

# The Basics of Advanced fMRI

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Section on Functional Imaging Methods

<http://fim.nimh.nih.gov>

Laboratory of Brain and Cognition

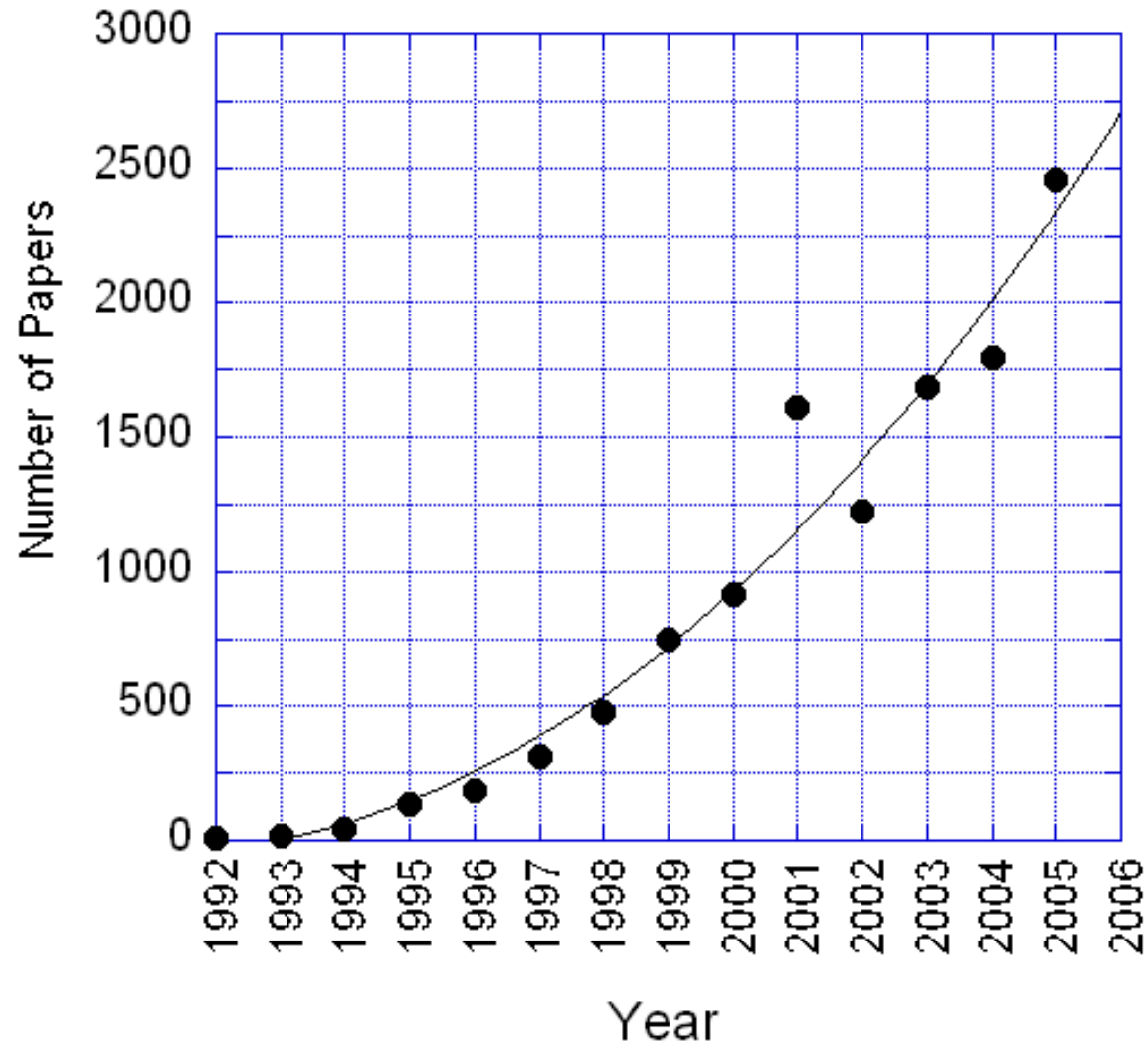
&

Functional MRI Facility

<http://fmrif.nimh.nih.gov>

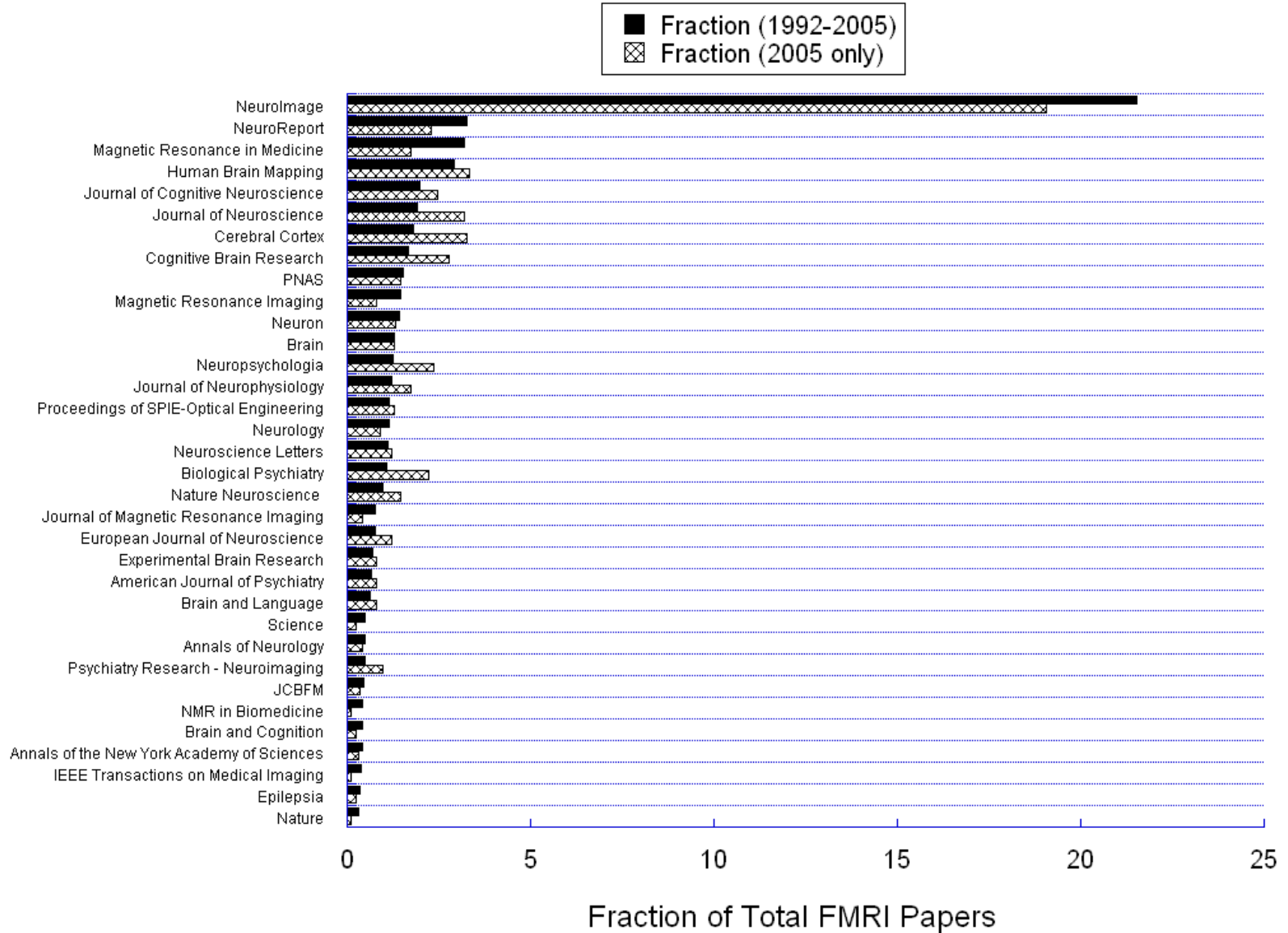


# fMRI Papers Published per Year

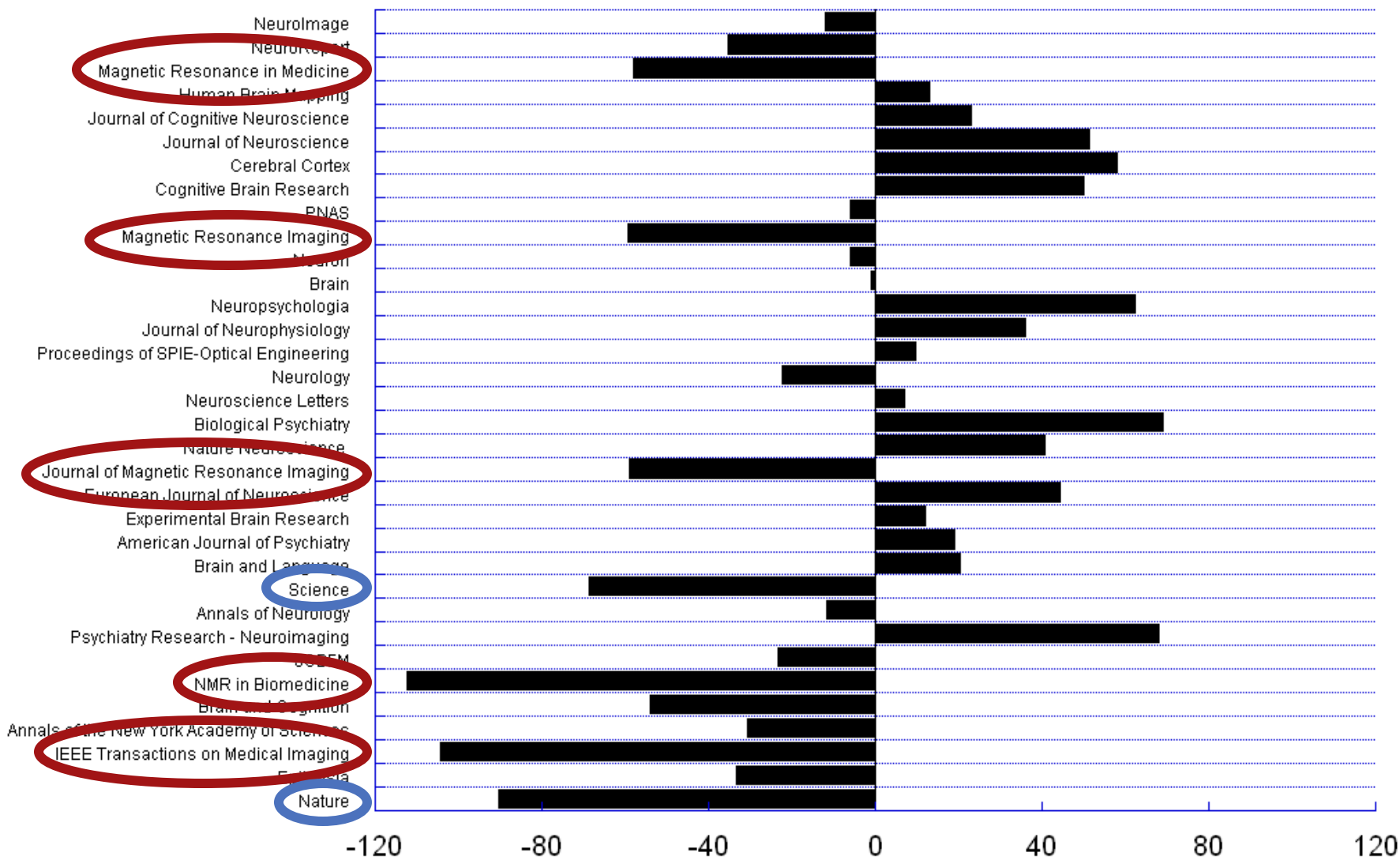


"fMRI" or "functional MRI"

# Breakdown of fMRI papers by Journal



Percent Change in fMRI Publications of 2005 relative to Average (1992 - 2005) for Each Journal



Percent Change (2005 relative to average from 1992 to 2005)

# How most fMRI studies are performed

## MRI parameters:

1.5T - 3T, 64 x 64 matrix, 3mm x 3mm x 5mm voxel size, whole brain, TR = 2 sec.

## Paradigm:

Block design or event-related, single or multiple conditions.

## Analysis:

Motion correct, multi-regression, spatial smoothing and spatial normalization, standard classical statistical tests, multi-subject averaging.

## Hypothesis:

A region or network of regions show modulation with a task. This modulation is unique to the task and/or population.

# How fMRI might be performed

## MRI parameters:

3T - 11.7T, 256 x 256 matrix, 0.5 x 0.5 x 0.5 voxel size, whole brain TR = 1sec or select slab TR = 100 ms.

## Paradigm:

Natural, continuous, or no stimuli/task. Simultaneous multi-modal, or multiple contrast measurements.

## Analysis:

Motion correct, dynamic Bo-field correction, no spatial or temporal smoothing, machine learning algorithms, pattern classification, hemodynamic parameter assessment, correlation with behavior.

## Hypothesis:

Similar to previous but using the high resolution patterns, fluctuations, dynamics, and contrast mechanisms that we are still figuring out how to interpret and extract.



1991

# Technology

Coil arrays  
High field strength  
High resolution  
Novel functional contrast

# Methodology

Connectivity assessment  
Multi-modal integration  
Pattern classification  
Task design

Fluctuations  
Dynamics  
Cross - modal comparison

Basic Neuroscience  
Behavior correlation/prediction  
Pathology correlation

# Interpretation

# Applications



# Technology

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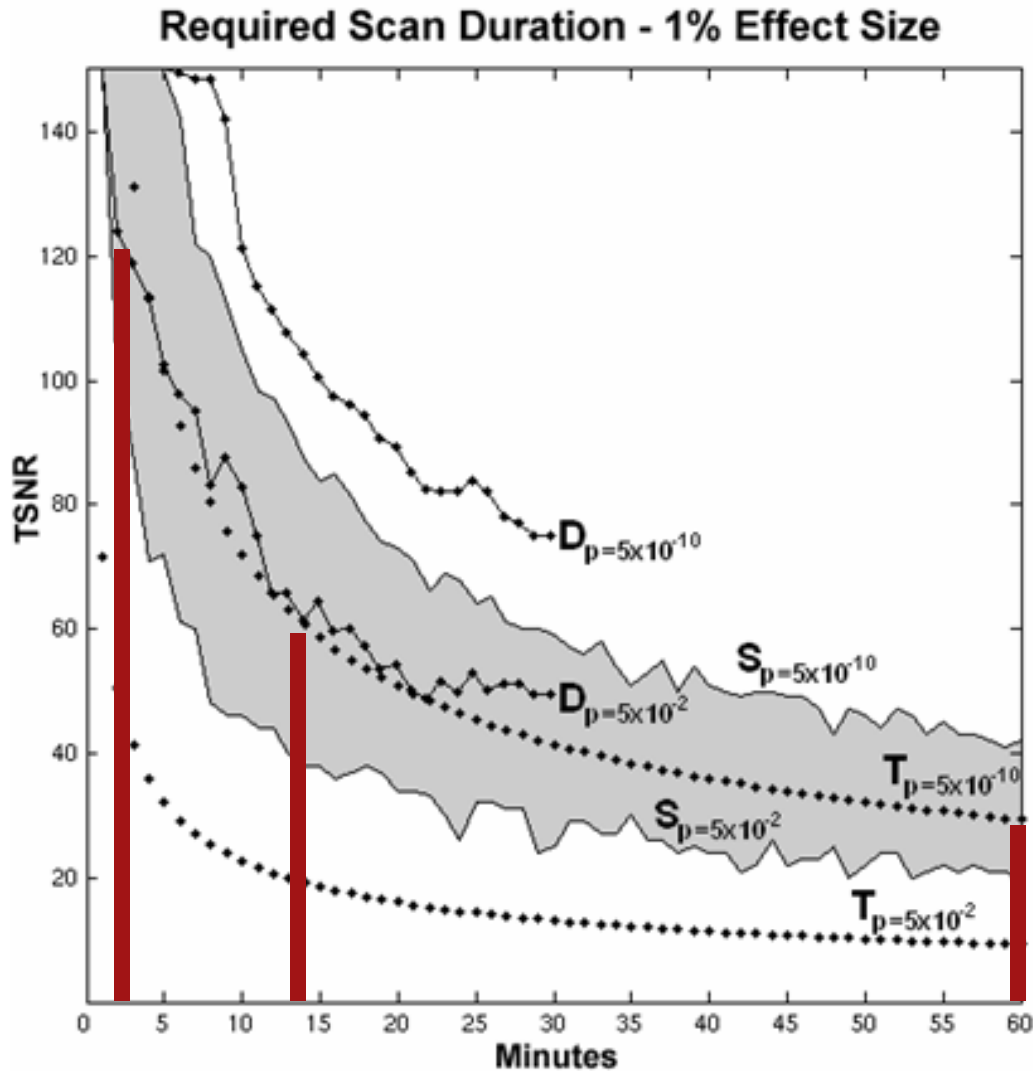
Fluctuations  
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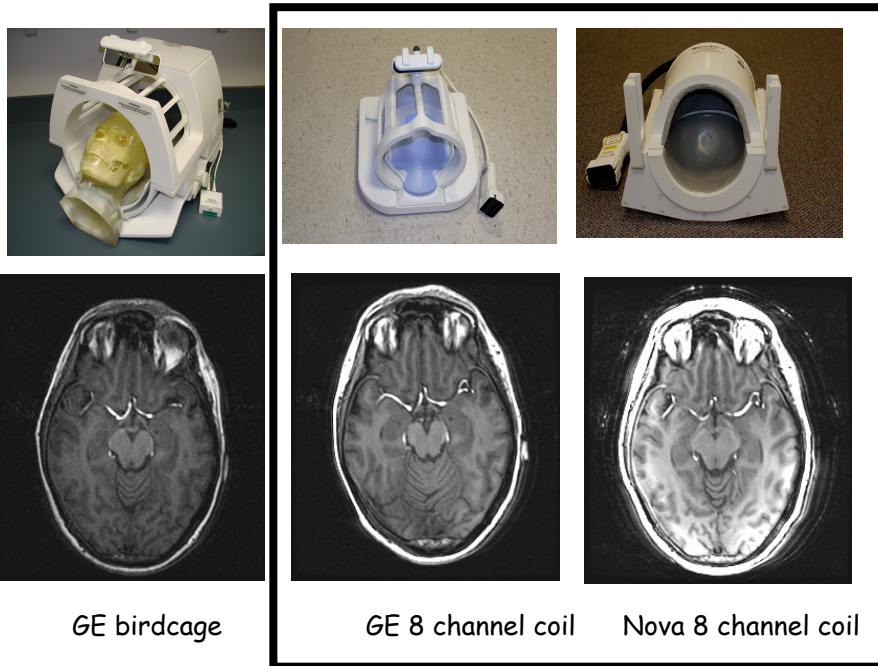
## Reasons for higher SNR

- Shorter scan duration
- Higher Resolution
- More subtle comparisons

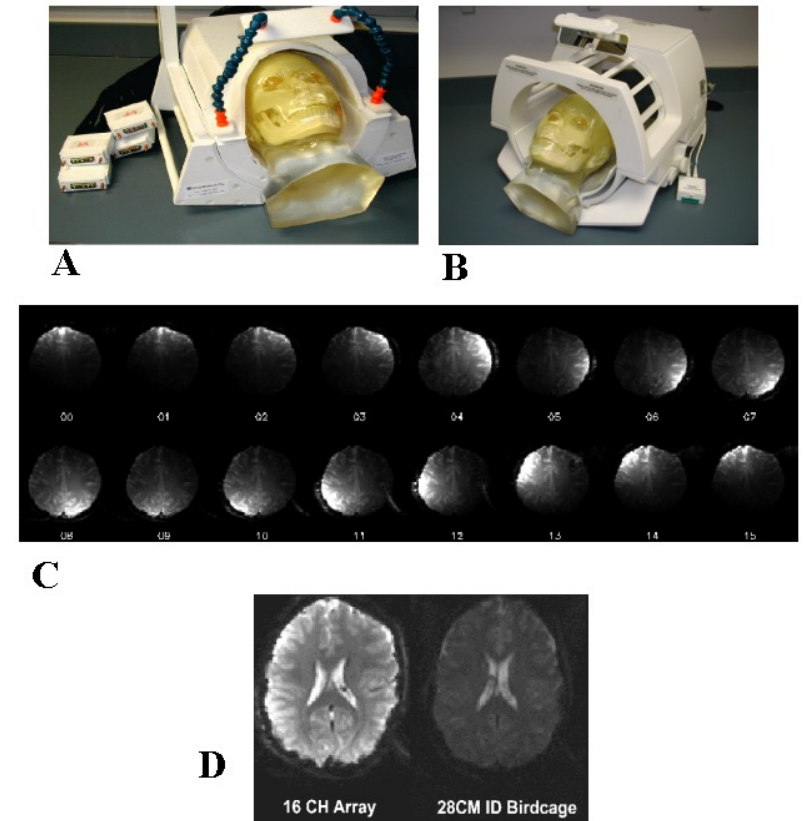
Murphy et al.

# Technology

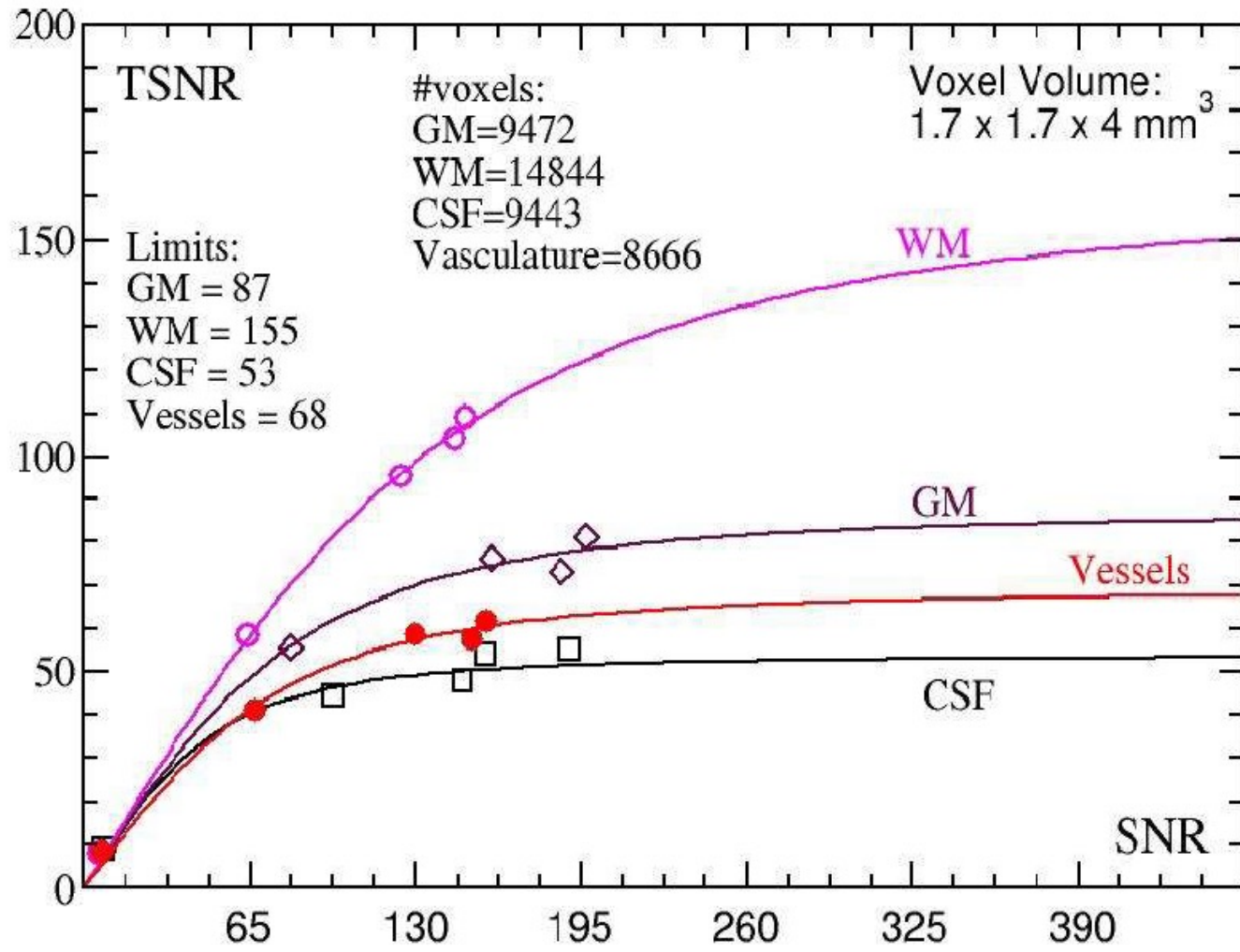
## 8 channel parallel receiver coil



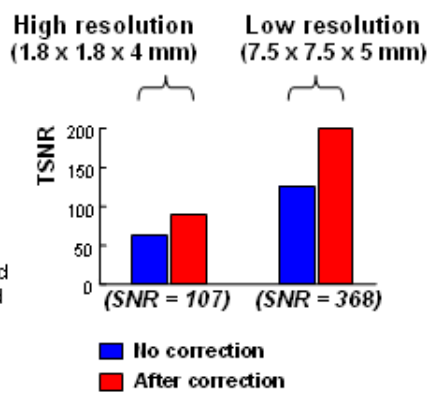
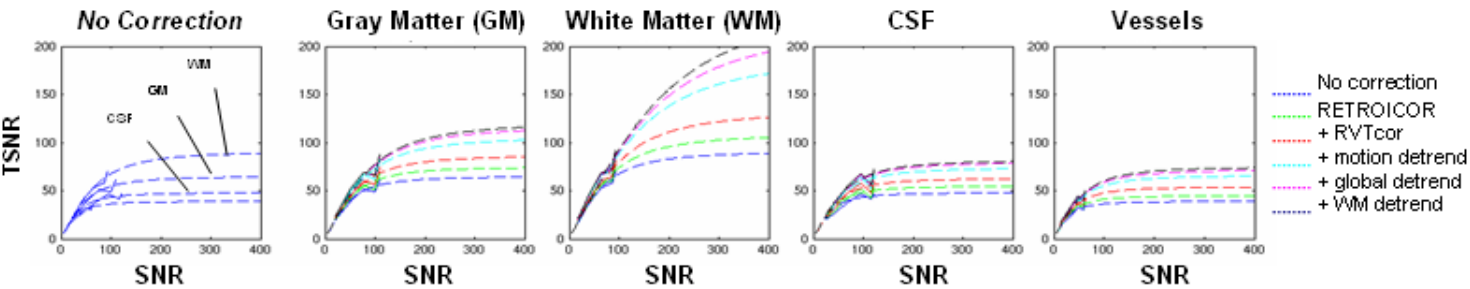
## 16 channel parallel receiver coil



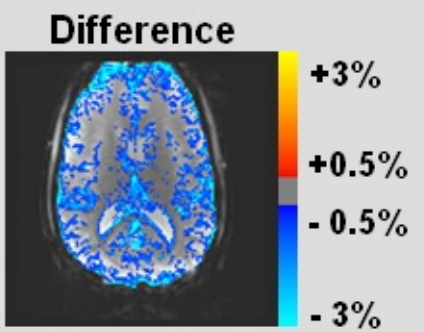
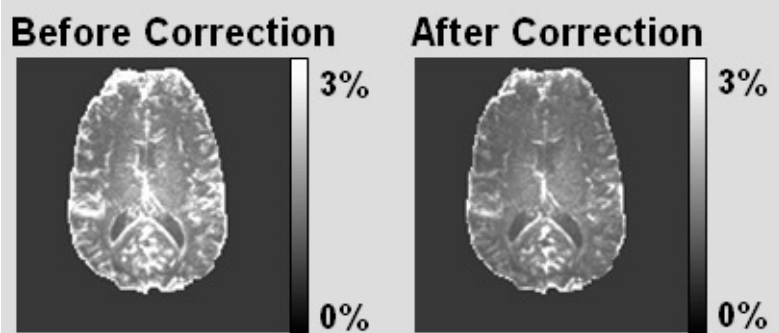
# Technology



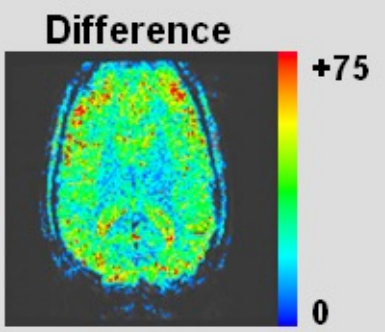
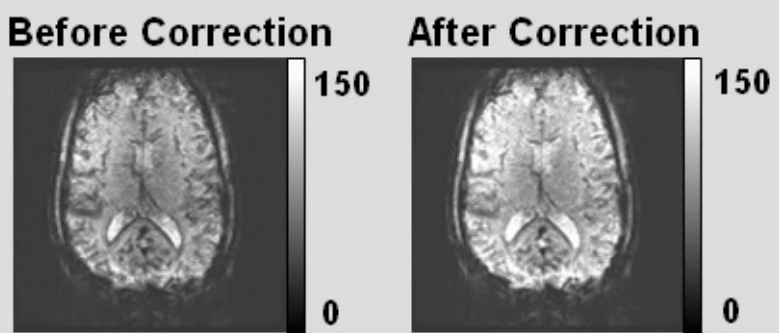
# Technology



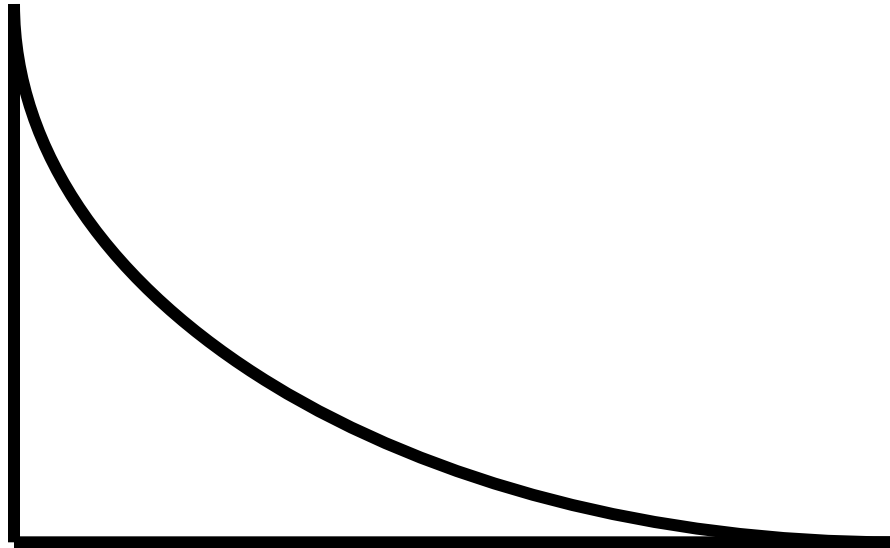
## Standard Deviation across time



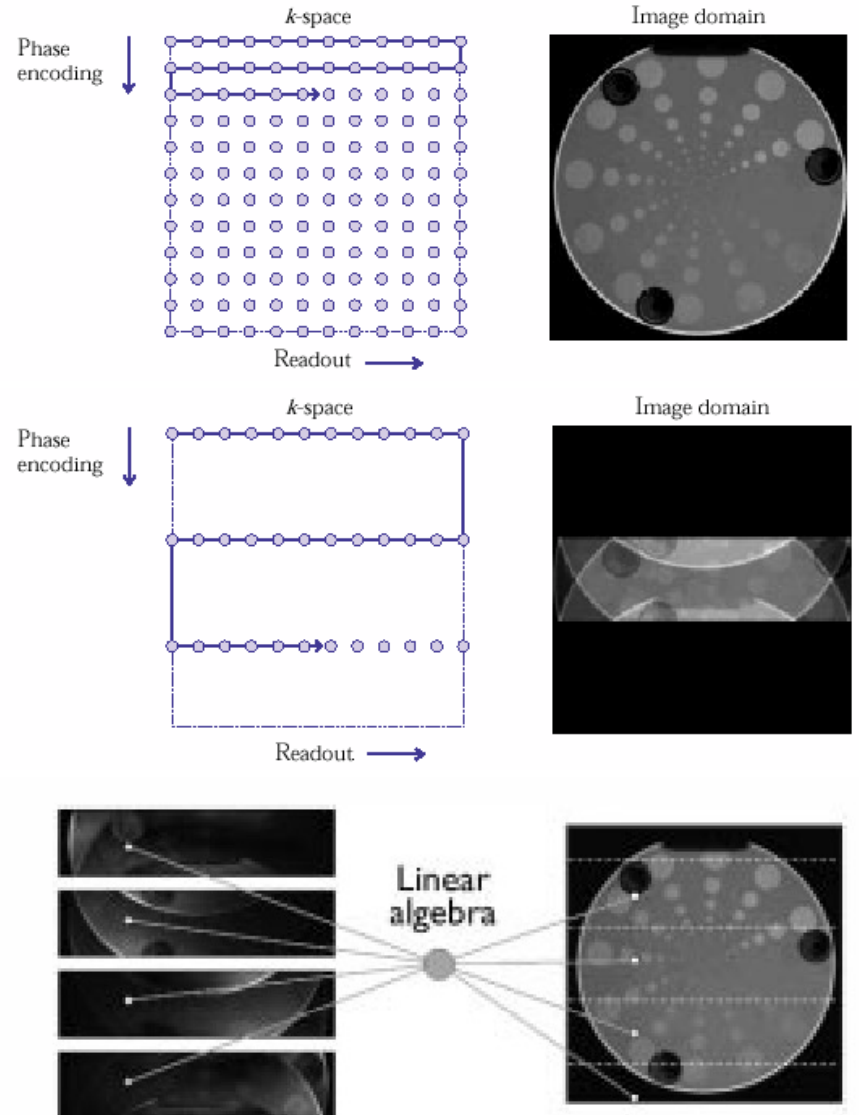
## TSNR



# Technology

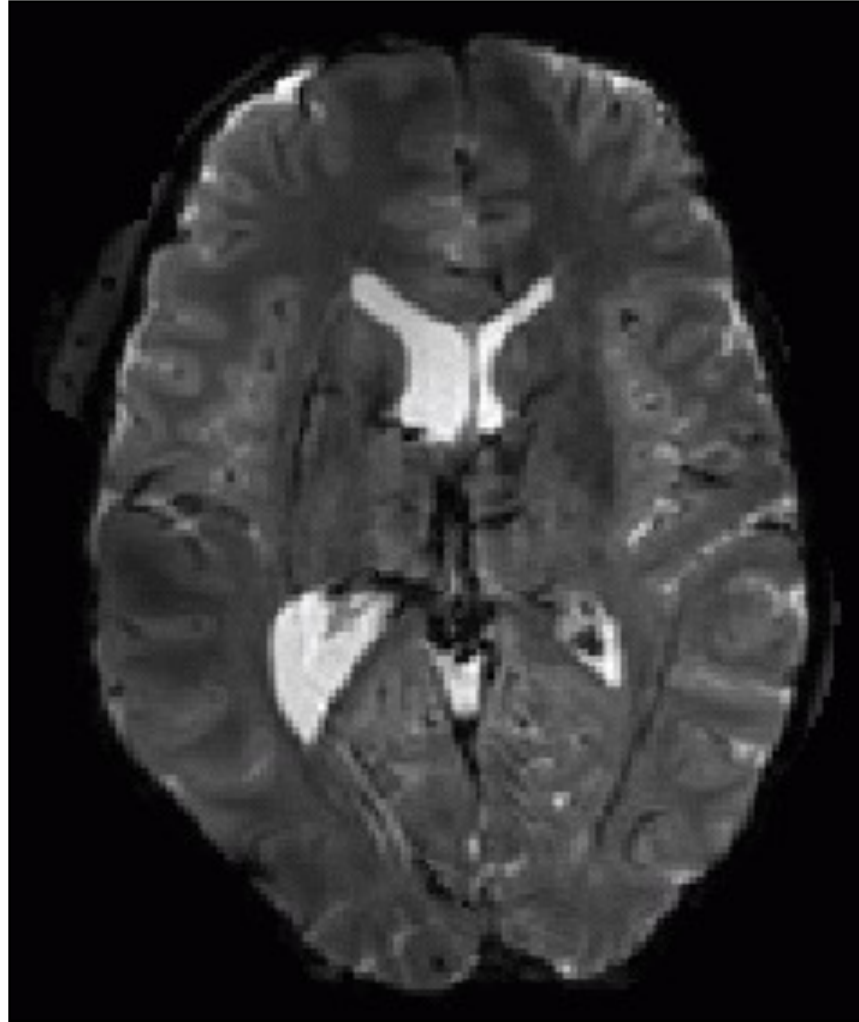


$\approx 5$  to  $30$  ms



Pruessmann, et al.

# Technology



3T single-shot SENSE EPI using 16 channels: 1.25x1.25x2mm



# Technology

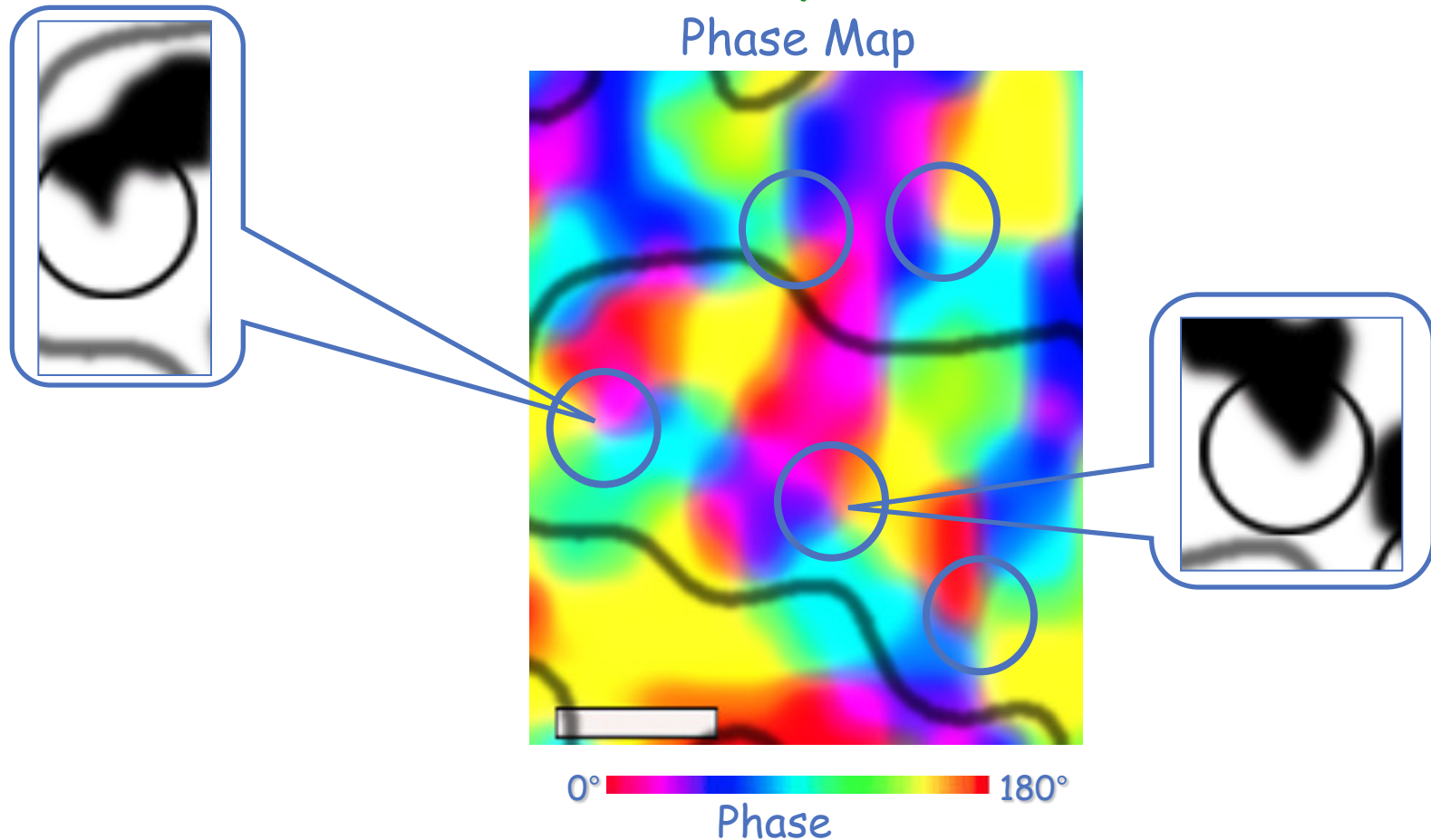


fiber bundles?

Courtesy Tie-Qiang  
Li, NINDS



# Orientation Columns in Human V1 as Revealed by fMRI at 7T



Yacoub, Ugurbil & Harel  
University of Minnesota / CMRR

HBM 2006: Thursday, June 15, 2006 at 9:30

Scalebar = 0.5 mm

## fMRI Contrast

- Volume (gadolinium)
- BOLD
- Perfusion (ASL)
- $\Delta\text{CMRO}_2$
- $\Delta\text{Volume}$  (VASO)
- Neuronal Currents
- Diffusion coefficient
- Temperature

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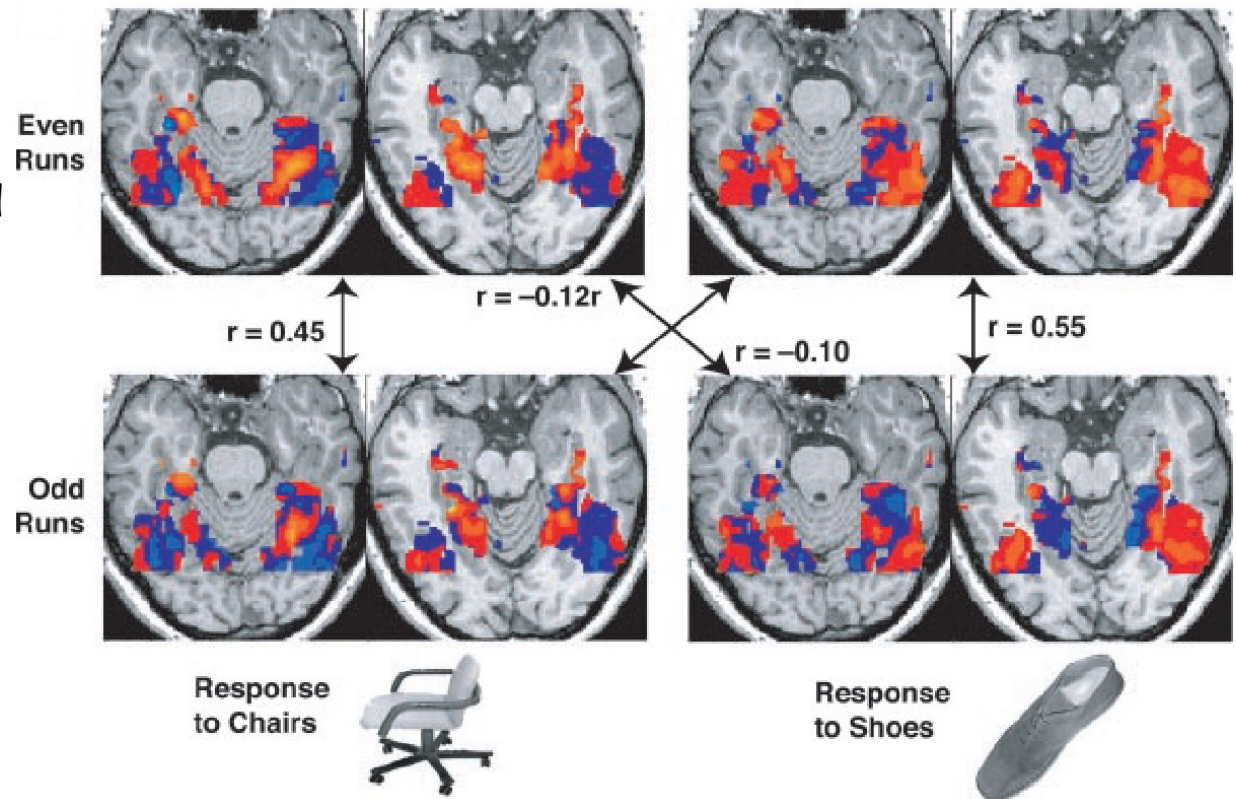
# Interpretation

# Applications

# Methodology

## Ventral temporal category representations

- Object categories are associated with distributed representations in ventral temporal cortex
- Present photos of common objects blocked by category.
- Use fMRI to measure the pattern of high and low responses across large areas of ventral temporal cortex.
- Observe stable, distributed "category representations"



Haxby et al. 2001

# Methodology

## Functional magnetic resonance imaging (fMRI) “brain reading”: detecting and classifying distributed patterns of fMRI activity in human visual cortex

David D. Cox<sup>a,b,\*</sup> and Robert L. Savoy<sup>a,b,c</sup>

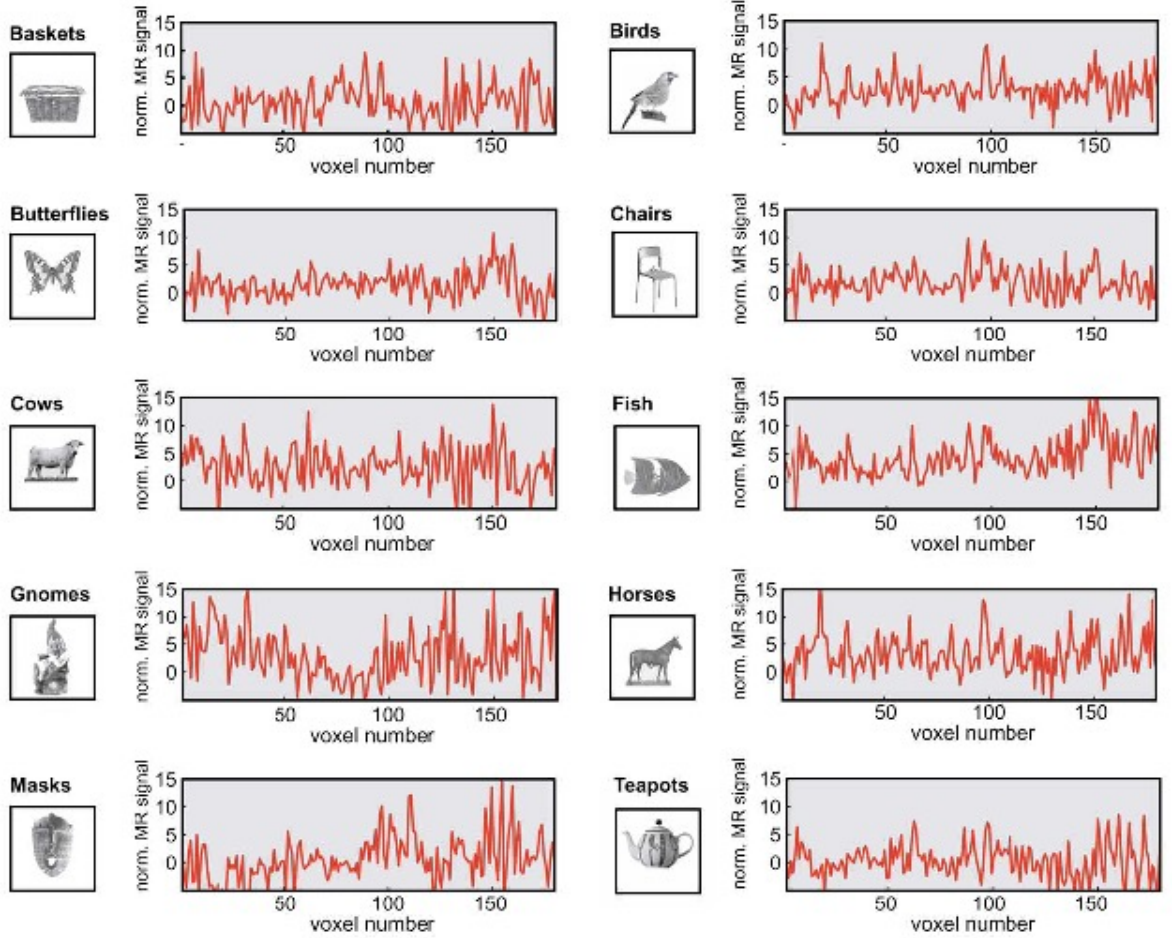
<sup>a</sup> Rowland Institute for Science, Cambridge, MA 02142, USA

<sup>b</sup> Athinoula A. Martinos Center for Structural and Functional Biomedical Imaging, Charlestown, MA 02129, USA

<sup>c</sup> HyperVision, Inc., P.O. Box 158, Lexington, MA 02420, USA

Received 15 July 2002; accepted 10 December 2002

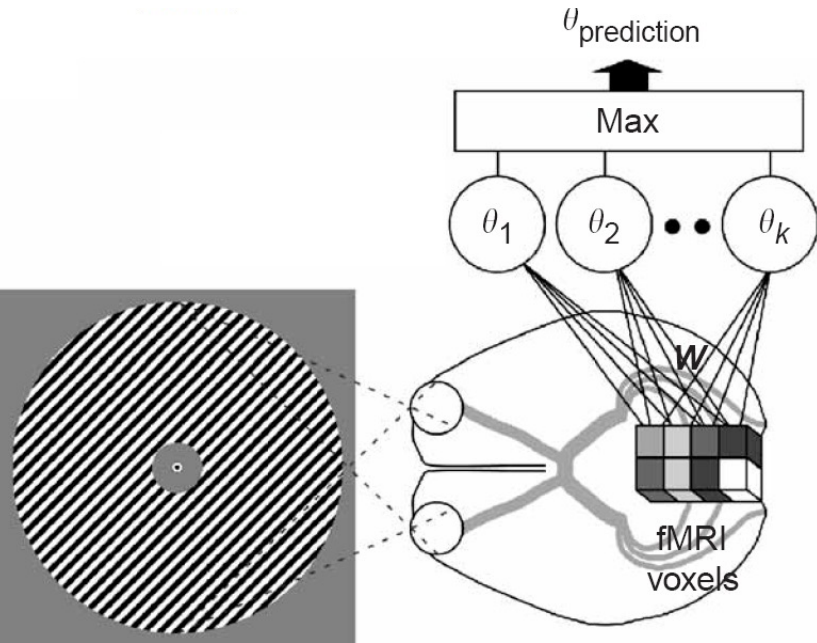
### NEUROIMAGE 19 (2): 261-270 Part 1 JUN 2003





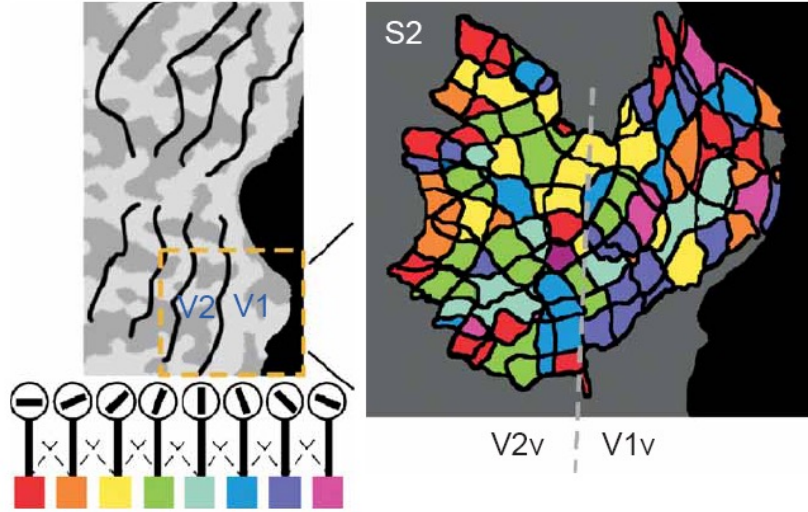
# Methodology

Iso-orientation domains are not resolved,  
but the viewed orientation can be predicted



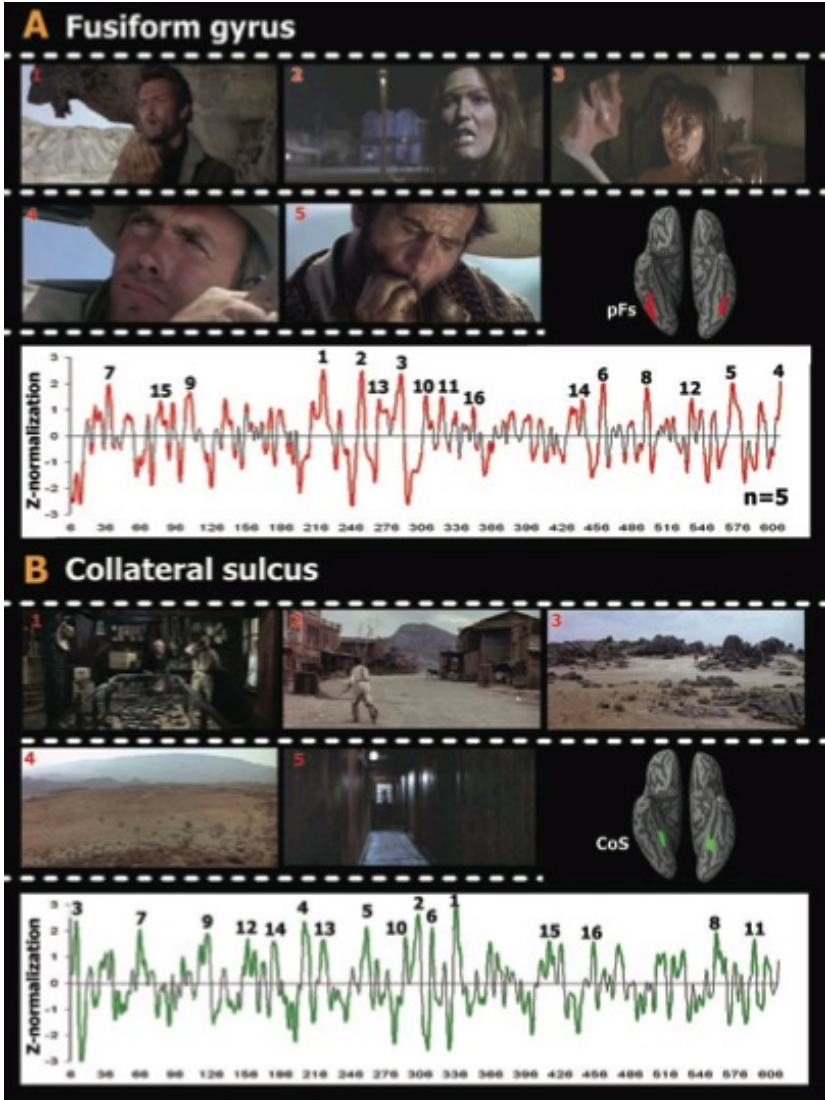
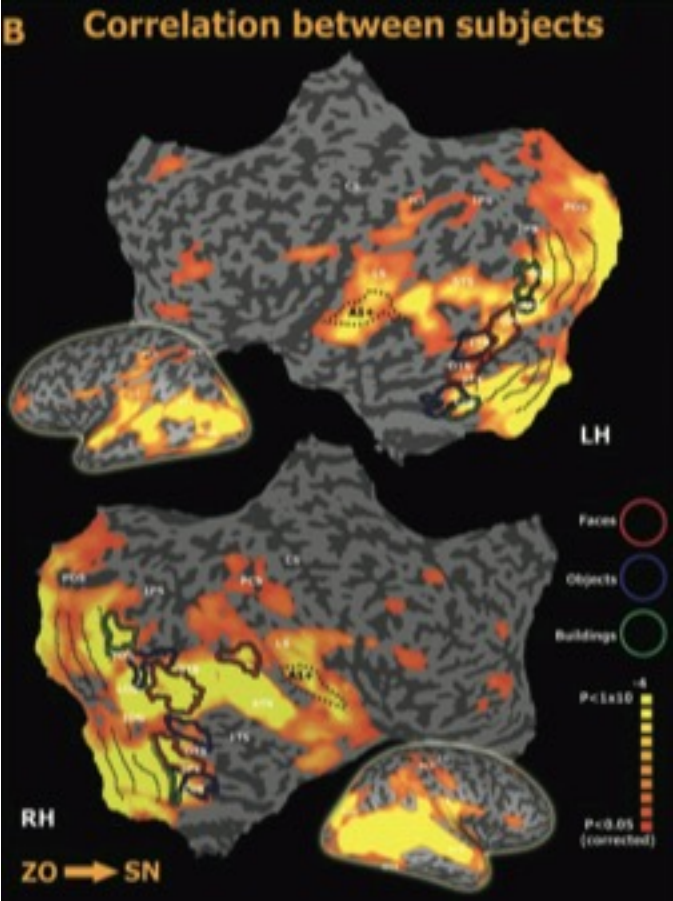
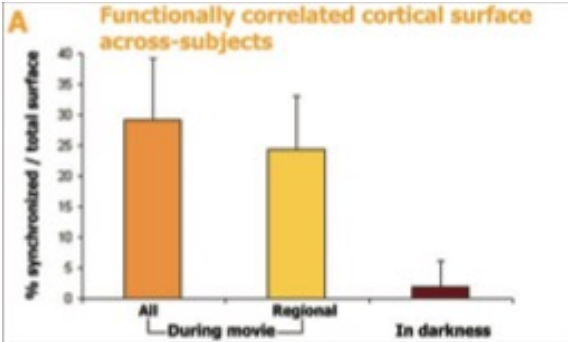
Haynes & Rees (2005)

## Lower spatial frequency clumping



Kamitani & Tong (2005)

# Methodology

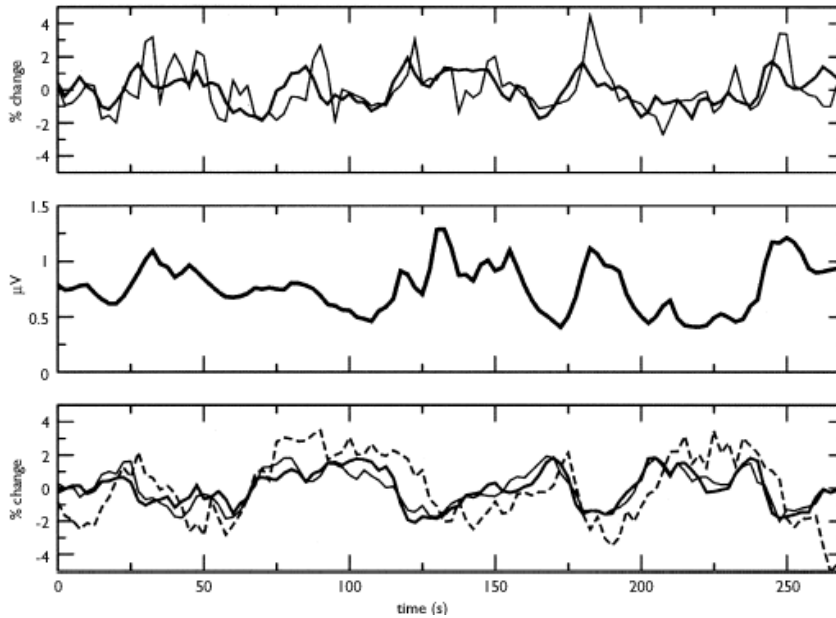


Hasson, et al (2004), Science, 303, 1634-1640

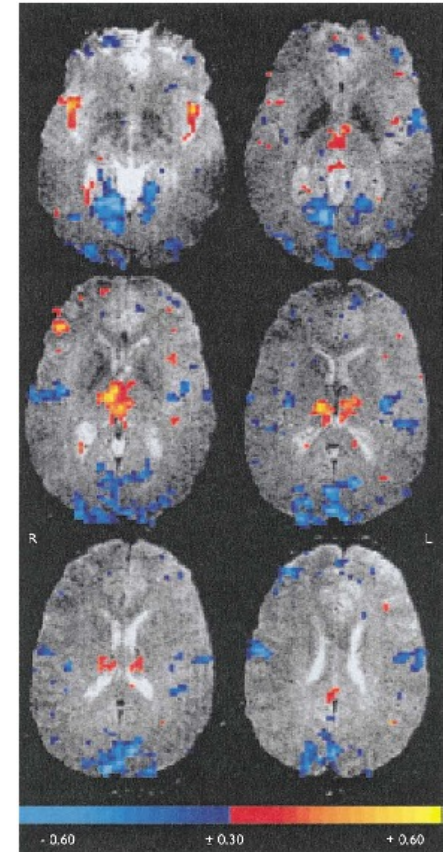
# Methodology

BOLD correlated with 10 Hz power during "Rest"

Positive  
10 Hz power  
Negative



Goldman, et al (2002), Neuroreport





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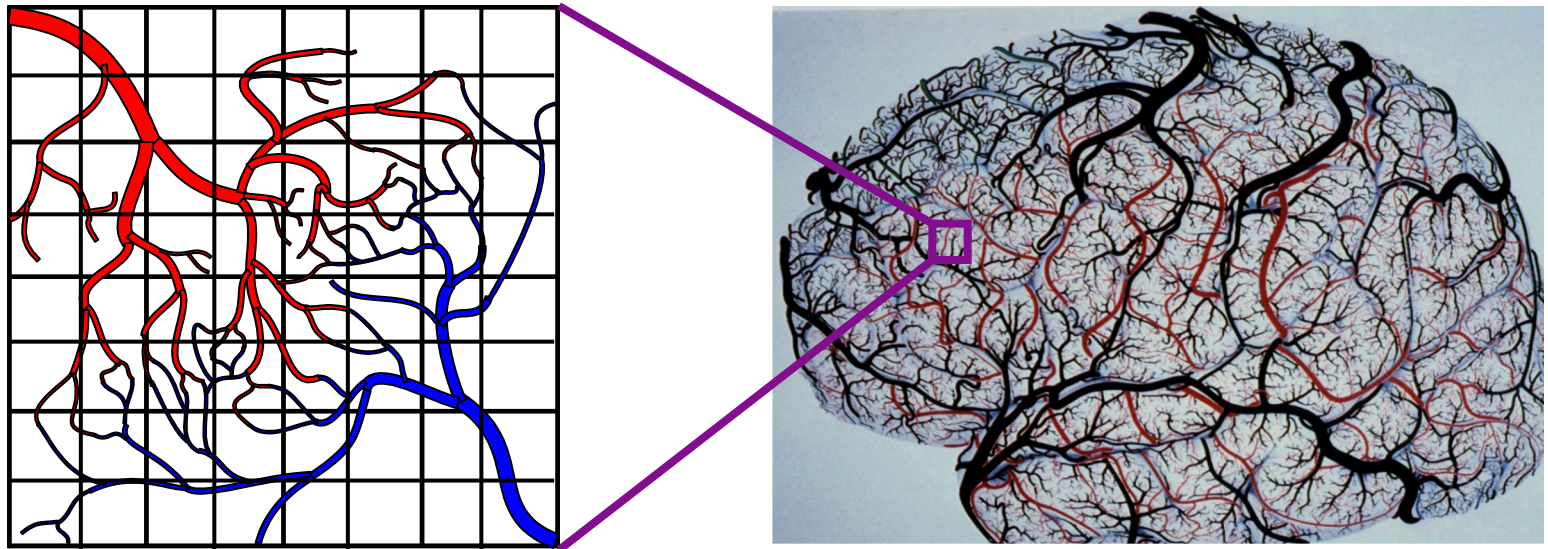
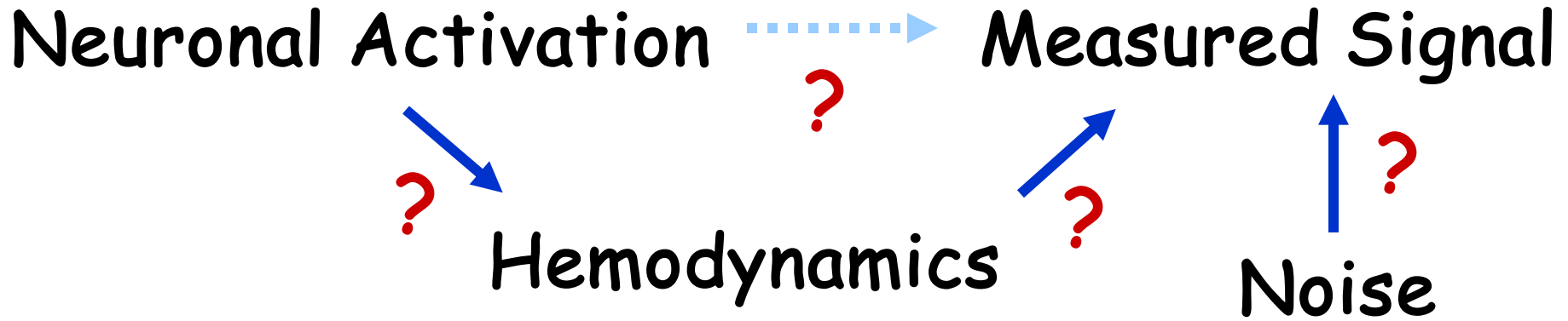
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# Interpretation

# Applications

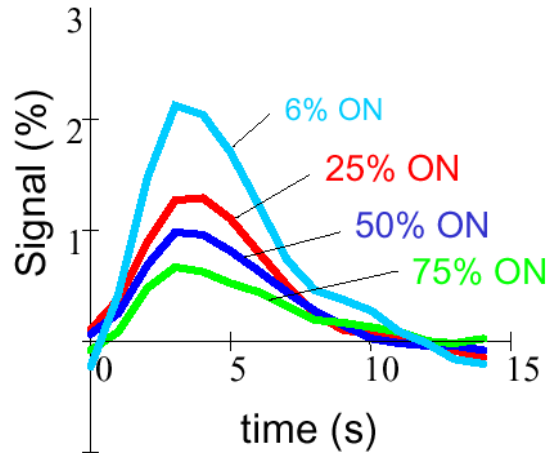
# Interpretation



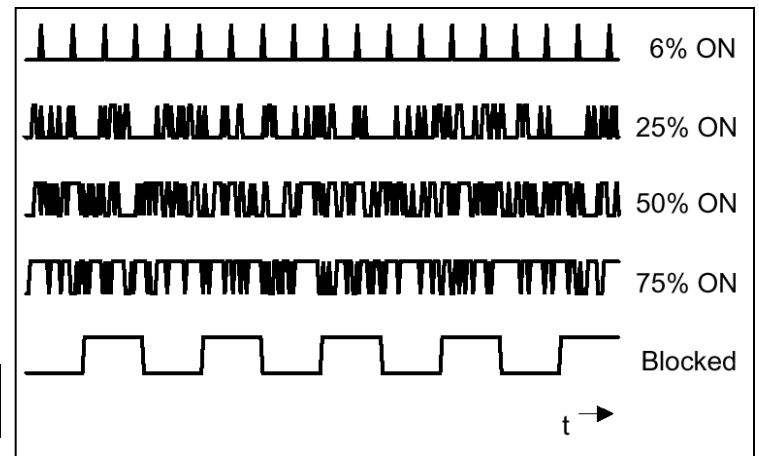
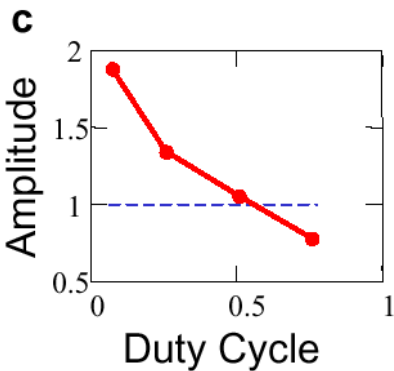
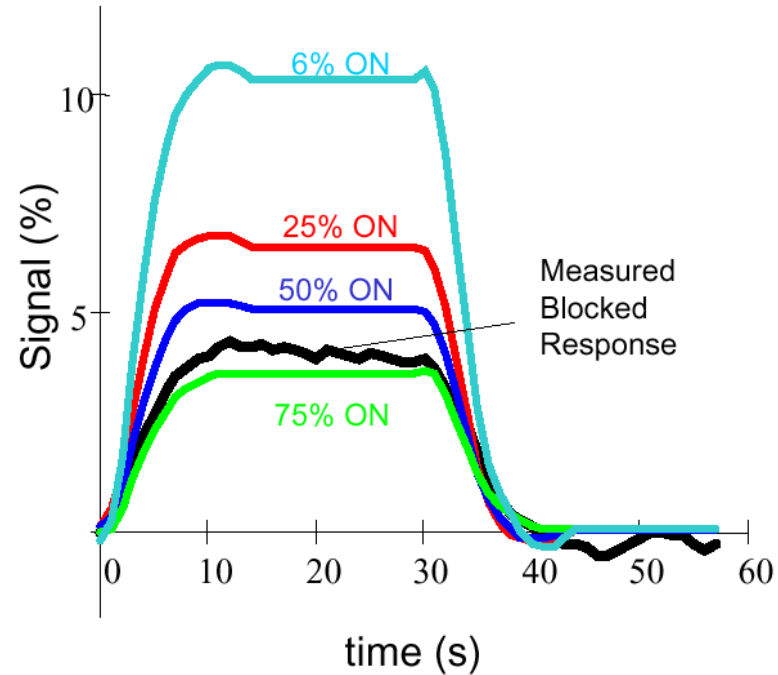
# Interpretation

# Duty Cycle Effects

**a** Measured Event-related Responses

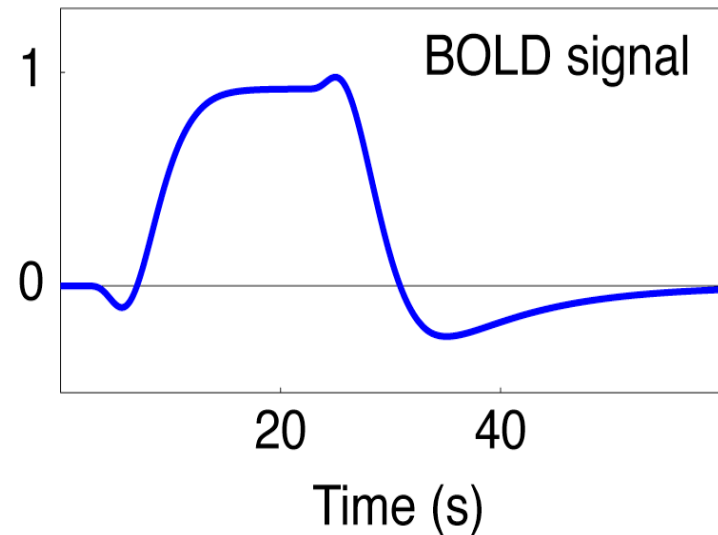
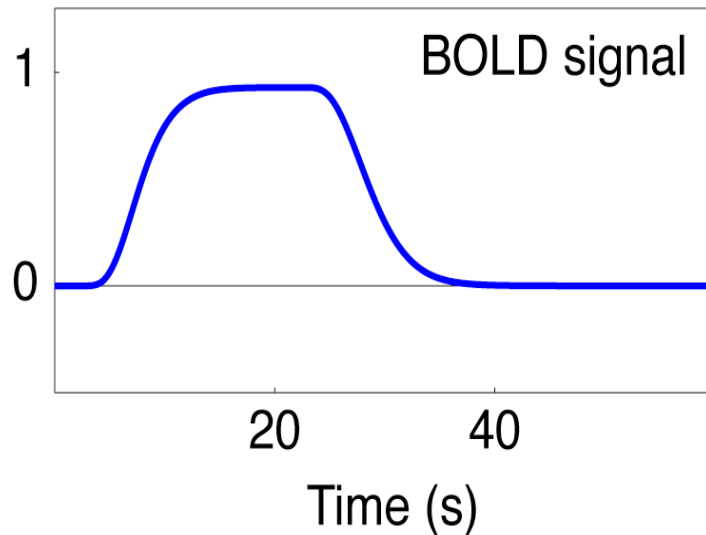
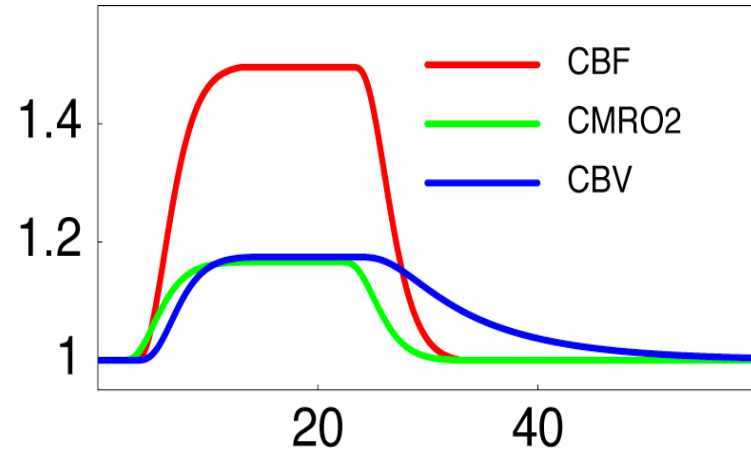
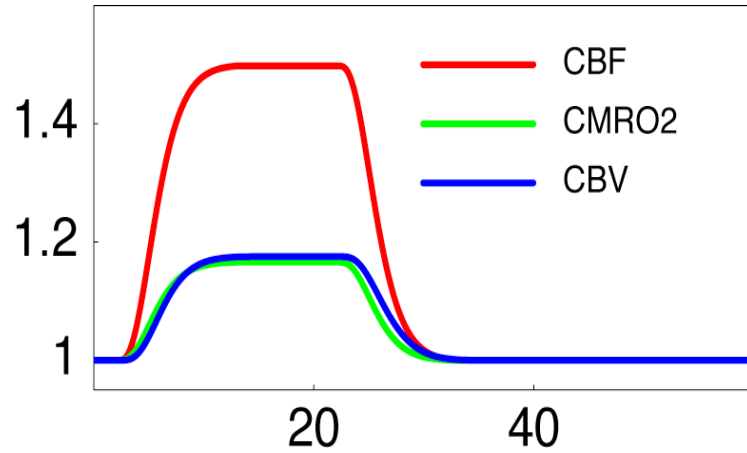


**b** Predicted Blocked Responses



# Interpretation

## BOLD Signal Dynamics



Courtesy Rick Buxton

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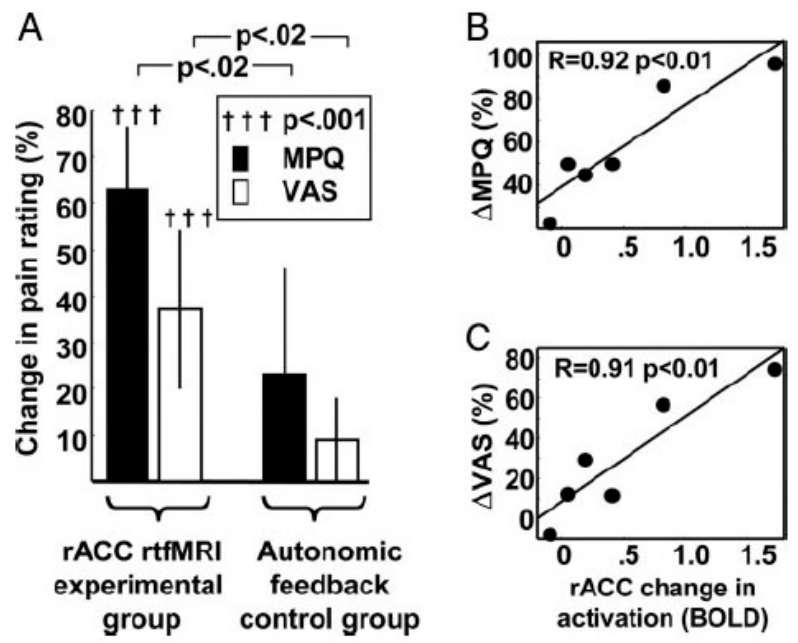
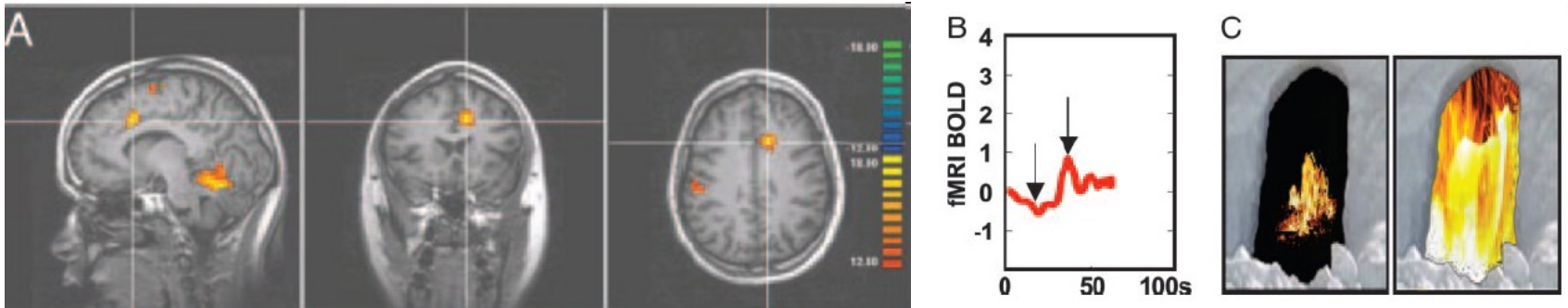
Basic Neuroscience  
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# Interpretation

# Applications

# Applications

## Real time fMRI feedback to reduce chronic pain



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

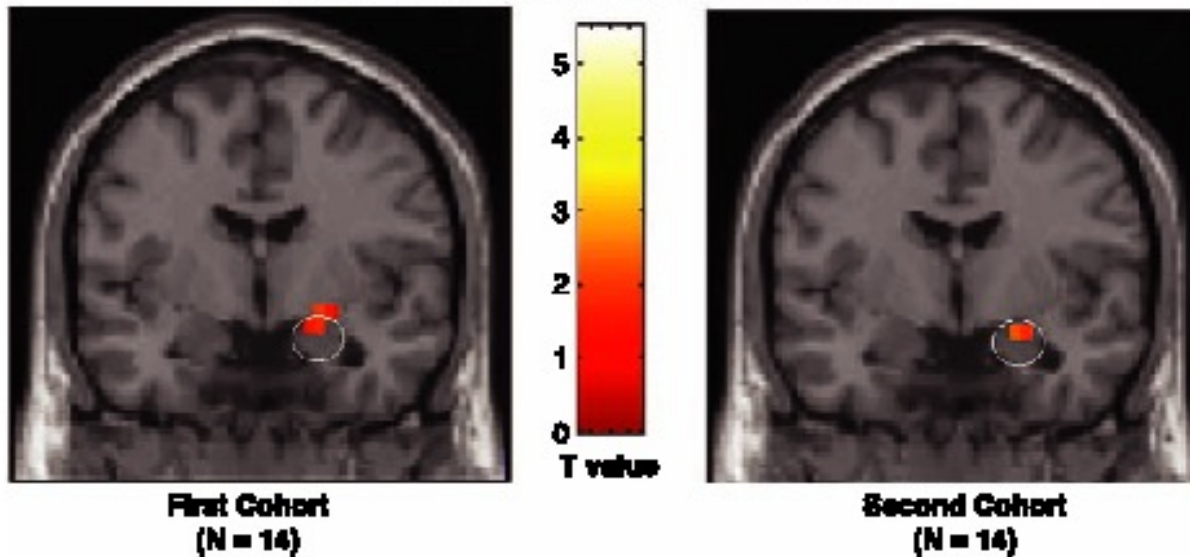
# Applications

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

## Serotonin Transporter Genetic Variation and the Response of the Human Amygdala

Ahmad R. Hariri,<sup>1</sup> Venkata S. Mattay,<sup>1</sup> Alessandro Tessitore,<sup>1</sup>  
Bhaskar Kolachana,<sup>1</sup> Francesco Fera,<sup>1</sup> David Goldman,<sup>2</sup>  
Michael F. Egan,<sup>1</sup> Daniel R. Weinberger<sup>1\*</sup>

**Amygdala Response: 2 Group > 1 Group**



# Uses

## Understanding normal brain organization and changes

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

## Clinical research

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

# Future Uses

## Complementary use for clinical diagnosis

- utilization of clinical research results
- prediction of pathology

## Clinical treatment and assessment

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

## Non clinical uses

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