Functional MRI:
Patterns, Fluctuations and a Focus on the Individual

Peter A. Bandettini, Ph.D.

Section on Functional Imaging Methods
Laboratory of Brain and Cognition
http://fim.nimh.nih.gov

&

Functional MRI Facility
http://fmrif.nimh.nih.gov

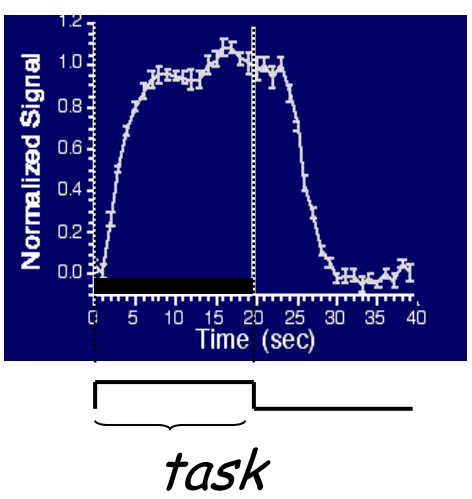
Overview of fMRI

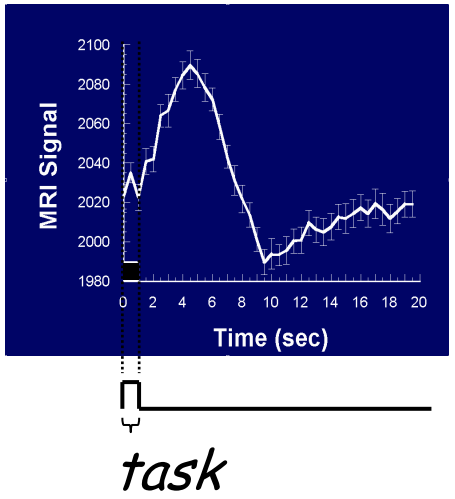
Functional Contrast:

- Blood volume
- Blood flow/perfusion
- Blood oxygenation

Spatial resolution:

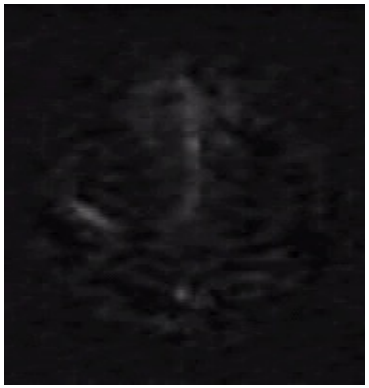
- Typical: 3 mm^3
- Upper: 0.5 mm^3





Temporal resolution:

- Minimum duration: < 16 ms
- Minimum onset diff: 100 ms to 2 sec



Sensitivity:

- tSNR = 40/1 to 120/1
- fCNR = 1/1 to 6/1

Interpretability issues:

- Neurovascular coupling, vascular sampling, blood, physiologic noise, motion and other artifacts, etc..

What fMRI Is Currently Being Used For

Research Applications

- -map networks involved with specific behavior, stimulus, or performance
- -characterize changes over time (seconds to years)
- -determine correlates of behavior (response accuracy, etc…)
- -characterization of groups or individuals

Clinical Research

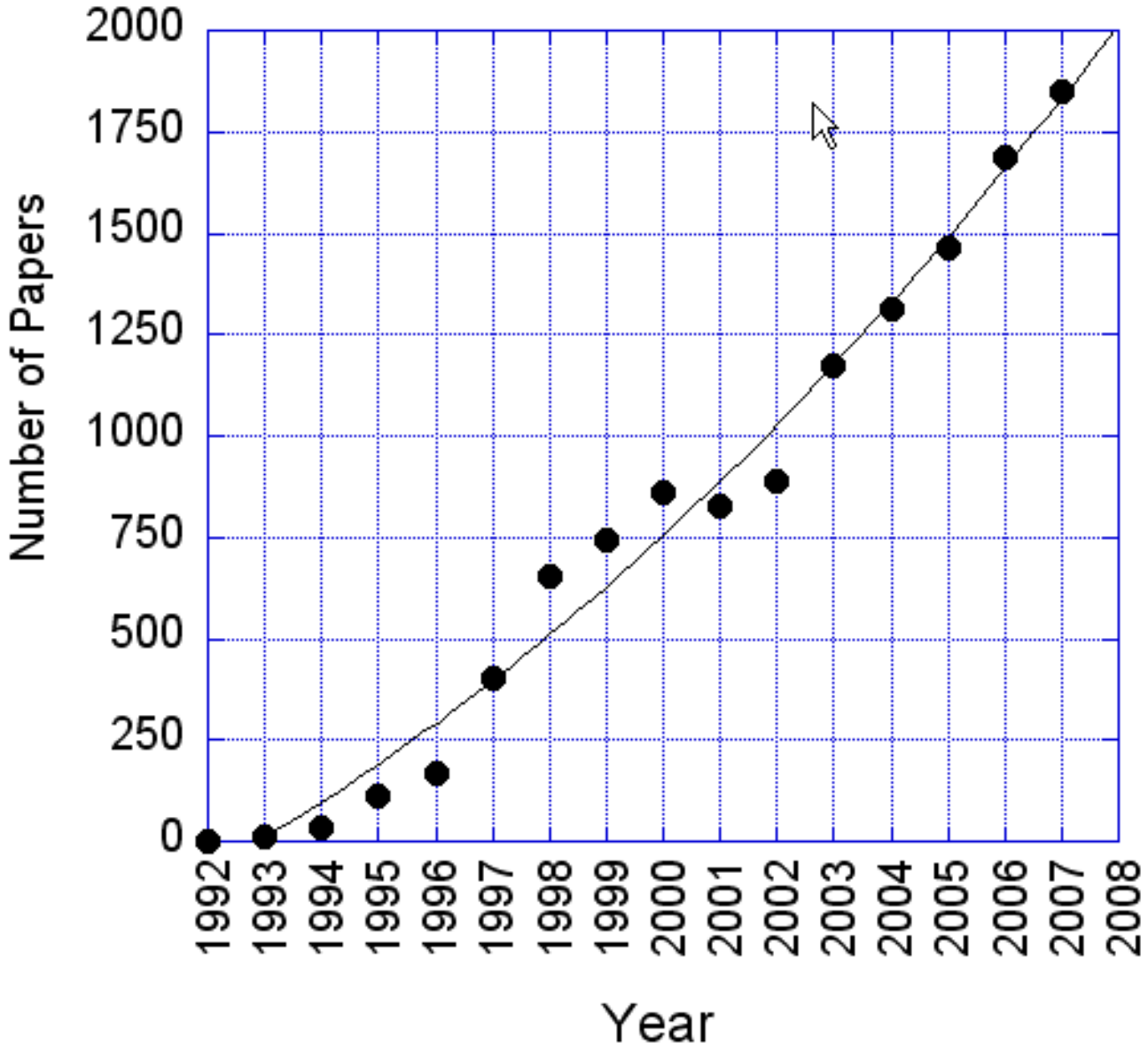
- -clinical population characterization (probe task or resting state)
- -assessment of recovery and plasticity
- -attempts to characterize (classify) individuals

Clinical Applications

- -presurgical mapping (CPT code in place as of Jan, 2007)

Scopus: Articles or Reviews Published per Year

"fMRI" or "functional MRI"



Technology

Coil arrays
High field strength
High resolution
Novel functional contrast

Methodology

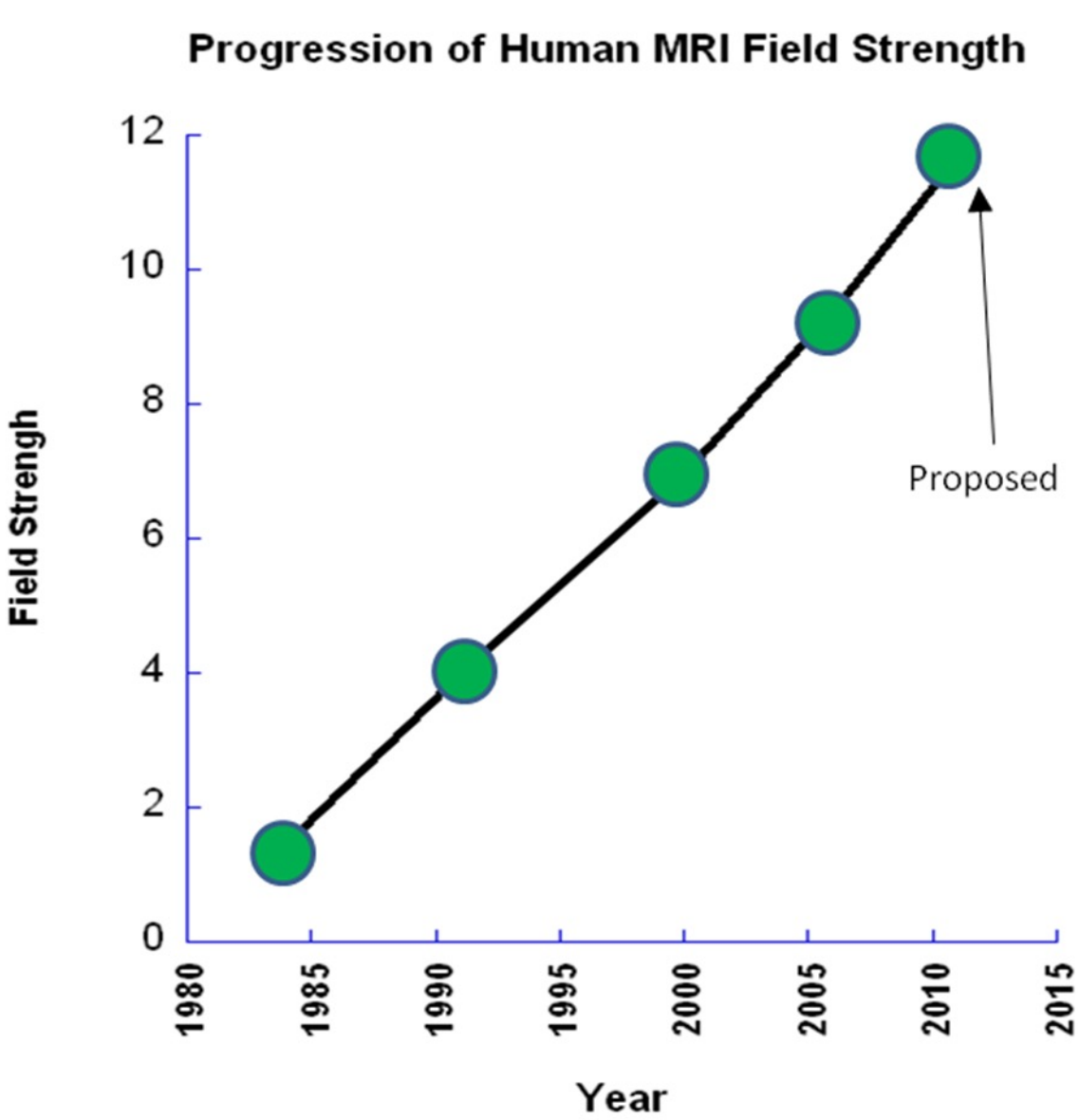
Functional Connectivity Assessment
Multi-modal integration
Pattern classification
Real time feedback
Task design (fMRIa…)

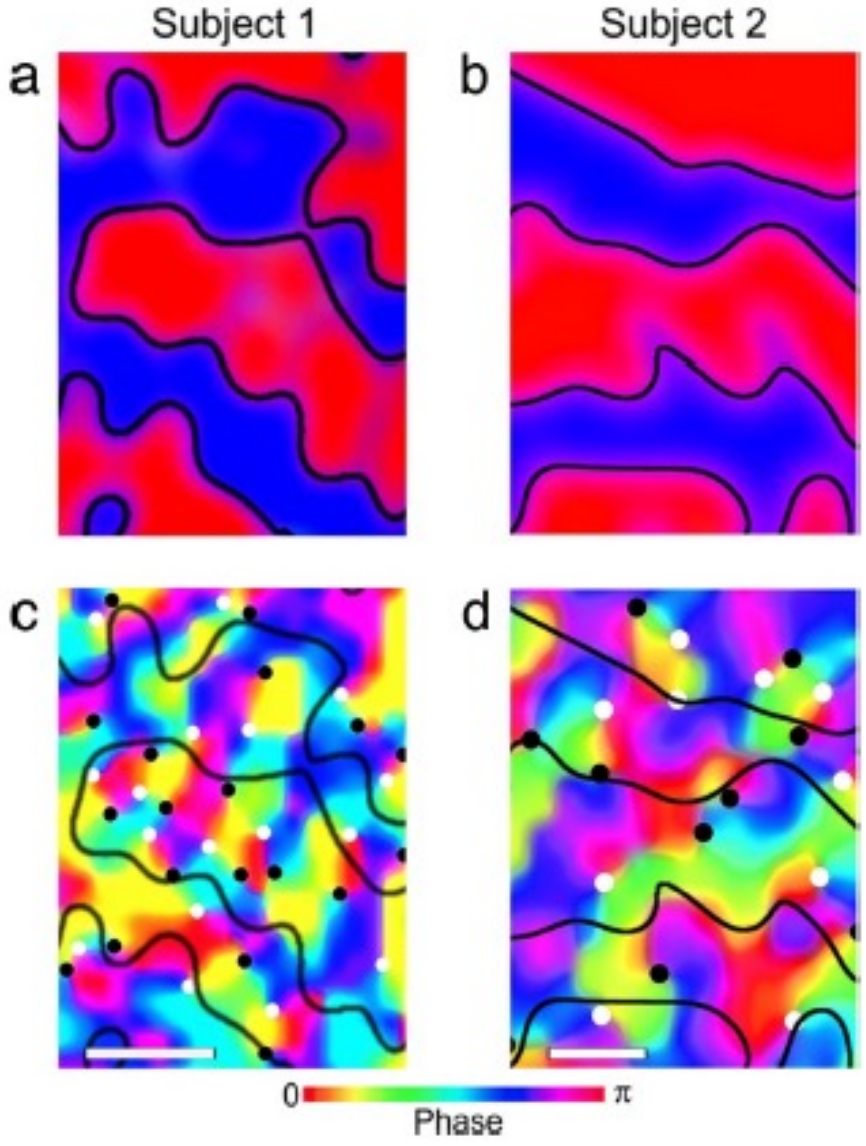
Fluctuations
Dynamics
Spatial patterns

Interpretation

Basic Neuroscience
Behavior correlation/prediction
Pathology assessment

Applications


Progression of Human MRI Field Strength
Field Strengh
0
2
4
6
8
10
12
1980
1985
1990
1995
2000
2005
2010
2015
Year
Proposed



Yacoub et al. PNAS 2008

fMRI Contrast

- Volume (gadolinium)
- BOLD
- Perfusion (ASL)
- $\Delta CMRO_2$
- ΔVolume (VASO)
- Neuronal Currents
- Diffusion coefficient
- Temperature

1. Patterns

2. Fluctuations

3. Individual Focus

1. Patterns

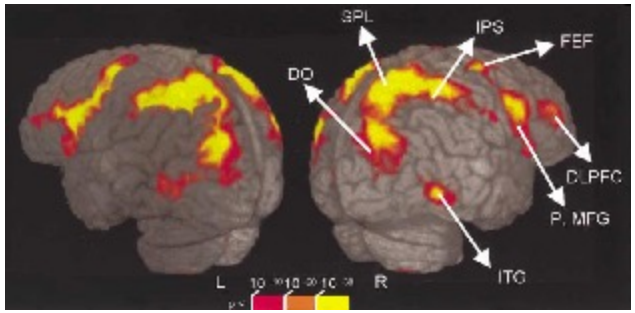
- Classical fMRI analysis:
  What's activated during a task?

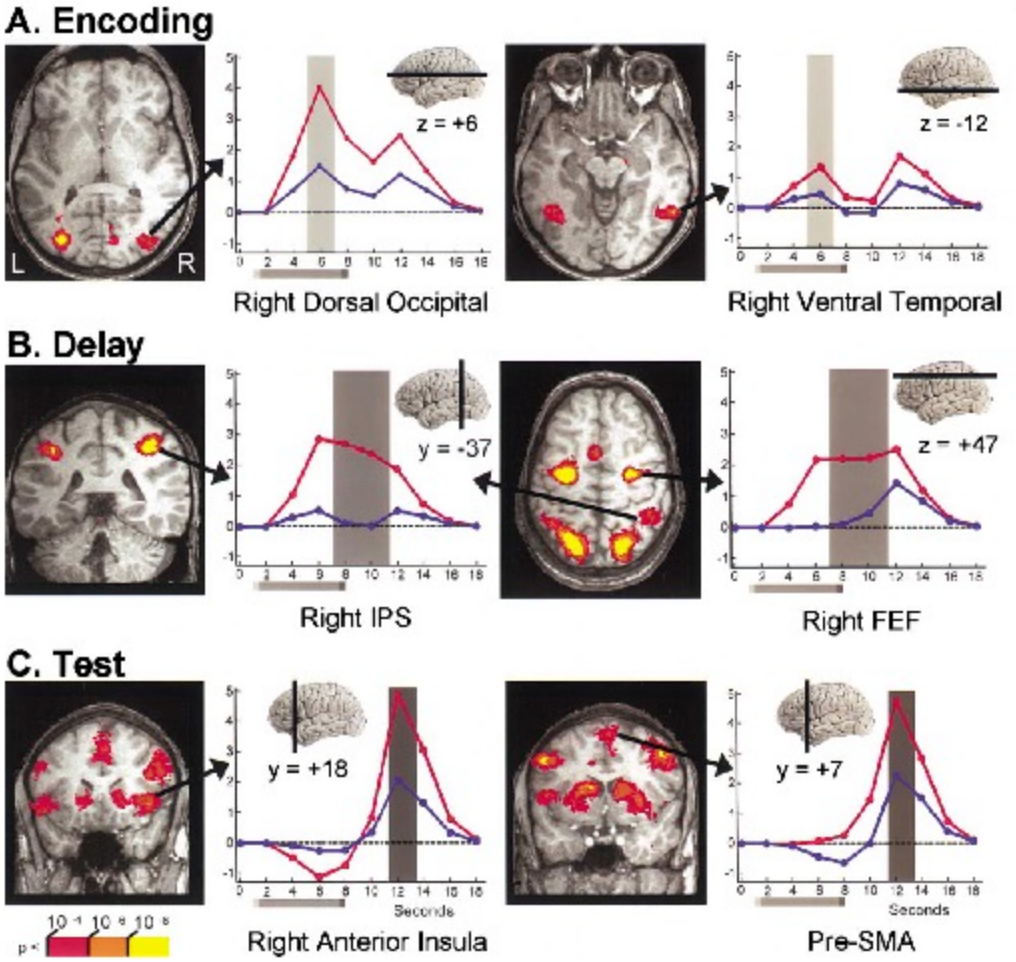
- Pattern-information analysis:
  Does a pattern carry a particular kind of information?

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

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

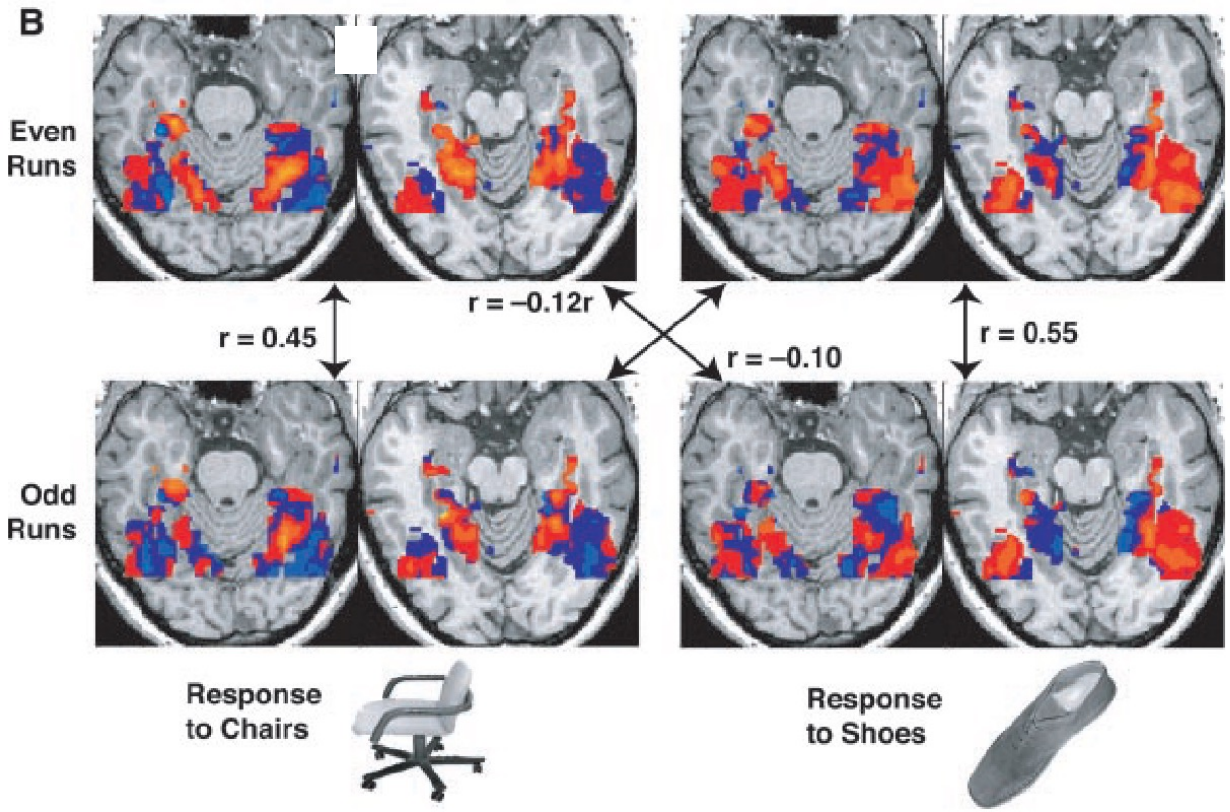
Luiz Pessoa,[1] Eva Gutierrez, Peter A. Bandettini, and Leslie G. Ungerleider
Laboratory of Brain and Cognition
National Institute of Mental Health
National Institutes of Health
Bethesda, Maryland 20892



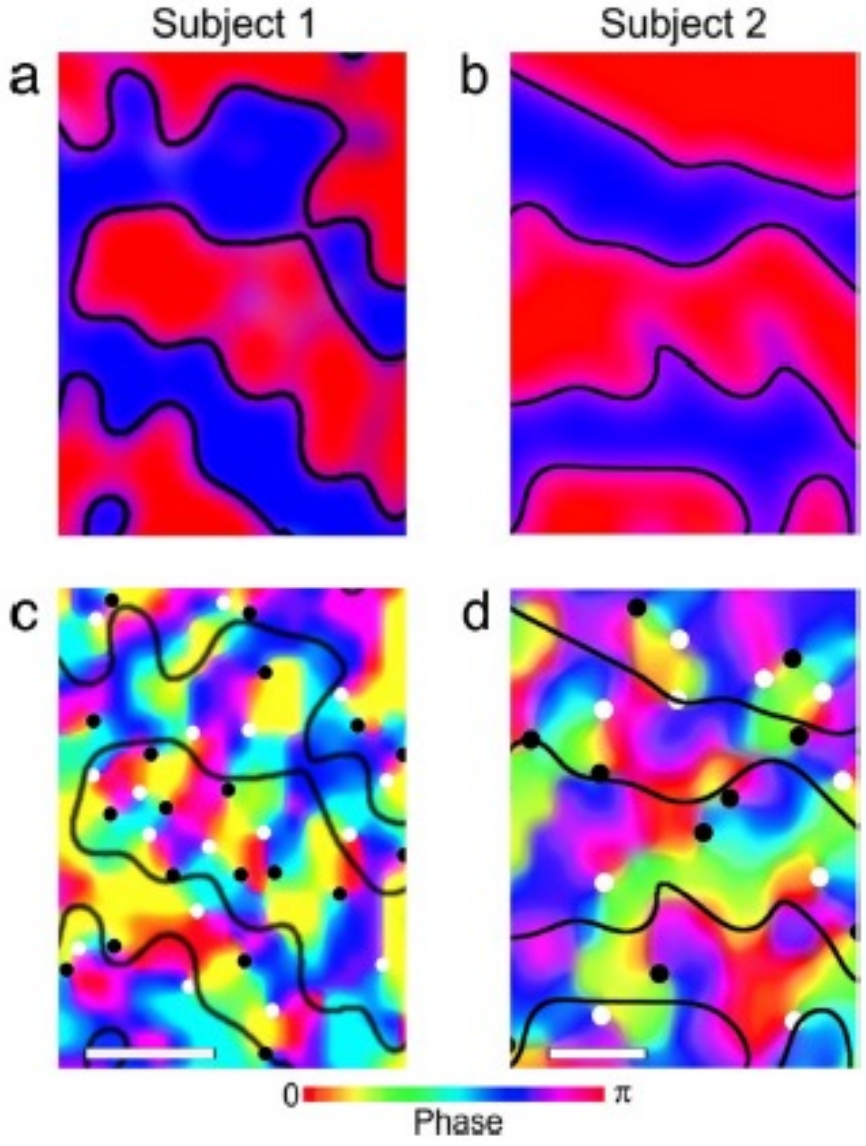


Ventral temporal category representations

Object categories are associated with distributed representations in ventral temporal cortex

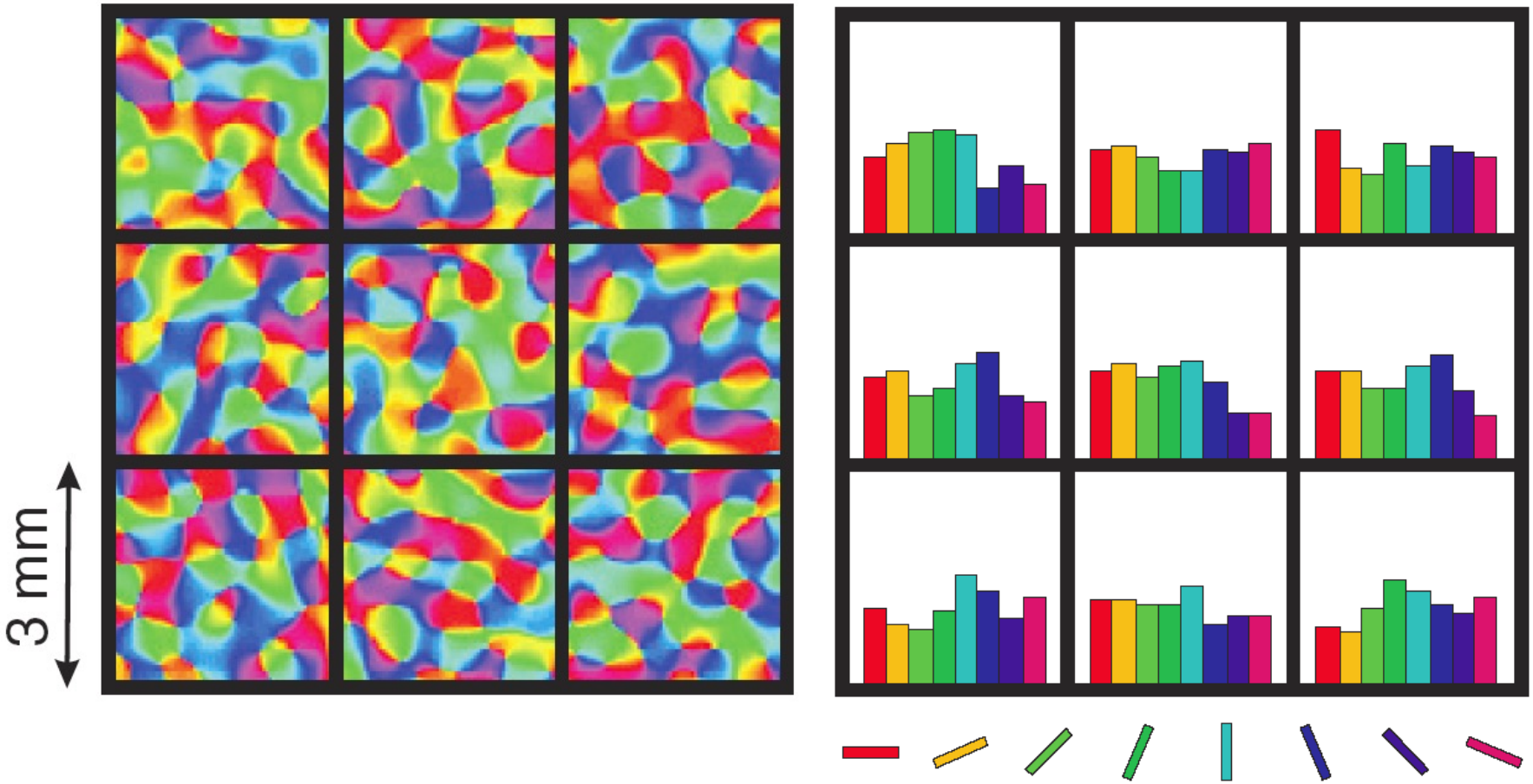


Haxby et al. 2001



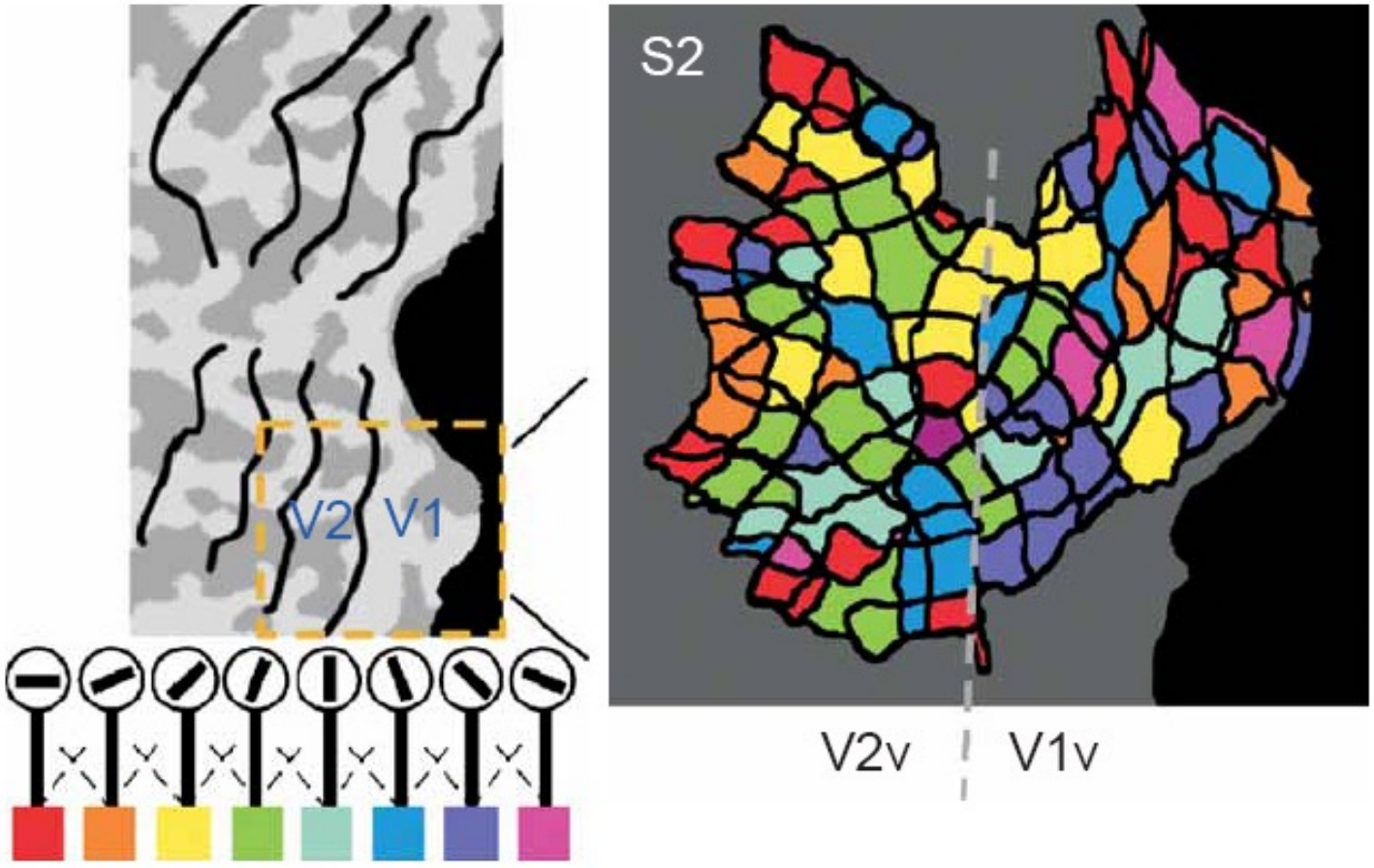
Yacoub et al. PNAS 2008

Methodology



Boynton (2005), News & Views on Kamitani & Tong (2005) and Haynes & Rees (2005)

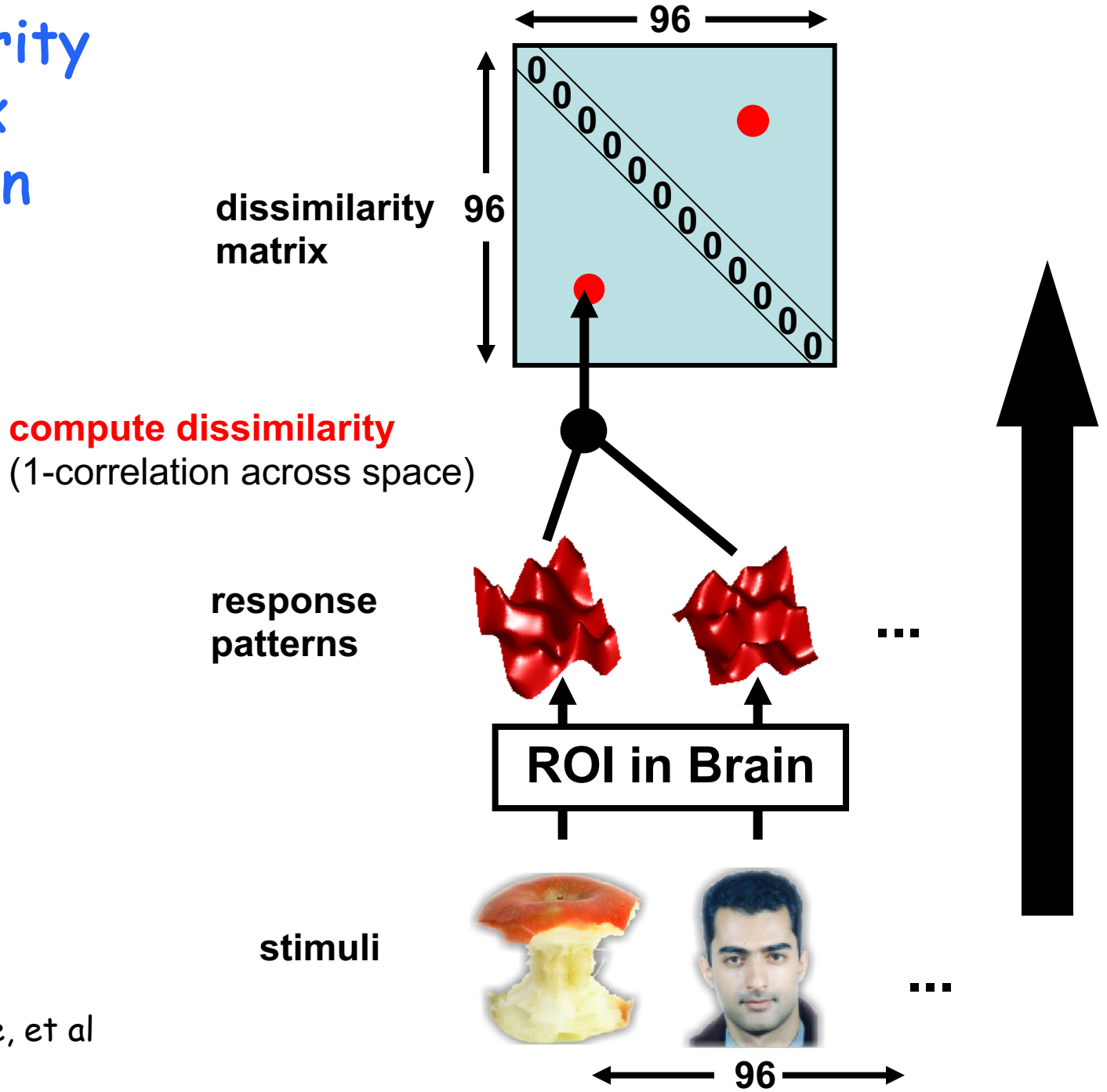
Lower spatial frequency clumping



Kamitani & Tong (2005)

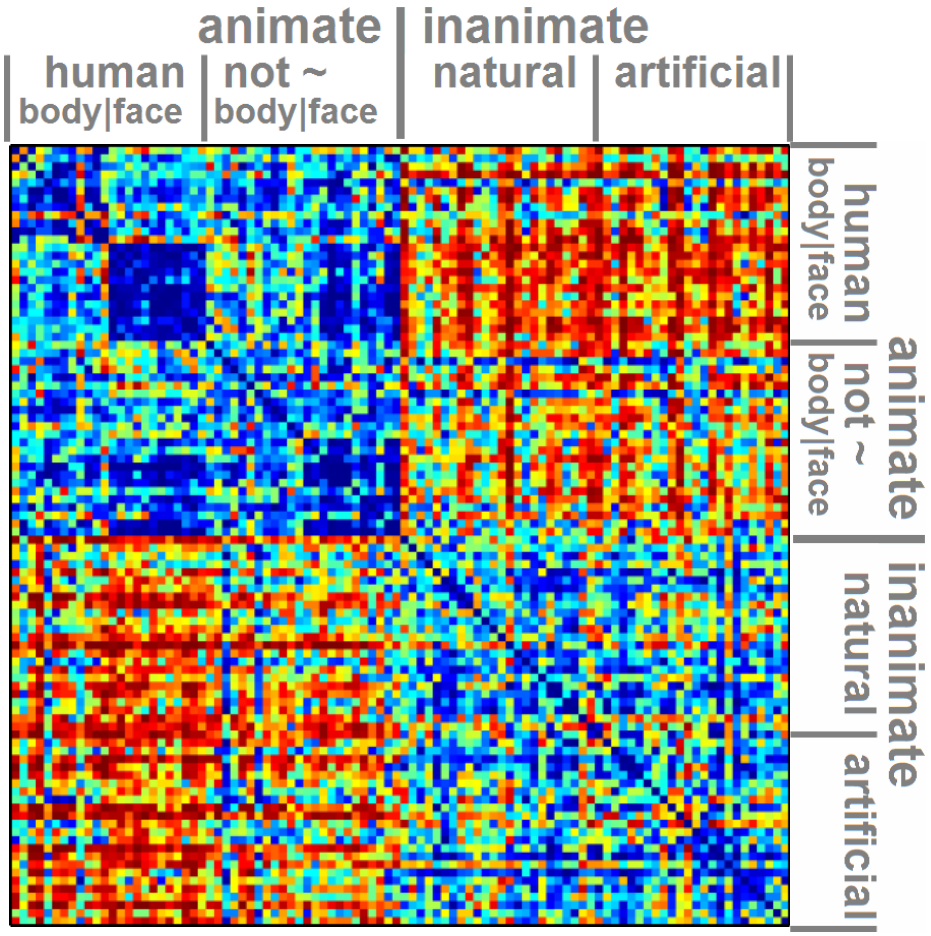
Visual Stimuli

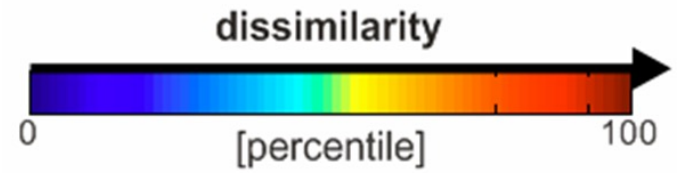
Dissimilarity Matrix Creation



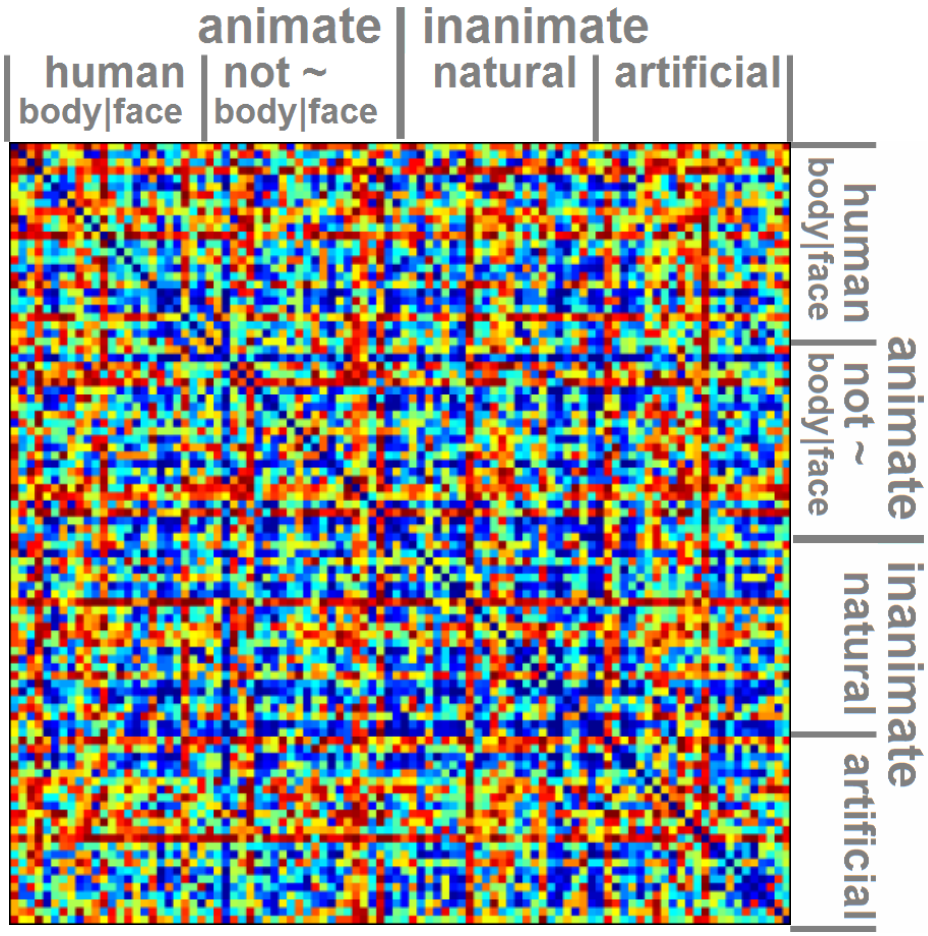
N. Kriegeskorte, et al

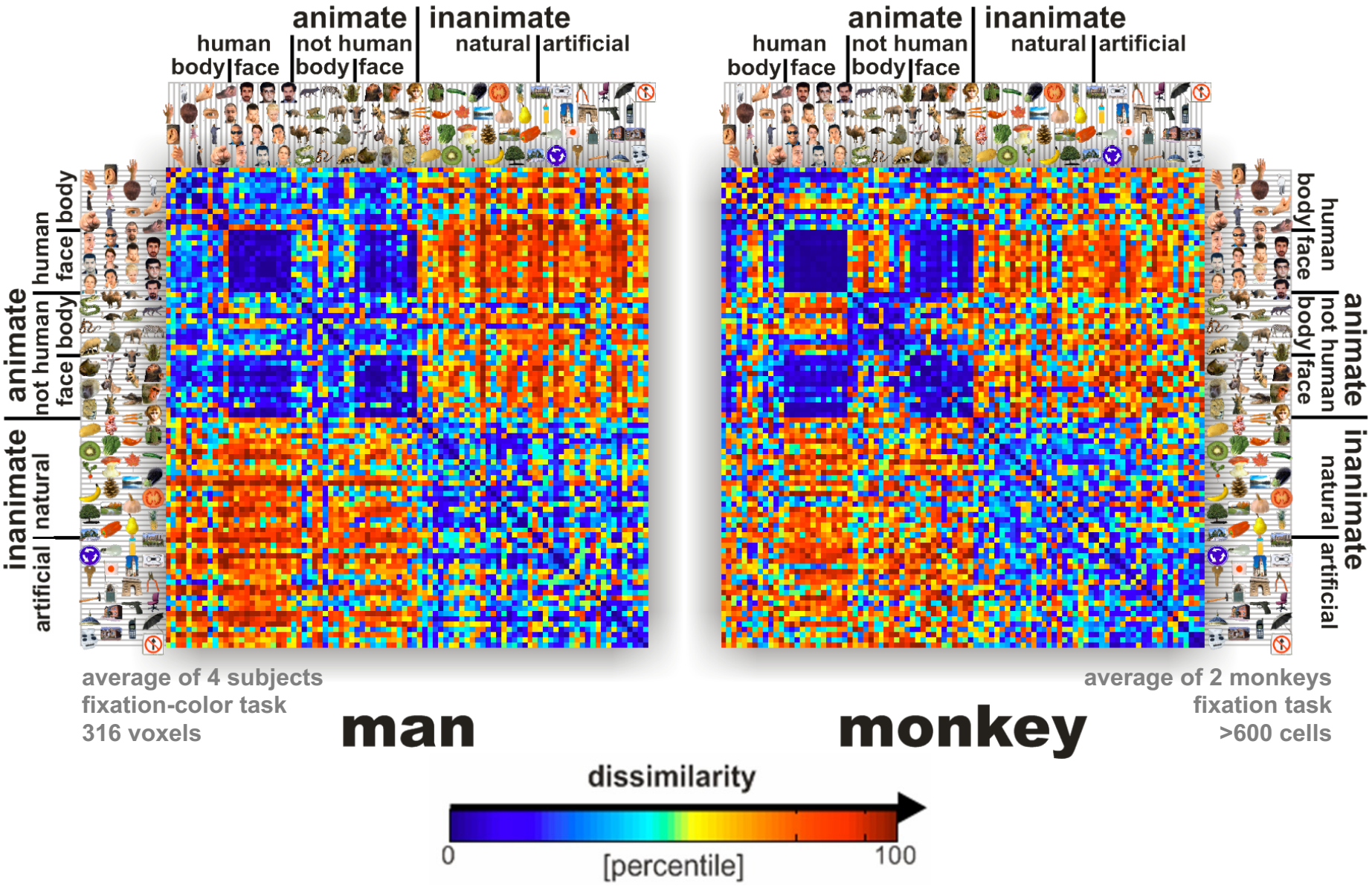
Human IT
(1000 visually most responsive voxels)





Human Early Visual Cortex
(1057 visually most responsive voxels)





N. Kriegeskorte, et al (in review)

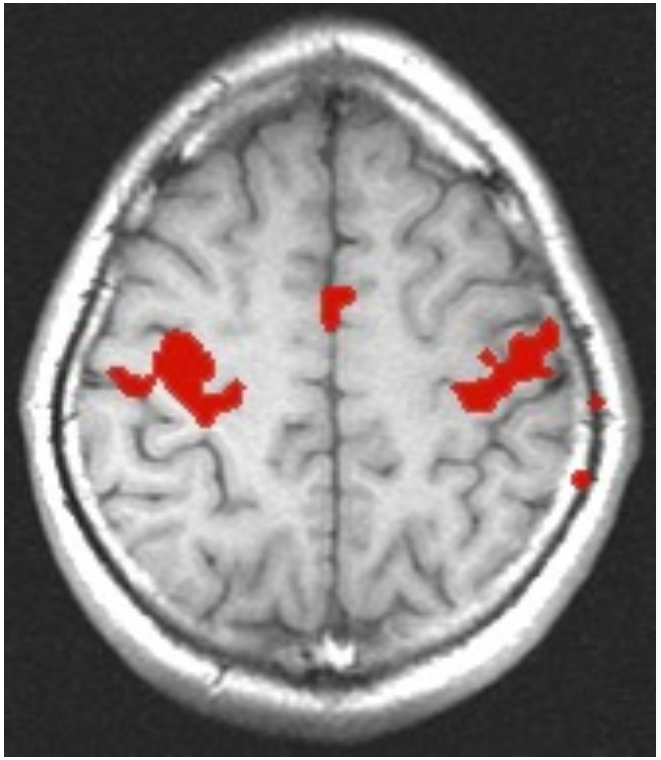
2. Fluctuations

Sources of time series fluctuations:

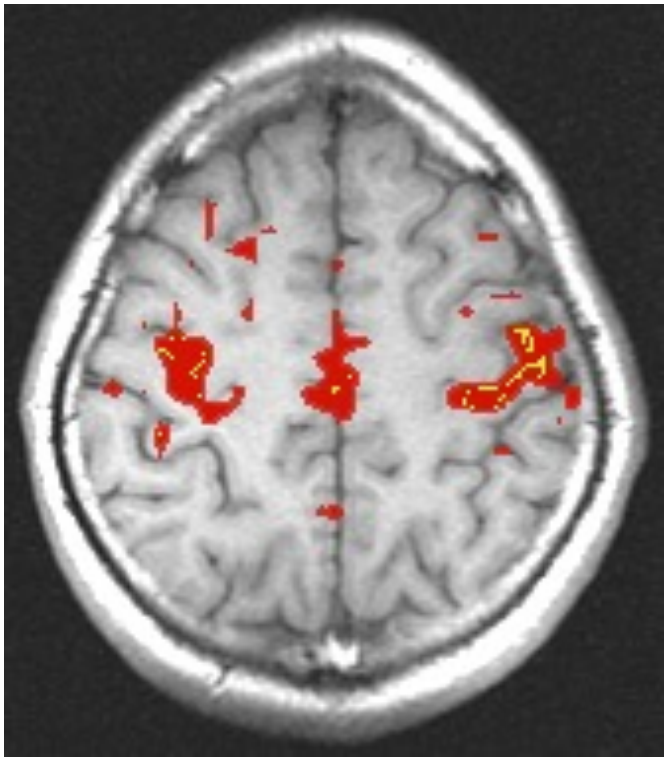
- Blood, brain and CSF pulsation
- Vasomotion
- Breathing cycle (B_0 shifts with lung expansion)
- Bulk motion
- Scanner instabilities
- Changes in blood CO_2 (changes in breathing)
- Spontaneous neuronal activity

Methodology

Resting State Correlations



Activation:
correlation with reference function



Rest:
seed voxel in motor cortex

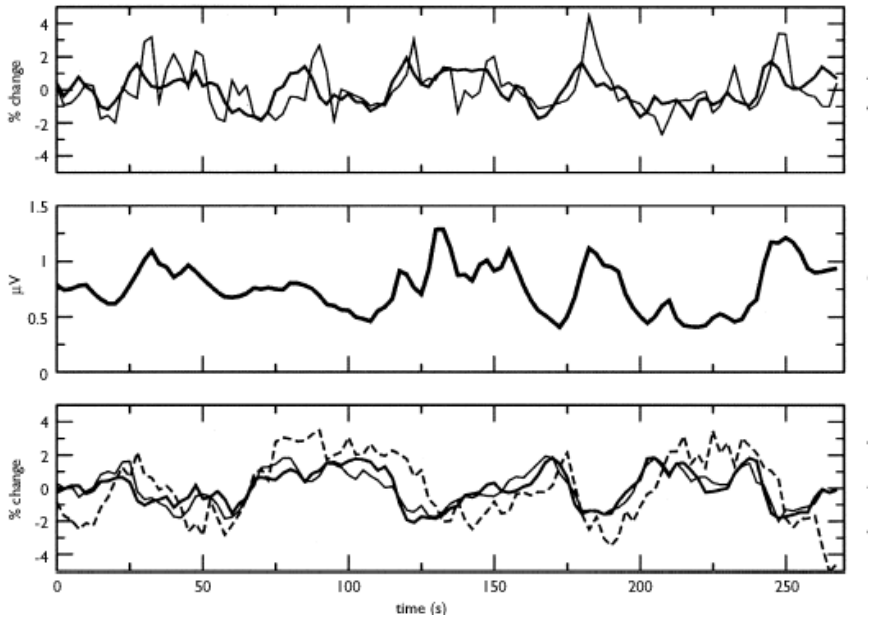
B. Biswal *et al.*, MRM, 34:537 (1995)

BOLD correlated with 10 Hz power during "Rest"

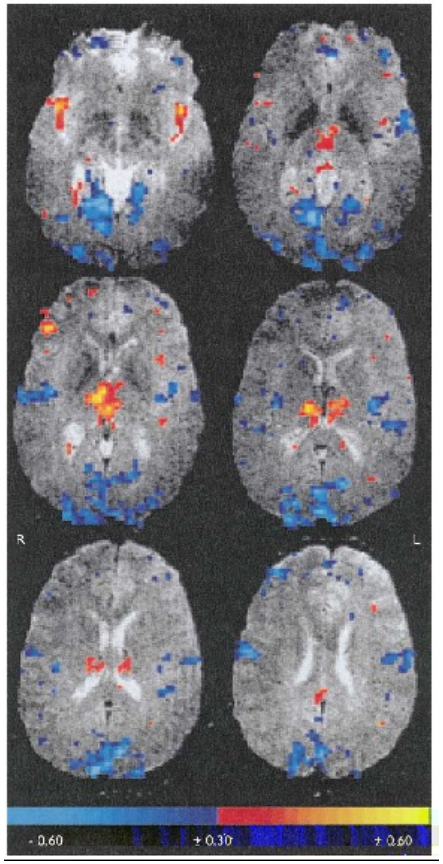
Positive

10 Hz power

Negative



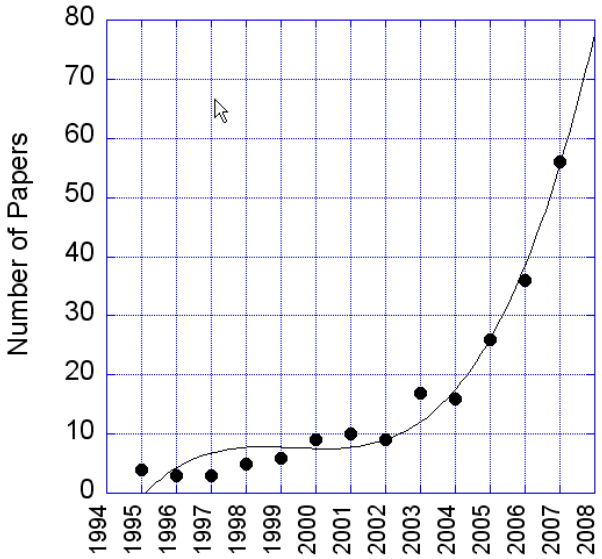
Goldman, et al (2002), Neuroreport

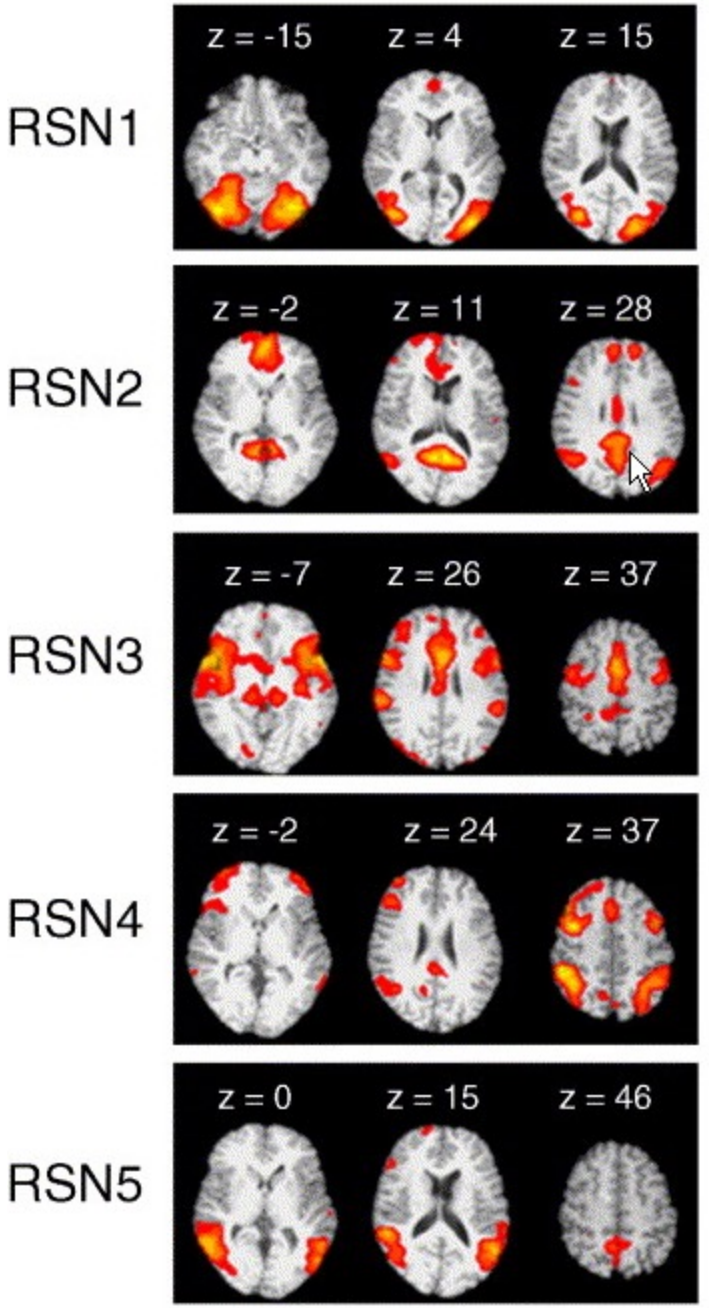


Methodology

Resting state networks identified with ICA

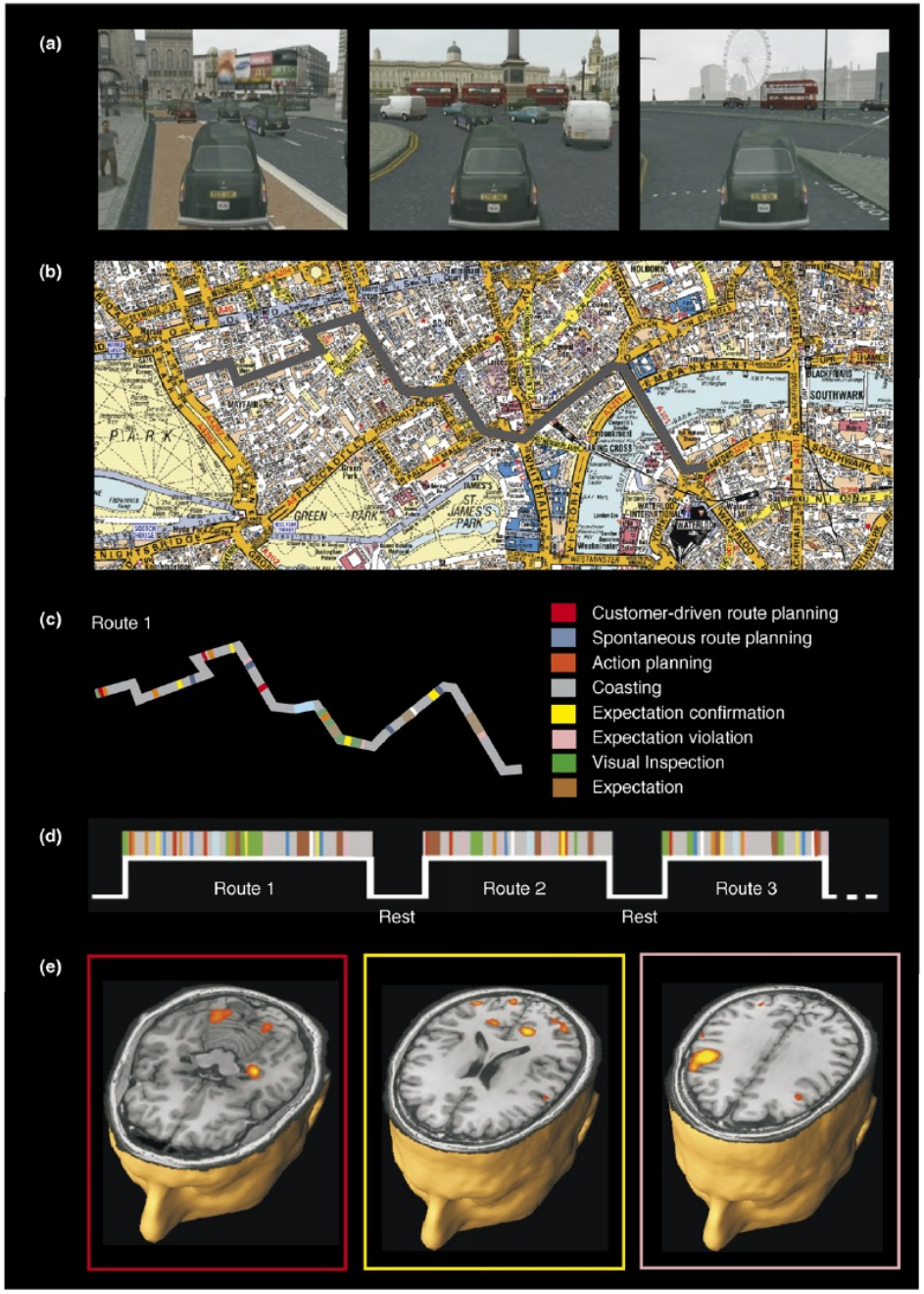
M. DeLuca, C.F. Beckmann, N. De Stefano,
P.M. Matthews, S.M. Smith,
fMRI resting state
networks define distinct modes
of long-distance
interactions in the human brain.
NeuroImage, 29, 1359-1367





Decoding human brain activity during real-world experiences

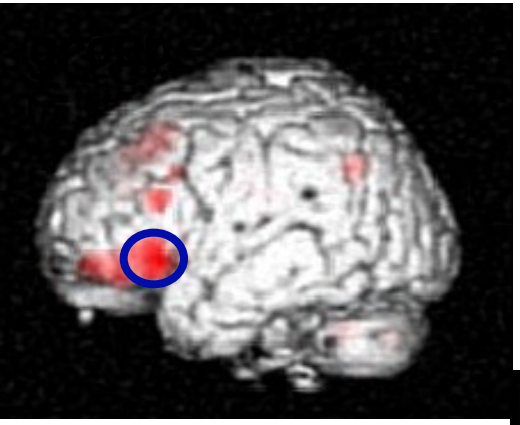
Hugo J. Spiers and Eleanor A. Maguire
TICS, 2007



2. Focus on the Individual

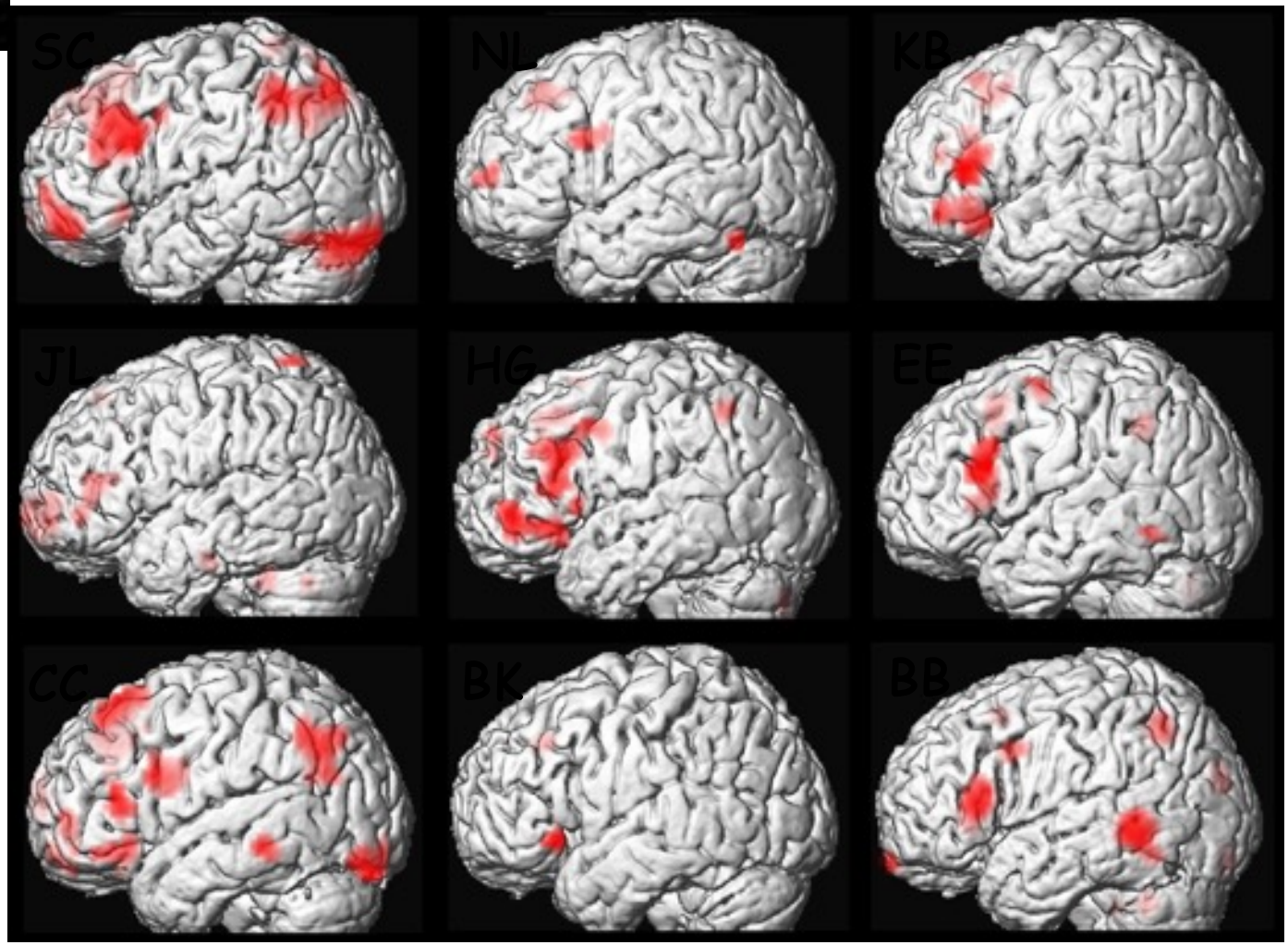
High sensitivity and resolution lends itself to individual assessment with fMRI

- Diagnosis of disorder
- Assessment of therapy
- Cognitive strategy
- Real time fMRI for therapy

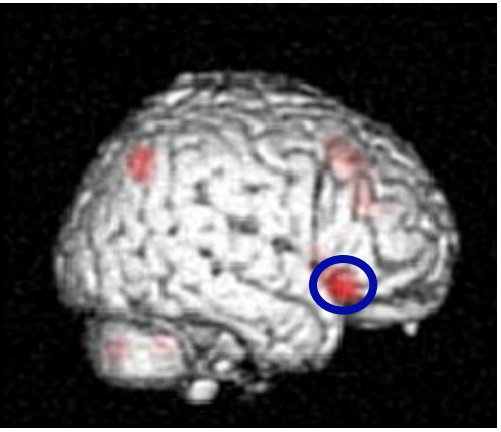


Individual Differences in Brain Activations During Episodic Retrieval Miller et al., 2002

Individual activations from the left hemisphere of the 9 subjects

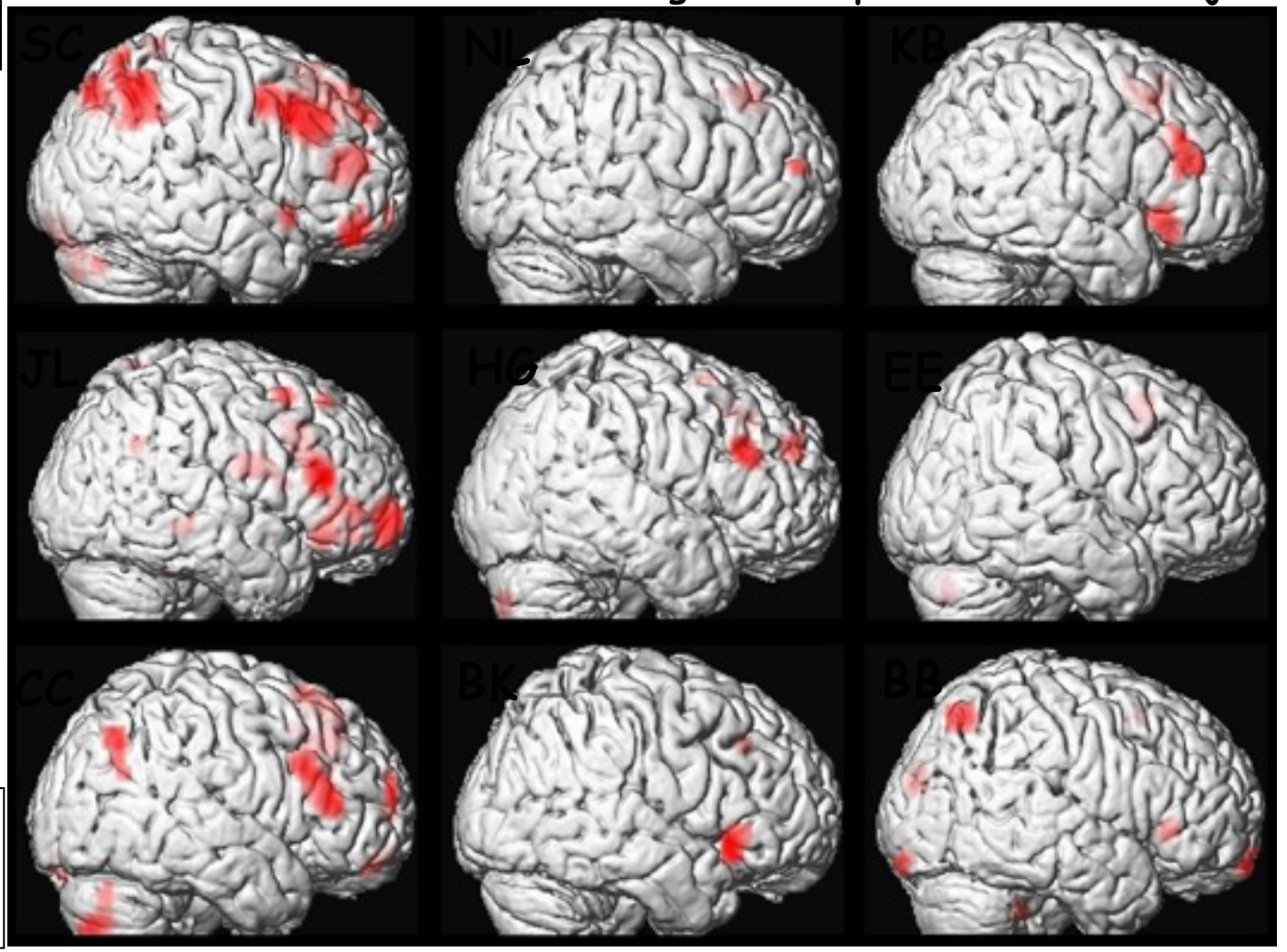


Courtesy, Mike Miler, UC Santa Barbara and Jack Van Horn, fMRI Data Center, Dartmouth University



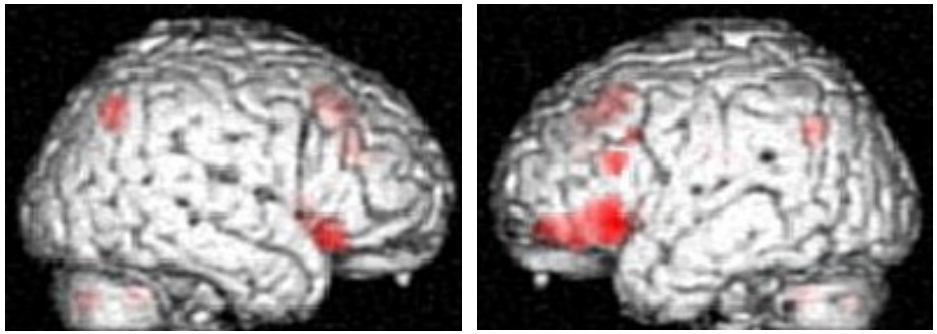
Individual Differences in Brain Activations During Episodic Retrieval Miller et al., 2002

Individual activations from the right hemisphere of the 9 subjects

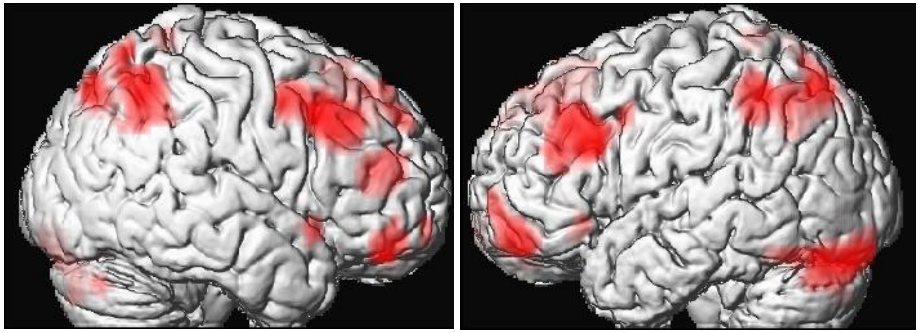


Courtesy, Mike Miler, UC Santa Barbara and Jack Van Horn, fMRI Data Center, Dartmouth University

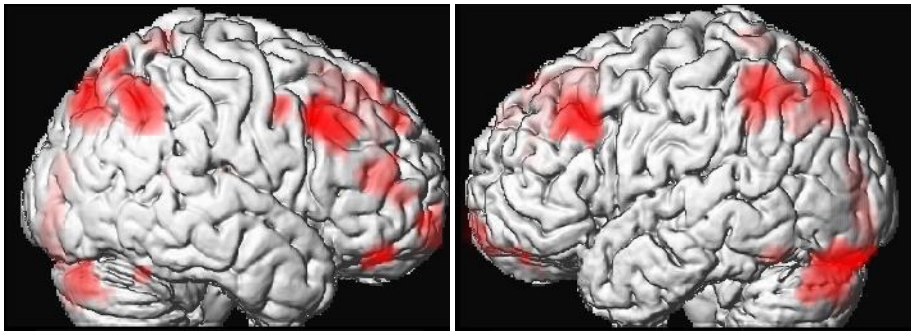
These individual patterns of activations are stable over time



Group Analysis of Episodic Retrieval



Subject SC



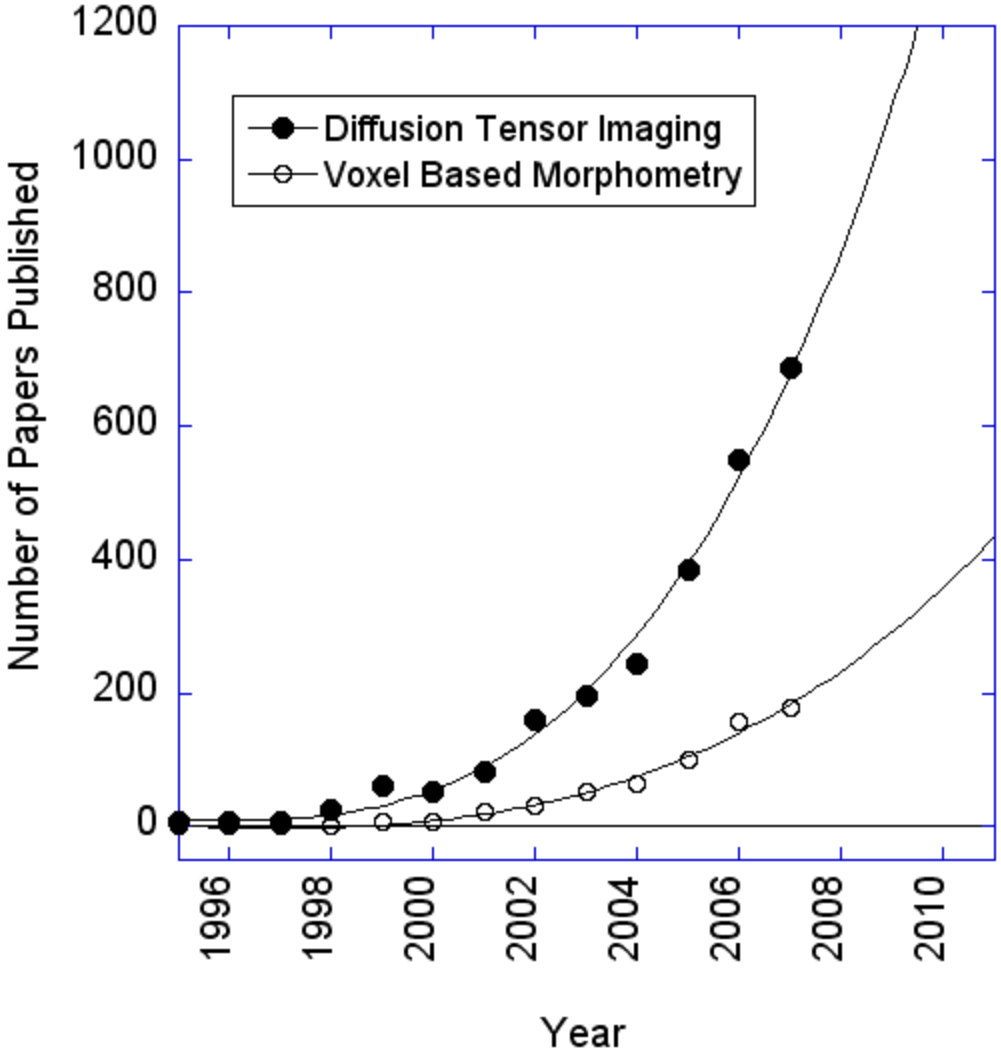
Subject SC 6 months later

Courtesy, Mike Miler, UC Santa Barbara and Jack Van Horn, fMRI Data Center, Dartmouth University

Emerging Technology

High resolution fMRI
Pattern effect processing / classification
Fluctuation characterization
Multimodal integration

How to best process, compare, and use these data?


Diffusion Tensor Imaging
Voxel Based Morphometry
Number of Papers Published
Year
0
200
400
600
800
1000
1200
1996
1998
2000
2002
2004
2006
2008
2010

Challenges and Opportunities in Non-Invasive Human Brain Imaging: *From Molecules to Circuits*

1. **Individual assessment using fMRI**
   - Resting state fluctuations, calibrated fMRI, or pattern effect mapping
   - Impact would be on diagnosis, assessment of therapy, decisions on therapy, and non-clinical.
   - A major obstacle is the wide variation in the data.
   - Proposed Solution: Higher resolution, signal to noise, calibration methods, classification methods, and multi-modal integration
2. **High field, high resolution, pattern effect assessment, resting state, and multi-modal integration are just emerging.**
   - Combination of high sensitivity, high resolution, better processing, and better multi-modal integration are emerging
   - Impact: The information obtained will be significantly more than “blobs of activation” or parametric changes with task modulation
   - Obstacle: Not enough methods focused grants or competitions
   - Proposed solution: More grants (or competitions) to develop this methodology.