Magnetic Resonance Methods for Functional and Anatomical Neuroimaging

(and for obesity related research)

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Section on Functional Imaging Methods
Laboratory of Brain and Cognition, NIMH
&
Functional MRI Facility, NIMH

- Functional MRI
- Voxel Based Morphometry

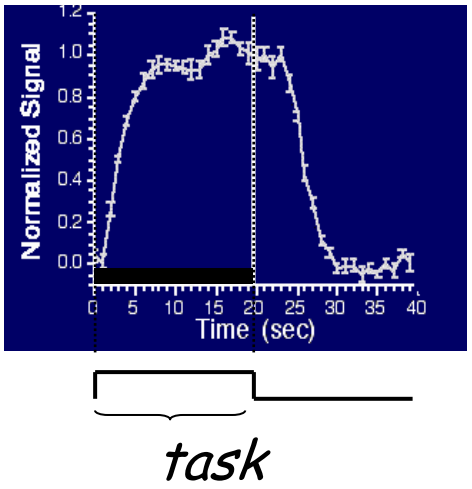
Functional MRI

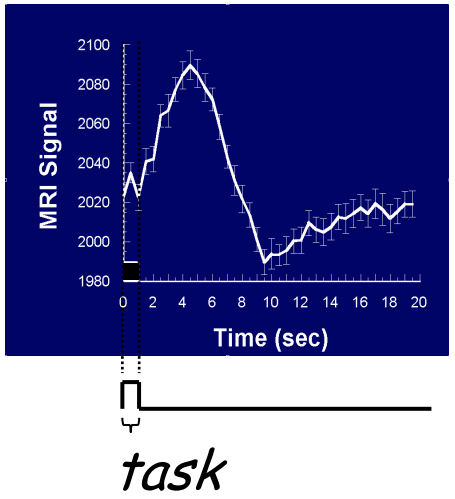
- Overview
- Resolution
- Interpretation
- Contrast
- Patterns
- Fluctuations
- Obesity Research

Overview of fMRI

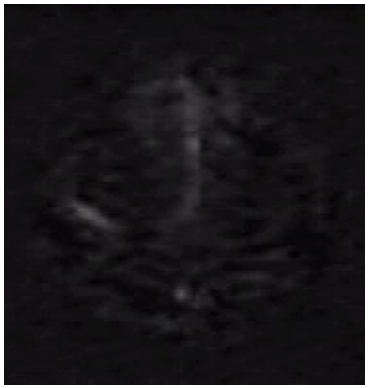
Functional Contrast:
- Blood volume
- Blood flow/perfusion
- Blood oxygenation

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..

How fMRI Is Currently Being Used

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

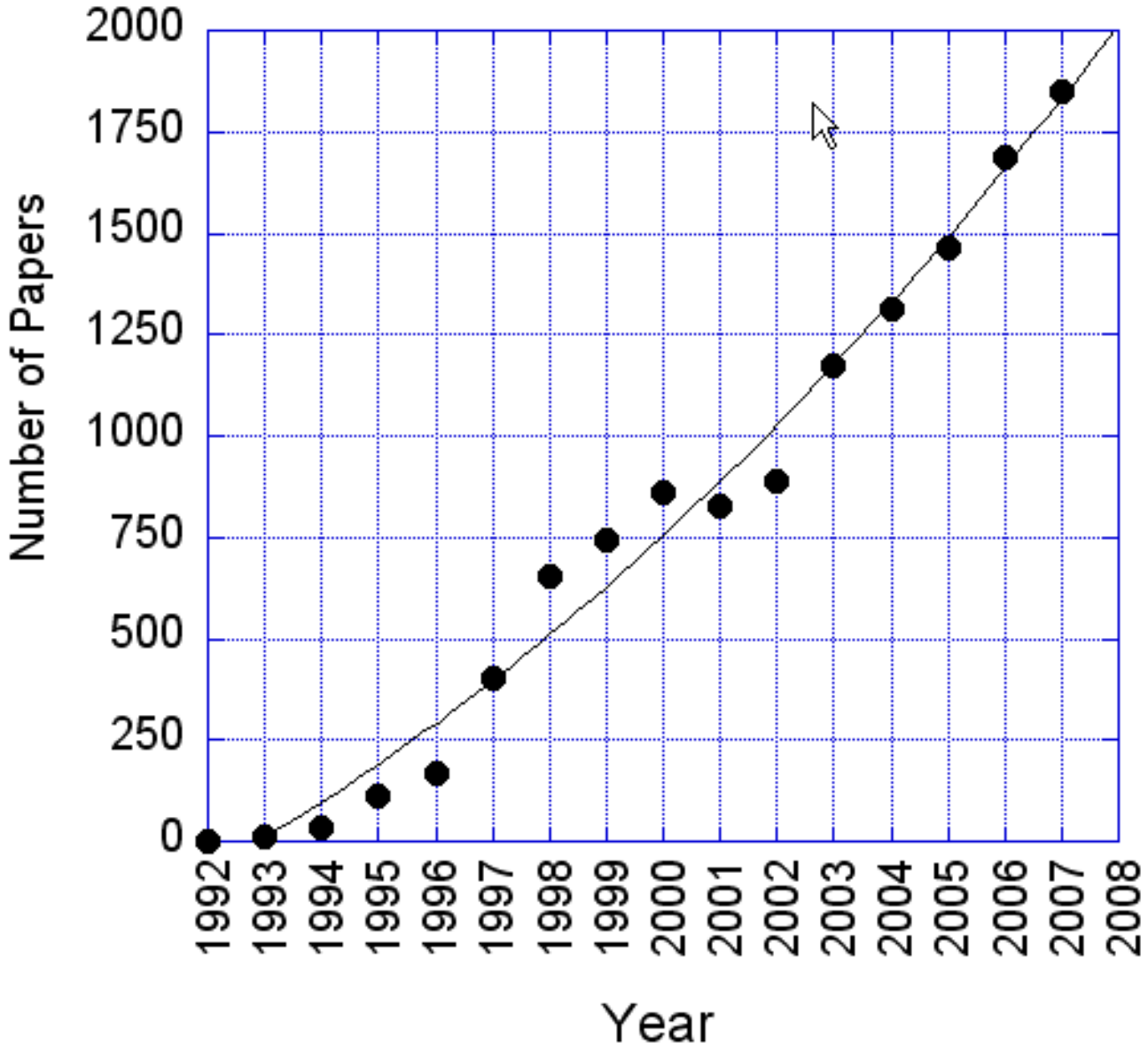
-clinical population characterization (probe task or resting state)
-assessment of recovery and plasticity
-attempts to characterize (classify) individuals

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

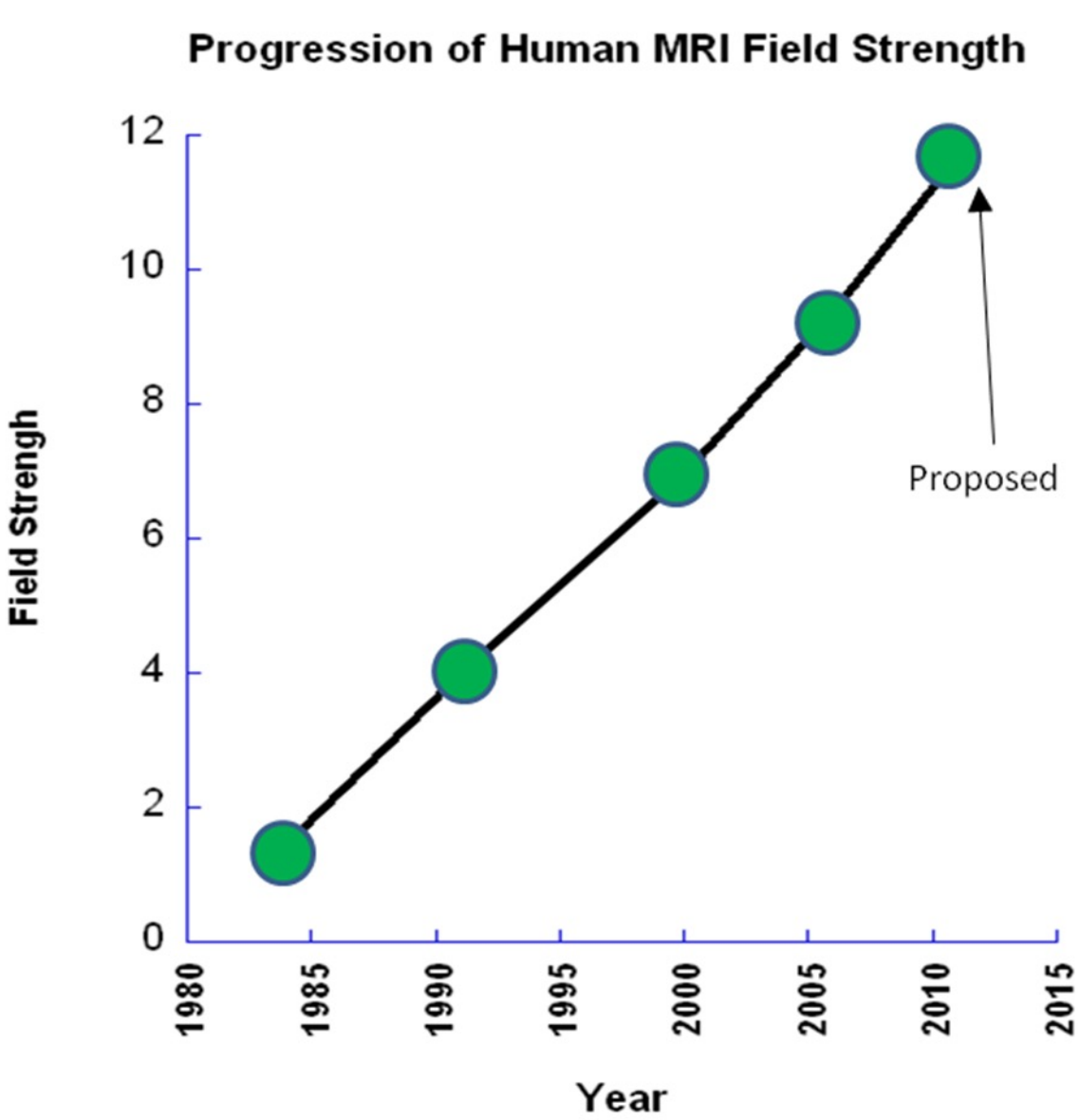
Functional Connectivity Assessment
Multi-modal integration
Pattern classification
Real time feedback
Task design (fMRIa…)

Interpretation

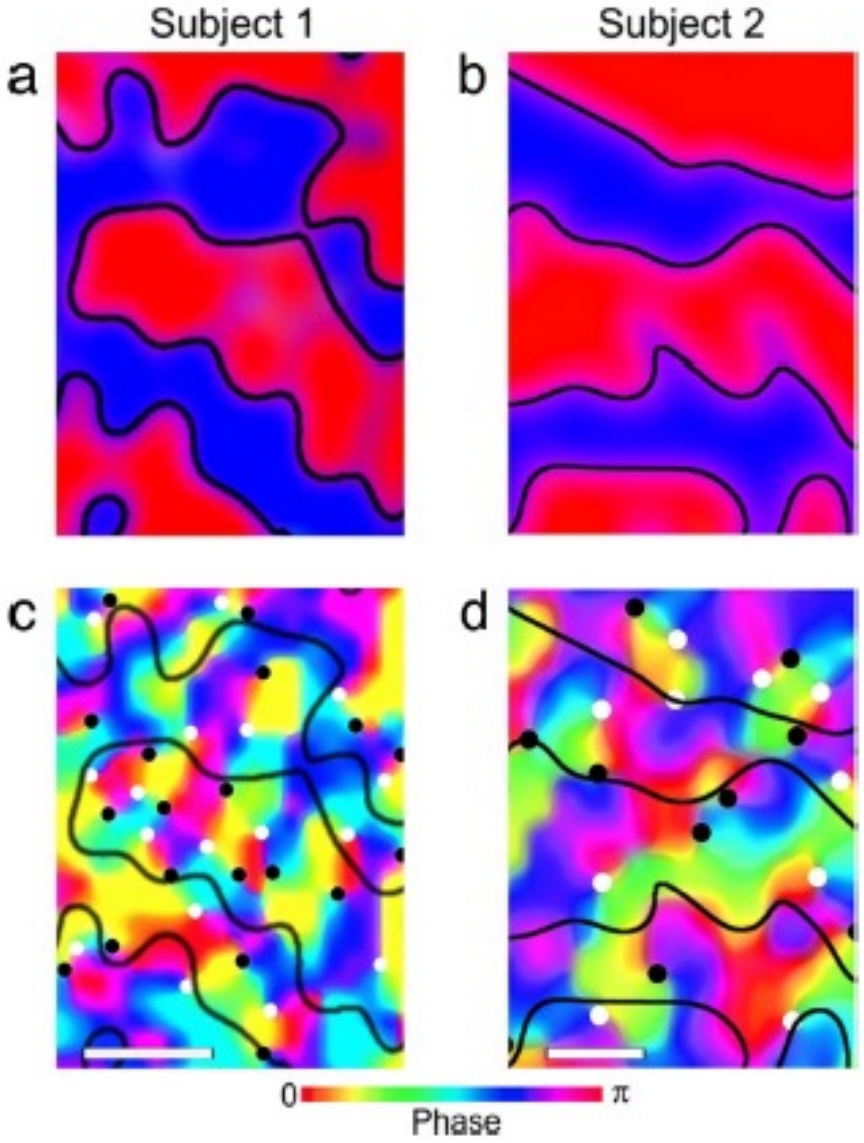
Fluctuations
Dynamics
Spatial patterns

Applications

Basic Neuroscience
Behavior correlation/prediction
Pathology assessment


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

Spatial Resolution

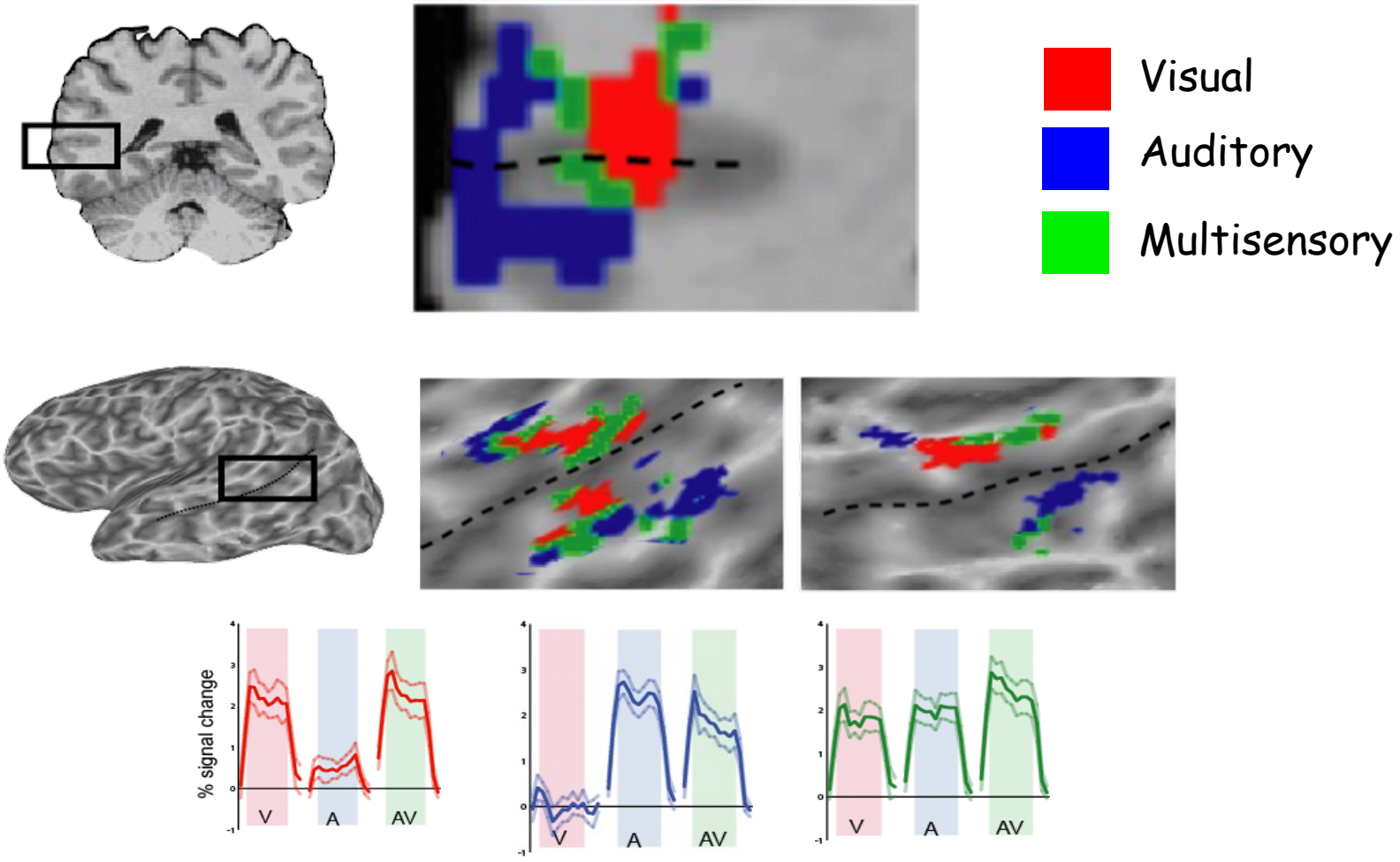


Yacoub et al. PNAS 2008

Spatial Resolution

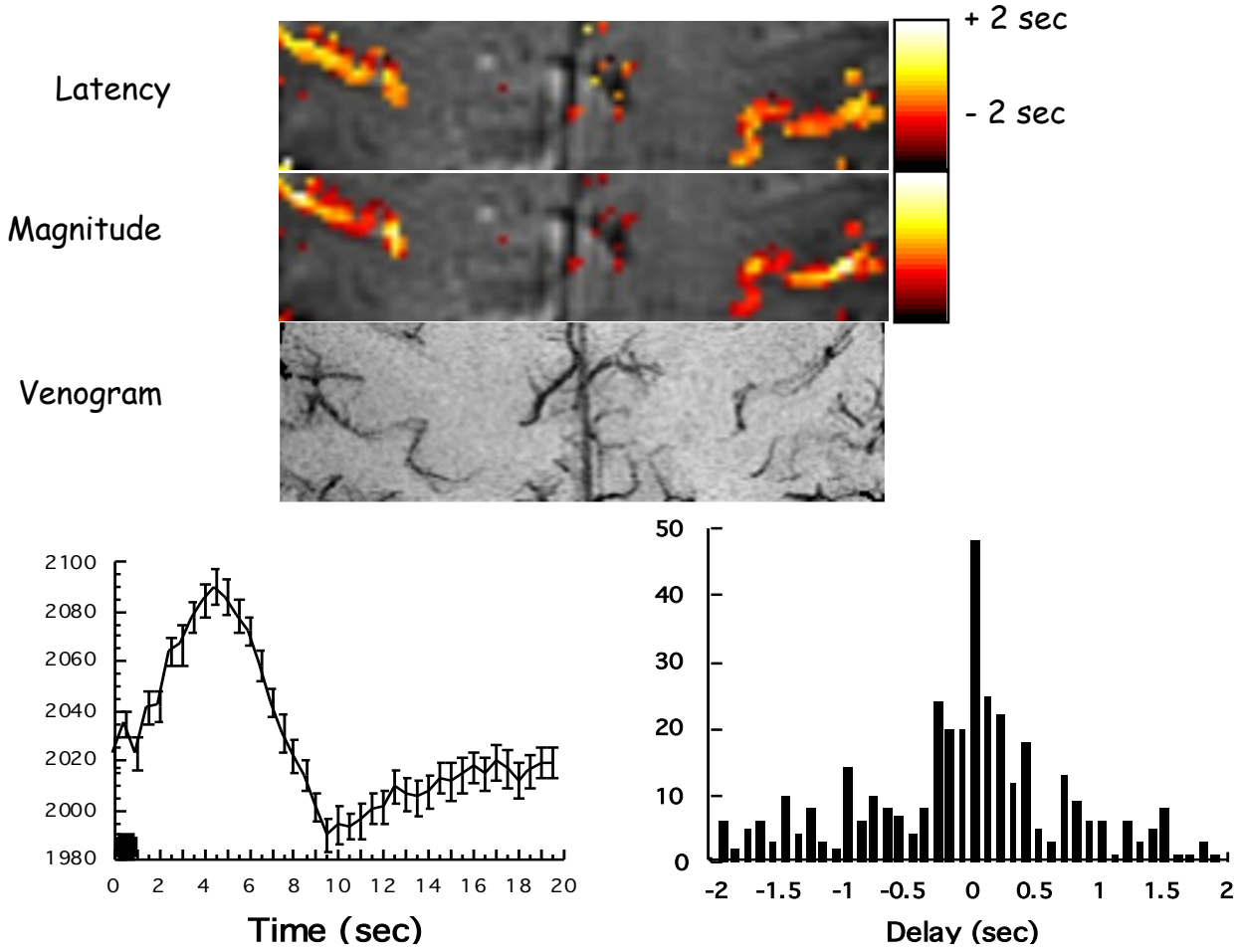
Multi-sensory integration

M.S. Beauchamp et al.,



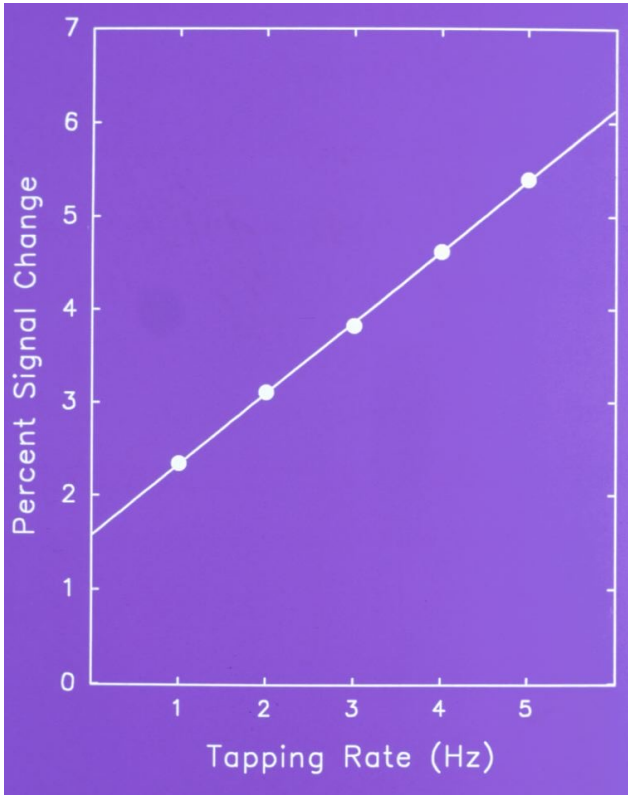
Temporal Resolution

Latency Variation



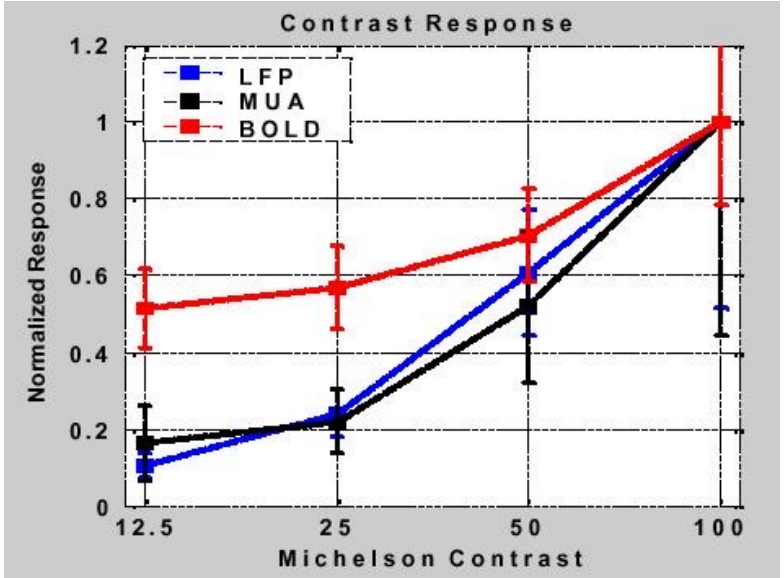
P. A. Bandettini, (1999) "Functional MRI" 205-220.

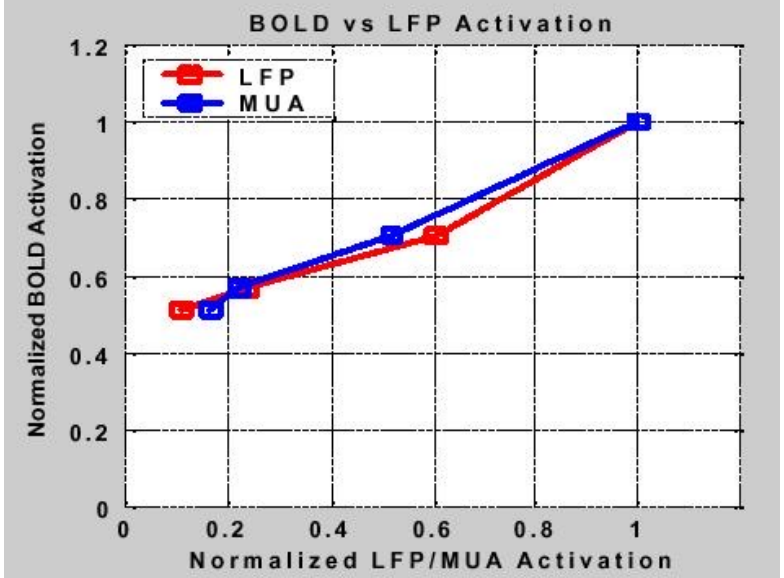
Relationship to Neuronal Activity



S. M. Rao et al, (1996) "Relationship between finger movement rate and functional magnetic resonance signal change in human primary motor cortex." *J. Cereb. Blood Flow and Met.* 16, 1250-1254.

Logothetis et al. (2001) "Neurophysiological investigation of the basis of the fMRI signal" Nature, 412, 150-157

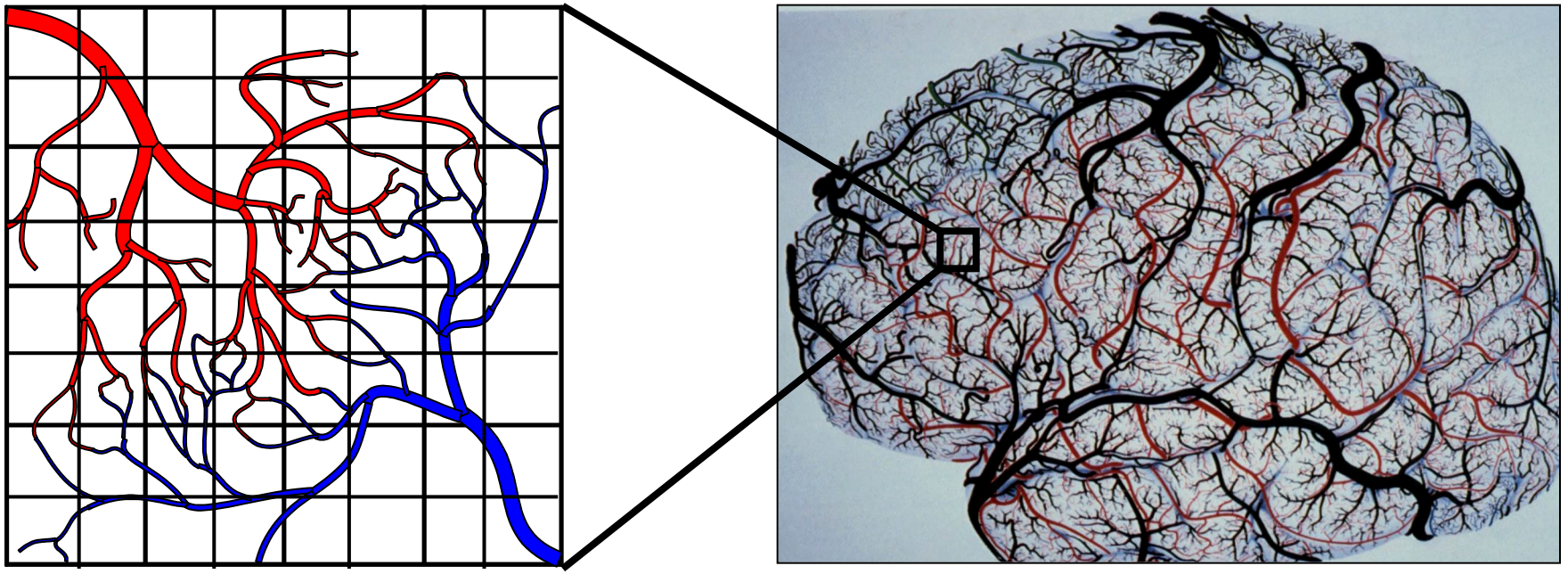




Neuronal Activation ? Measured Signal

? Hemodynamics ?

? Noise



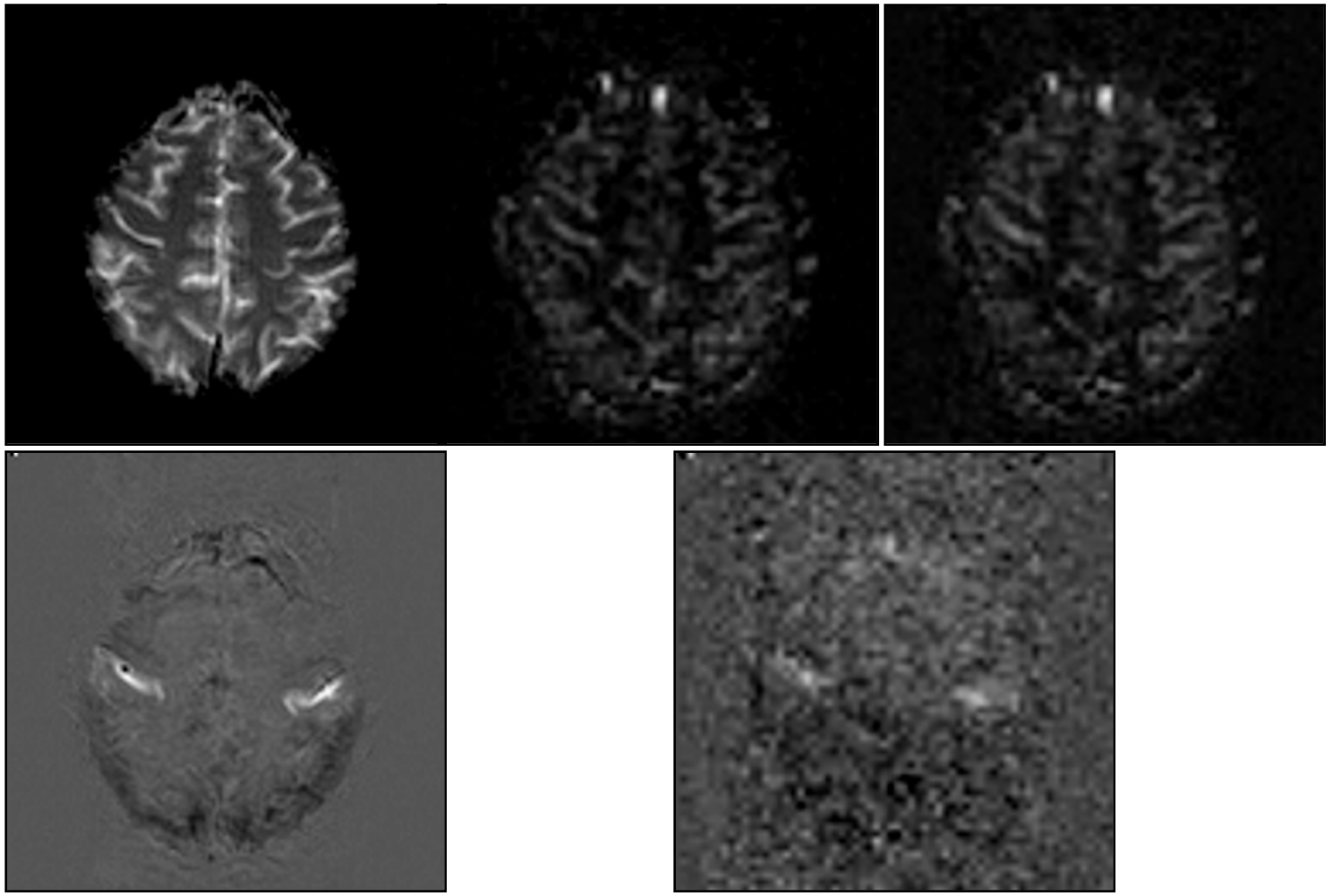
fMRI Contrast

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

Perfusion

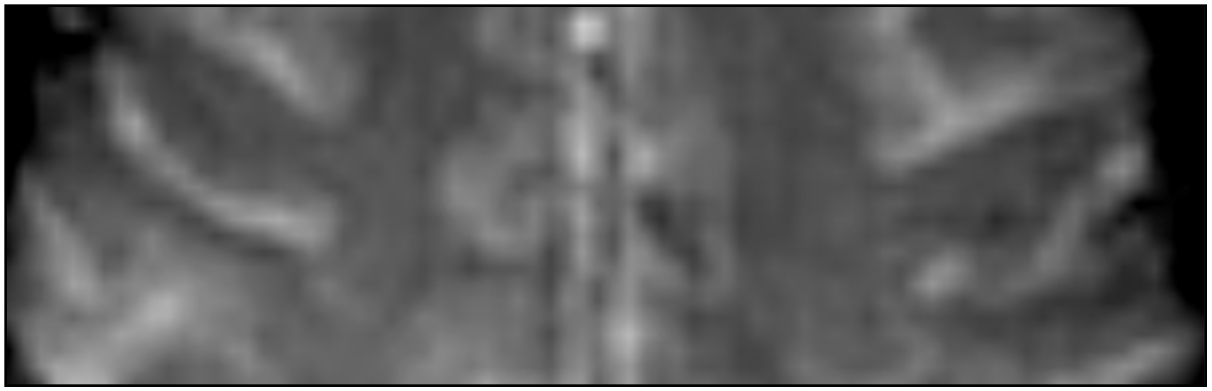
BOLD

Rest *Activation*

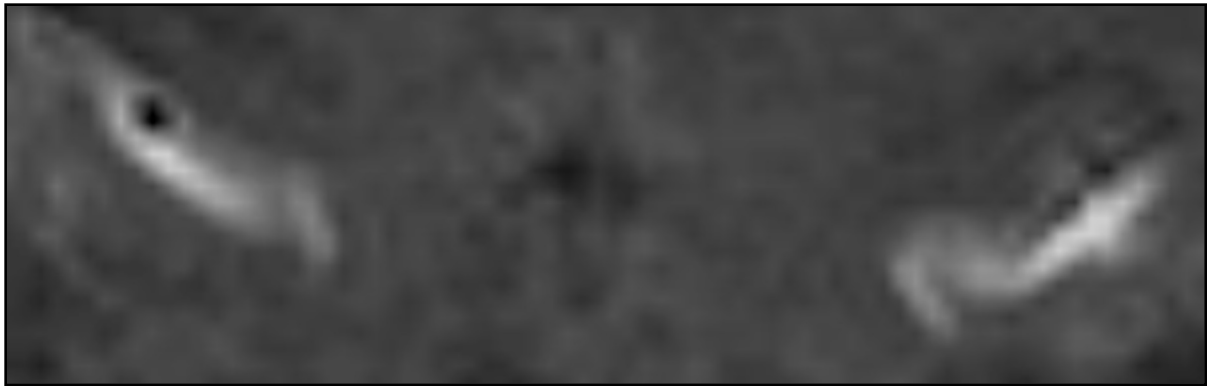


P. A. Bandettini, E. C. Wong, Magnetic resonance imaging of human brain function: principles, practicalities, and possibilities, *in* "Neurosurgery Clinics of North America: Functional Imaging" (M. Haglund, Ed.), p.345-371, W. B. Saunders Co., 1997.

Anatomy



BOLD

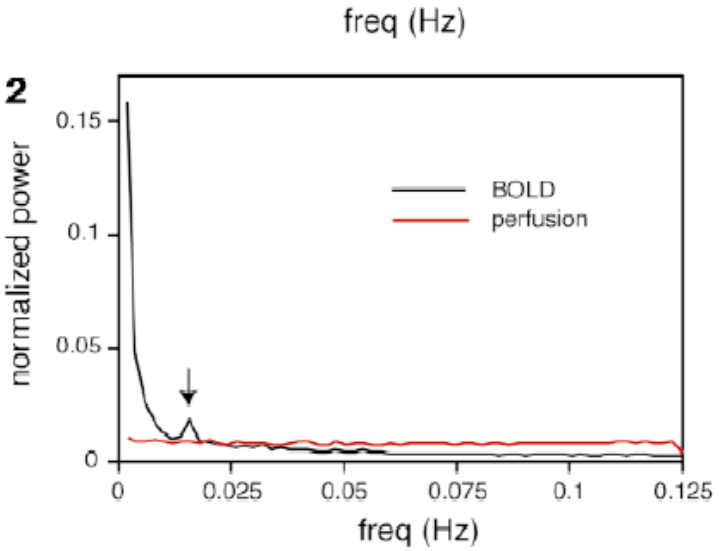


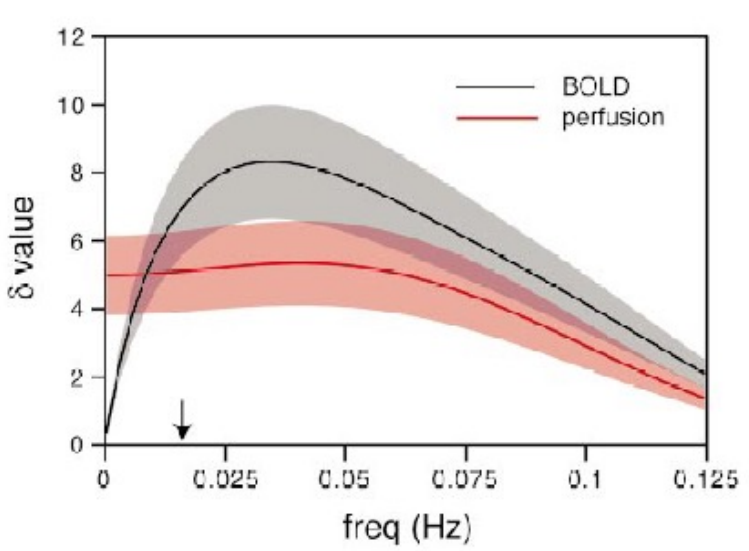
Perfusion

P. A. Bandettini, E. C. Wong, Magnetic resonance imaging of human brain function: principles, practicalities, and possibilities, *in* "Neurosurgery Clinics of North America: Functional Imaging" (M. Haglund, Ed.), p.345-371, W. B. Saunders Co., 1997.

Stability of Perfusion Imaging

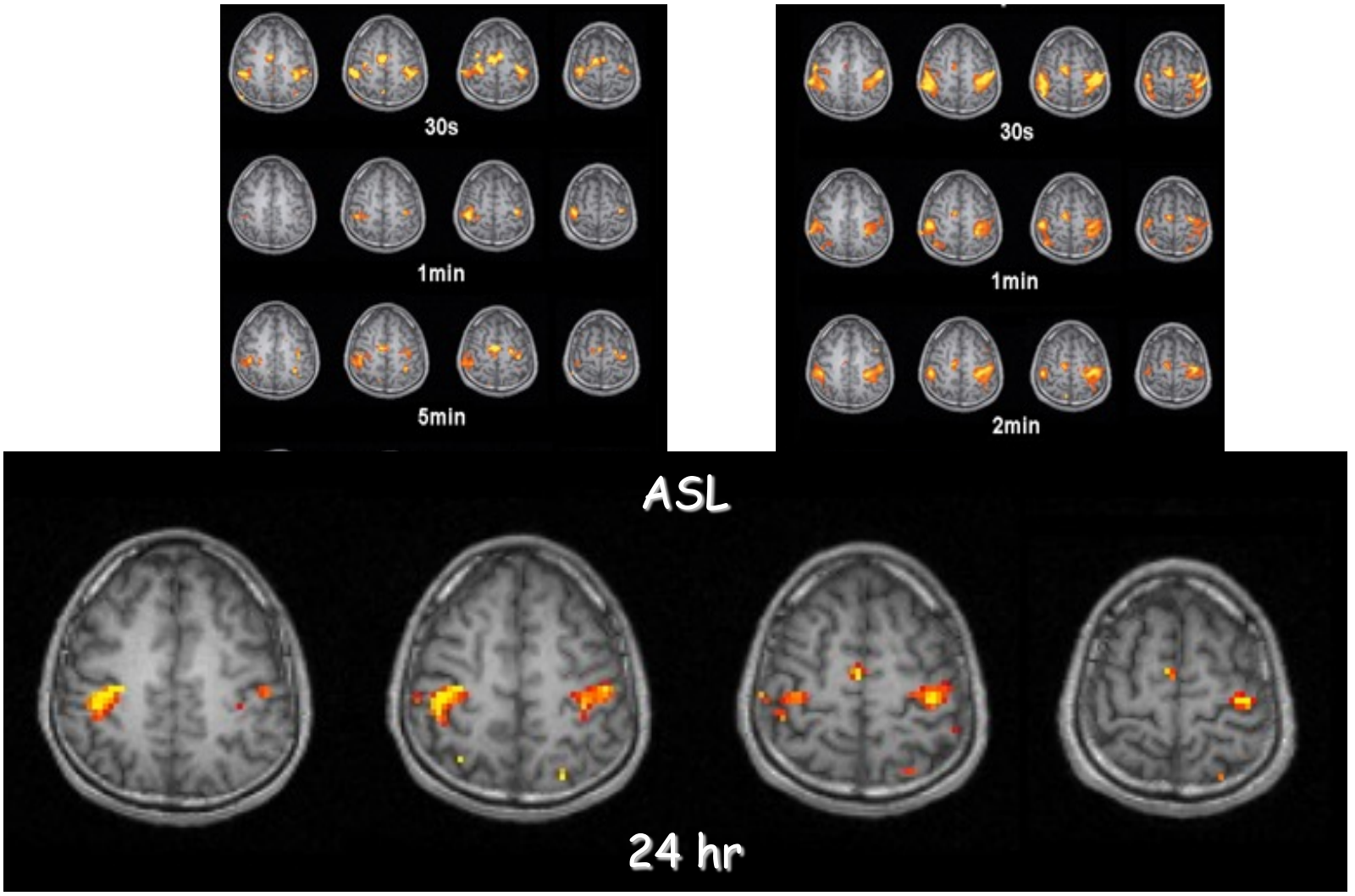
Perfusion is better than BOLD for slow "state change" comparisons..





GK Aguirre et al, (2002) NeuroImage 15 (3): 488-500

Perfusion vs. BOLD: Low Task Frequency



- Classical fMRI analysis:

  What's activated during a task?

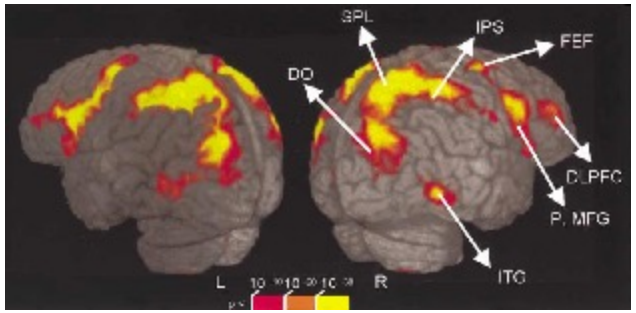
- Pattern-information analysis:

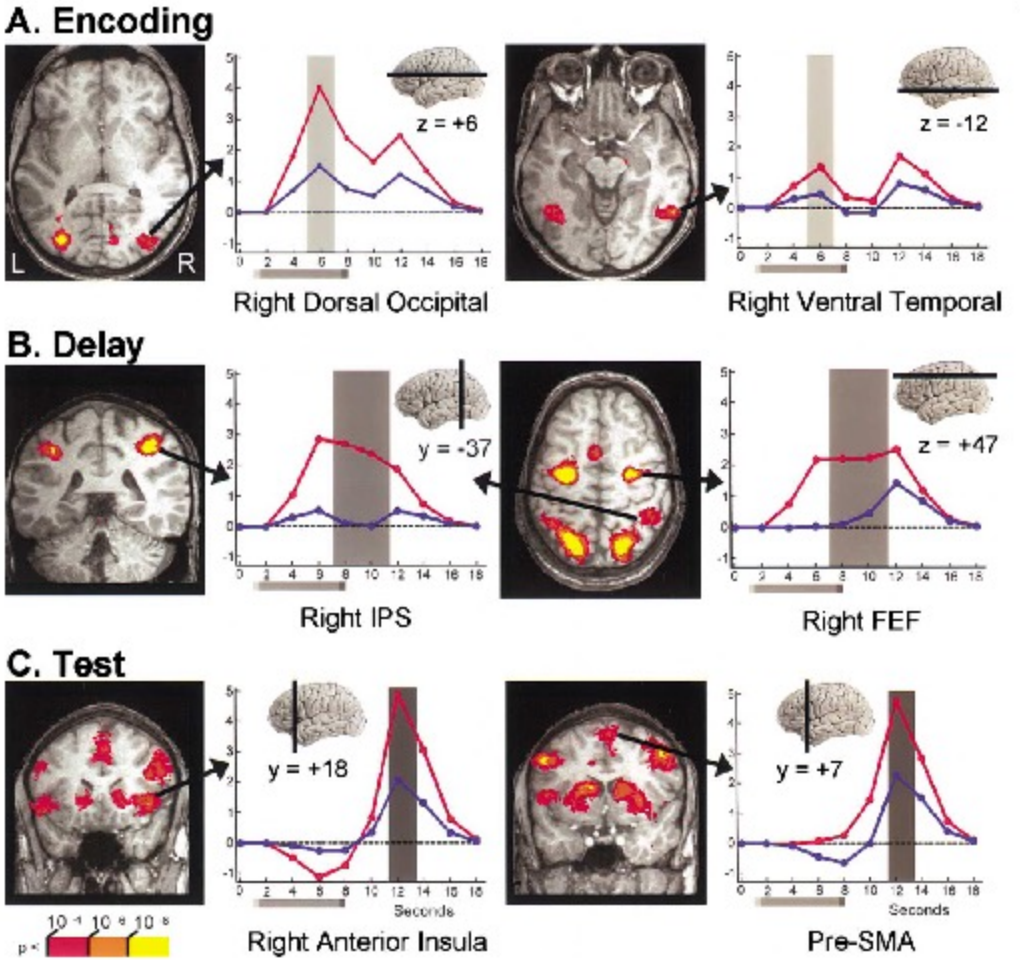
  Does a pattern carry a particular kind of information?

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

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

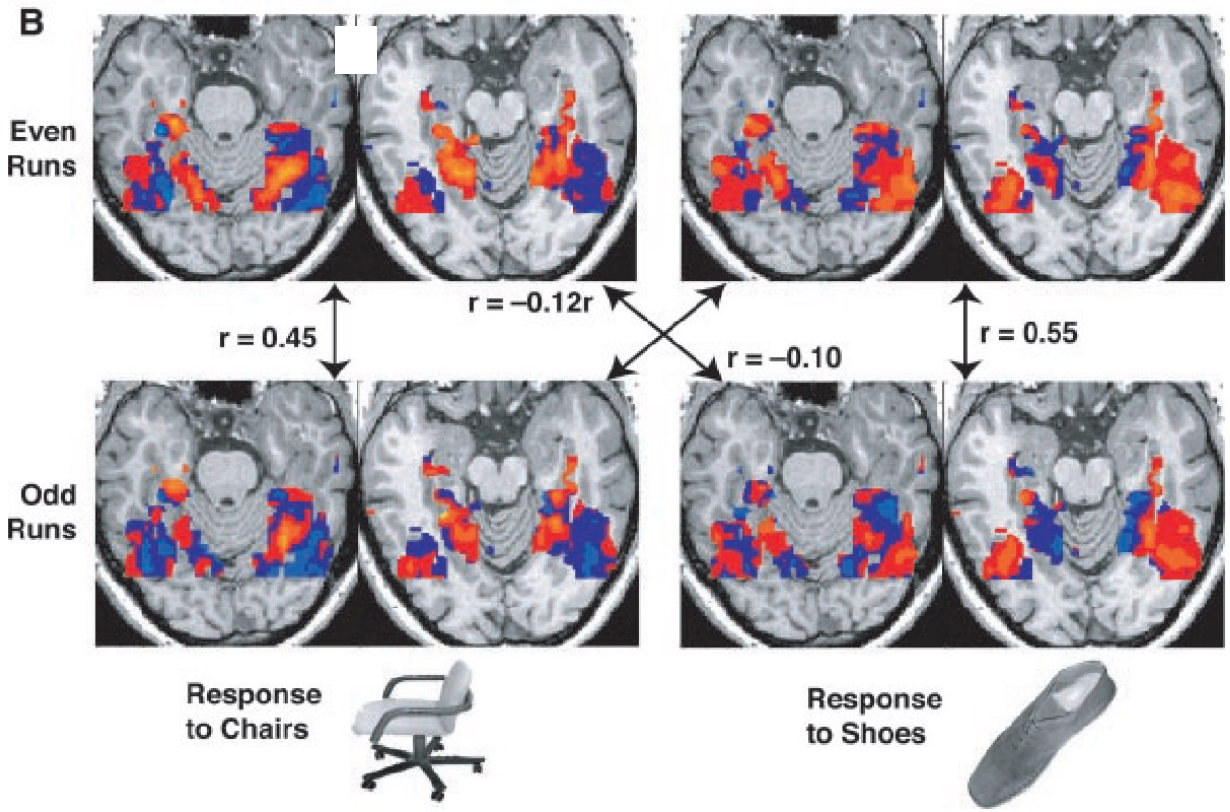
Luiz Pessoa,[1] Eva Gutierrez, Peter A. Bandettini, and Leslie G. Ungerleider
Laboratory of Brain and Cognition
National Institute of Mental Health
National Institutes of Health
Bethesda, Maryland 20892





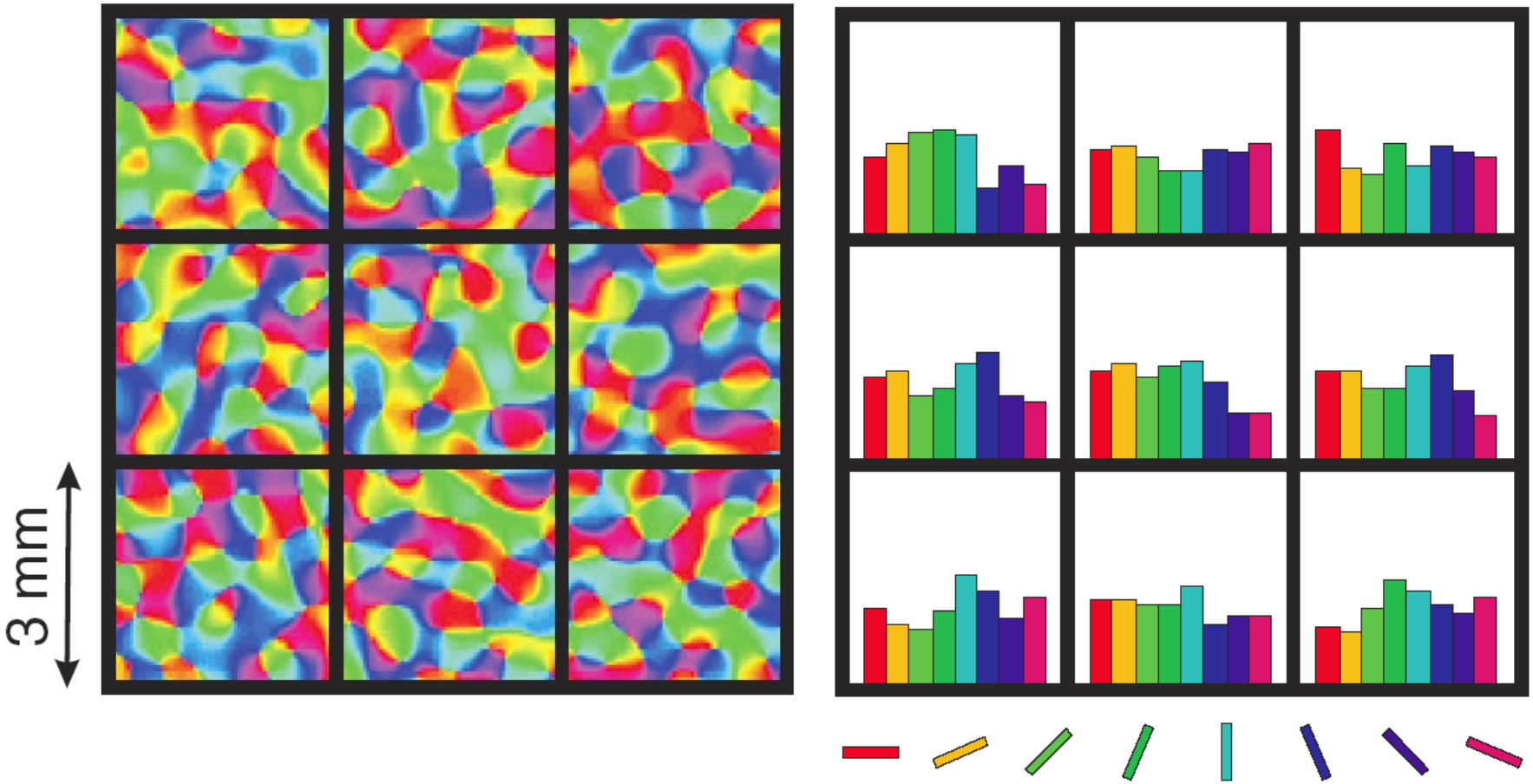
Ventral temporal category representations

Object categories are associated with distributed representations in ventral temporal cortex



Haxby et al. 2001

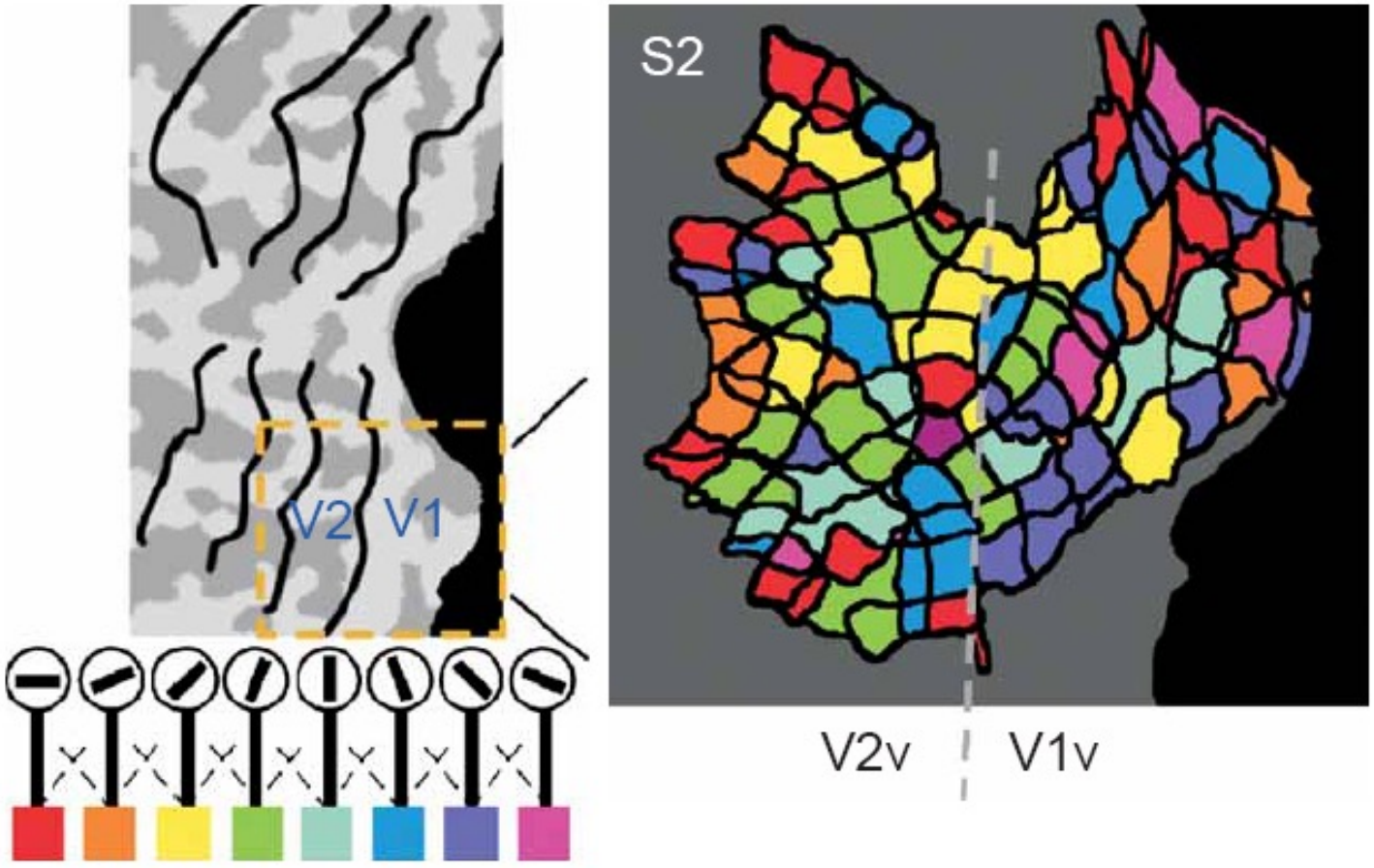
fMRI - patterns



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

Lower spatial frequency clumping

Orientation viewing decoding

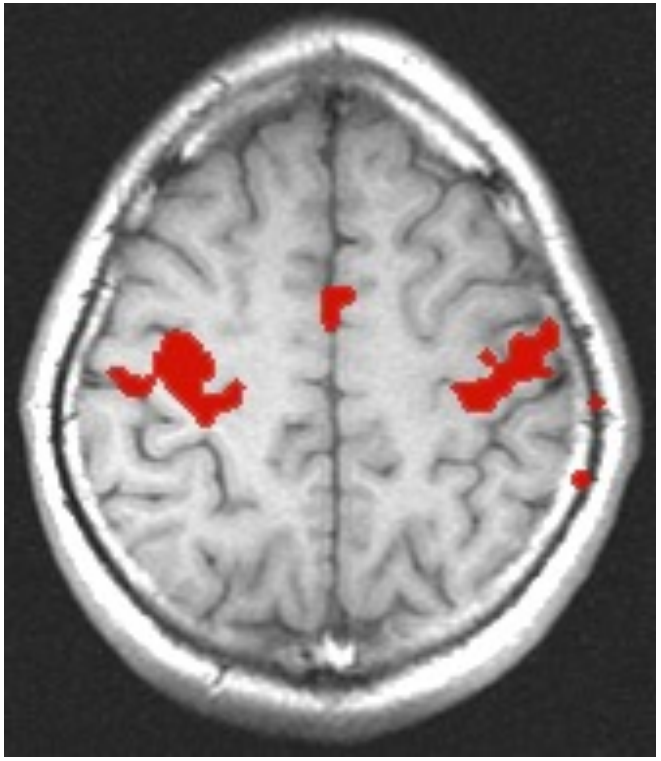


Kamitani & Tong (2005)

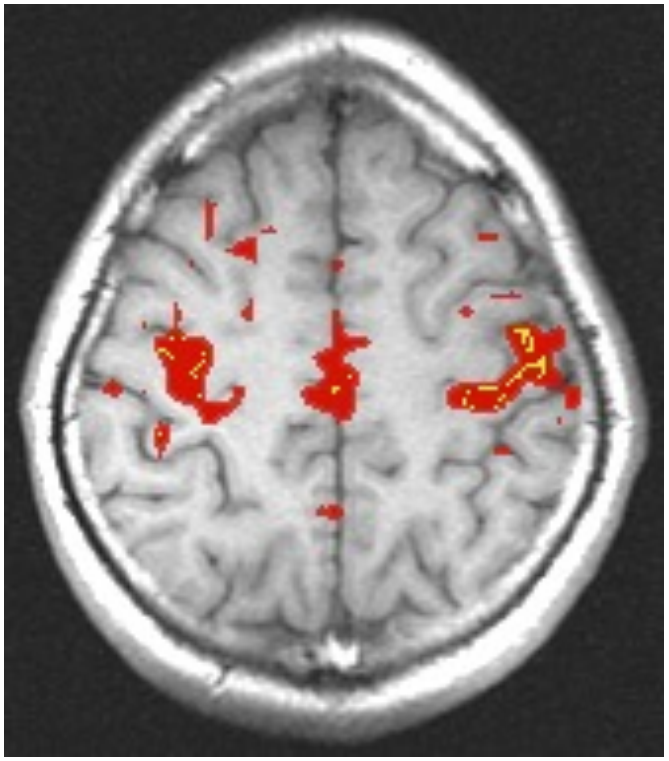
Sources of time series fluctuations:

- 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

Resting State Correlations



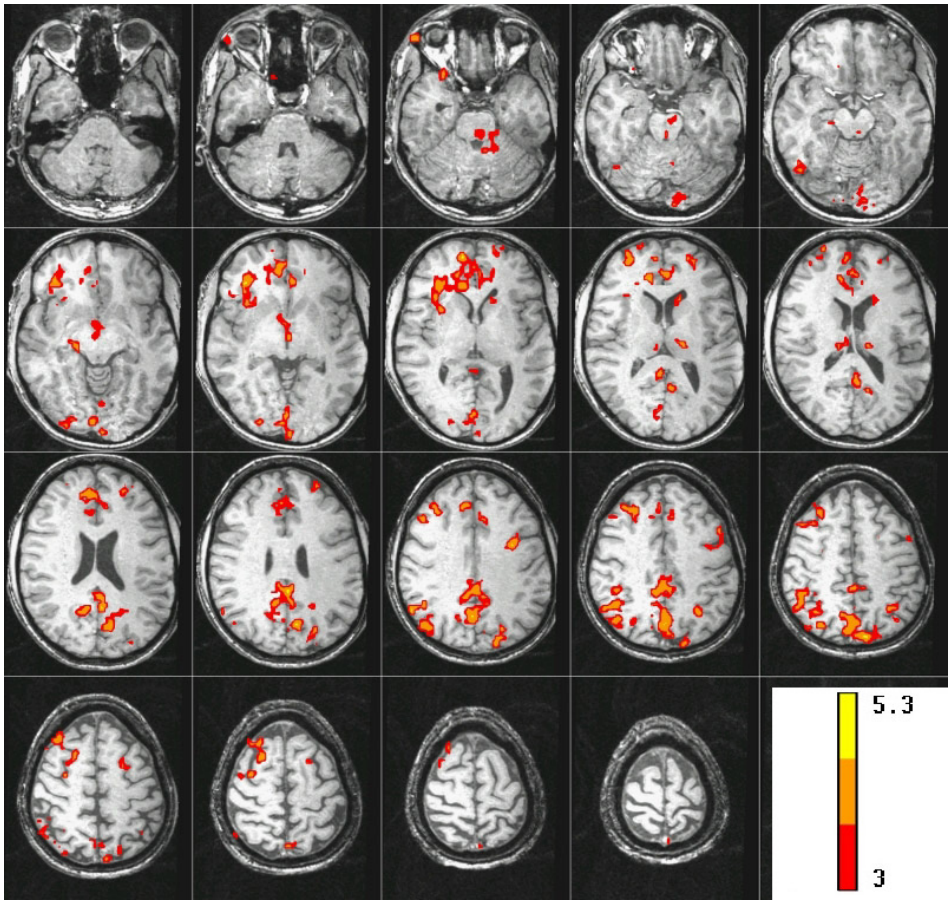
Activation:
correlation with reference function



Rest:
seed voxel in motor cortex

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

BOLD correlated with SCR during "Rest"



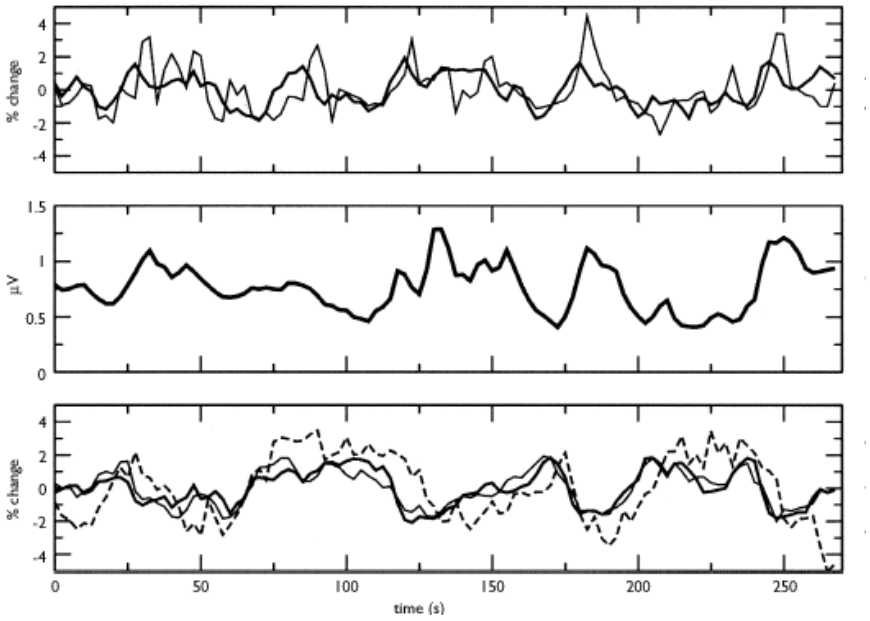
J. C. Patterson II, L. G. Ungerleider, and P. A Bandettini,
NeuroImage 17: 1787-1806, (2002).

BOLD correlated with 10 Hz power during "Rest"

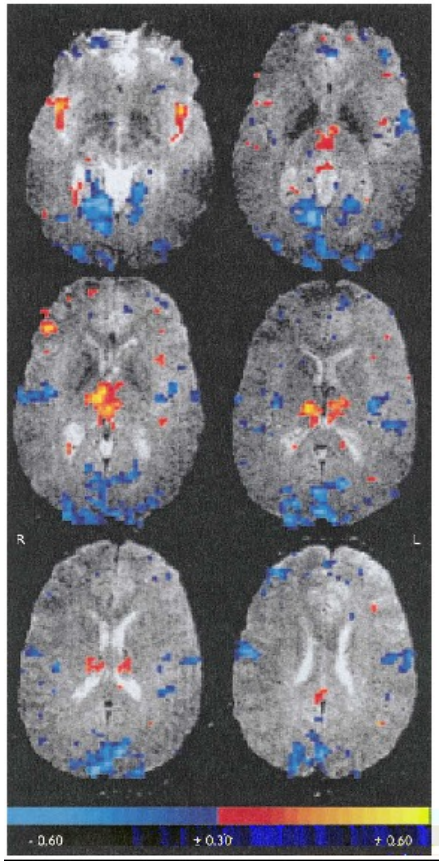
Positive

10 Hz power

Negative

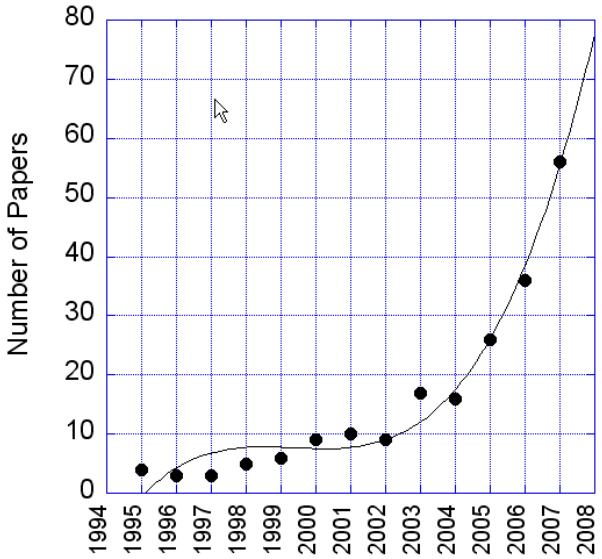


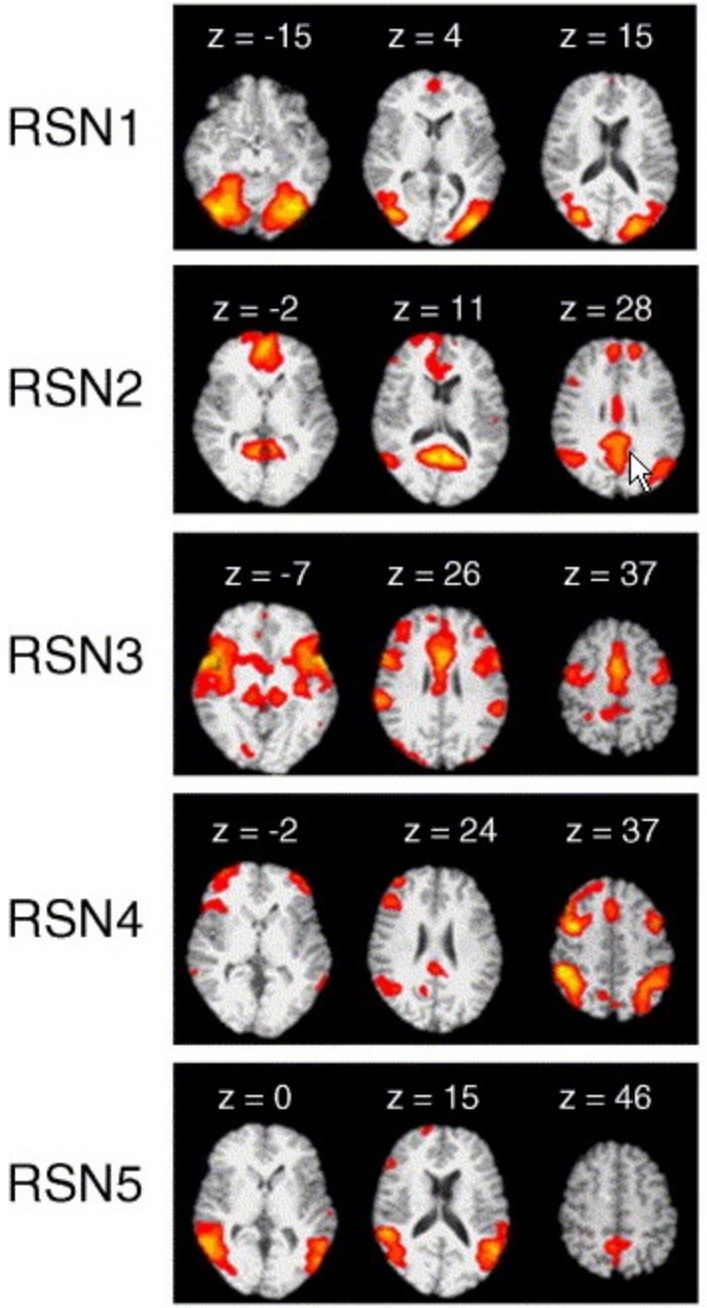
Goldman, et al (2002), Neuroreport



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

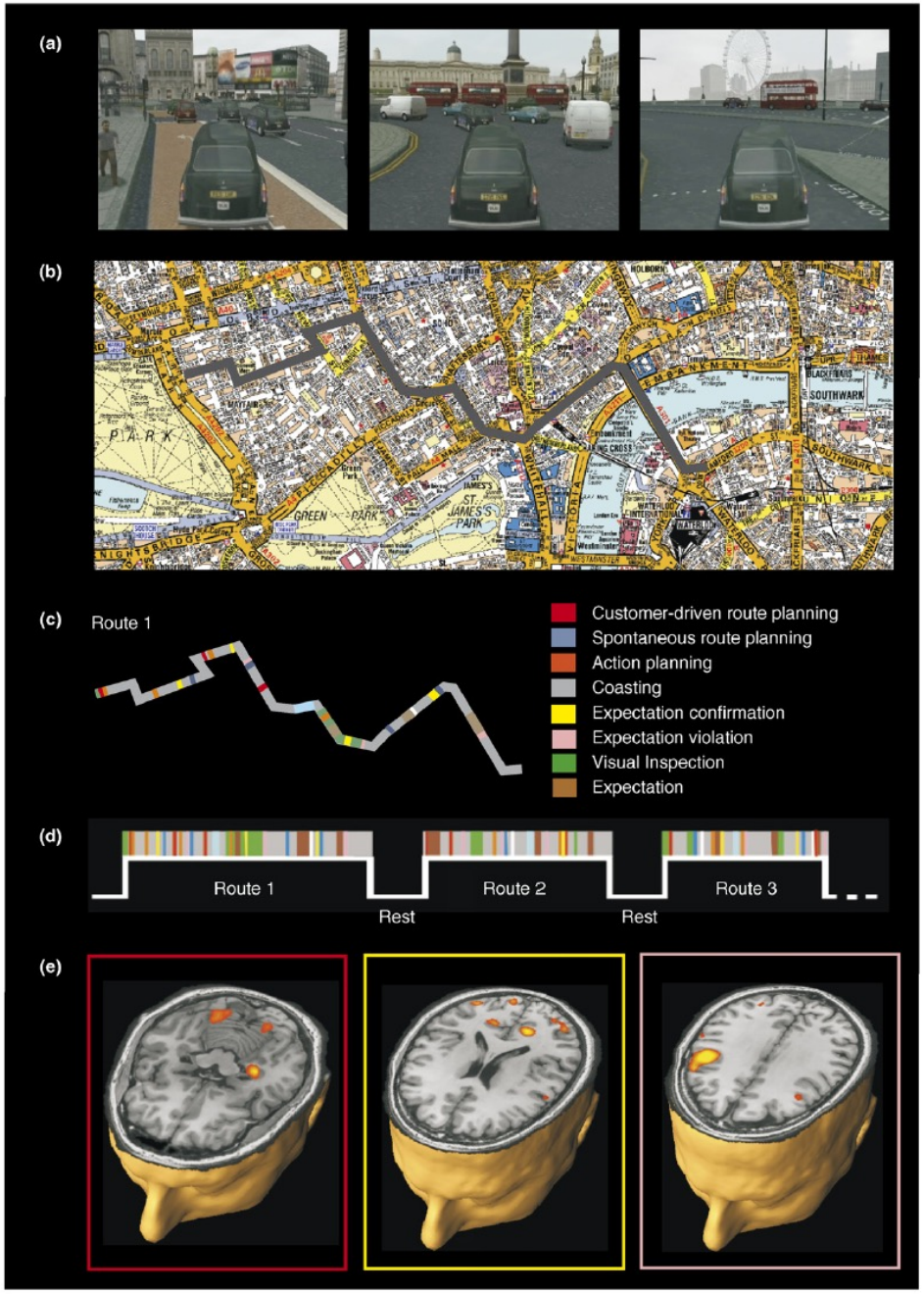




fMRI - fluctuations

Decoding human brain activity during real-world experiences

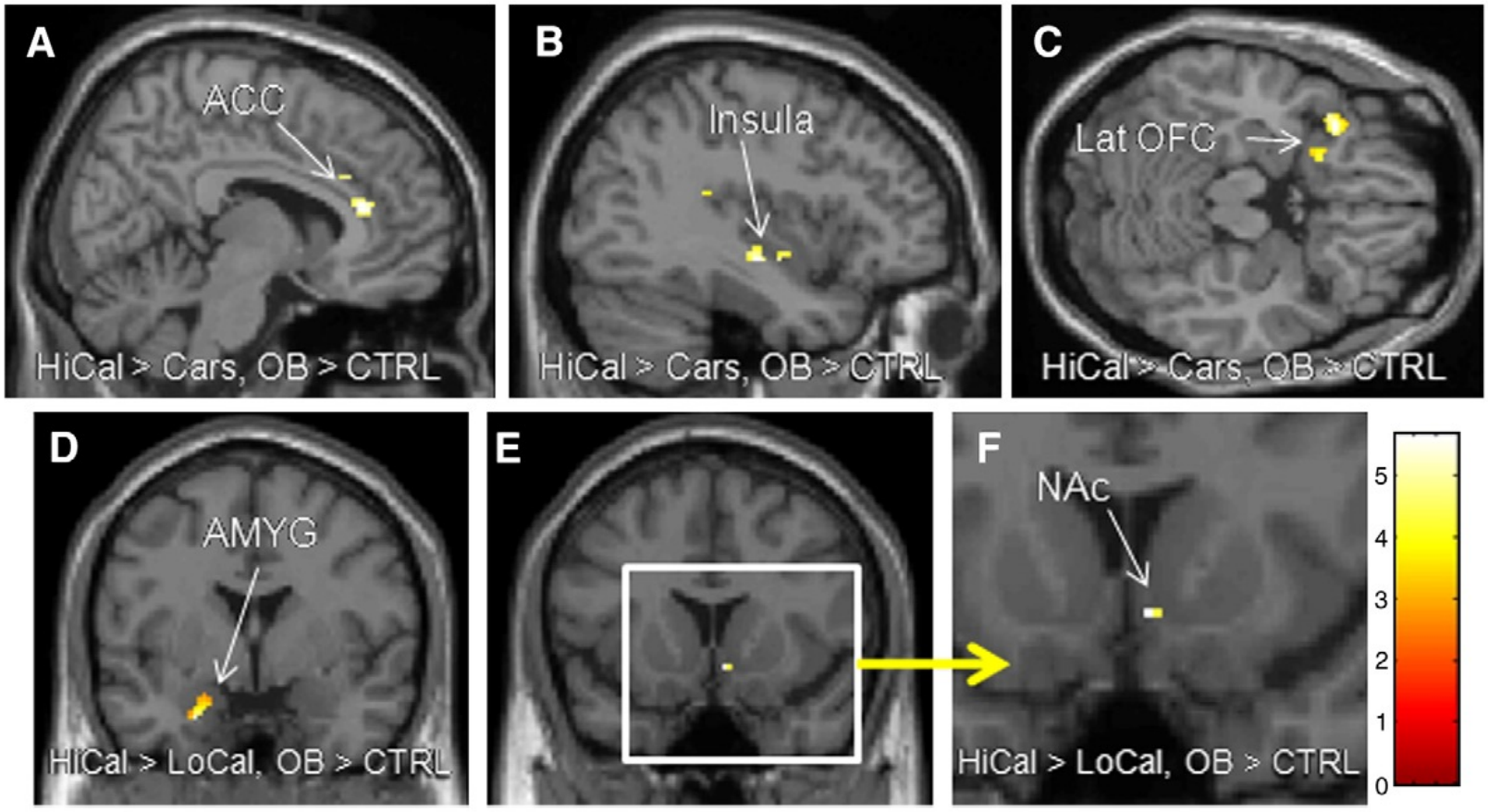
Hugo J. Spiers and Eleanor A. Maguire
TICS, 2007



Some Applications to Obesity Research

- High vs. Low Calorie Food Viewing
- Hunger vs. Satiety while viewing food
- Food vs. Non-food viewing
- Food craving induction
- Leptin Modulation
- Hypothalamus activity with glucose ingestion

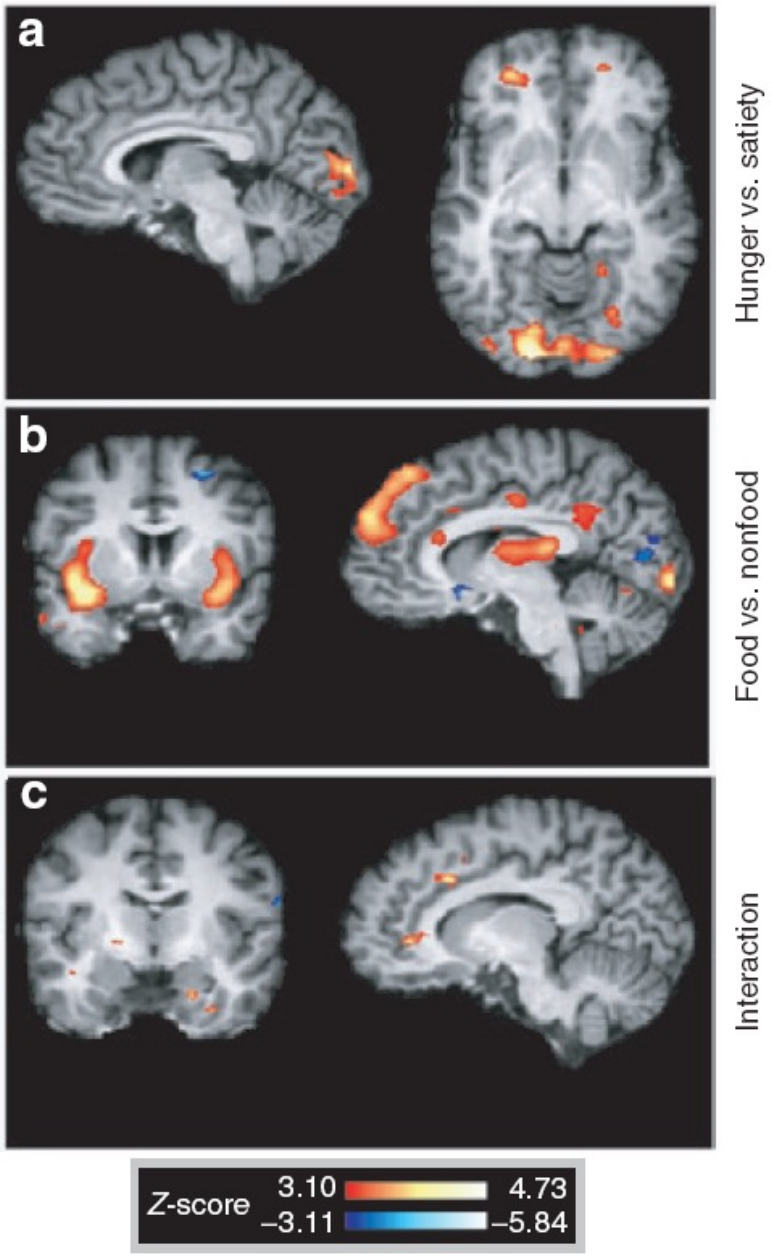
Greater activation in Obese subjects to high calorie foods



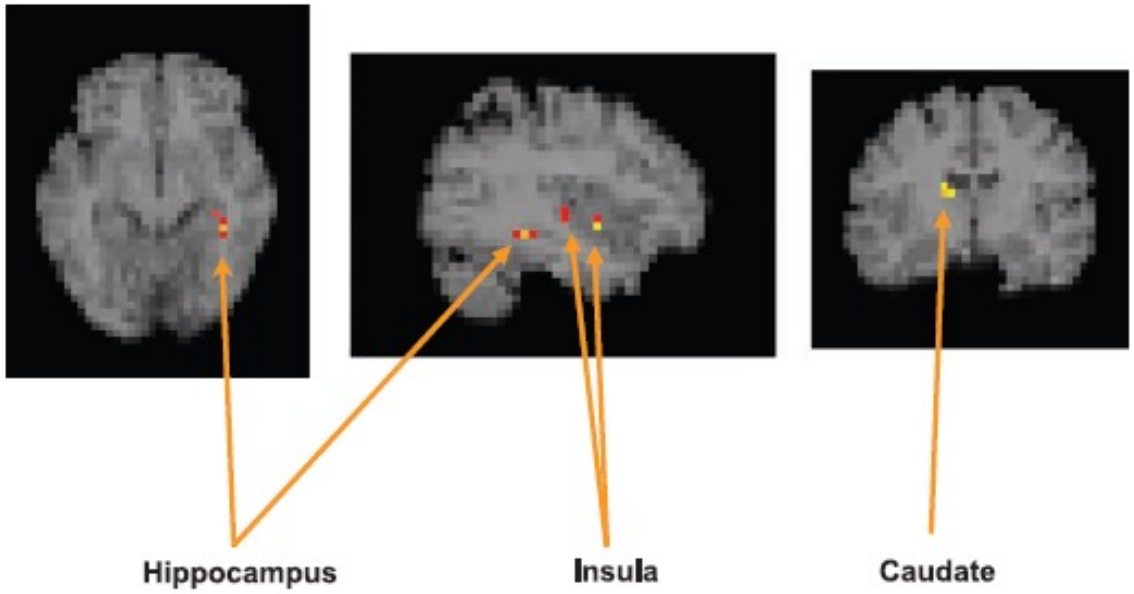
Stoeckel, L. E., *et al. 2008. Widespread reward-system activation in obese women in response to pictures of high-calorie foods. NeuroImage.* ***41: 636-647.***

Effects of Hunger and Food Viewing

Fuhrer, D., S. Zysset & M. Stumvoll. 2008. Brain activity in hunger and satiety: An exploratory visually stimulated fMRI study. Obesity. **16: 945-950.**

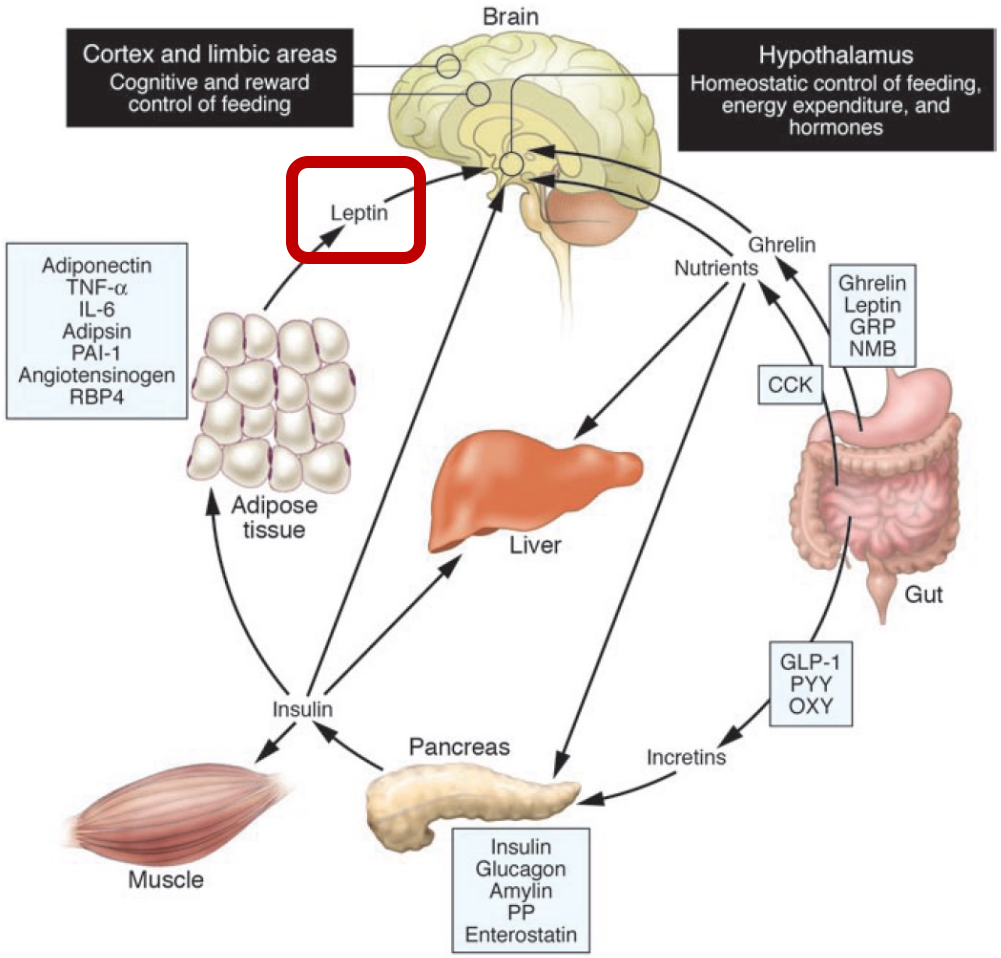


Areas Involved with Craving



Pelchat, M. L., *et al.* 2004. *Images of desire: Food-craving activation during fMRI.* NeuroImage. **23: 1486-1493.**

fMRI – obesity research



Ahima, R. S. 2008. Revisiting leptin's role in obesity and weight loss. Journal of Clinical Investigation. 118: 2380-2383.

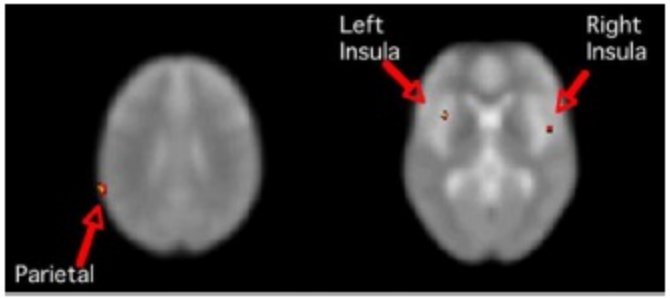
Viewing food with/without Leptin suppplement

Baicy, K., *et al. 2007. Leptin replacement alters brain response to food cues in genetically leptin-deficient adults. Proceedings of the National Academy of Sciences of the United States of America.* ***104: 18276-18279.***

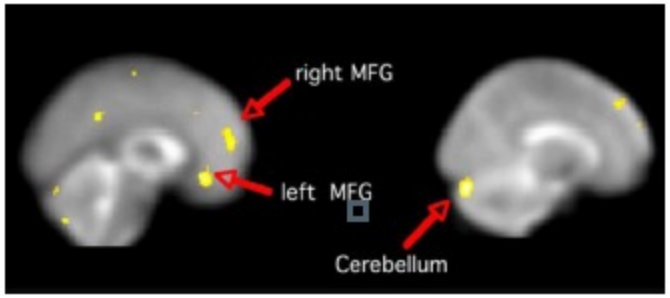
Rosenbaum, M., *et al. 2008. Leptin reverses weight loss-induced changes in regional neural activity responses to visual food stimuli. Journal of Clinical Investigation.* ***118: 2583-2591.***

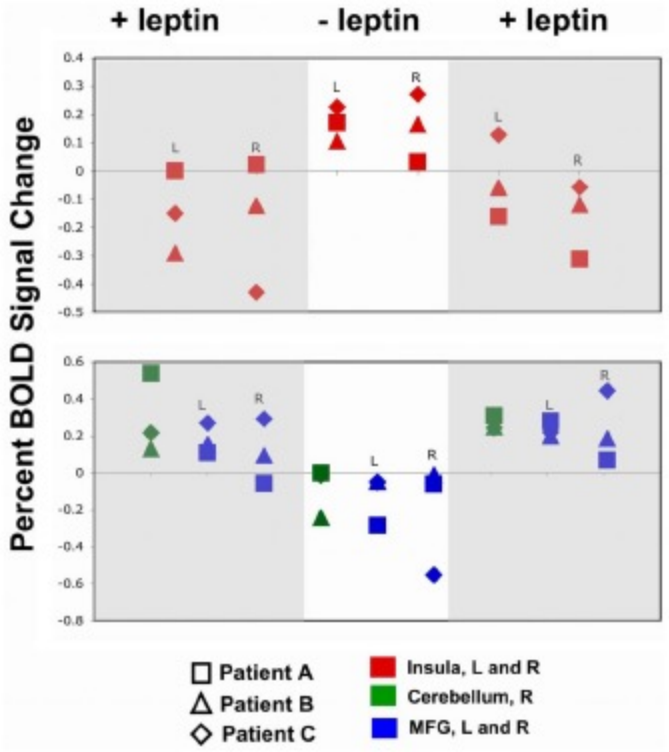
Leptin replacement effects in leptin-deficient adults

Reduced Leptin



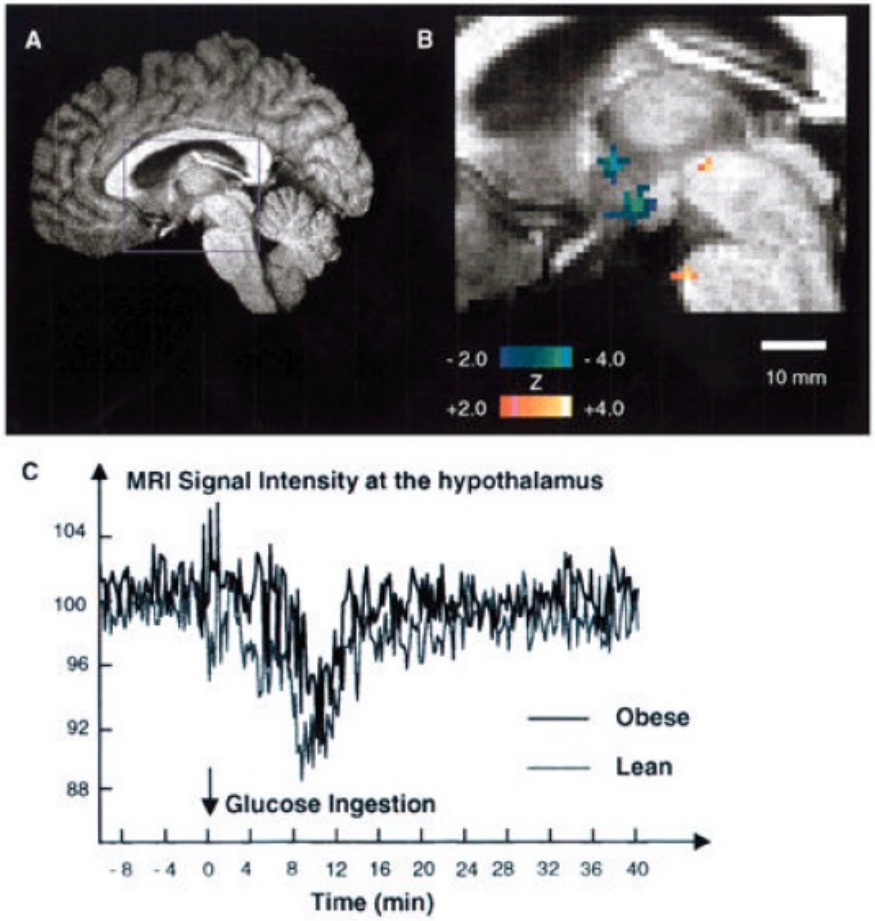
Increased Leptin





Baicy, K., *et al. 2007. Leptin replacement alters brain response to food cues in genetically leptin-deficient adults. Proceedings of the National Academy of Sciences of the United States of America. 104: 18276-18279.*

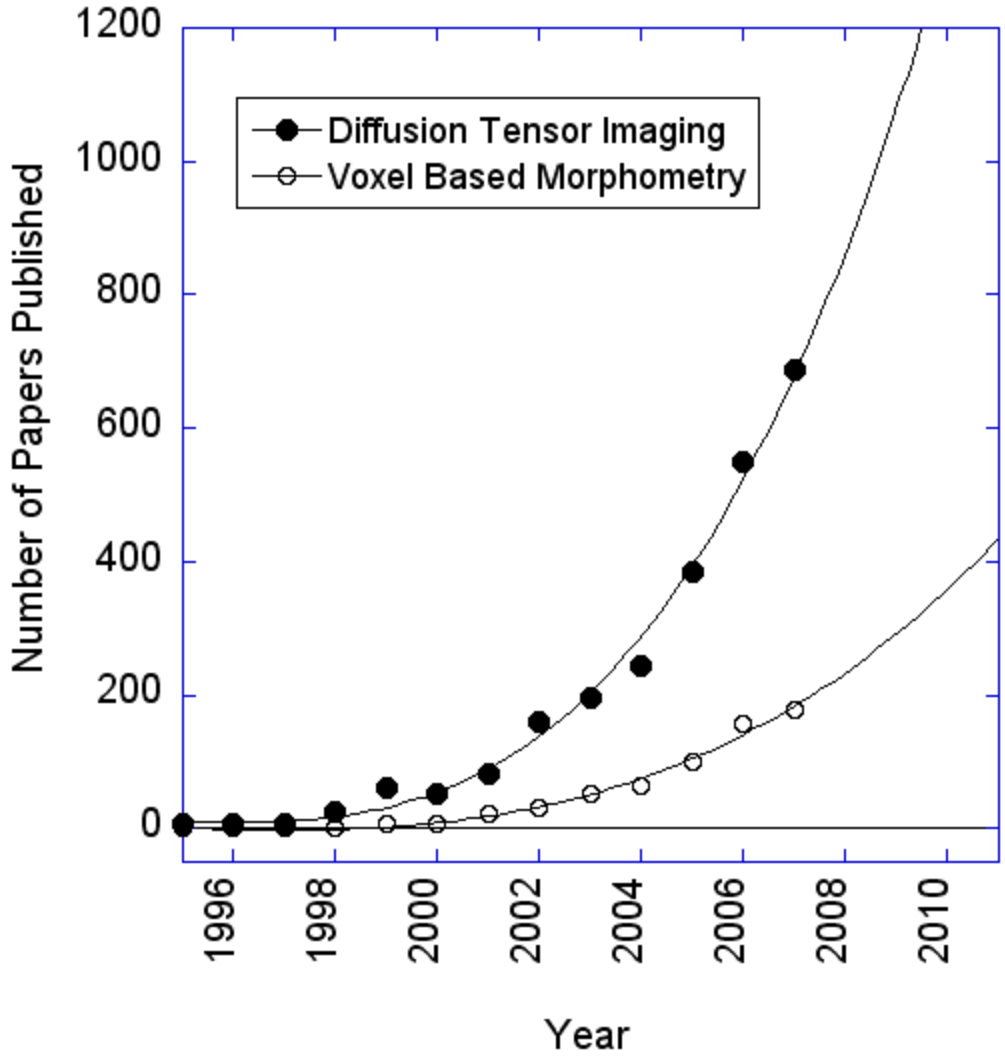
Reduced Glucose ingestion – induced Hypothalamus Inhibition with Obese subjects



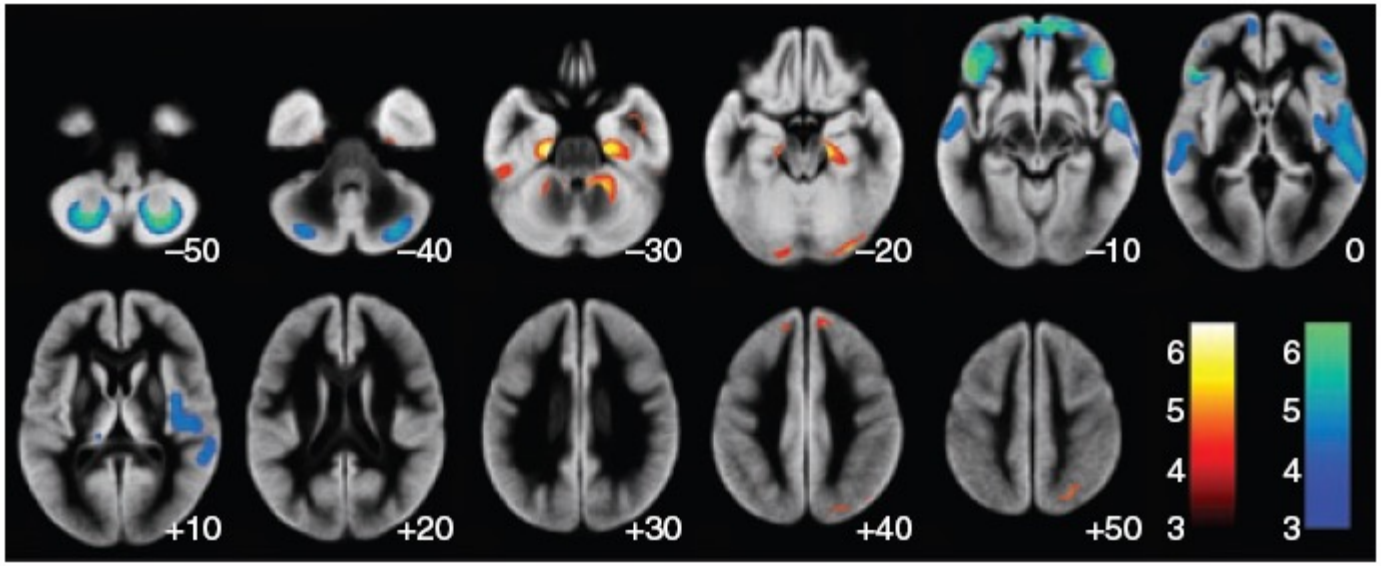
Matsuda, M., *et al. 1999. Altered hypothalamic function in response to glucose ingestion in obese humans. Diabetes.* ***48: 1801-1806.***

- Functional MRI
- Voxel Based Morphometry

VBM


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

Relationship to Body Mass Index

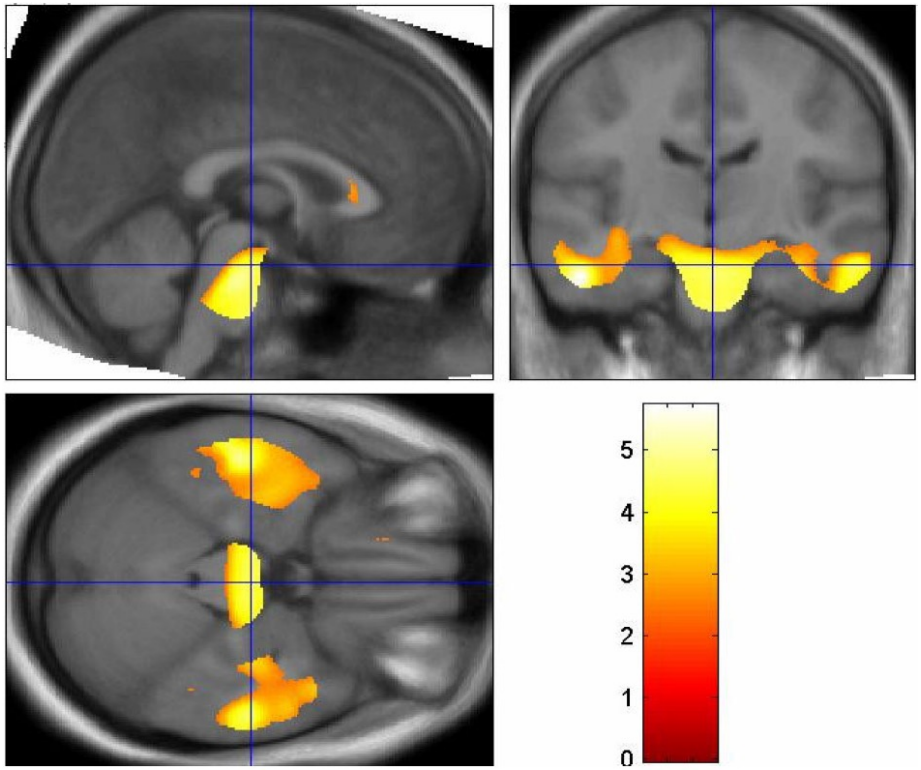


Taki, Y., *et al. 2008.* *Relationship between body mass index and gray matter volume in 1,428 healthy individuals.* *Obesity.* ***16: 119-124.***

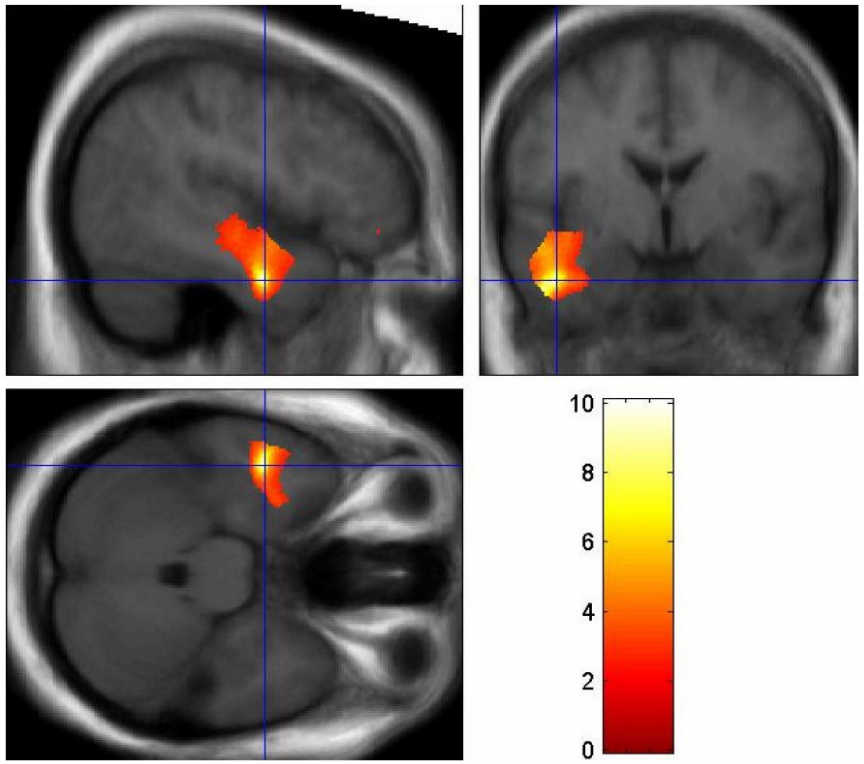
VBM

White Matter Changes

Difference in White Matter: Obese vs. Non-obese



Decreases in White Matter With Dieting



Haltia, L. T., *et al. 2007. Brain white matter expansion in human obesity and the recovering effect of dieting. Journal of Endocrinology and Metabolism.* ***92: 3278-2495.***

Future Directions

Focus more on individuals rather than group studies

- Assessment of causes
- Assessment of types of treatment and therapy
- Use of real time fMRI for therapy
- Resting state fluctuations
- More detailed moment to moment assessment of changes
- High resolution and pattern classification coupled with therapy