NEUROIMAGING AT NIH*

Sean Marrett / FMRIF / NIMH

Functional MRI Summer Course 2018

*Neuromodulation too

OUTLINE

1. MRI and neuroimaging resources
   - Functional MRI Facility
   - Scientific Statistical Computing Core / AFNI Galactic HQ
   - MEG
   - In-vivo NMR Facility/Mouse Imaging Facility
   - Neurophysiological Imaging Facilty
   - Scientific Instrumentation Branch
2. Some history of brain MRI@NIH and examples of methods/studies developed here
3. Overview of research in FMRIF
4. Postcard presentations of work by selected FMRIF PI's

OTHER NEUROIMAGING RESOURCES@NIH

- Scientific Statistical Computing Core

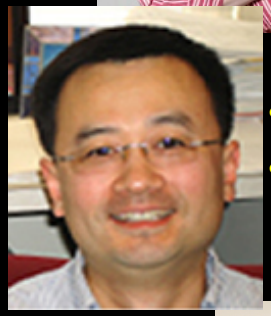
- In-vivo NMR Facility/Mouse Imaging Facility and Neurophysiological Imaging Facilty (NHP) - Building 39 / MRS Core

- Section on Instrumentation
- Data science and sharing team
- Machine learning team
- Biowulf/HPC (3100 nodes/81000 core + GPU Linux cluster)
  - 20Pb storage

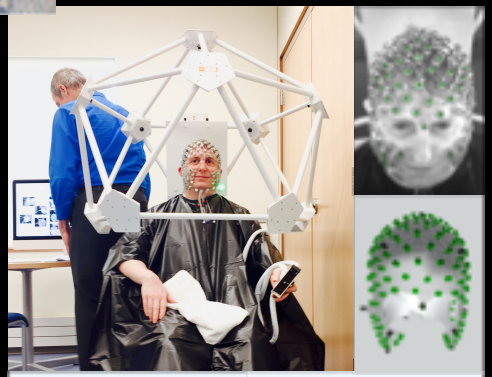
MEG/MRS/SIMULTANEOUS EEG/FMRI

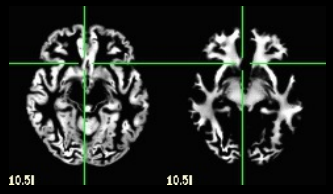
- MEG

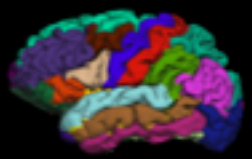
- MRS

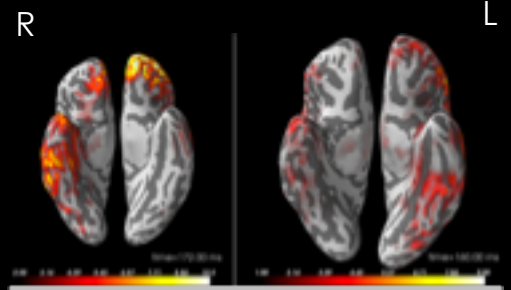


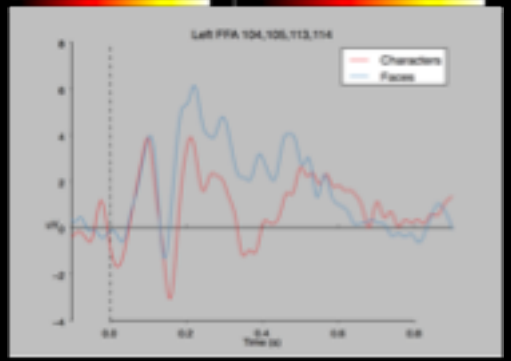
- MRS methods development
- 13C / Glu / Gln / GSH (glutathione) quantification











(F)MRI AT NIH

1. History of developing technology and methods, investigating contrast mechanisms as well as applying standard and cutting edge techniques

2. Expertise ranging from novel coil design to pulse sequence development thru experimental paradigms to multimodal imaging, machine learning …

3. Wide array of clinical and basic neuroscience questions being investigated

Not always easy to know everything that is going on and who is doing what.

Ask us early and ask often if you have questions or ideas

NEUROMODULATION AT NIH

1. Early work (1990s) by Cohen, Hallet, Wasserman and others on TMS - developing technology and methods
2. TMS used by many groups in NIMH and NINDS
3. Non-invasive neuromodulation unit (NNU) establish by Sarah Lisanby in 2016
    1. NNU now moving/installing simultaneous TMS/FMRI system on 3TD

INCOMPLETE LIST OF SCIENTIFIC AND TECHNICAL INNOVATIONS

1. Natural history of multiple sclerosis studied with MRI
2. Functional MRI using EPI / high-field FMRI
3. Diffusion weighted imaging DWI/ diffusion tensor imaging
4. Longitudinal studies of normal and clinical brain development (and analysis)
5. Gradient coil design
6. Practical parallel coil/receiver design
7. Using multi-echo BOLD and ICA for denoising
8. FMRI decoding/informational mapping
9. Ultra-high field susceptibility-weighted phase imaging
10. Laminar FMRI imaging using CBV at ultra-high field (VASO)

(SHORT) HISTORY OF FMRI AND BRAIN MRI AT NIH

1. In-Vivo NMR Center (established 1987)
2. Early FMRI studies in animals (Bob Turner, 1987)
3. Initial human functional studies (4T 1993)
4. Some key developments from NIH MRI researchers
5. Digest of Neuromodulation

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, 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.

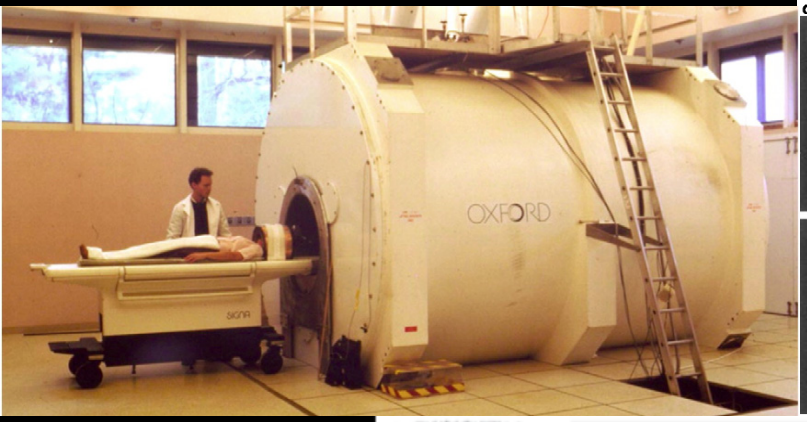
While imaging of human anatomy is perhaps the most widely known aspect of NMR, the procedure has been used at NIH for more than 30 years for basic research in organic and physical chemistry, and, more recently, for biochemistry and physiology. NMR can provide information on the structure of molecules.

"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. Ching-Nien Chen, BEIB; Jadie Ireland, ORS; Dr. Andrew Dwyer and Dr. Joseph Frank, CC-Diagnostic Radiology Department.

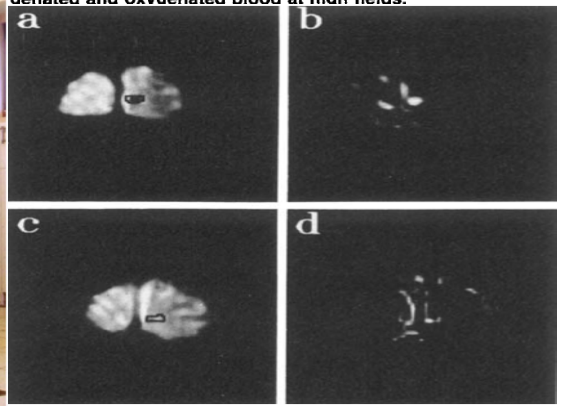
Robert Turner – EPI FMRI/DWI/Hardware



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

Functional Mapping

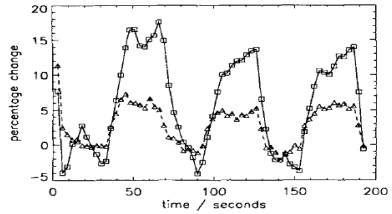


FIG. 2. Plot of fractional change in 4 T (squares) and 1.5 T (triangles) EPI image intensity versus time in the eight-voxel regions of interest in the visual cortex shown in Fig. 1, for a volunteer experiencing alternate 30-s periods of rest and photic stimulation. Details of acquisition for the 4 and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

Contents lists available at ScienceDirect

NeuroImage

journal homepage: www.elsevier.com/locate/ynimg

Review

The NIH experience in first advancing fMRI

Robert Turner *

Department of Neurophysics, Max-Planck-Institute for Human Cognitive Brain Sciences, Stephanstrasse 1A, 04103 Leipzig, Germany

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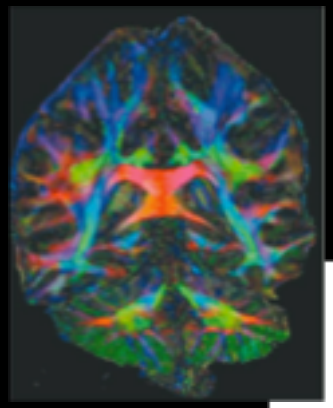
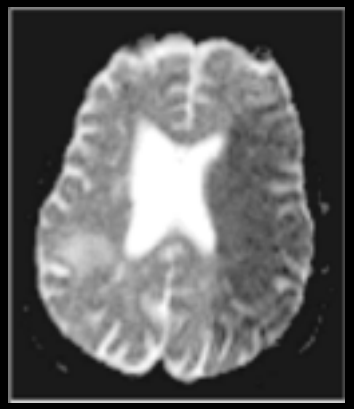
ABSTRACT

The introduction of functional MRI at NIH in 1992 was the outcome of research goals first formulated by Turner in 1983. Between 1988 and 1990, Turner worked at NIH on actively-shielded gradient coils and the implementation of EPI-based techniques, especially diffusion-weighted EPI. His work on hypoxia in cat brain in 1990 directly inspired Ken Kwong's demonstration of BOLD contrast in humans at MGH in May 1991.

Peter Basser – DTI





Estimation of the Effective Self-Diffusion *Tensor* from the NMR Spin Echo

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

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The diagonal and off-diagonal elements of the effective self-diffusion tensor, $\mathbf{D}^{\text{eff}}$, are related to the echo intensity in an NMR spin-echo experiment. This relationship is used to design experiments from which $\mathbf{D}^{\text{eff}}$ is estimated. This estimate is validated using isotropic and anisotropic media, i.e., water and skeletal muscle. It is shown that significant errors are made in diffusion NMR spectroscopy and imaging of anisotropic skeletal muscle when off-diagonal elements of $\mathbf{D}^{\text{eff}}$ are ignored, most notably the loss of information needed to determine fiber orientation. Estimation of $\mathbf{D}^{\text{eff}}$ provides the theoretical basis for a new MRI modality, diffusion *tensor* imaging, which provides information about tissue microstructure and its physiologic state not contained in scalar quantities such as T_1, T_2, proton density, or the scalar apparent diffusion constant.

edge an explicit relationship between the effective self-diffusion tensor and the NMR signal has not been elucidated. Moreover, the off-diagonal elements of $\mathbf{D}^{\text{eff}}$ have not been measured or even considered. Their importance cannot be minimized (*16*). Although differences among $\mathbf{D}^{\text{eff}}$'s diagonal elements, D^{eff}_{xx}, D^{eff}_{yy}, and D^{eff}_{zz}, are a necessary condition to demonstrate anisotropic diffusion, all diagonal and off-diagonal elements of $\mathbf{D}^{\text{eff}}$ must be known to characterize it adequately, and specifically to infer the mean microscopic displacements of protons.[1]

In this paper, we show how to calculate the effects of anisotropic diffusion on the NMR signal in imaging and spectroscopy by relating the diagonal and off-diagonal elements

Succesful MRI entrepeneurs at NIH

Alan P. Koretsky, Ph.D.

Senior Investigator

Laboratory of Functional and Molecular Imaging

NINDS

Scientific Director

NINDS

VIEW SITE

Robert Balaban
(SD NHLBI)

1991 – Rapoport & Giedde begin longitudinal pediatric study of normal brain development.
1992 – 4T installed in NHLBI in NMRF
1992 – First successful FMRI @ NIH

1992 – Peter Basser publishes first DTI paper

1995 – Plasticity/Motor learning FMRI (Ungerleider/Turner)
1997 – Ungerleider, Haxby, Martin – Vision, attention, FFA etc
1999 – Alan 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

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

2006-2010

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

2010 – Upgrade of 3T-C to mr750 platform

2011-2018

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

2011 – 1.5T GE replaced by Siemens Skyra 3T
2012 – 11.7T (human) gets to field (& quenches)
2015 – NIAAA Siemens Prisma (NIMH & NINDS 25% time each)

2016 - 2017 – upgrade of 3T-A/3T-B
2018 - NMRF 7T (!!)
2018 – 11.7T returns to NIH (!!!)

GROWTH IN FMRI AND BRAIN MRI IN NMRF AND FMRIF NIH

1987 – 1x1.5T Scanner
2000 – First commercial dedicated 3T scanners
2002 – 7T (experimental)
2010 – 7T (clinical) 11.7T
2018 – 6x3T scanners + 2x7T + 1x11.7T

~7000 exams/subjects per year

All papers involving MRI from Bethesda

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

7888 document results Choose date range to analyze: 1981 to 2015 Analyze

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

Year	Documents
2015	550
2014	592
2013	586
2012	590
2011	488
2010	458
2009	485
2008	439
2007	406
2006	414
2005	351
2004	340
2003	332
2002	257
2001	208
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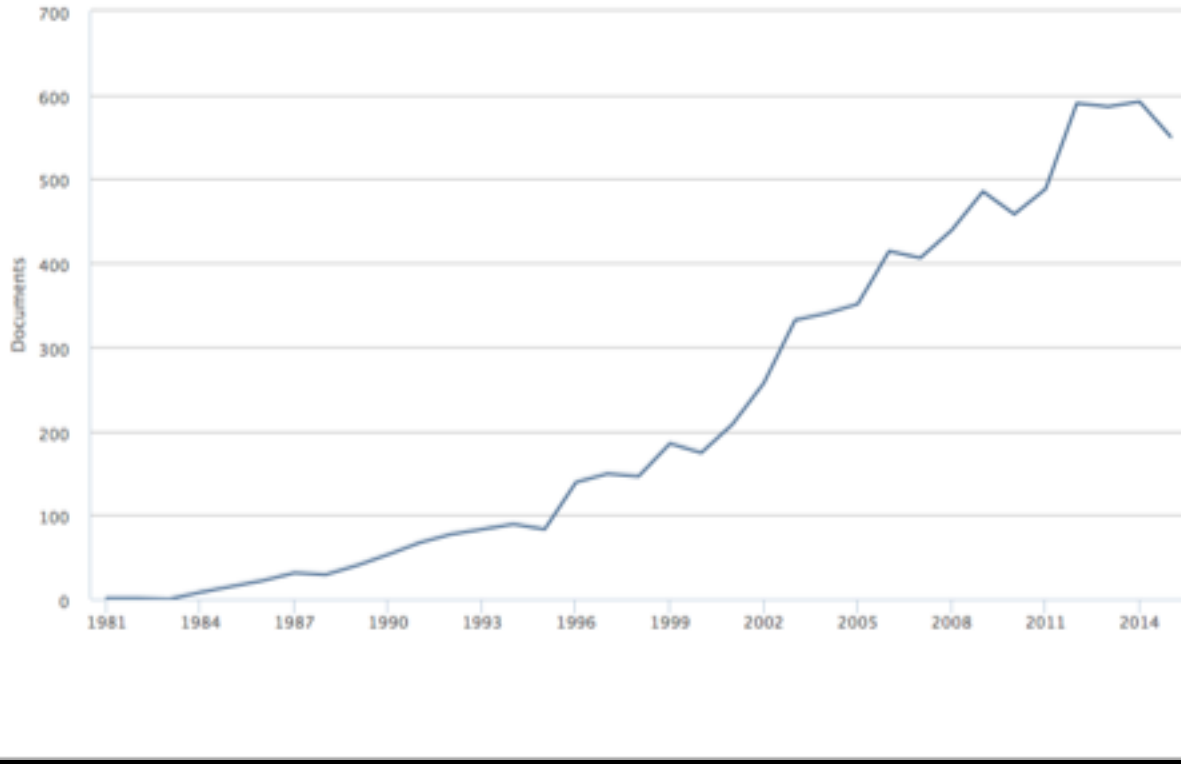
1999	185



FMRIF Publications: 2000-2018

- **More than 1200 papers** (31 PI's using the core)
  - 70% from NIMH
  - 20% from NINDS
  - 5-10% from other institutes

- **92000 citations**

- **H-index > 150**

- **Listing of all papers up to 2015:**

https://fmrif.nimh.nih.gov/public/FMRIF_all_Aug2015.xlsx/at_download

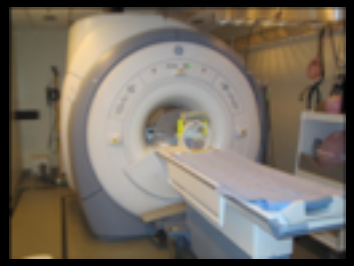
In-Vivo NMR Center Magnets

FMRIF Scanners

3TA
GE MR750

- *GE 32-channel head coil*
- *GE HNS coil*
- *P31 loop coil*
- *Quadrature spectroscopy coil (GABA experiments)*
- *GE Quadrature head coil*

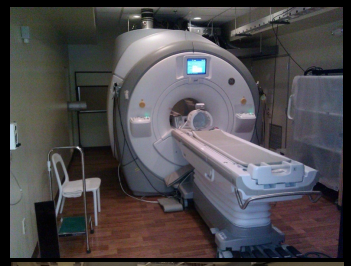
Gradient: 50 mT/m, Slew Rate: 200/m/s



3TB

- *GE 32-channel head coil*
- *GE Quadrature head coil*
- *Nova Medical 16-channel head-coil*

Gradient: 50 mT/m, Slew Rate: 200/m/s



3TC

- *GE 32-channel head coil*
- *GE Quadrature head coil*
- *Nova Medical 32-channel head coil*

Gradient: 50 mT/m, Slew Rate: 200T/m/s

3TD
Siemens Skyra

- *Siemens 20-channel head coil*
- *Siemens 32-channel head coil*
- *Siemens 12-channel spine array (built into table)*

Gradient: 45 mT/m, Slew Rate: 200T/m/s

7T
Siemens

- *Siemens 1-channel Tx / 32-channel Rx coil*
- *Siemens 8-channel Tx / 32-channel Rx coil*
- *QED dual-tuned 1H / 31P coil*

Gradient: 70 mT/m, Slew Rate: 200T/m/s

NIAAA 3T: Siemens Prisma

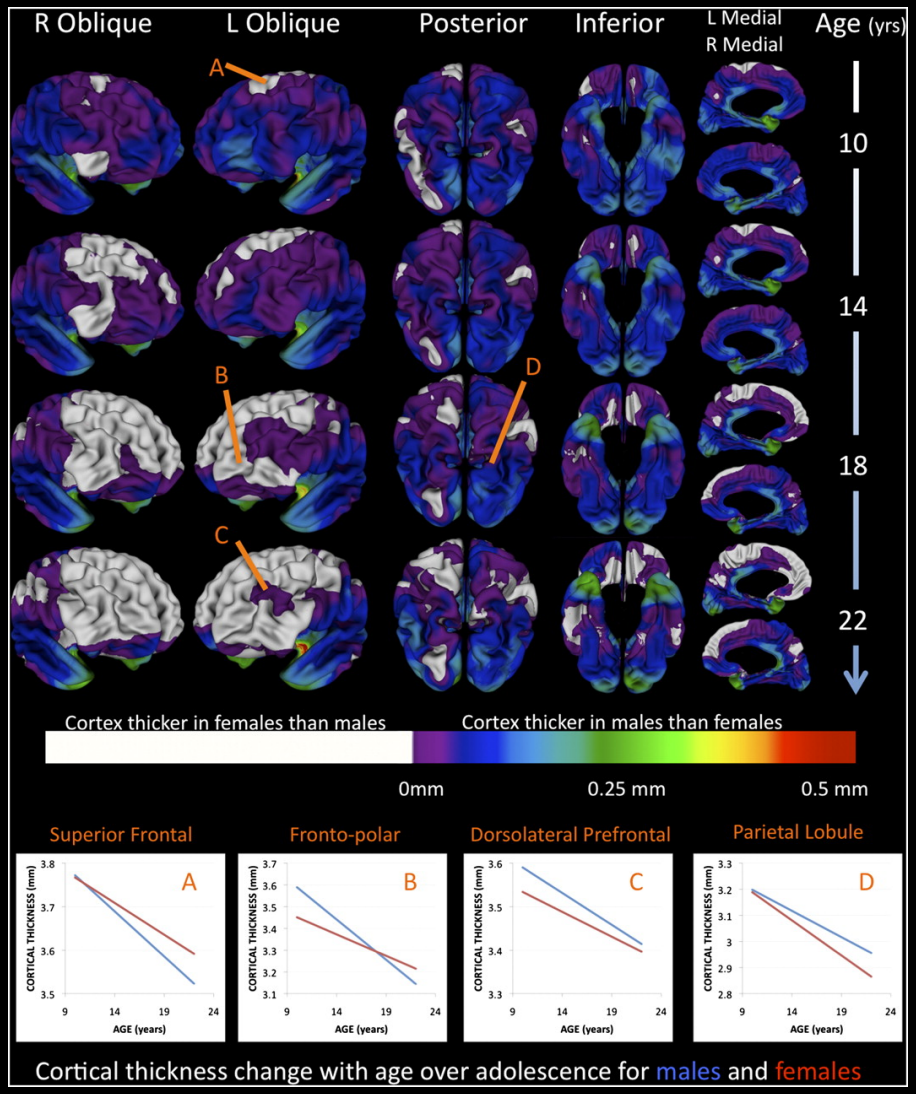
- *Siemens 20-channel head coil*
- *Siemens 64-channel head-neck coil*
- *Siemens 12-channel spine array (built into table)*

Gradient: 80 mT/m, Slew Rate: 200T/m/s

other resources

ARMIN RAZNAHAN (DEVELOPMENTAL NEUROGENOMICS – AKA @BOGGLERAPTURE)

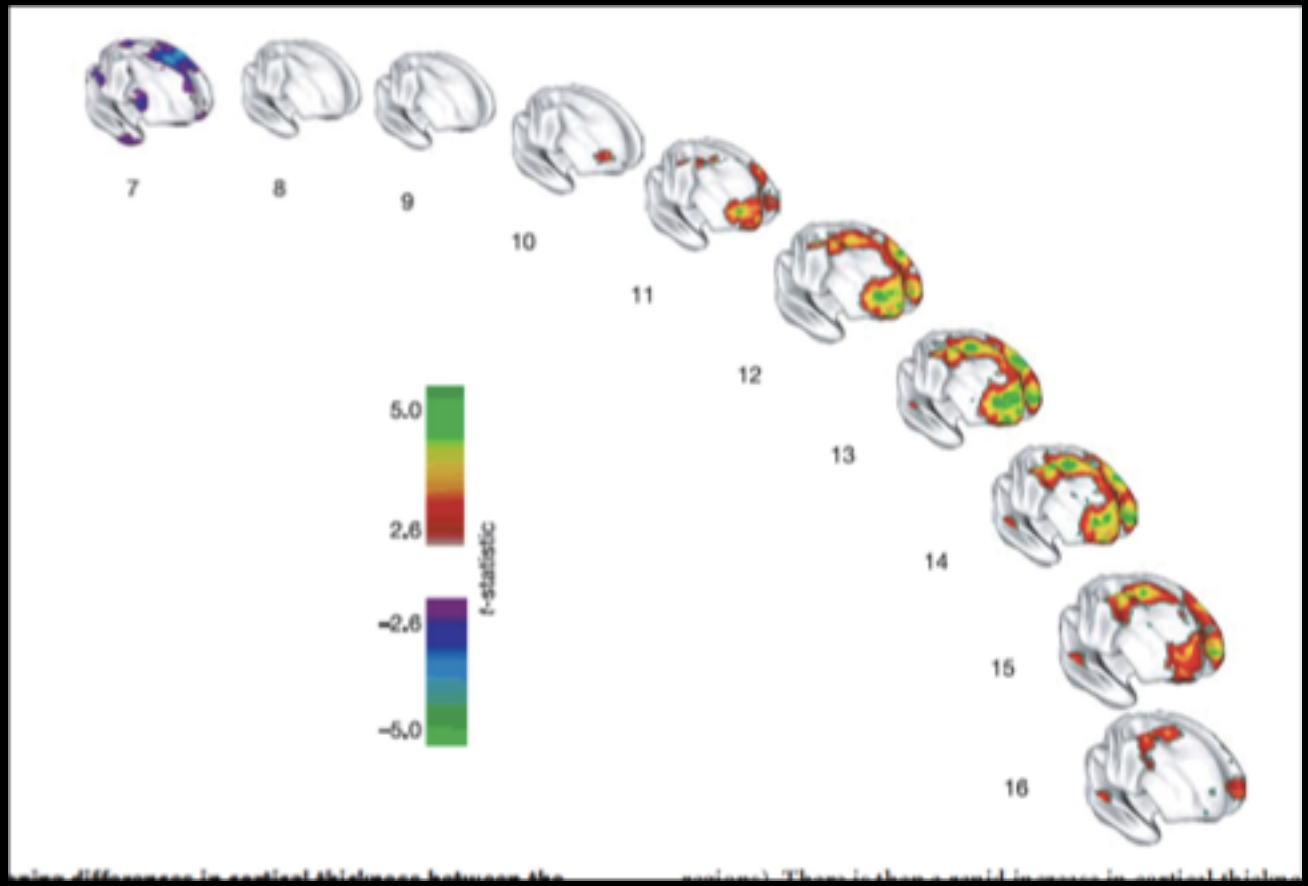
- Longitudinal MRI studies of brain development in children
- Linking genetics and environment to brain development
- Methodology – impact of motion on imaging-derived phenotypes



PROMO, longitudina

PHIL SHAW/NHGRI NEUROBEHAVIORAL UNIT

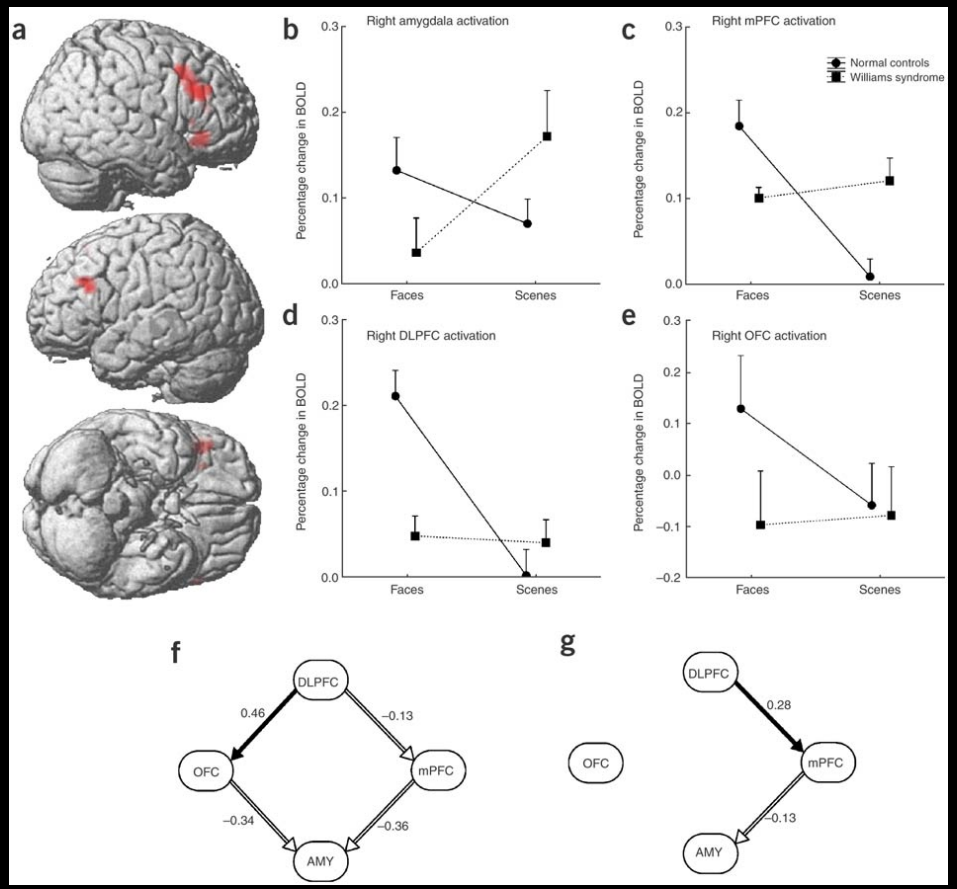
- Longitudinal studies of brain development in youths with ADHD
- CPB Alumnus / Well known studies of brain development & IQ etc
- Cortical development trajectories

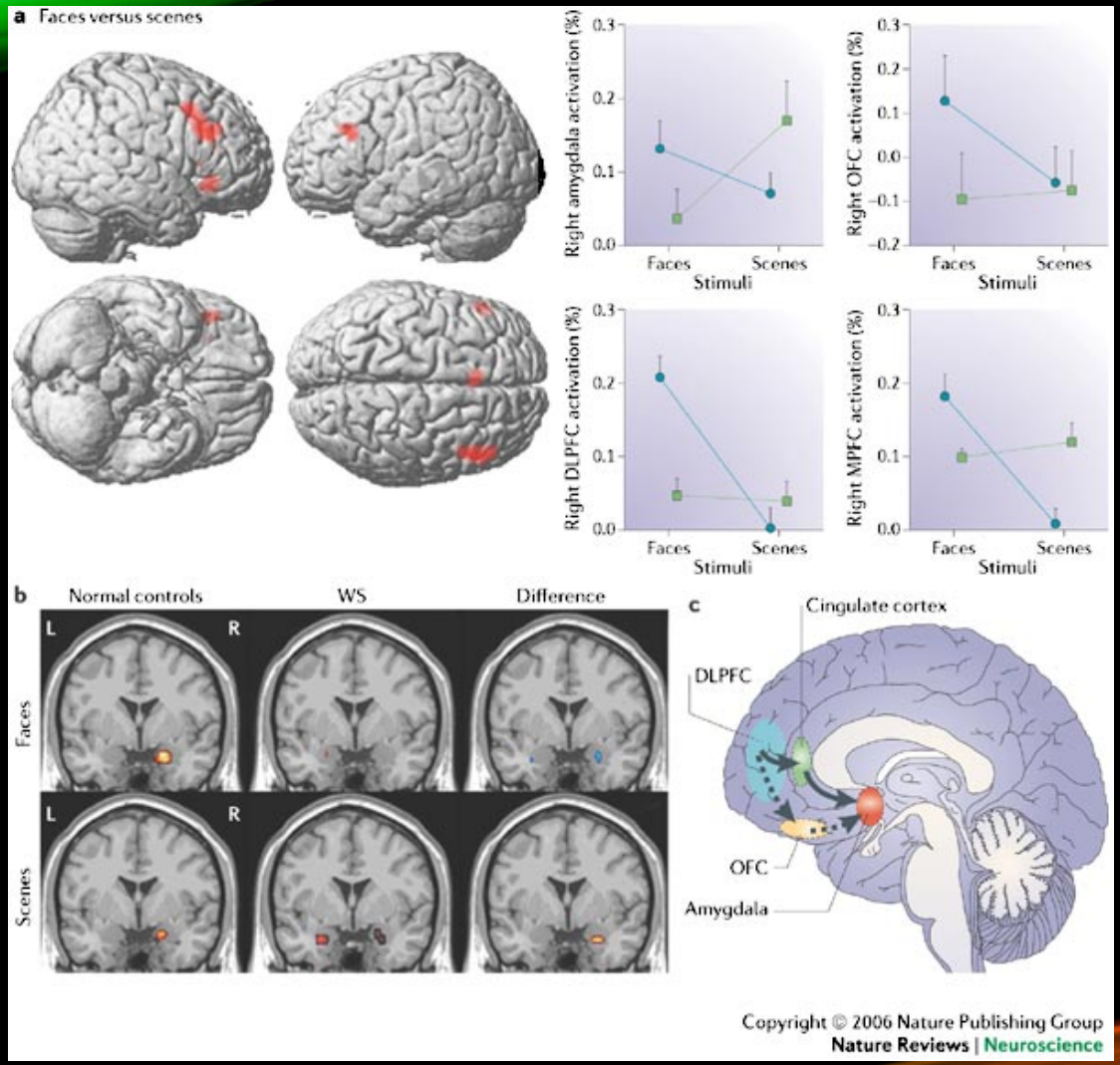


- Intellectual ability and cortical development in children and adolescents , Shaw, P., et al (2006) Nature, 440 (7084), pp.
- Attention-deficit/hyperactivity disorder is characterized by a delay in cortical maturation Shaw, P., et al (2007) PNAS
- Neurodevelopmental trajectories of the human cerebral 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

KAREN F. BERMAN / SECTION INTEGRATIVE NEUROIMAGING

- Developmental neuropsychiatric disorders – imaging genomics including schizophrenia
- Genetics of social cognition (Williams Syndrome)
- Multi-modality imaging



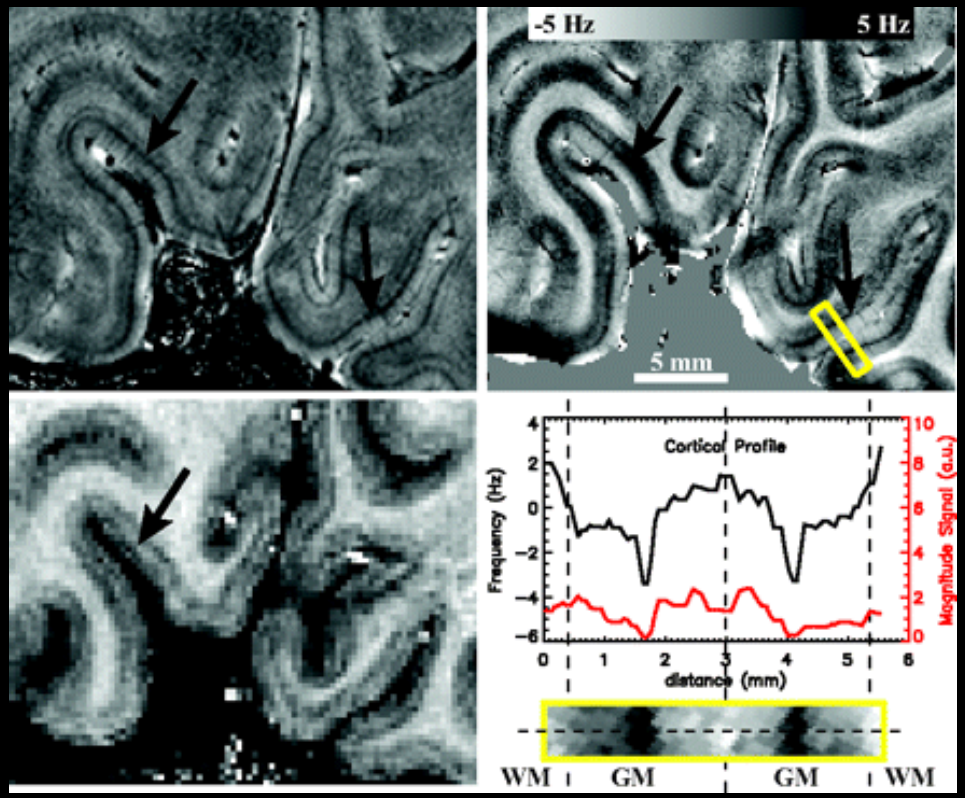


From Berman Group:. *Nature Reviews Neuroscience* **7**, 380–393 (May 2006)

nature REVIEWS NEUROSCIENCE

JEFF DUYN/ADVANCED MRI (METHODS DEVELOPMENT)

- Imaging methods/technology especially parallel imaging
- Magnetic susceptibility contrast imaging – mechanisms & applicati
- 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&reco

- 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) Neur
- Susceptibility contrast in high field MRI of human brain as a function of tissue iron content Yao, B. et al (2009) NeuroImag
- 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

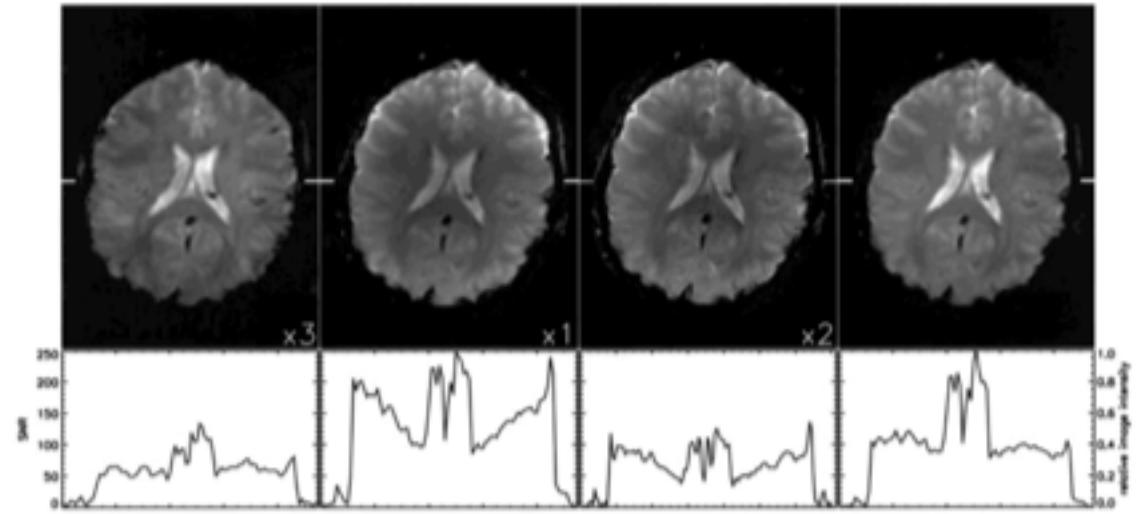
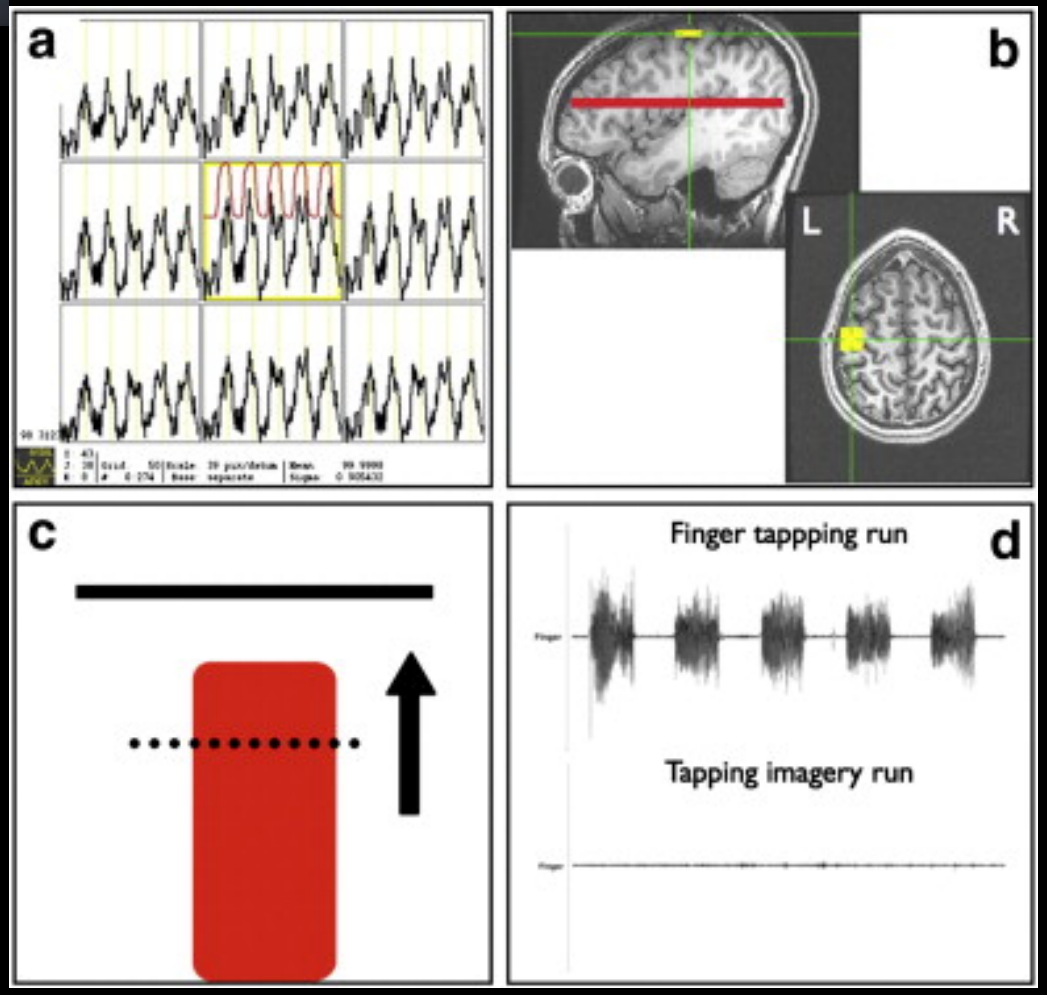


FIG. 2. Performance of the 16-channel coil compared to the standard 28-cm GE birdcage head coil. The top row shows a single slice of the acquired EPI data. The three leftmost images are SNR maps. Their relative scaling factor is indicated in the lower right corner of the image. The rightmost image shows 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

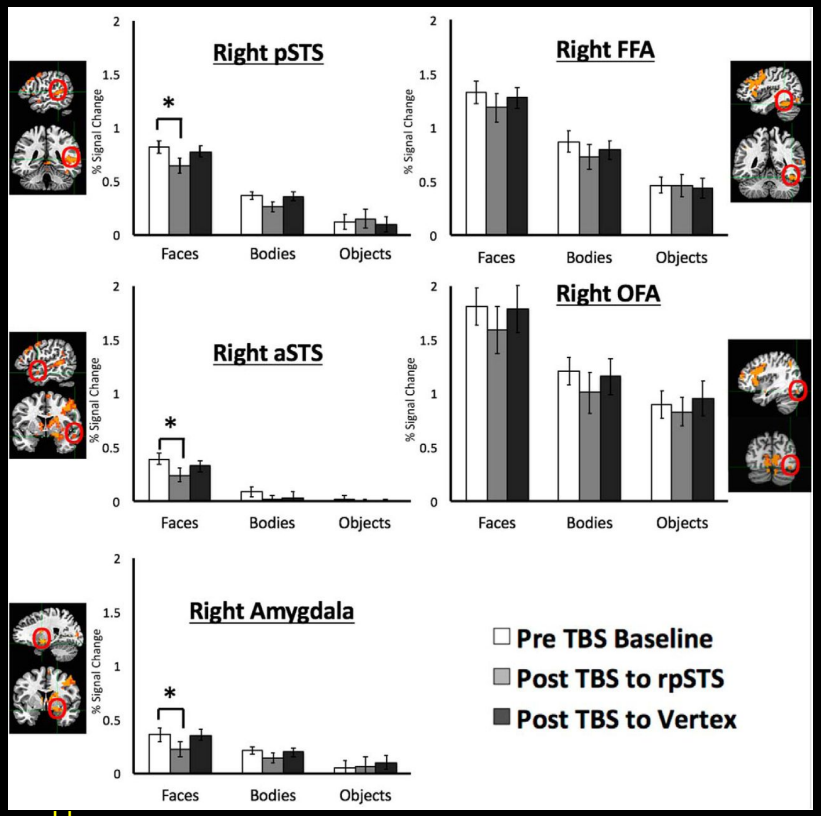


- Voon et al, Dopamine and impulse control

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

LESLIE UNGERLEIDER/NEUROCIRCUITY SECTION

Early FMRI adopter
Functional architecture of perceptual and attention systems
Functional anatomy of face processing
Comparative NHP/human imaging/anatomical studies
Combining TMS and fMRI



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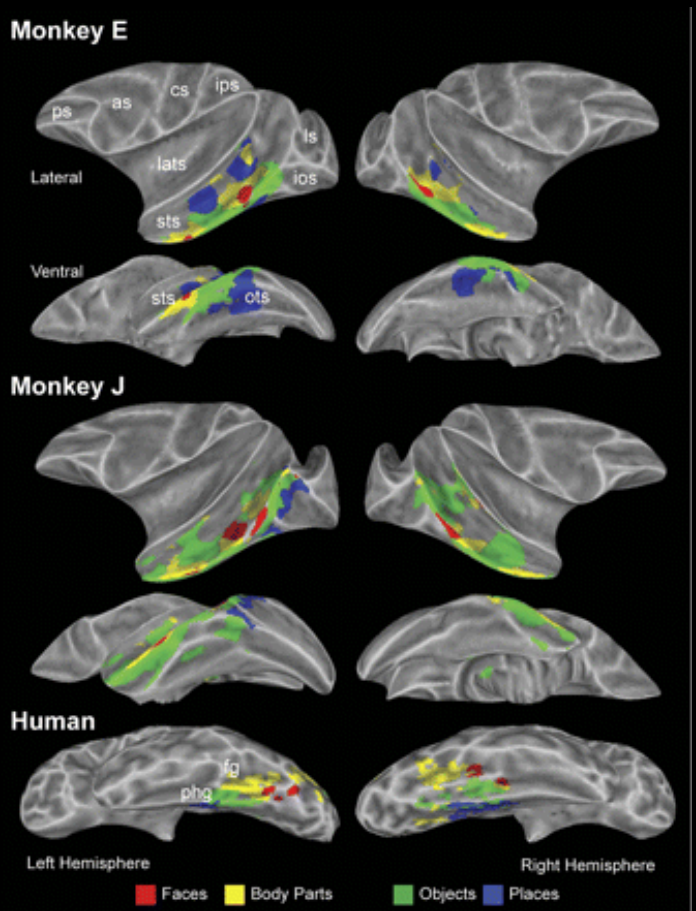
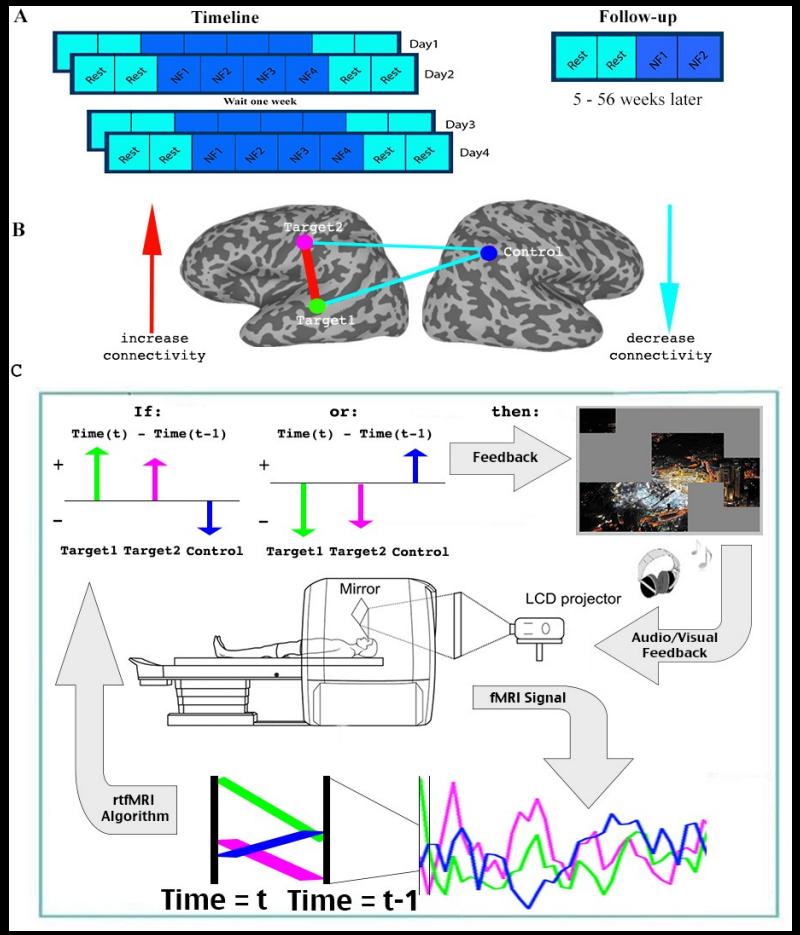


ALEX MARTIN/SECTION ON COGNITIVE NEUROPSYCHOLOGY

- Neural foundation of memory and social cognition
- Object and category semantic representation in cortex
- Representation of social network information in normals & autistics
- Real-time fMRI & neurofeedback



- Direct modulation of aberrant brain network connectivity through real-time NeuroFeedback
- (Ramot et al eLife 2017)

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

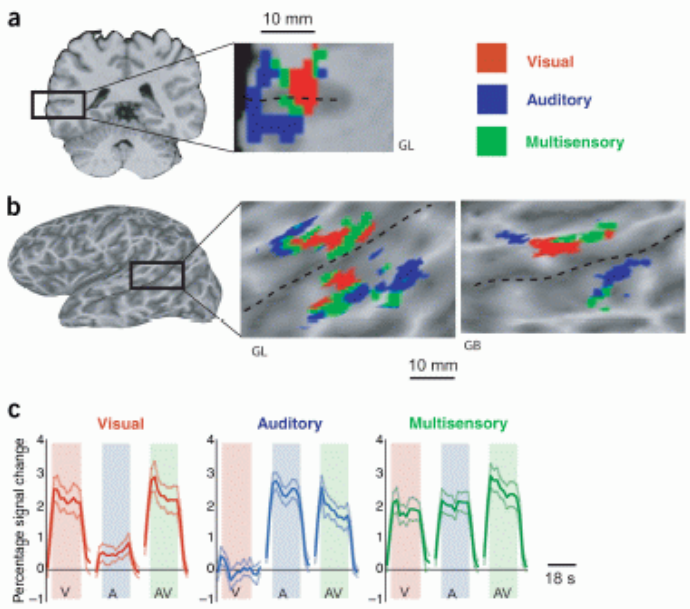


Figure 1 Patchy organization within the STS-MS. (a) Coronal section with enlargement of the left STS (dashed line). Colors show relative response to unisensory visual (V) and auditory (A) tools. Orange (visual patches): V > A, $P < 0.05$. Blue (auditory patches): A > V, $P < 0.05$. Green (multisensory 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

- Director FMRIF
- Maximizing information extracted from FMRI time series
- Multi-echo EPI for improved fMRI & rs-fMRI clustering
- Understanding rsFMRI mechanisms and confounds
- Information mapping/decoding FMRI
- 7T -High-resolution/layer-specific imaging with CBV and BOLD

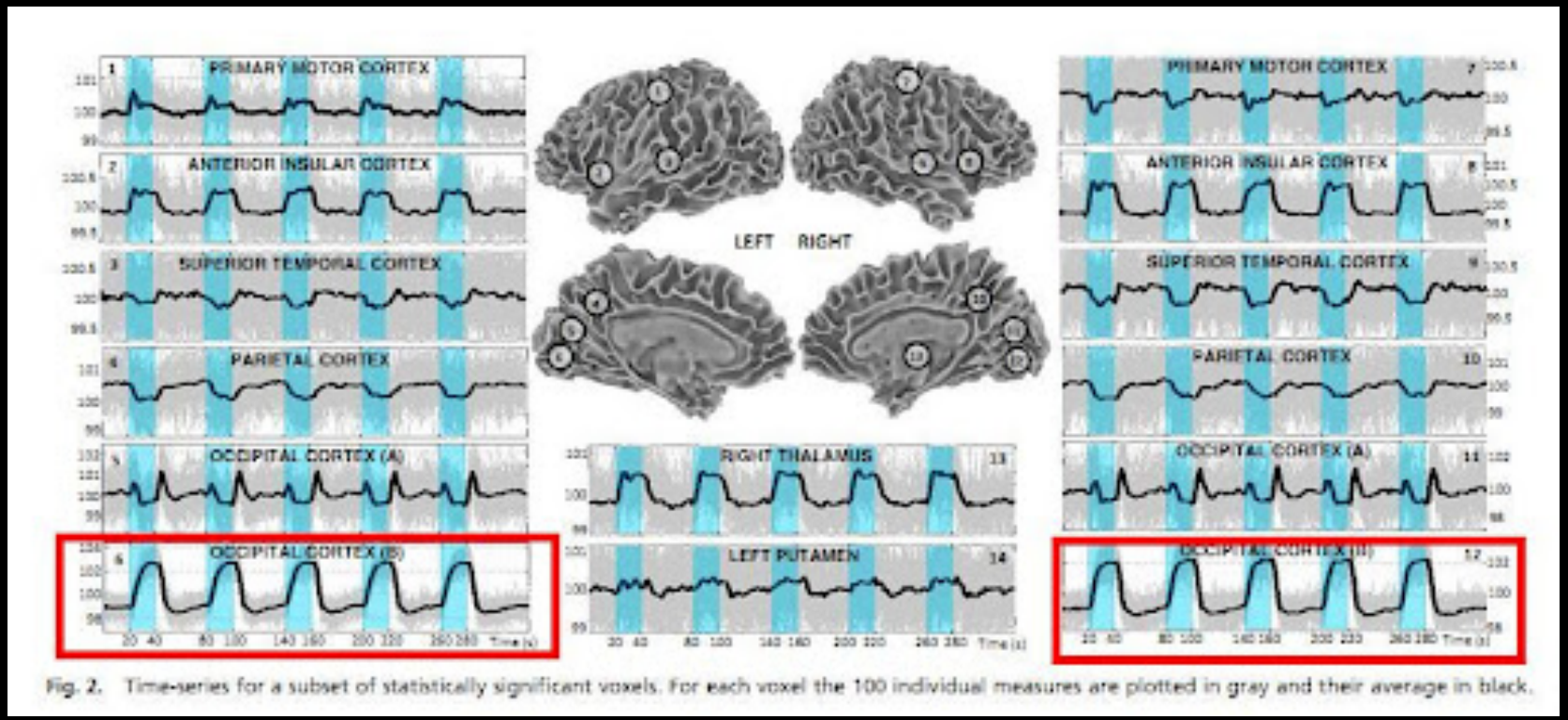
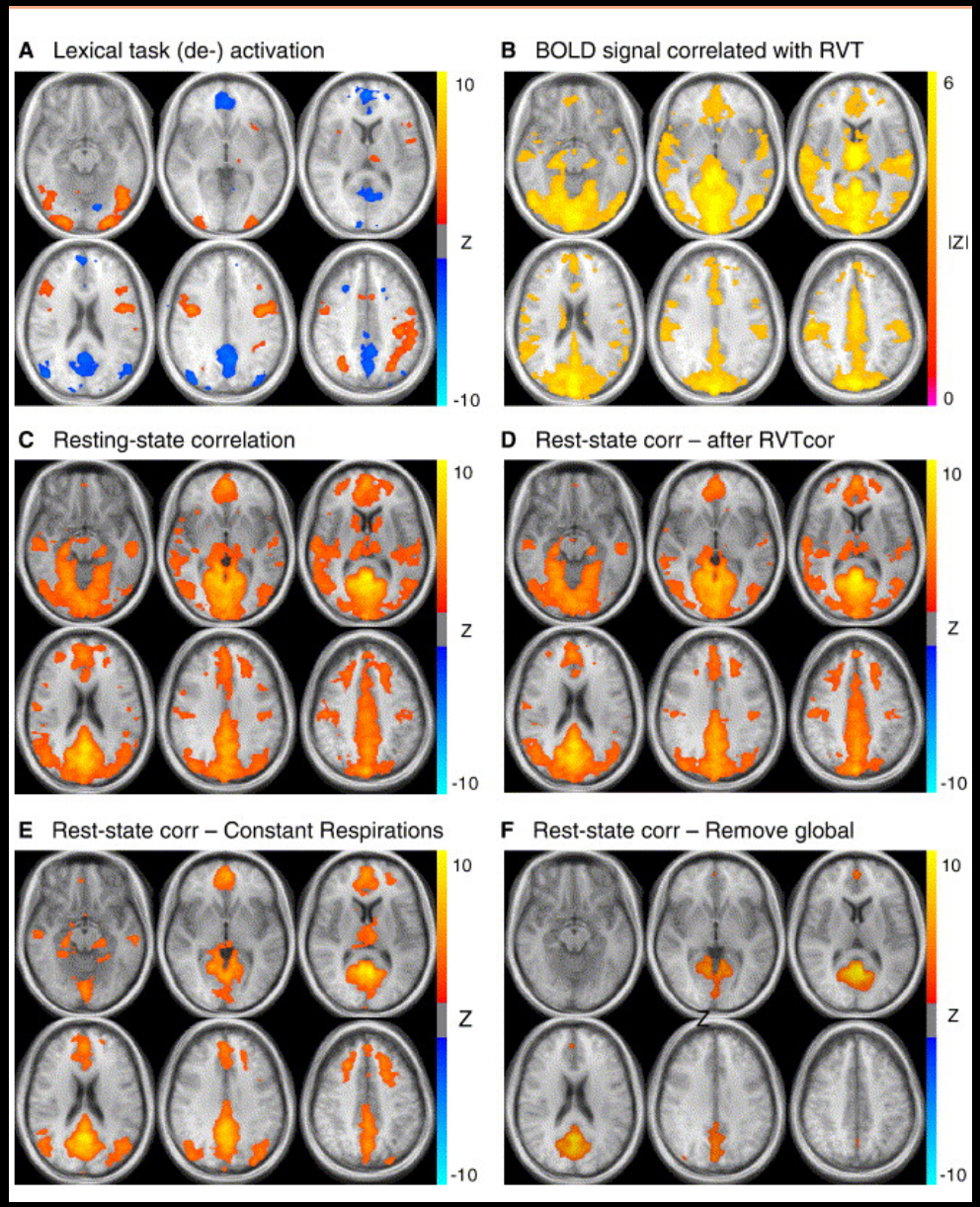


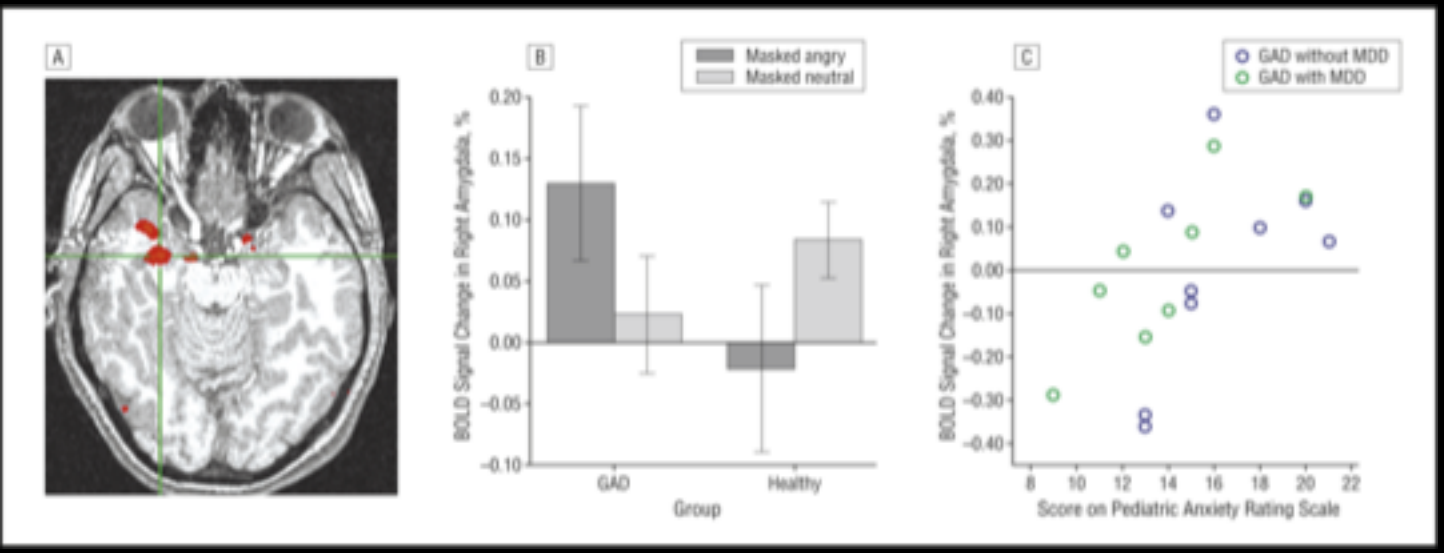
Fig. 2. Time-series for a subset of statistically significant voxels. For each voxel the 100 individual measures are plotted in gray and their average in black.

SEPARATING RESPIRATORY-VARIATION-RELATED FLUCTUATION FROM NEURONAL-ACTIVITY-RELATED FLUCTUATIONS IN FM (BIRN ET A



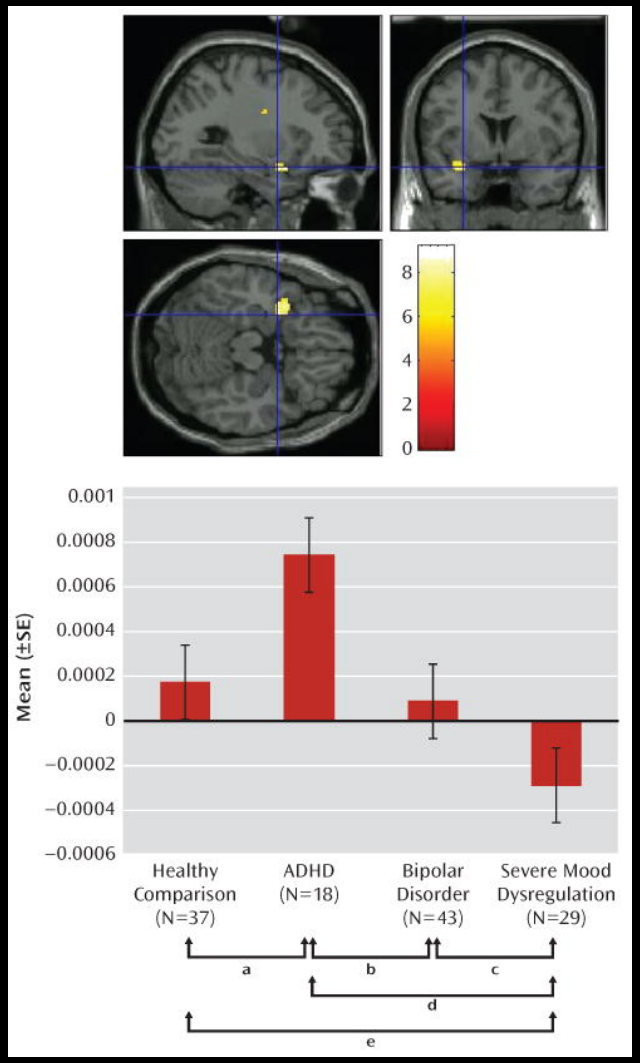
DANIEL PINE/ DEVELOPMENTAL &AFFECTIVE NEUROSCIENCE

- fMRI studies pediatric & adolescent anxiety
- Fear and threat processing in adolescent patient groups
- Individual differences in neurocognitive function and treatment outcome



ELLEN LEIBENLUFT/BIPOLAR DISORDERS

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



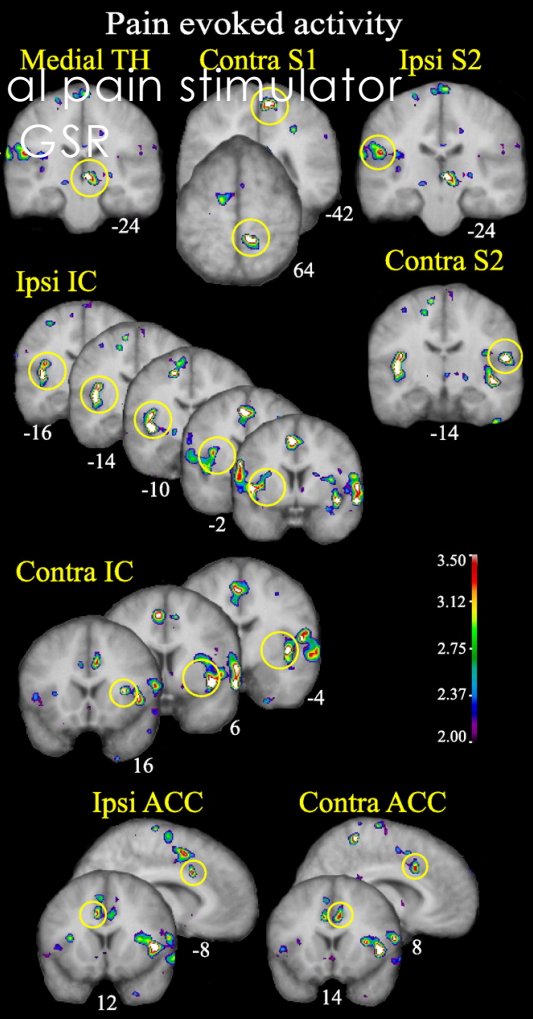
- **Cross-sectional & longitudinal abnormalities in brain structure in children with SMD or BD (Adelman et al, 2012)**
- **Amygdala activation during emotion processing of neutral faces in children with severe mood dysregulation versus ADHD or bipolar disorder (Brotman et al, AM. J Psychiatry, 2010)**

Catherine Bushnell/NCCIH

- 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.



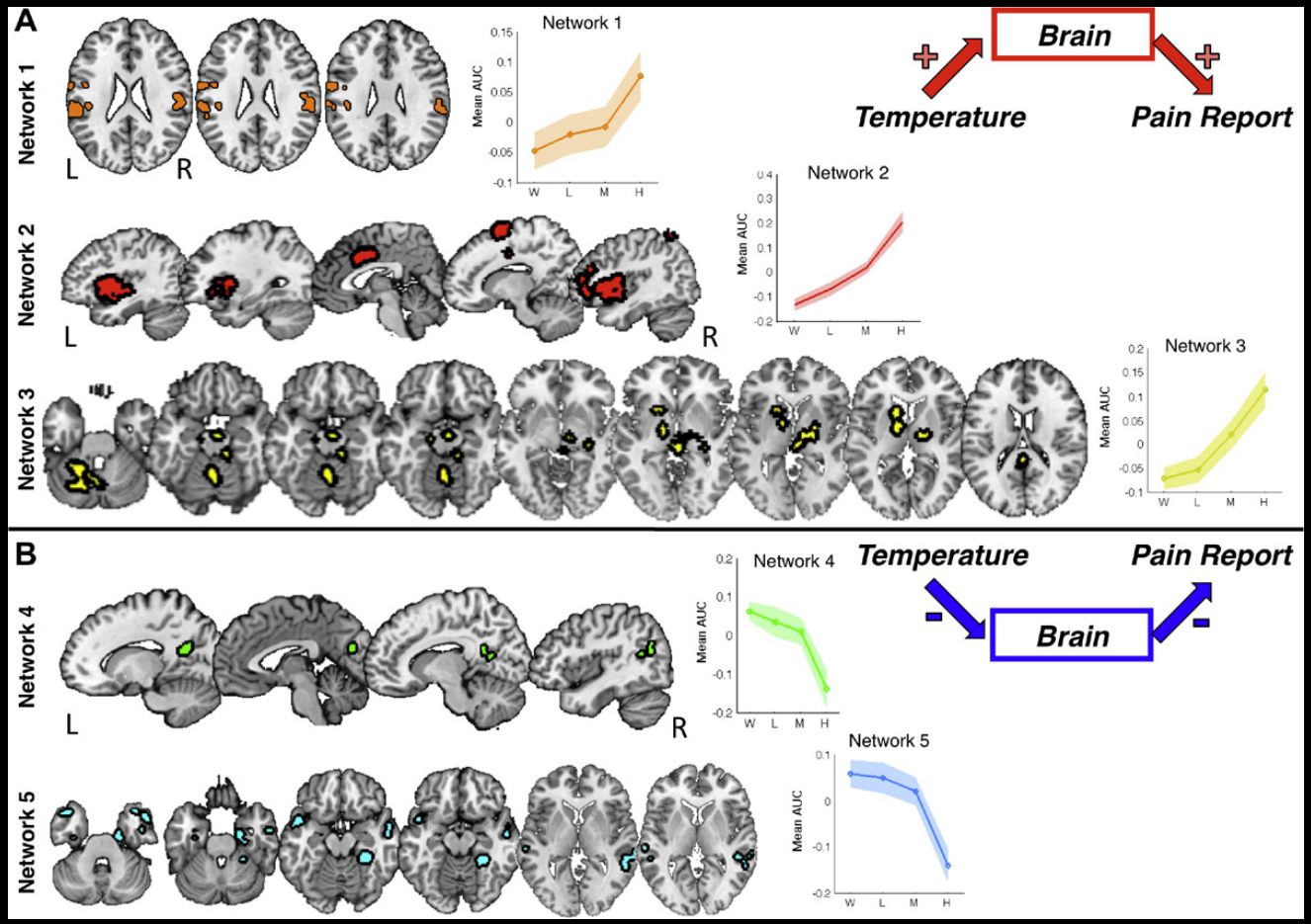
Chantal Villemure, and M. Catherine Bushnell J. Neurosci. 2009;29:705-715

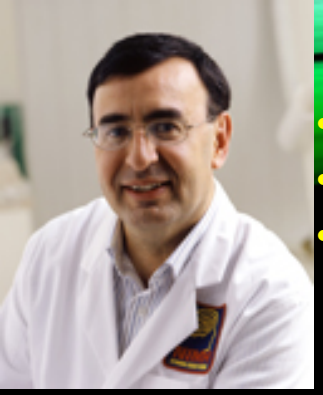
Lauren Atlas/NCCIH
(Affective Neuroscience&Pain)

Recruited from NYU in 2015

studies of how belief and expectation influence pain perception

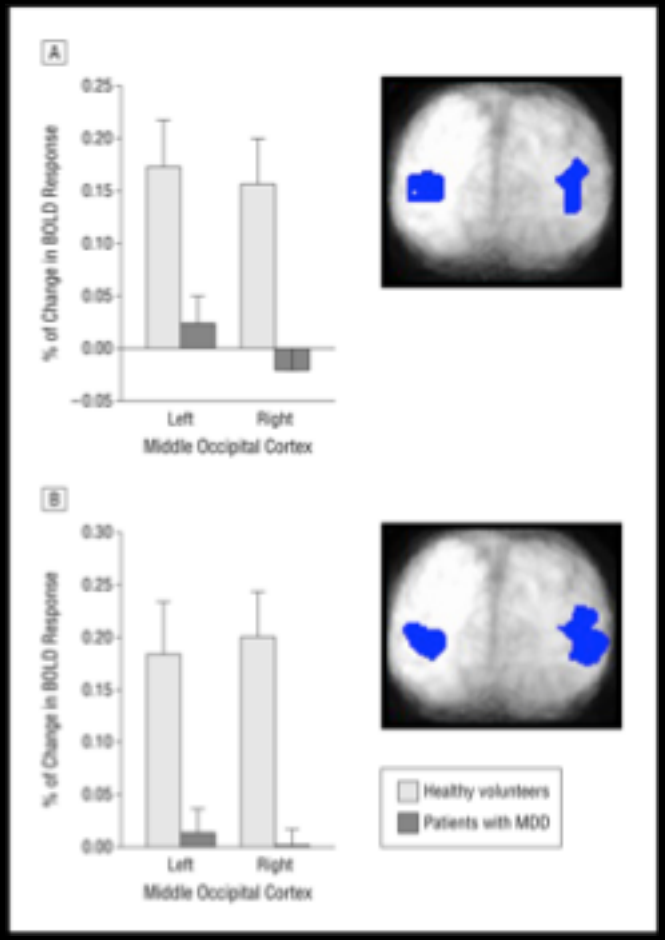
Uses: thermal pain stimulator
Analgesics, eye tracking, GSR





CARLOS ZARATE/EXPERIMENTAL THERAPEUTICS

- Multimodal studies of fast-acting glutamatergic antidepressants
- Functional MRS
- Studies treatment of MDD with simultaneous EEG/FMRI

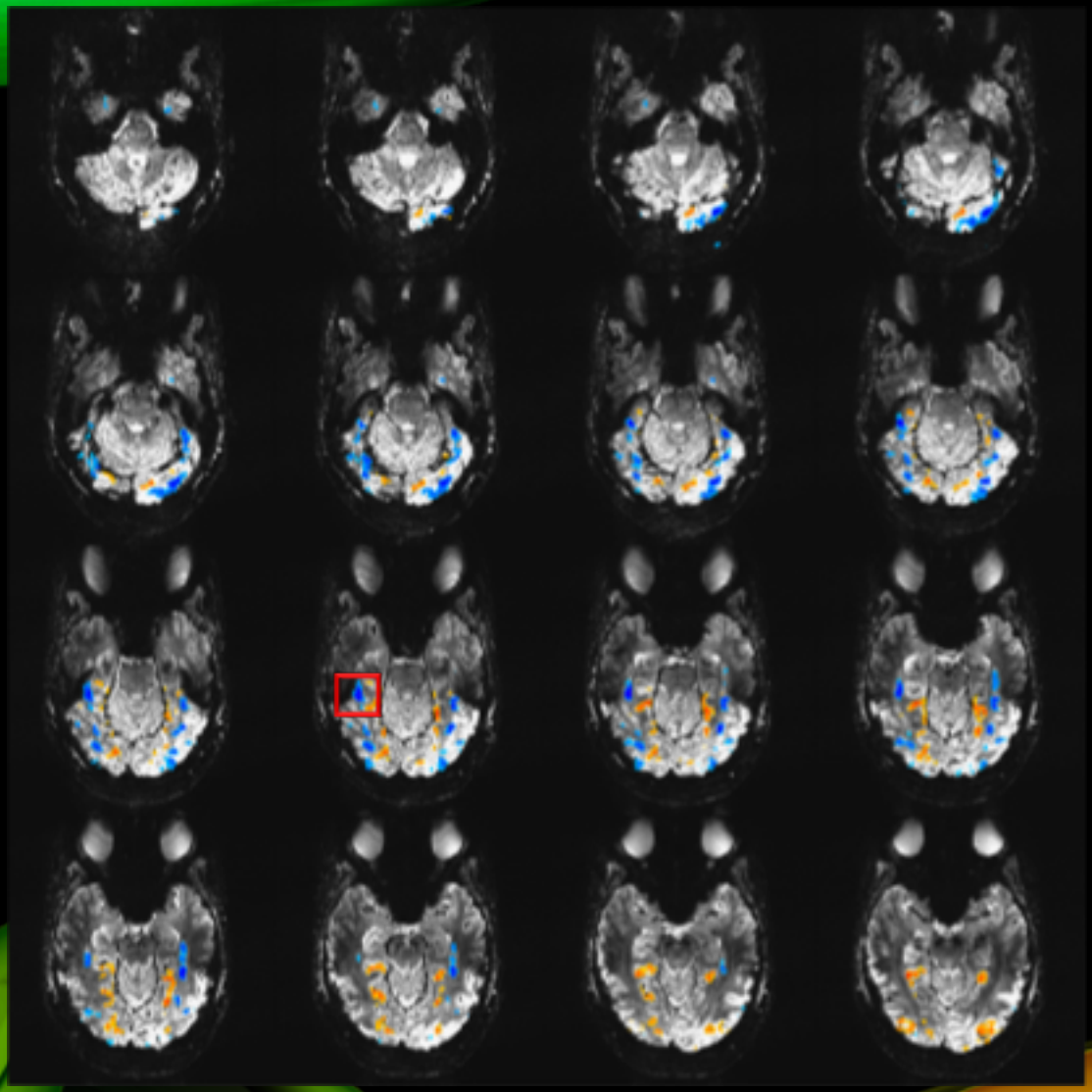


7T MRI (FMRIF) – 2011

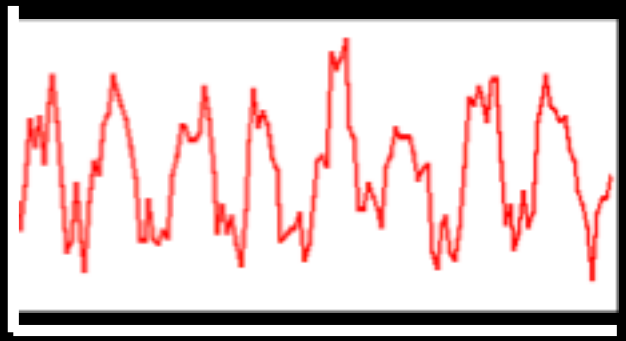
Actively-shielded 7T MRI

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

32-channel head coil

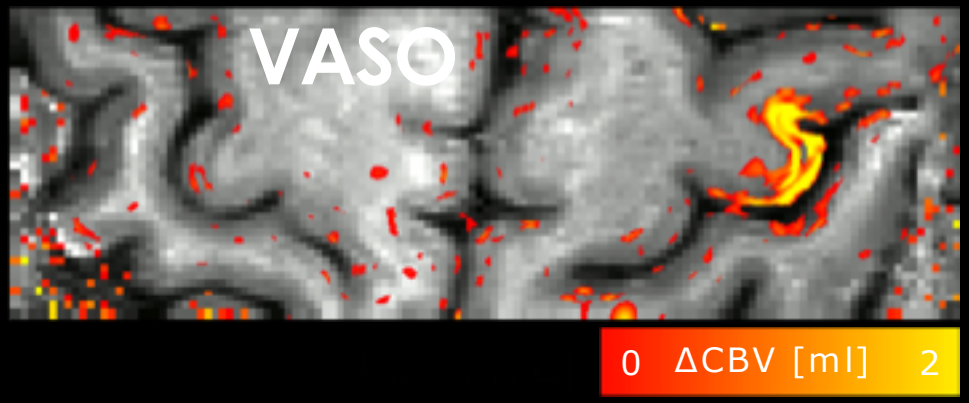


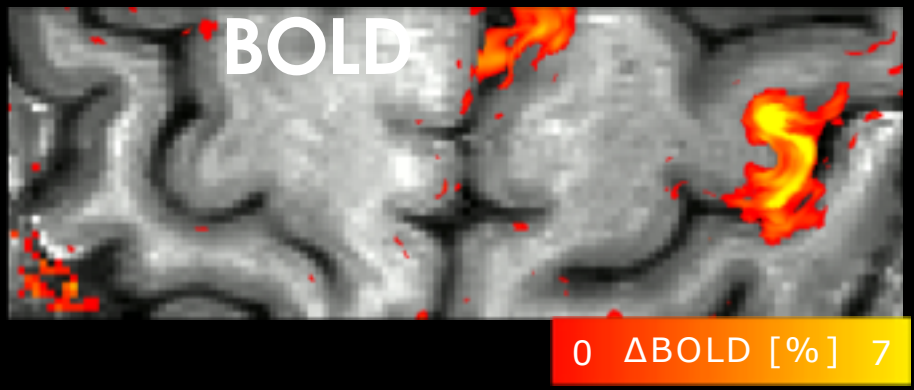
R FFA



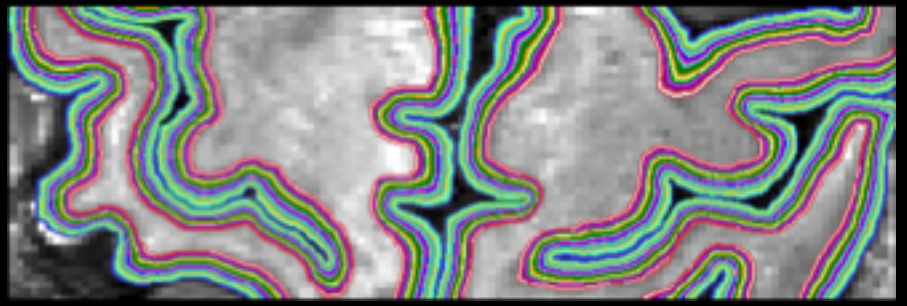
Courtesy: Silson & Bake

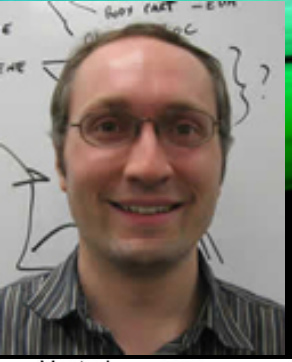
7T FMRI
HIGH-RESOLUTION FMRI AT 7T





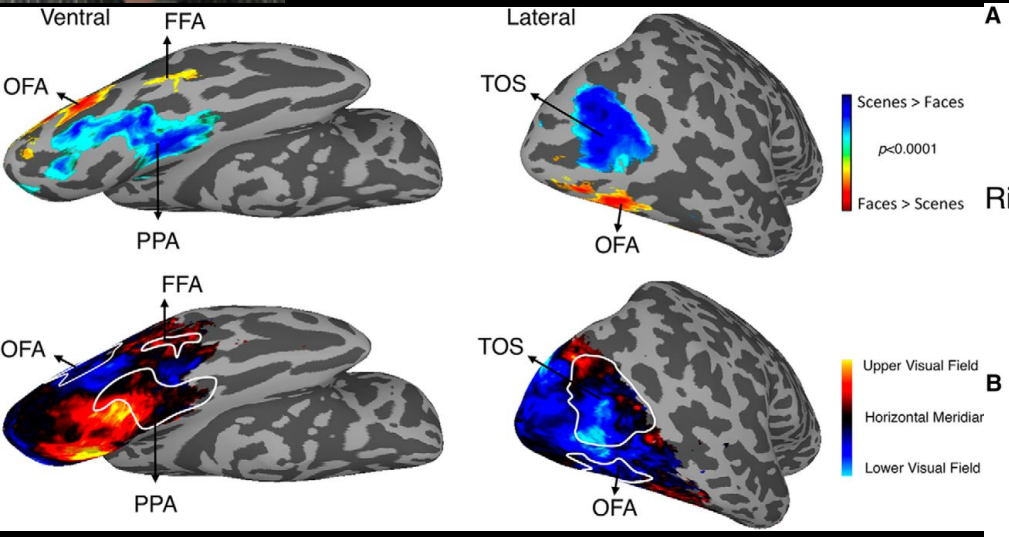
0.8mmx0.8mmx1.5mm
(Huber/Bandettini)

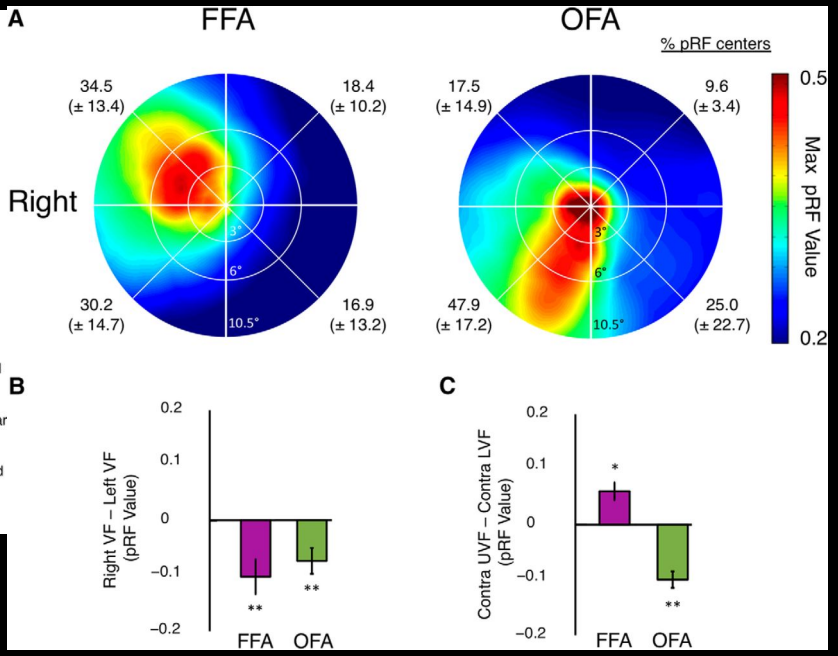




CHRIS BAKER/SECTION ON LEARNING AND PLASTICITY

- Object, face and body representations in the human brain/task eff
- Neural basis of visual object learning/
- Interaction between bottom-up & top-down processing



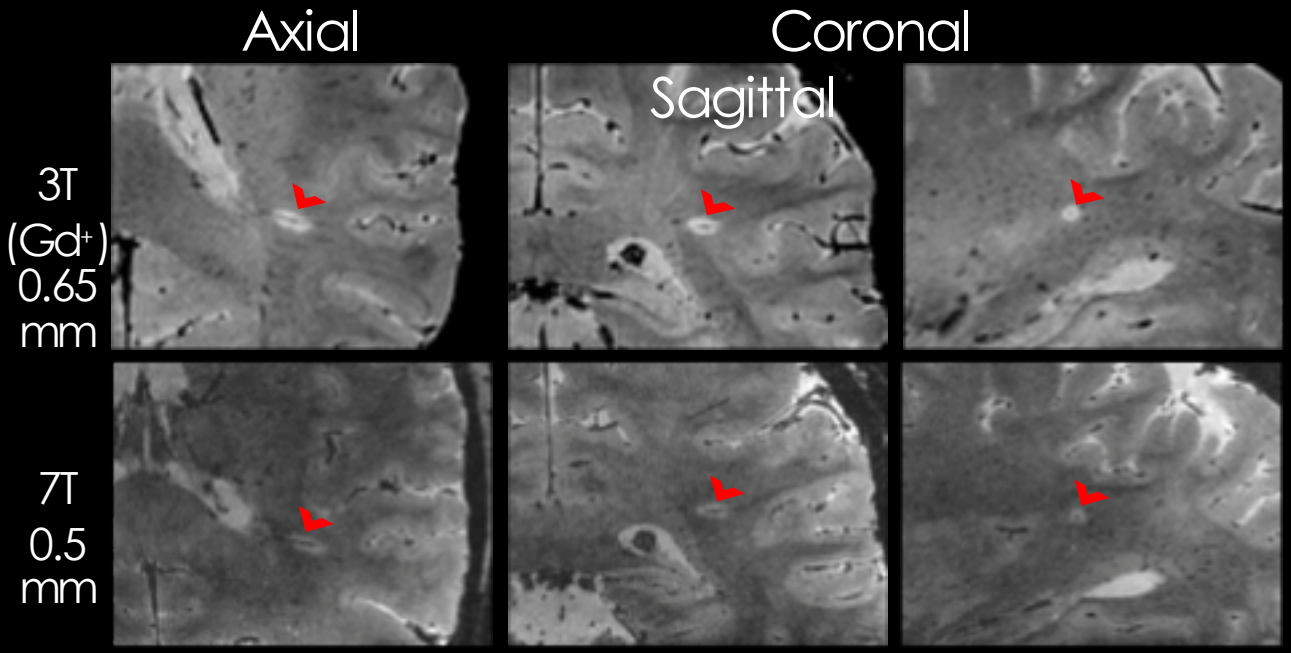


DANNY REICH/TRANSLATIONAL NEURORADIOLOGY UNIT

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

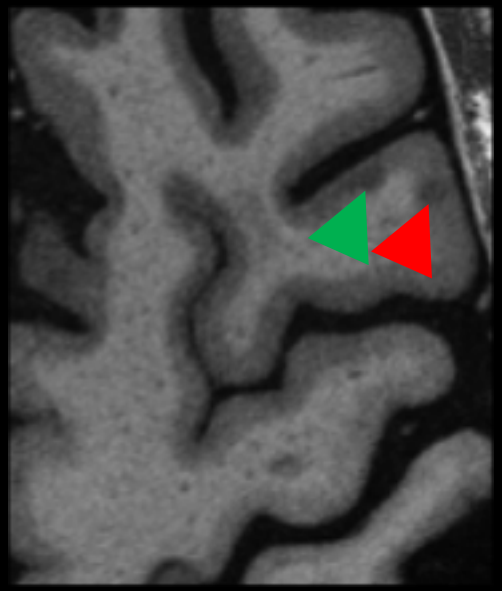
In vivo detection of central veins inside MS lesions

T2-weighted 3D segmented EPI*

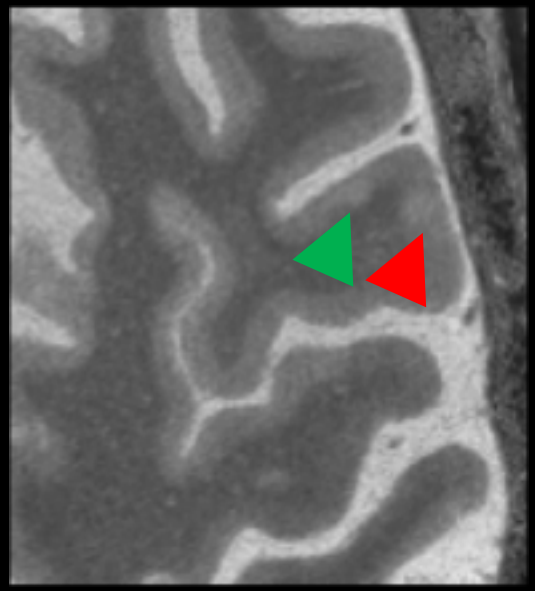


In vivo detection of cortical MS lesions @ 7T

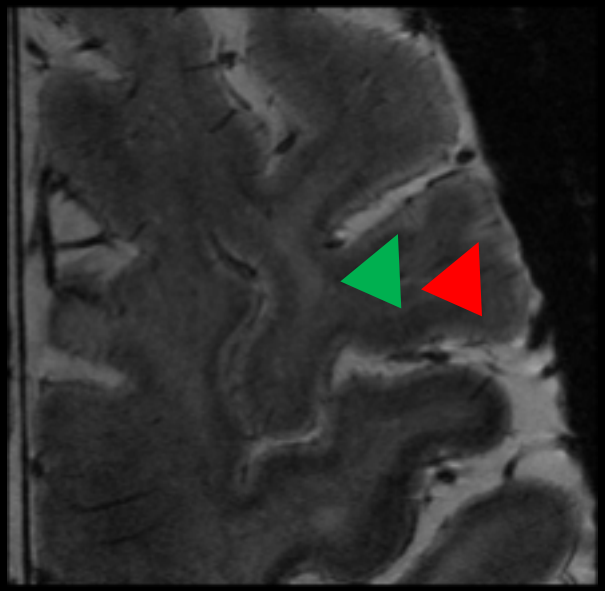
Subpial lesion
Intracortical lesion



T1w MP2RAGE (350 µm iso)



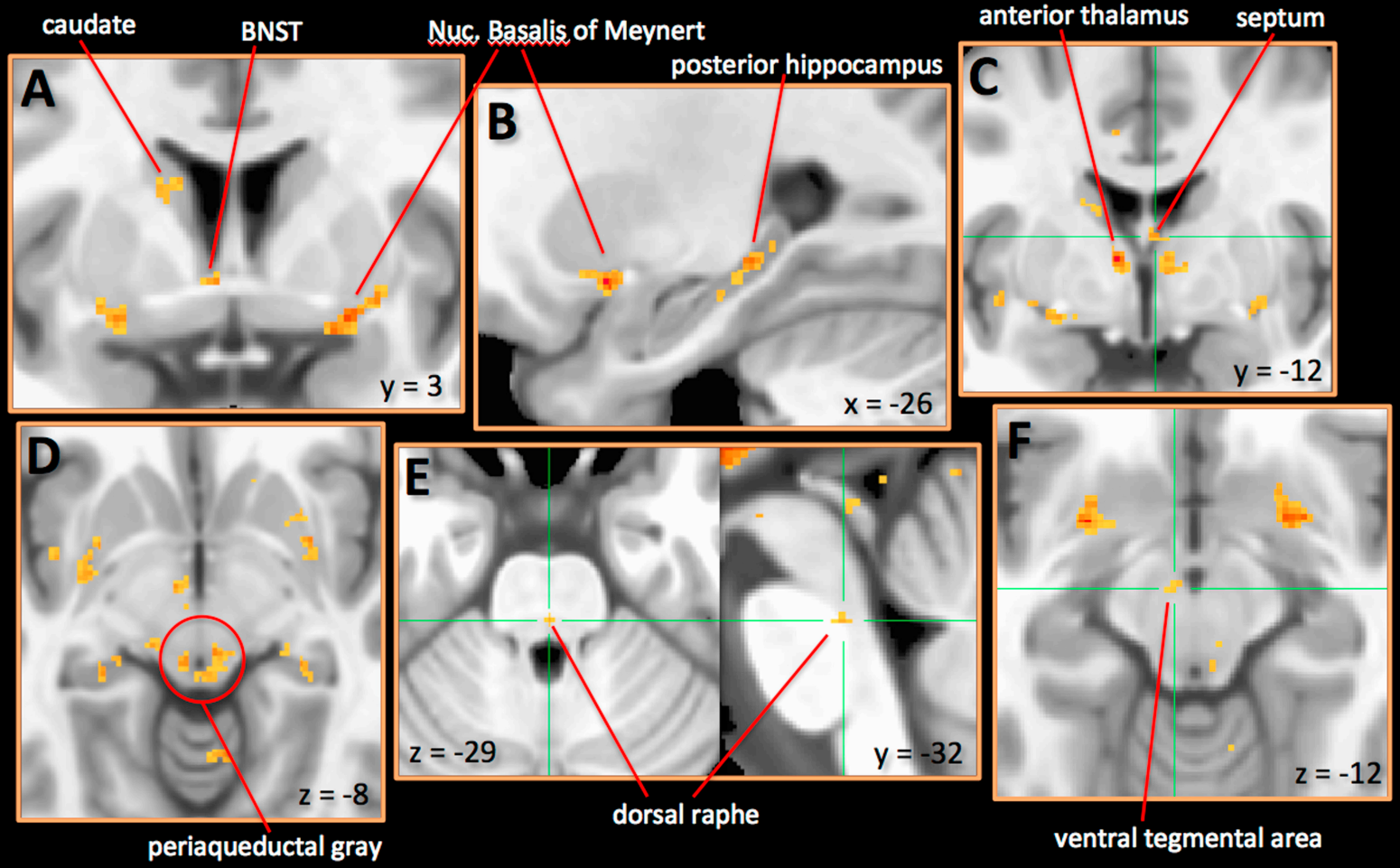
T1 map MP2RAGE (350 µm iso)



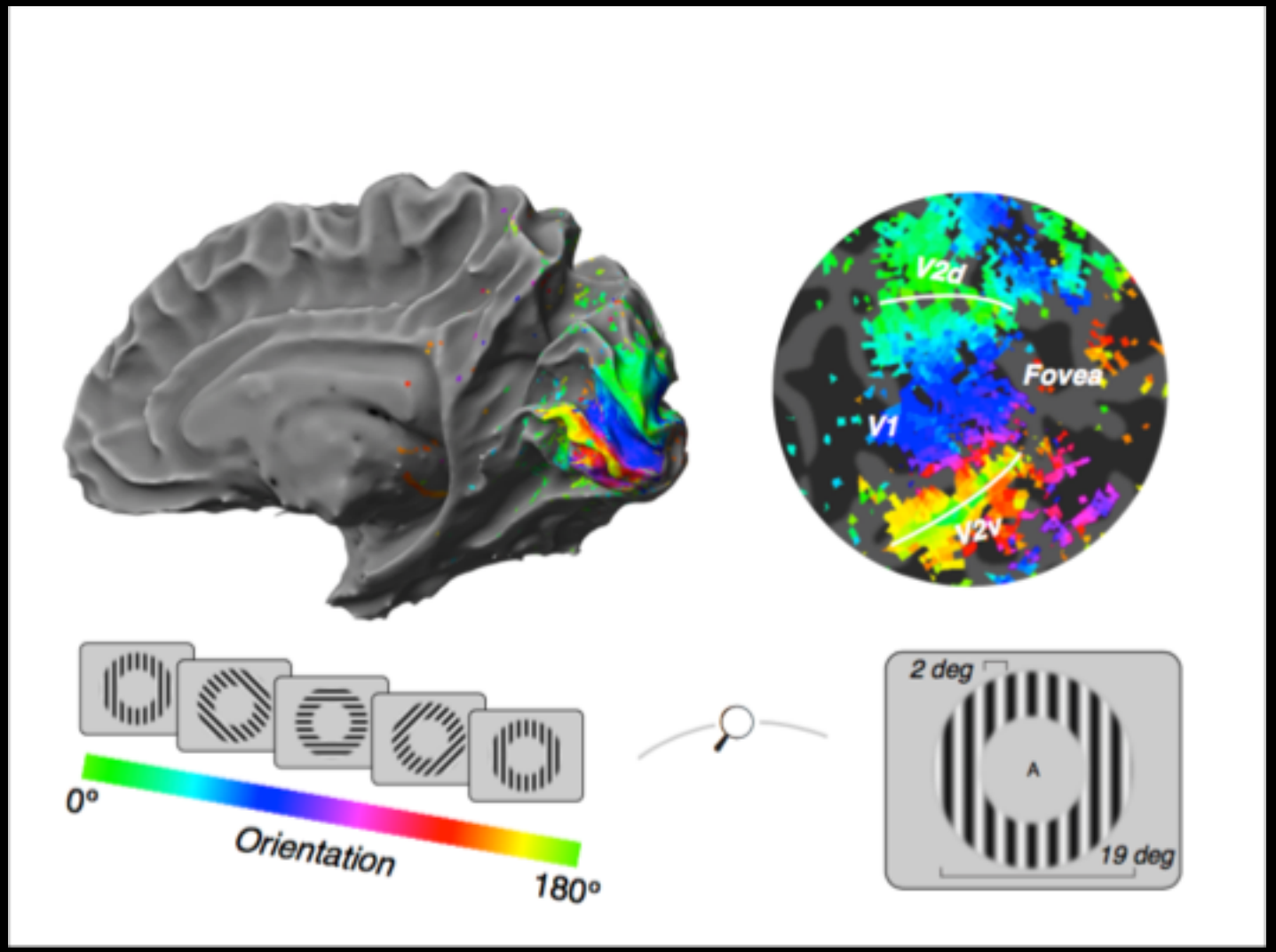
T2*w 2D GRE (250 µm in-plane)

CHRISTIAN GRILLION/NEUROBIOLOGY OF FEAR AND ANXIETY

- Phasic and sustained threat
- Electric shock in the magnet
- FMRI & 7T studies(!)



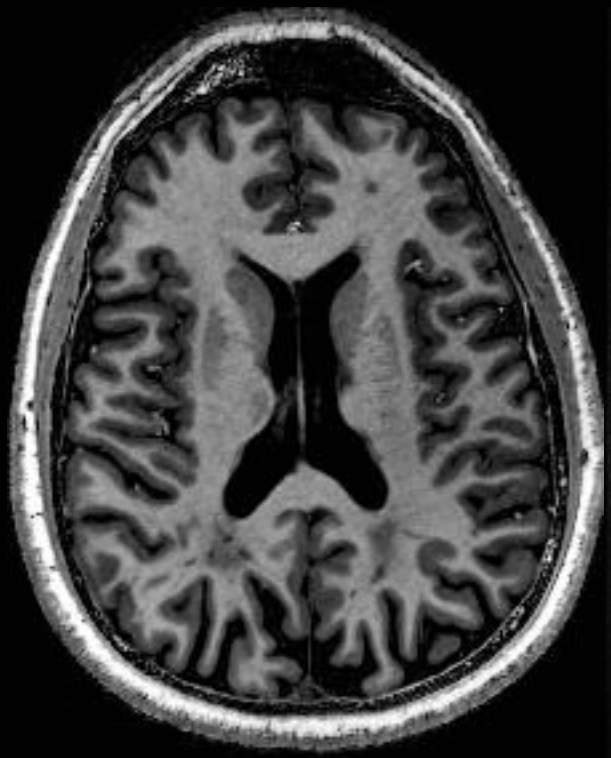
ELI MERIAM - FMRI OF SPATIAL VISION
STRIATE & EXTRA-STRIATE CORTEX
SPATIAL MAPS
SPATIAL REMAPPING / EYE MOVEMENTS



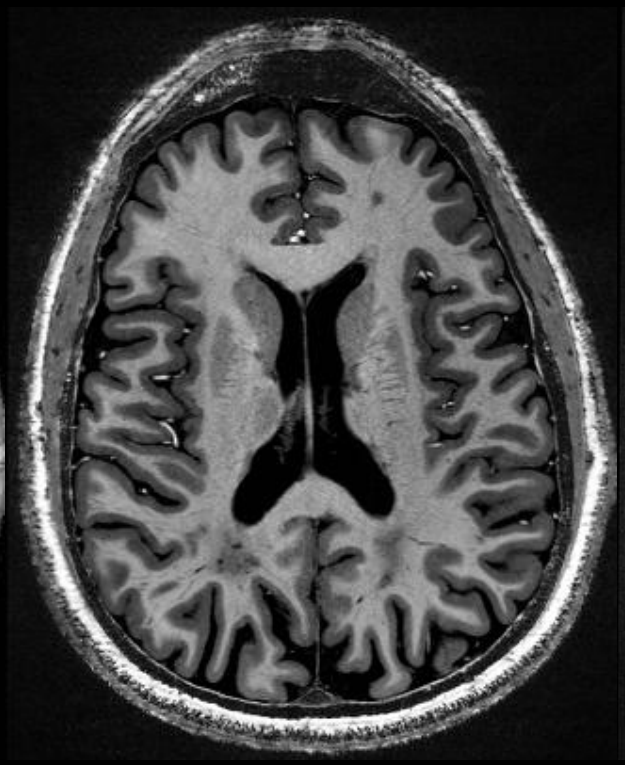

SIEMENS
MAGNETOM Terra

Pushing the resolution of in vivo anatomical imaging

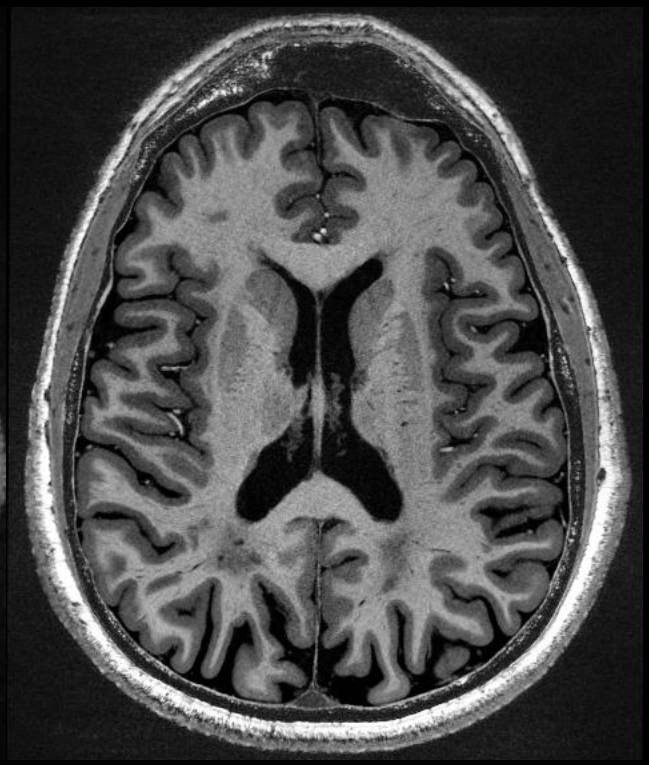
T1-weighted 3D MP2RAGE @ 7T



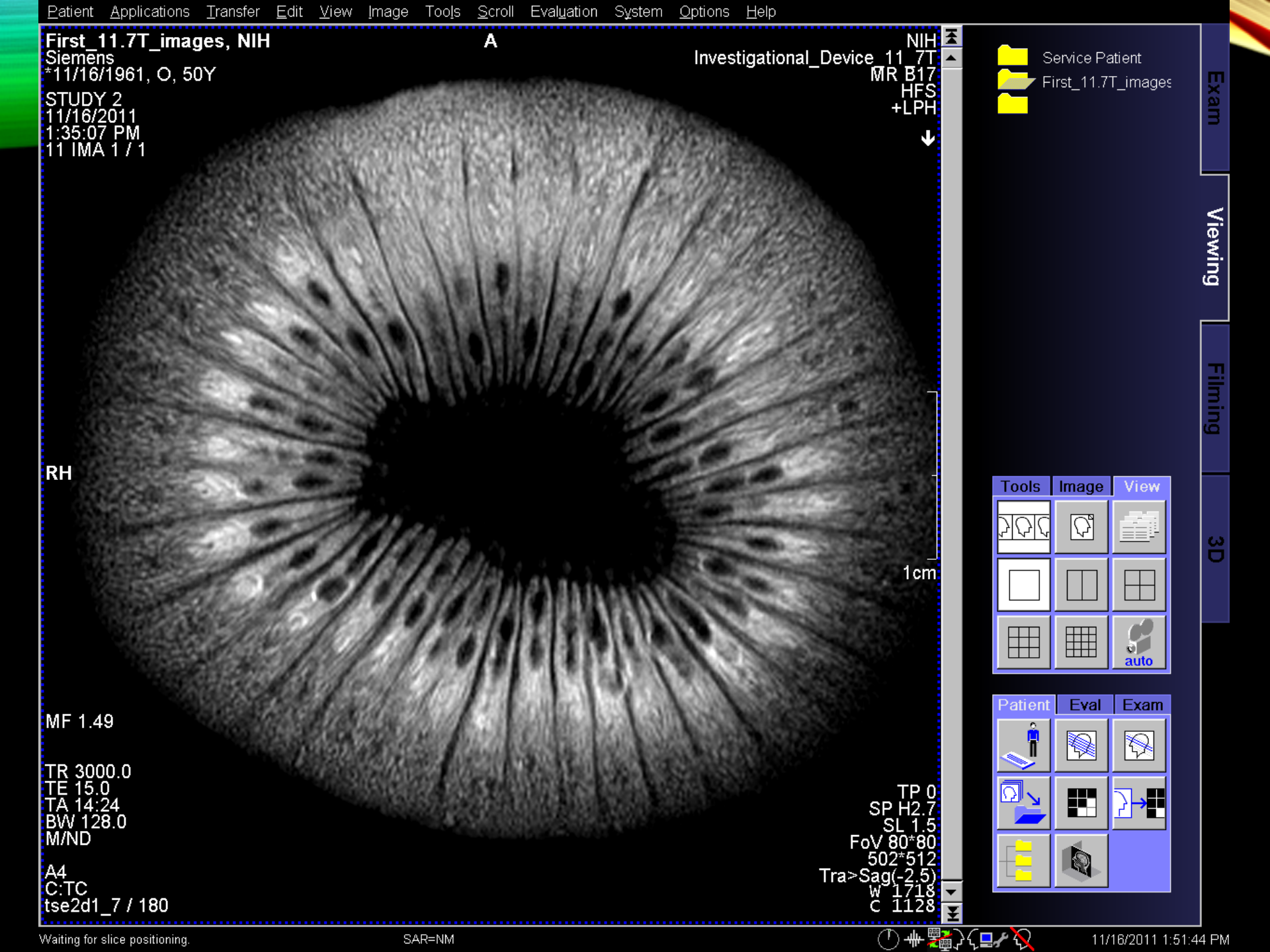
700 μm iso
(10 min)



500 μm iso
(40 min)



350 μm iso
(60 min)


Patient Applications Transfer Edit View Image Tools Scroll Evaluation System Options Help
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Investigational_Device_11_7T
MR B17
HFS
+LPH
RH
1cm
MF 1.49
TR 3000.0
TE 15.0
TA 14:24
BW 128.0
M/ND
A4
C:TC
tse2d1_7 / 180
TP 0
SP H2.7
SL 1.5
FoV 80*80
502*512
Tra>Sag(-2.5)
W 1718
C 1128
Service Patient
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Exam
Viewing
Filming
3D
Tools
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Exam
Waiting for slice positioning.
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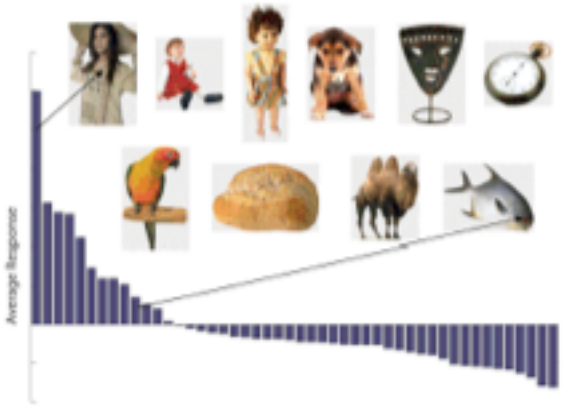
CONCLUSION:

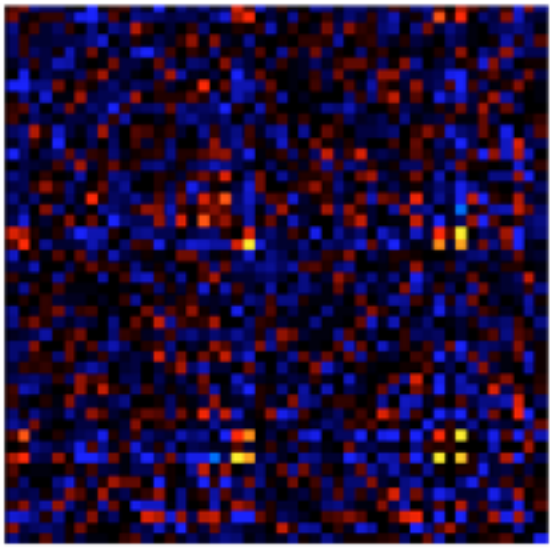
SINGLE-ITEM SINGLE-EVENT

Probing representations with 768 unique conditions

To avoid bias in our sample we chose 768 stimuli from a commercial object database (48 categories * 16 exemplars). We then extracted responses from our independently defined ROIs.

Right FFA





Subject 1

Subject 2

We can recover face-selectivity from the responses to single stimuli.

RESOURCES FOR MRI - HUMAN

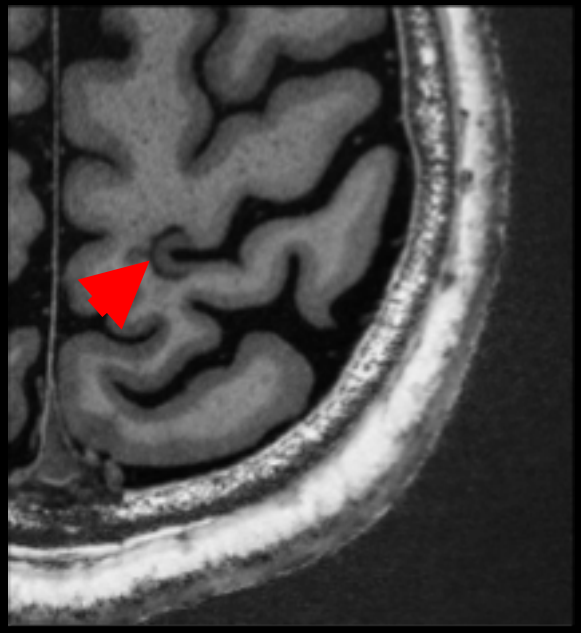
1. NIH MRI Research Facility (NMRF)
   - 3T-Siemens-Skyra (Sep 2011)
2. FMRIF (NIMH & NINDS – 470 hrs/week of scan time)
   - 2 x 3T GE HDx
   - 1 x 3T-GE-mr750 (June 2011)
   - 1 x 3T-Siemens-Skyra (Sep 2011)
   - 7T Siemens/Magnex (Jan 2011)
3. NINDS/NIMH
   - 11.7T Siemens/Magnex (world's first 2011-2012)
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

(SHORT) HISTORY OF FMRI AND BRAIN MRI AT NIH

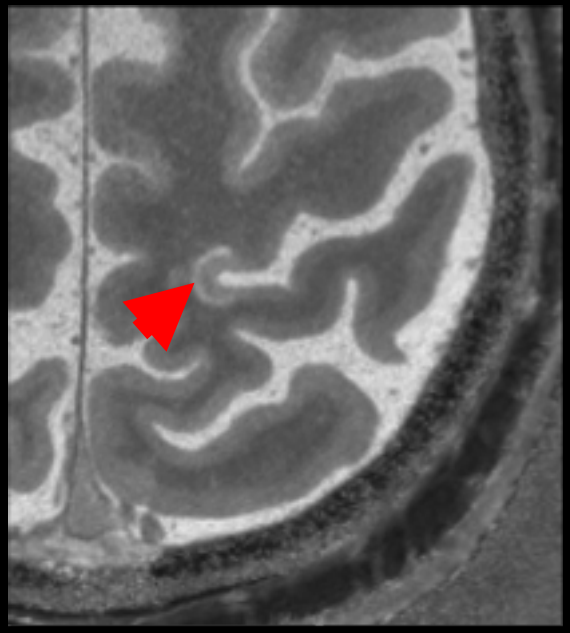
1. In-Vivo NMR Center (established 1987)
2. Early FMRI studies in animals (Bob Turner, 1987)
3. Initial human functional studies (4T 1993)
4. Key developments from NIH MRI researchers
   - DTI (LeBihan, Baser (1992), Pierpaoli etc)
   - High-field imaging (4 Tesla, 7 Tesla and now 11.7T)
   - Magnetization 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

In vivo detection of cortical MS lesions @ 7T

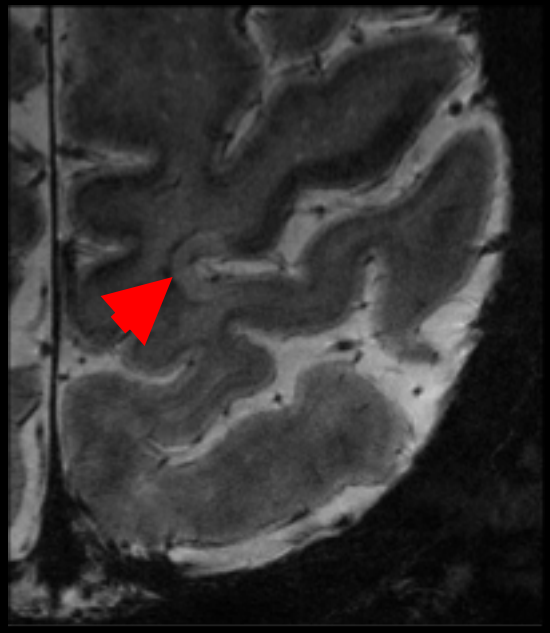
Leukocortical lesion



T1w MP2RAGE (350 µm iso)



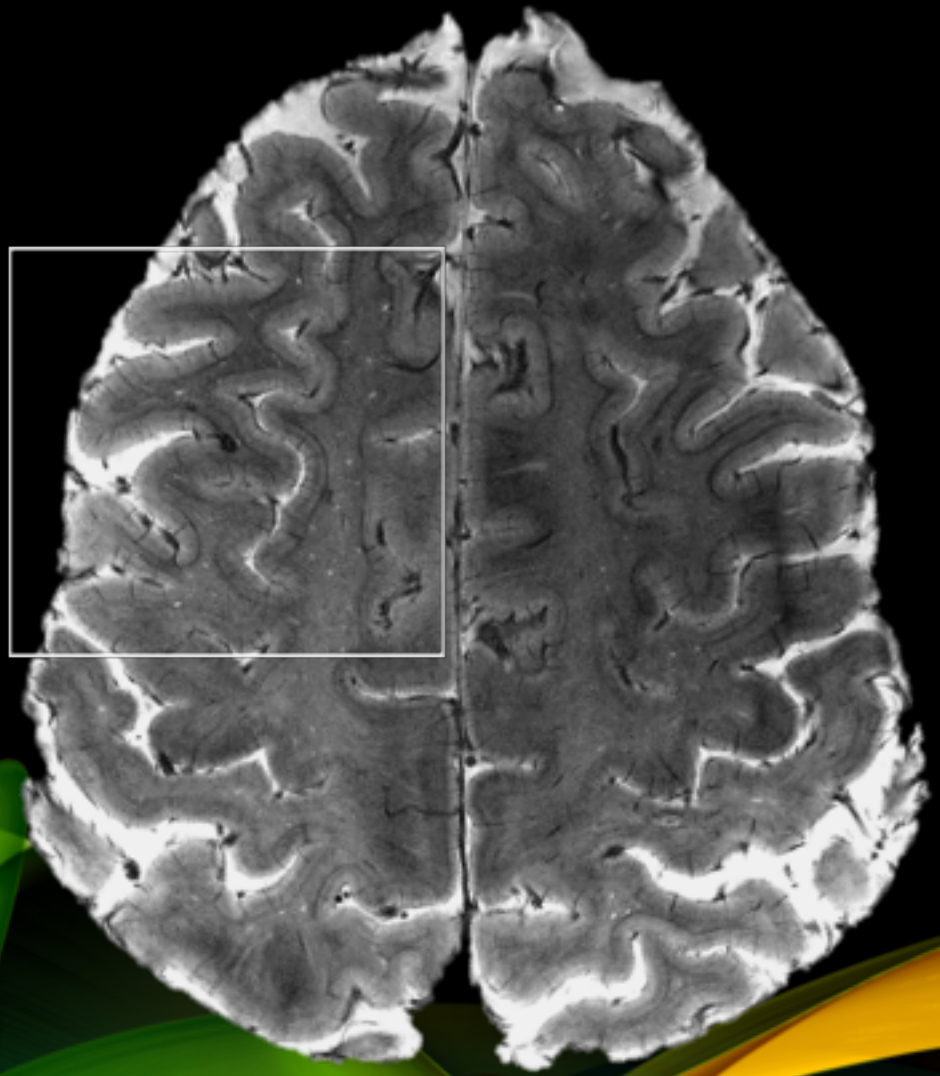
T1 map MP2RAGE (350 µm iso)

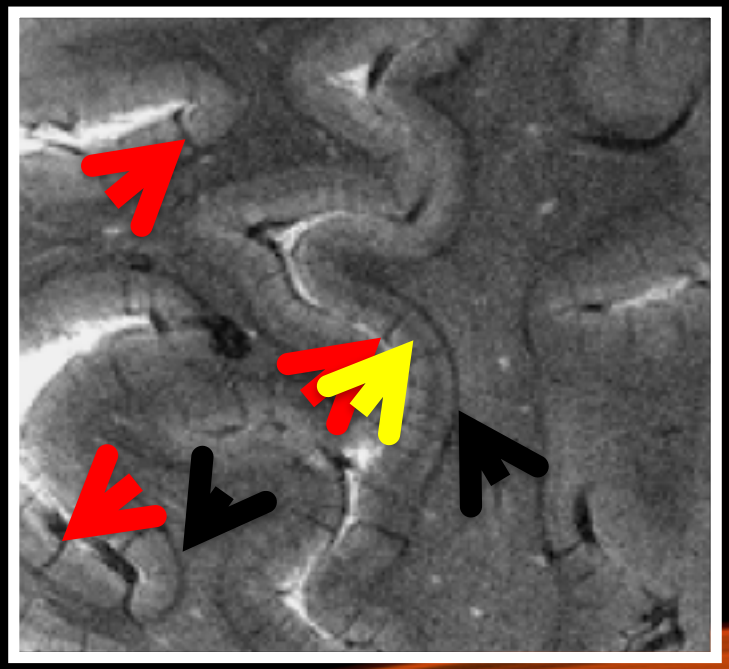


T2*w 2D GRE (250 µm in-plane)

Cortex imaging with 7T MRI

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





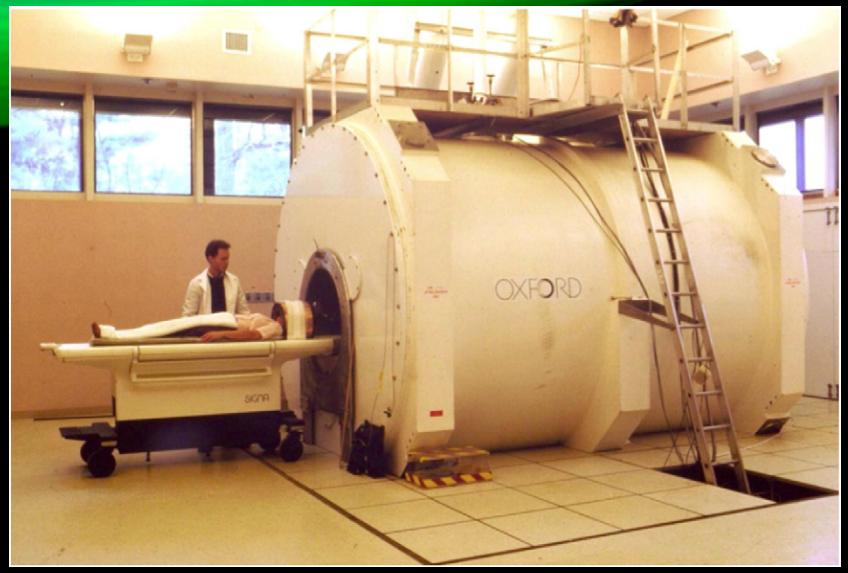
in-plane resolution = 200 μm x 200 μm

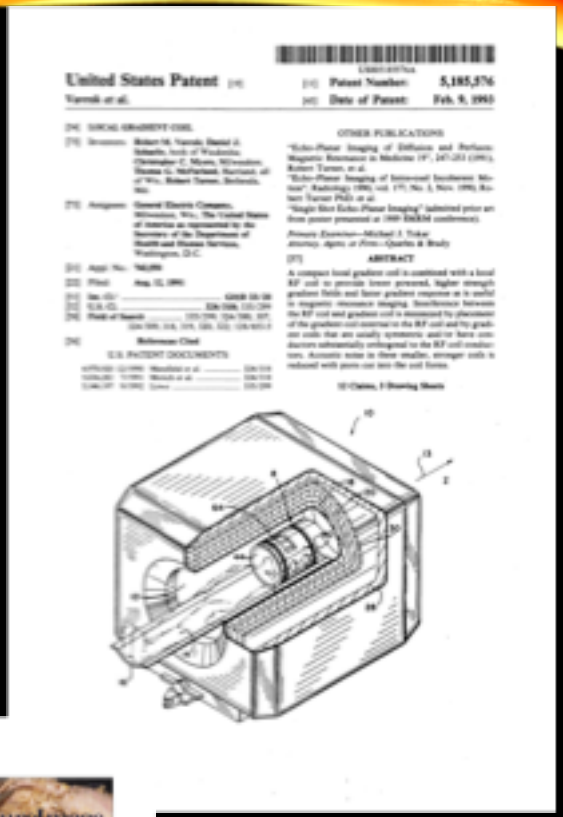
1986-90	1991-95	1996-00	2001-05	2006-10	2011-15	2016-18

TIMES

WHAT MAKES THE NMRF/FMRIF SPECIAL?

- WIDE RANG





United States Patent [19]

Varrek et al.

[11] Patent Number: 5,185,576

[45] Date of Patent: Feb. 9, 1993

[54] LOCAL GRADIENT COIL

[75] Inventors: Robert M. Turner, Daniel J. Schmitt, both of Waukesha; Christopher C. Myers, Milwaukee; Thomas G. McFarland, Hartland; all of Wis.; Robert Turner, Bethesda, Md.

[73] Assignee: General Electric Company, Milwaukee, Wis.; The United States of America as represented by the Secretary of the Department of Health and Human Services, Washington, D.C.

[21] Appl. No.: 740,099

[22] Filed: Aug. 12, 1991

[51] Int. Cl.[5] G01R 33/20

[52] U.S. Cl. 324/318; 335/299; 324/322

[58] Field of Search 324/318, 319, 320, 322; 335/299, 216

[56] References Cited

U.S. PATENT DOCUMENTS

OTHER PUBLICATIONS

"Echo-Planar Imaging of Diffusion and Perfusion", Magnetic Resonance in Medicine 19, 247-253 (1991), Robert Turner, et al.

"Echo-Planar Imaging of Intravoxel Incoherent Motion", Radiology (1990), vol. 177, No. 2, Nov. 1990, Robert Turner PhD et al.

"Single-Shot Echo-Planar Imaging" (abstract price article from poster presented at 1989 SMRM conference)

Primary Examiner—Michael J. Tokar
Attorney, Agent, or Firm—Quarles & Brady

[57] ABSTRACT

A compact local gradient coil is combined with a local RF coil to provide lower powered, higher strength gradient fields and faster gradient response as is useful in magnetic resonance imaging. Interference between the RF coil and gradient coil is minimized by placement of the gradient coil external to the RF coil and by gradient coils that are axially symmetric and/or have conductors substantially orthogonal to the RF coil conductors. Acoustic noise in these smaller, stronger coils is reduced with pairs coil into the coil forms.

10 Claims, 5 Drawing Sheets

NeuroImage xxx (2011) xxx–xxx

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NeuroImage

journal homepage: www.elsevier.com/locate/ynimg

Review

The NIH experience in first advancing fMRI

Robert Turner *

Department of Neurophysics, Max-Planck-Institute for Human Cognitive Brain Sciences, Stephanstrasse 1A, 04103 Leipzig, Germany

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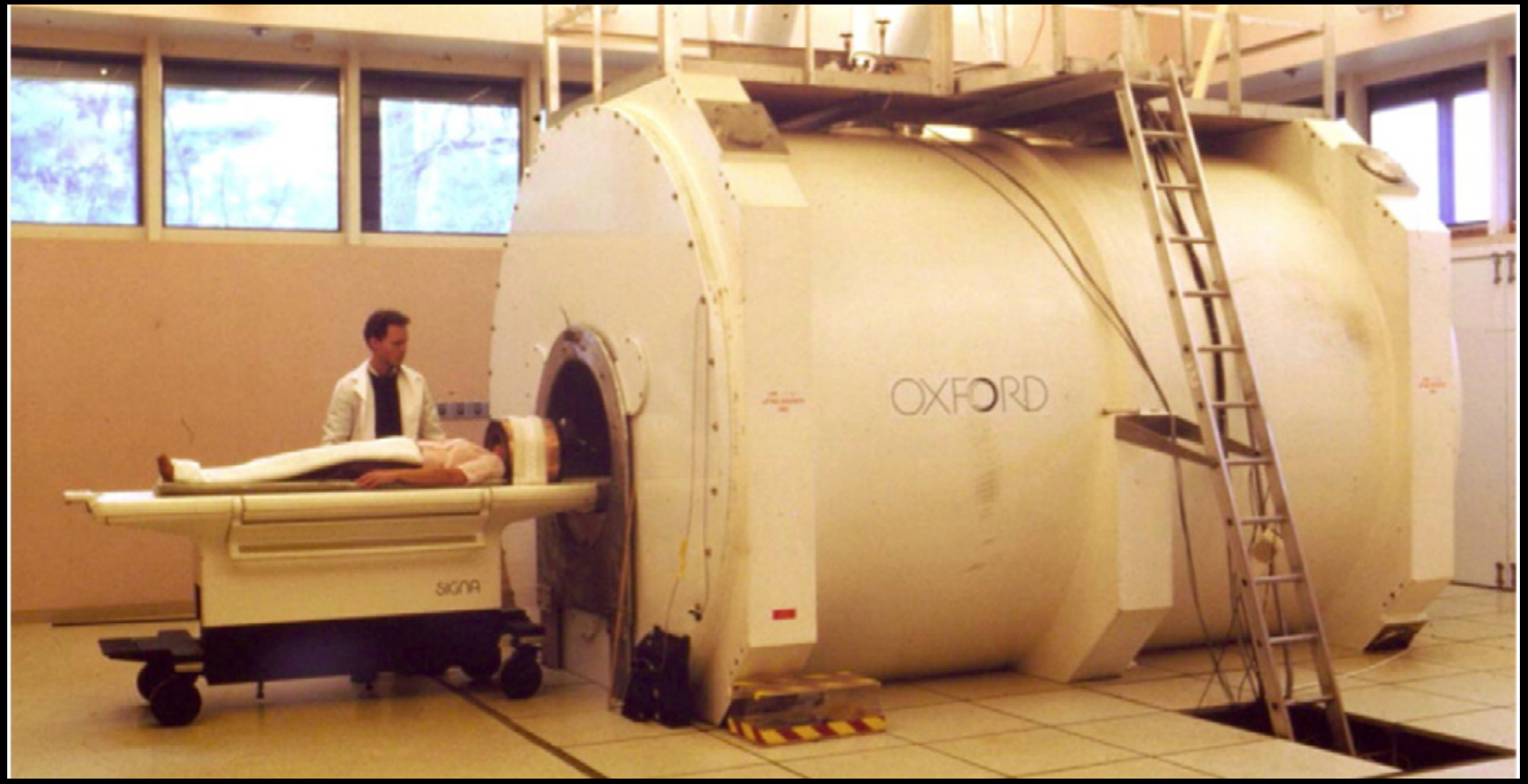
ABSTRACT

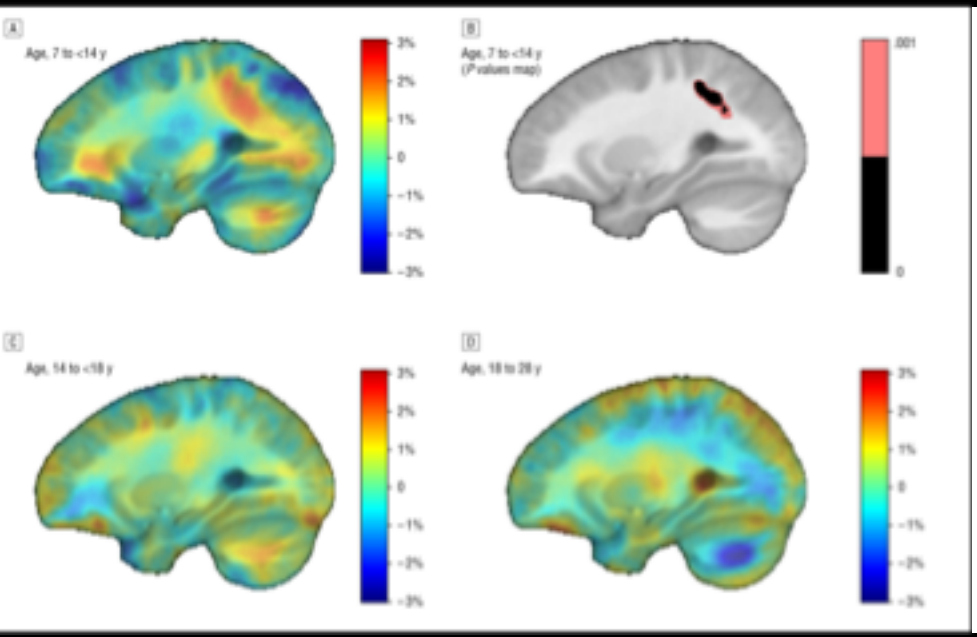
The introduction of functional MRI at NIH in 1992 was the outcome of research goals first formulated by Turner in 1983. Between 1988 and 1990, Turner worked at NIH on actively-shielded gradient coils and the implementation of EPI-based techniques, especially diffusion-weighted EPI. His work on hypoxia in cat brain in 1990 directly inspired Ken Kwong's demonstration of BOLD contrast in humans at MGH in May 1991. Turner collaborated actively with this MGH team, the first group to map entirely noninvasively human brain

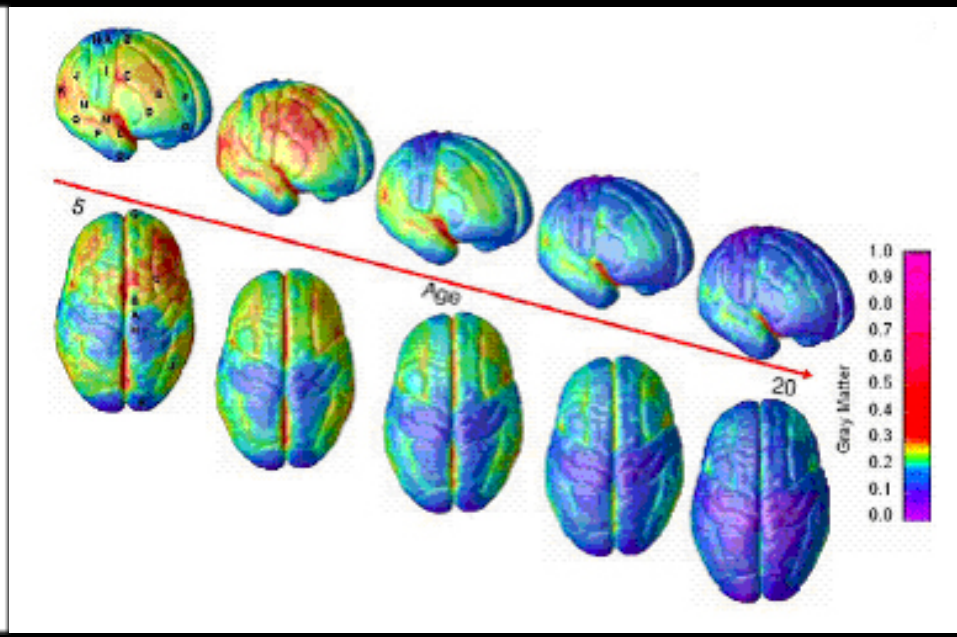
NIH 4T



JUDY RAPOPORT/CHILDHOOD PSYCHIATRY

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



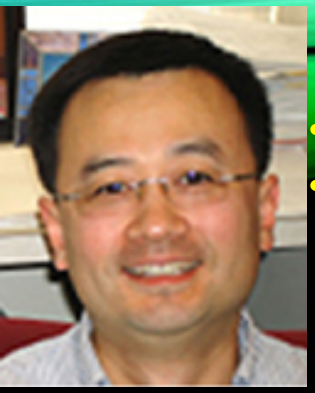


Longitudinal MRI, genomics

FMRIF & NMRF Scanner History

Time

1 Scanner	May, 2000: Installed **first GE 3T VHi**
2 Scanners	Nov, 2002: Installed **second GE 3T VHi**
3 Scanners	Aug, 2004: Inherited **GE 1.5T**
4 Scanners	Nov, 2007: Replaced **first GE 3T VHi** with **2 x GE 3T HDx**
	Jan, 2011: Replaced **GE 3T VHi** with **Siemens 7T**
5 Scanners	June, 2011: Obtained **GE 750**
	Aug, 2011: Replaced **GE 1.5T** with **Siemens Skyra 3T**
	Spring, 2015: NIAAA 3T-Prisma operational (25% NIMH, 25% NINDS)
	Jan 2017: Upgrade **2 x GE 3T to MR750**
	Fall 2018 : NMRF 7T (!)



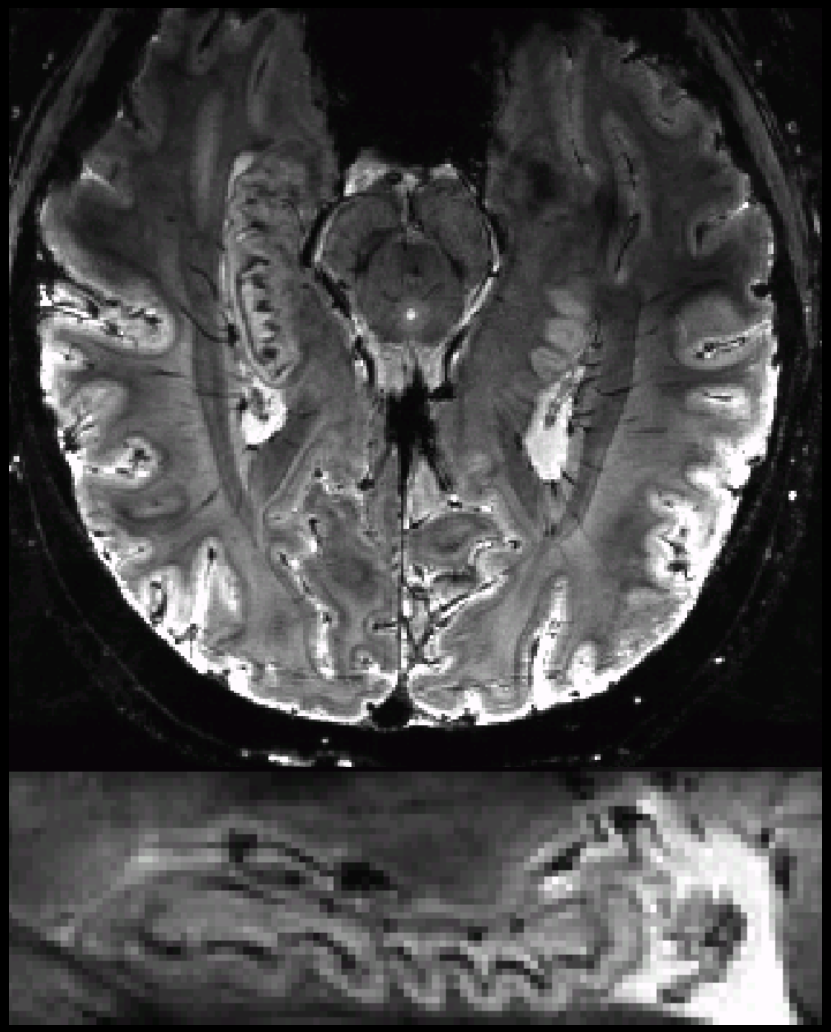
JUN SHEN/ MRS SECTION

- MRS methods development
- 13C / Glu / Gln / GSH (glutathione) quantification

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

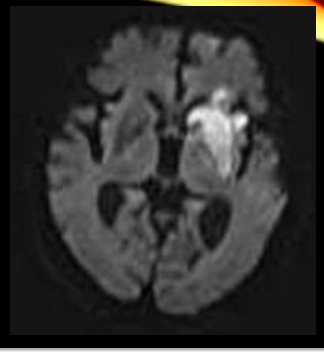
MAJOR DEPRESSIVE DISORDER (MDD) AND BRAIN STRUCTURE

- High resolution hippocampal mapping at 7T
- Assessing curvature, surface area, and shape
- 0.5mm iso, T2* weighted (48 slices, 7min acq)



Zarate & Nugent & Thomas.

Denis Le Bihan –diffusion MRI and DTI



Review Article

Diffusion MR Imaging: Clinical Applications

Denis Le Bihan,[1] Robert Turner,[2] Philippe Douek,[3] and Nicholas Patronas[1,4]

Water self-diffusion, a recently discovered source of contrast on MR images, has already shown promise for some clinical applications. Most studies have been of the brain, essentially for technical reasons. Diffusion is useful in distinguishing the different components of brain tumors (cystic regions, edema, necrosis) from the tumor core itself. Recent studies have shown that diffusion is anisotropic in brain white matter (i.e., dependent on the fiber tract's orientation in space), offering new insights into myelin disorders. Diffusion is also dramatically altered in the minutes following ischemic injury in the cat brain, which may have tremendous impact for the diagnosis and management of hyperacute stroke. With ultrafast acquisition schemes, diffusion imaging has also been used outside the CNS, for instance, in the eye and kidney. Future applications include diffusion-localized spectroscopy and temperature imaging. This article reviews recent progress in this field and suggests potential applications.

tively immobile tissues and of having favorable MR characteristics, such as long T1 and T2 relaxation times. Body studies are far more difficult, although preliminary results of diffusion imaging of the kidneys have been reported and are shown here. Also, the possibility of applying to perfusion imaging techniques similar to those used in diffusion imaging has been suggested [2, 3]. However, technical difficulties have limited application of such perfusion imaging. Also, the feasibility of using diffusion imaging in vivo was not demonstrated overnight. The initial technique, based on spin-echo two-dimensional Fourier transform (2DFT) imaging [4, 5], was slow, sensitive to motion artifacts, and implemented on MR units with imperfect gradient systems, so that some researchers expressed justifiable concerns about the meaning of the

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