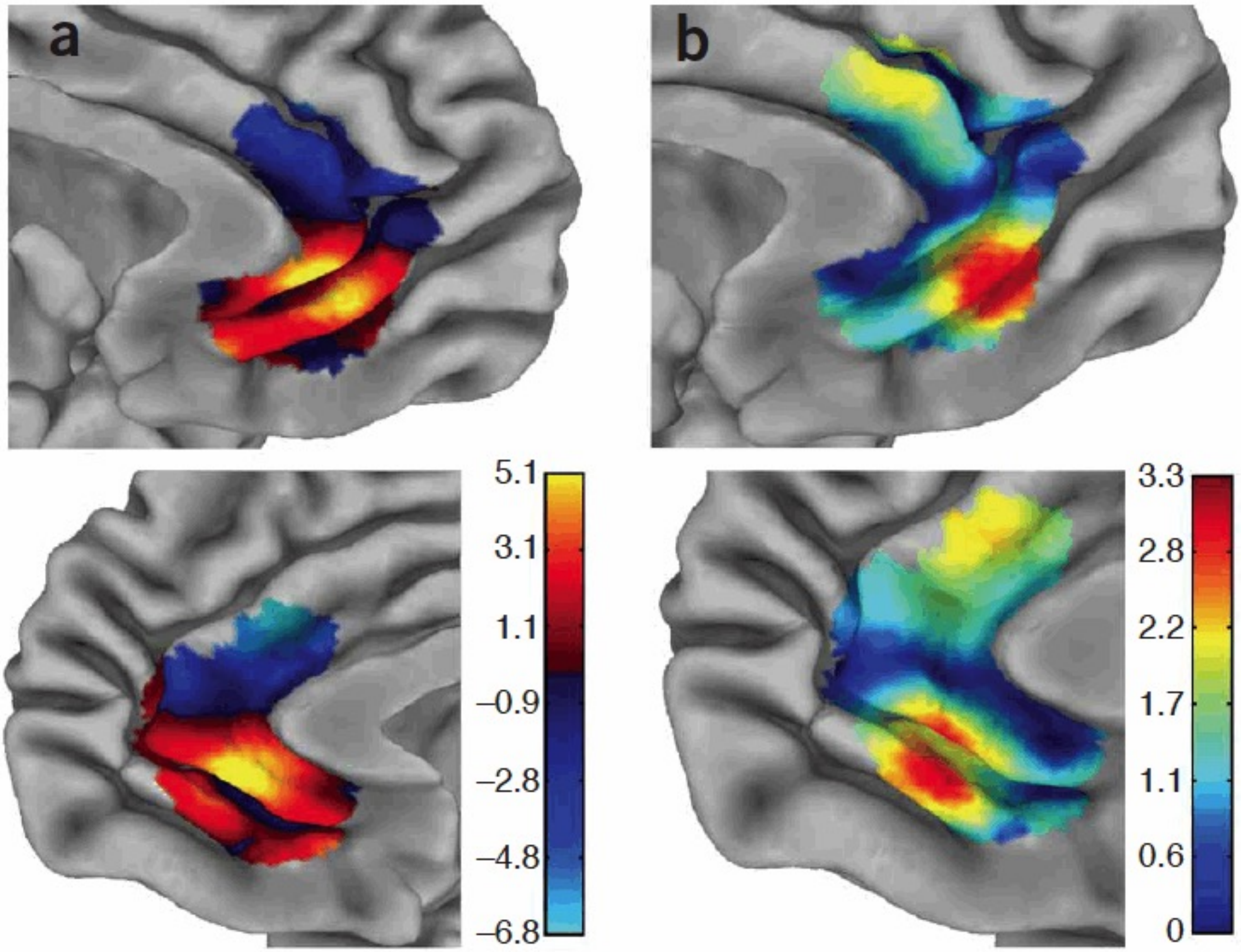
Effect of COMT genotype on fMRI activation during the two-back working memory task.



Egan M F et al. PNAS 2001;98:6917-6922

PNAS

GCAP



Early Technical Innovators

Bob Balaban (MT / CEST) NHLBI - 1989
Bob Turner (EPI/FMRI) NHLBI - 1991
Peter Basser (DTI) NICHD - 1992
Peter Bandettini (FMRI) - 1992

Early Adopters – Clinical/Longitudinal

Jay Giedd – pediatric developmental/clinical
Judy Rapoport – clinical/development
1991
Henry McFarland – clinical/longitudinal, MS
1989
Karen Berman – imaging genetics

Early Adopters – FMRI

Leslie Ungerleider – vision, visual attention
1995
Alex Martin – representation of knowledge
`   1997
Allen Braun – cross-modal plasticity, deafness
Mark Hallet – clinical/movement disorders

Clinical applications

Daniel Pine – clinical/develop/anxiety

Ellen Leibenluft – clinical/child bipolar/

James Blair – clinical

Christian Grillon – fear conditioning
Chris Baker – (7T) plasticity/visual percepti
Sue Swedo – developmental
Carlos Zarate – clinical/depression/therapy
Leonardo Cohen – plasticity/clinical
Daniel Reich,M.D – (7T) clinical/MS
William Theodore clinical/epilepsy
Eric Wasserman – Methods TMS/NIRS

Technical Innovations

Jeff Duyn (parallel receive,

susceptibility phase imaging)
Jun Shen – methods/MRS

NIMH

Bruno Averback – Plasticity/reward
Chris Baker – plasticity/visual perception
Peter Bandettini - methods
Karen Berman – clinical
James Blair - clinical
Jay Giedd – developmental/clinical
Christian Grillon – fear conditioning
Ellen Leibenluft – clinical/child bipolar/
Alex Martin – clinical/autism/ cognitive
Daniel Pine – clinical/develop/anxiety
Jun Shen – methods/MRS
Sue Swedo - developmental
Leslie Ungerleider – cognitive/
Daniel Weinberger – clinical (?)
Carlos Zarate – clinical/depression/therapy

NINDS

Leonardo Cohen – plasticity/clinical
Jeff Duyn - methods
Mary K. Floeter – clinical/spinal
Mark Hallet – clinical/movement disorders
?John Park
Daniel Reich,M.D clinical/MS (7T)
William Theodore clinical/epilepsy
Eric Wasserman – Methods TMS/NIRS

NICHD

Peter Basser - Methods

NIDCD

Allen Braun - Cognitive

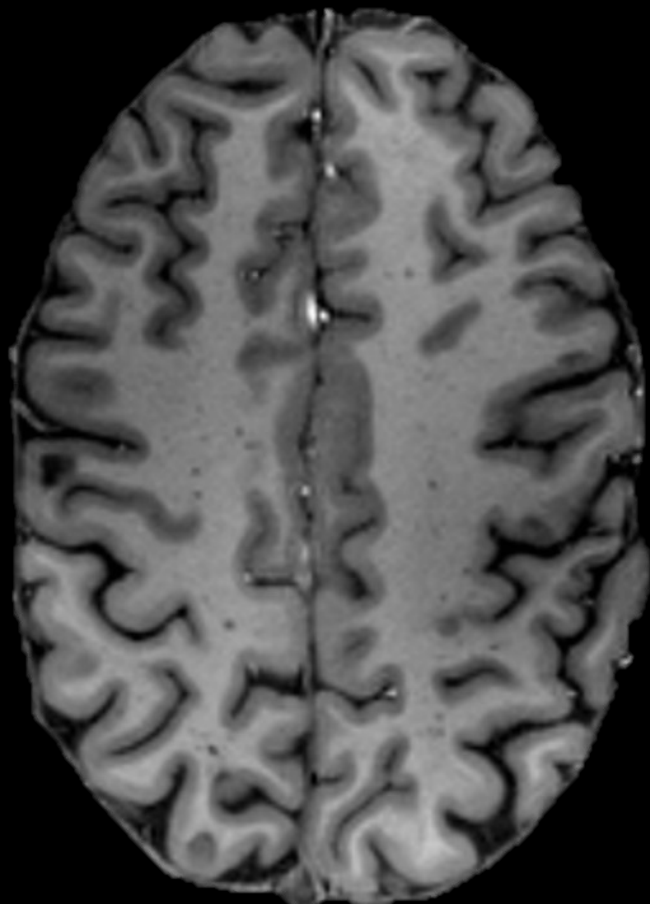
NHGRI

Phil Shaw – Clinical/Developmental ADHD

NCCAM

Catherine Bushnell - Pain

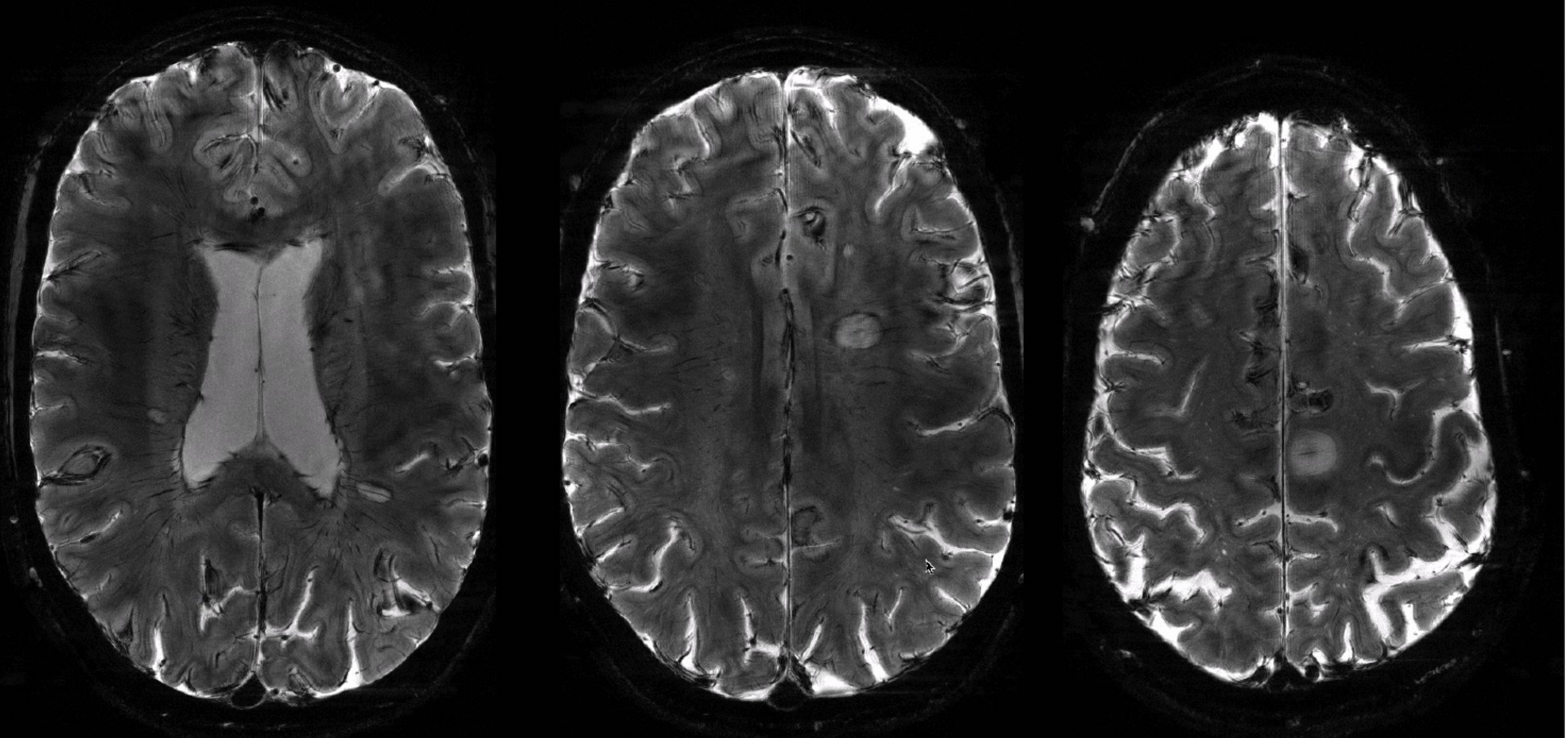
Topography of cortical lesions with 7T MRI



T1w, 0.7 mm isotropic

48-year-old SPMS, EDSS 6.5 and disease duration 18 years

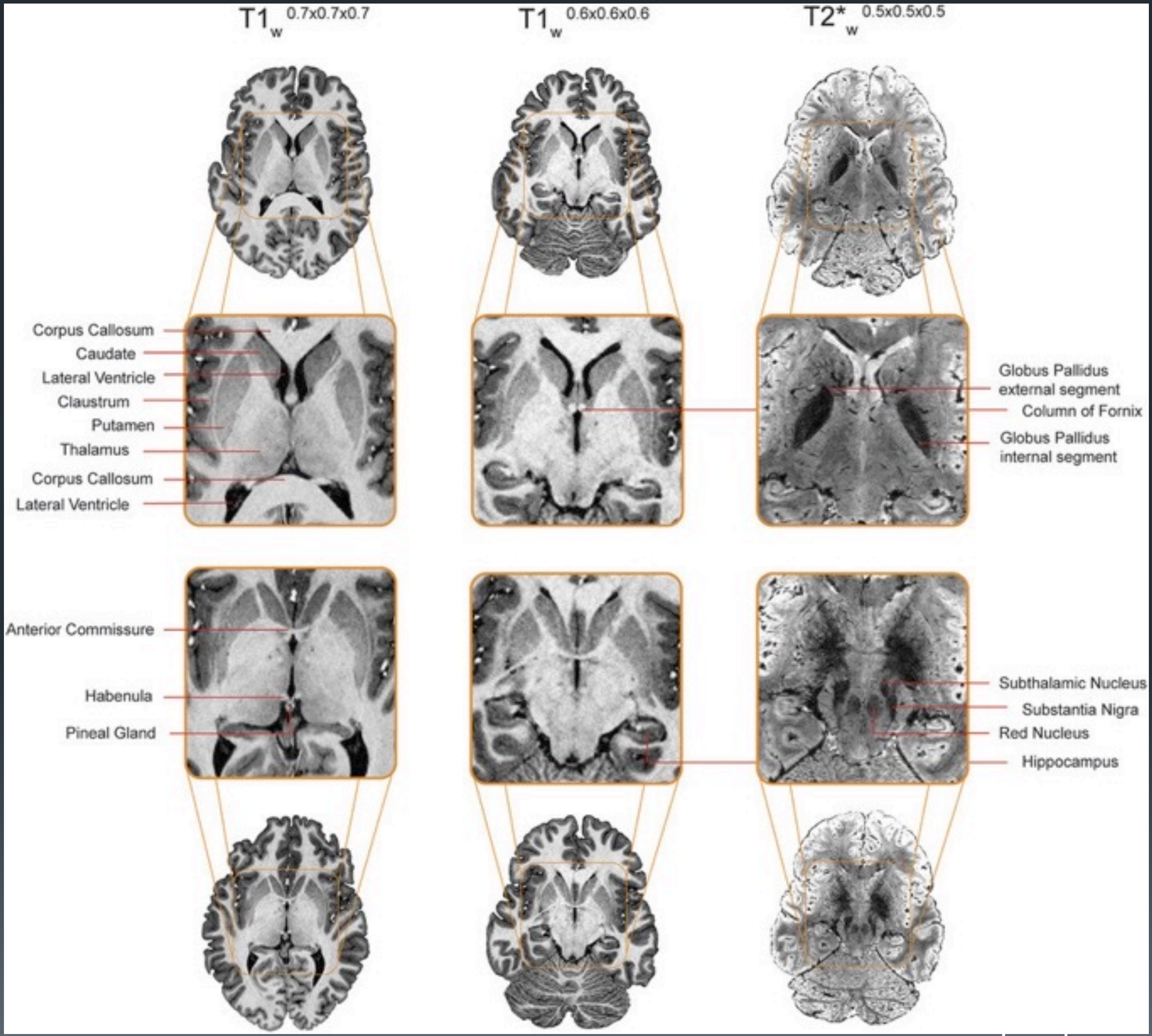
High-resolution GRE imaging in MS



T_2^* weighting ($0.25 \times 0.25 \times 1.5$ mm^3)

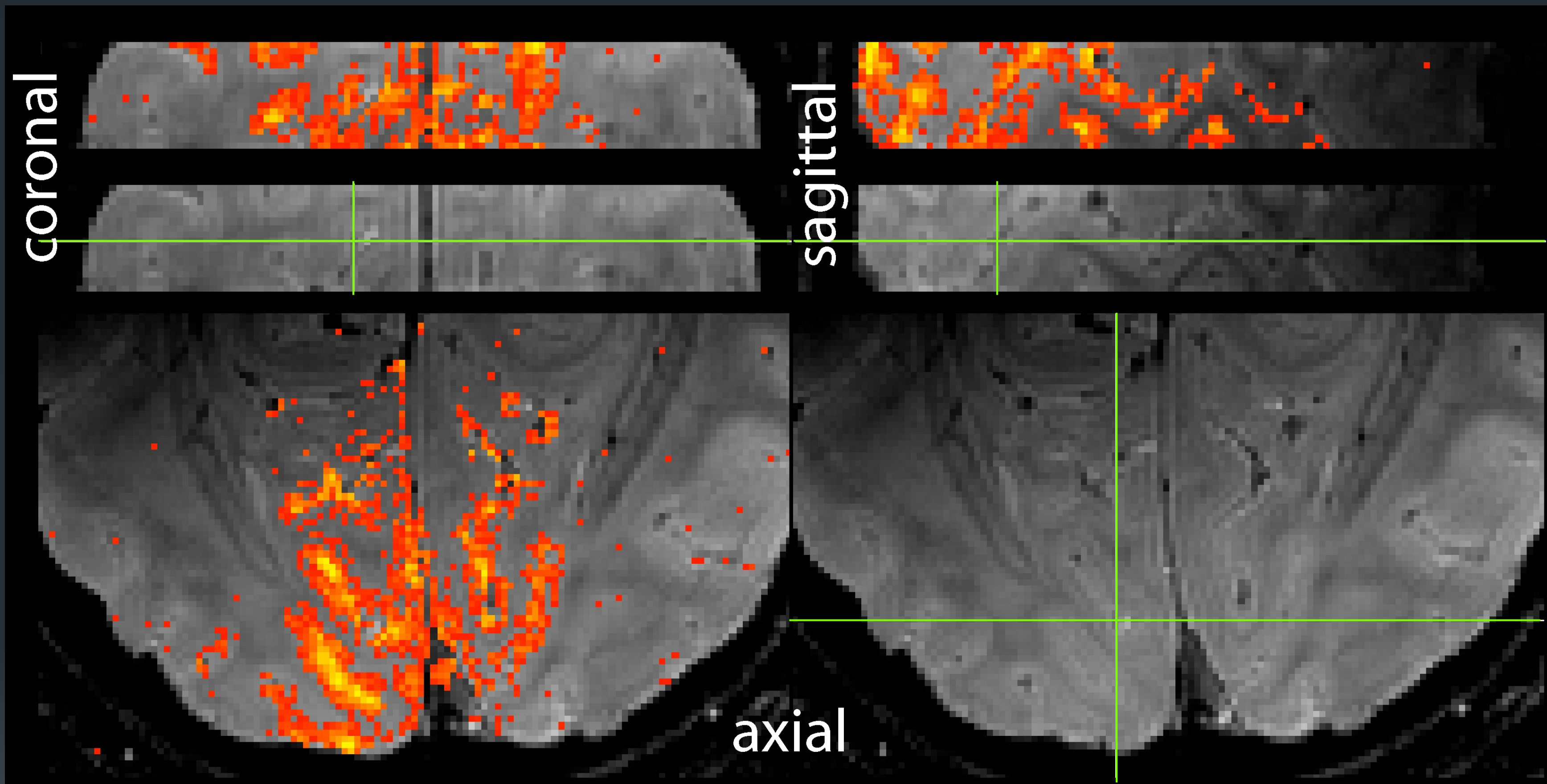
PS, MG, DR

MP2RAGE AT 7T



Forstmann et al, Scientific Data

7T FMRI



High-res 7T: 0.58 x 0.58 x 0.58 mm^3 = 0.2 mm^3
High-res 3T: 1 x 1 x 1 mm^3 = 1 mm^3
Conventional 3T: 3 x 3 x 3 mm^3 = 27 mm^3
(FMRIB/Karla Miller)