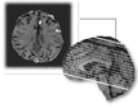


Neuroscience 2003

Functional Brain Imaging



*Joy Hirsch, Ph.D., Professor
Director, fMRI Research Center
Columbia University Health Sciences
NI Basement*

www.fmri.org

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A Brief Outline

A. Hypothesis of functional specificity

B. Brain Mapping Techniques

1. Functional Magnetic Resonance Imaging, fMRI
2. Somatosensory Evoked Potential, SSEP
3. Direct Cortical Stimulation
4. Positron Emission Tomography, PET
5. Magnetoencephalography, MEG
6. Electroencephalography, EEG

C. Integration of Brain Mapping Techniques

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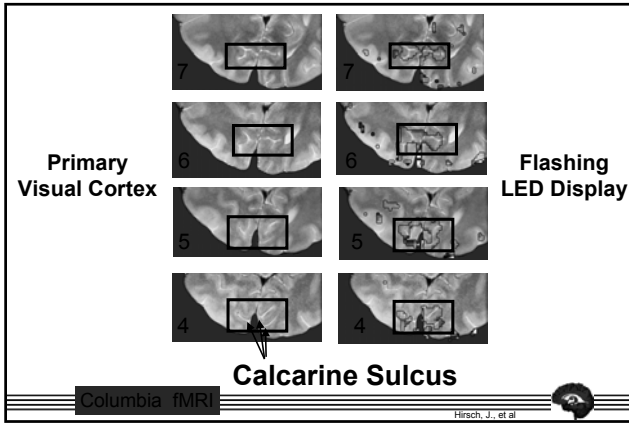
A. Hypothesis of functional specificity

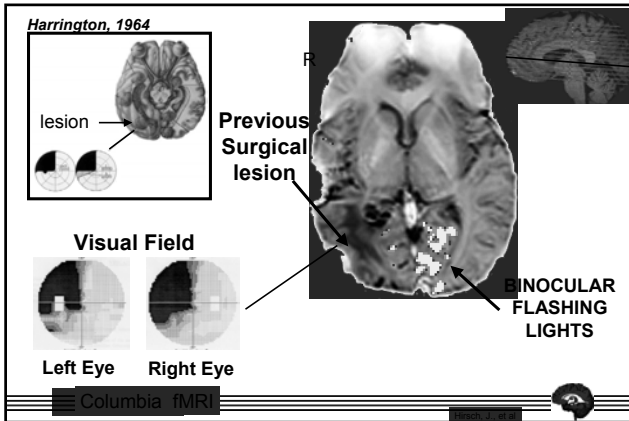
1. Specializations of single brain areas

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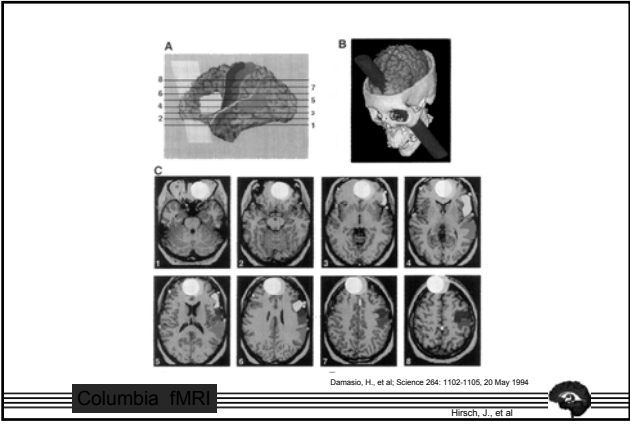


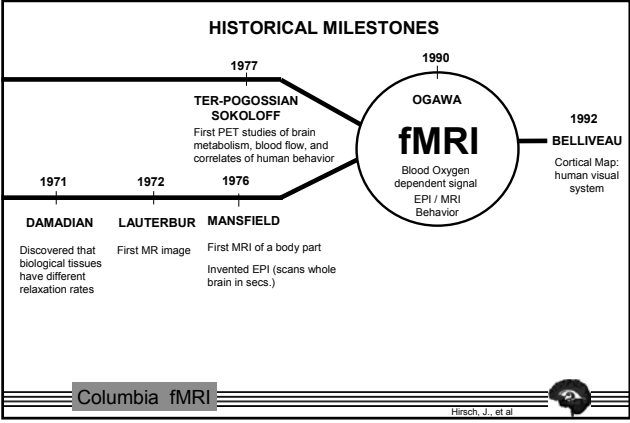


HISTORICAL MILESTONES					
1841	1874	1890	1909	1950	
BROCA Aphasia and lesions in GFI	WERNICKE Aphasia and lesions in GTs	ROY & SHERRINGTON Relationship between neural activity and vascular changes	BRODMANN Cytoarchitectonic regions of cortex	PENFIELD Intraoperative cortical maps	
1845	FARADAY Magnetic properties of blood	1936	PAULING Magnetic state of hemoglobin changes with oxygenation RABI Discovery of Magnetic Resonance	1945	PURCELL BLOCK Demonstrated NMR in condensed matter
				1971	HOUNSFIELD CORMACK Invention of Computed Tomography

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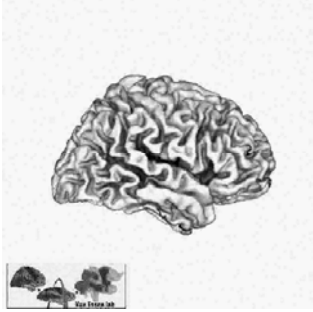


A. Hypothesis of functional specificity

- 1. Specializations of single brain areas**
- 2. Specializations of multiple brain areas**

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Functional Organization of Visual Cortex



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B. Brain Mapping Techniques

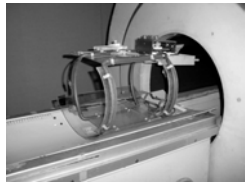
1. Functional Magnetic Resonance Imaging, fMRI

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Early Developments in MR Solved the Occluded-Structure Problem

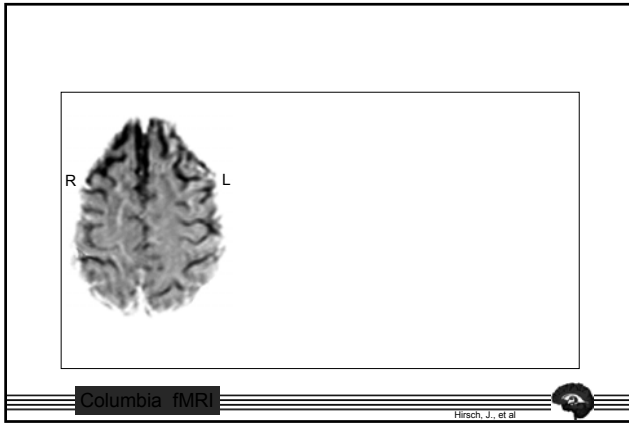


Sadek K. Hilal, M.D., Ph.D.
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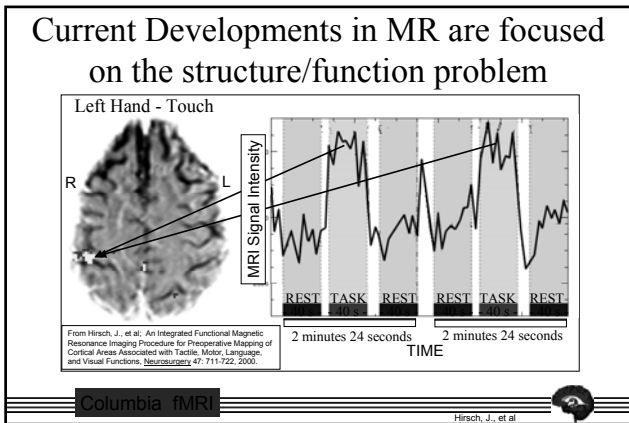




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B. Brain Mapping Techniques

1. Functional Magnetic Resonance Imaging, fMRI

a. Source of signal

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PHYSIOLOGY

NEURAL ACTIVATION
IS ASSOCIATED WITH AN
INCREASE IN BLOOD FLOW

O2 EXTRACTION IS
RELATIVELY UNCHANGED

RESULT:
REDUCTION IN THE
PROPORTION OF DEOXY HGB
IN THE LOCAL VASCULATURE

PHYSICS

DEOXY HGB
IS PARAMAGNETIC

AND DISTORTS THE LOCAL
MAGNETIC FIELD CAUSING
SIGNAL LOSS

RESULT:
LESS DISTORTION OF THE
MAGNETIC FIELD RESULTS IN
LOCAL SIGNAL INCREASE



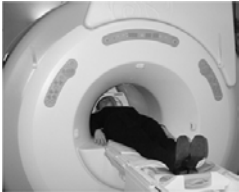
B. Brain Mapping Techniques

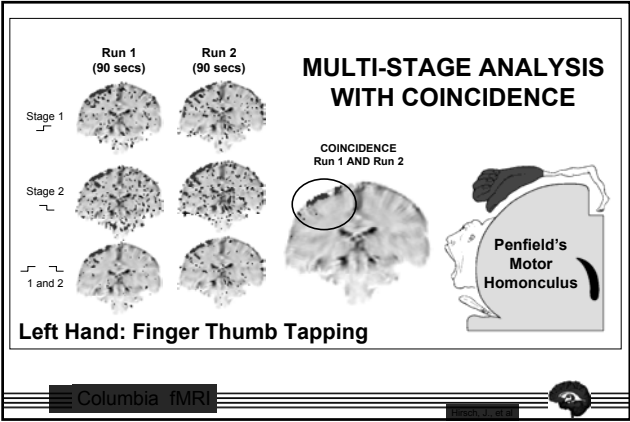
1. Functional Magnetic Resonance Imaging, fMRI

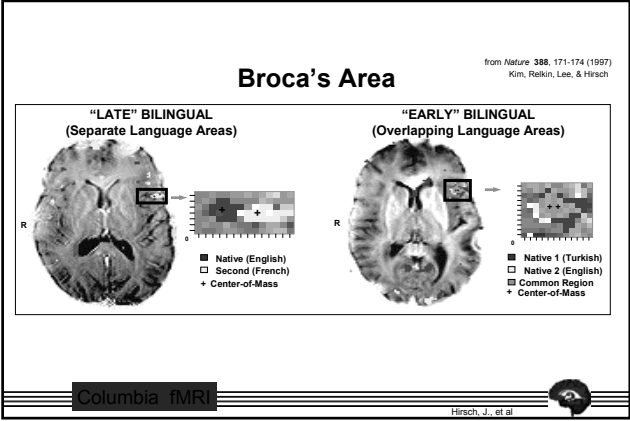
- a. Source of signal
- b. Measurement techniques



Imaging While Naming Objects







B. Brain Mapping Techniques

1. Functional Magnetic Resonance Imaging, fMRI

- a. Source of signal
- b. Measurement techniques
- c. Computation for analysis
- d. Individual brain maps

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Conventional Imaging **Functional Imaging Before Surgery**

Tumor Tumor

R

Left Hand: Sensory/Motor

CC 23 (AB)

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Conventional Imaging

Tumor

R

CC 23 (AB)

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Conventional Imaging **Functional Imaging Before Surgery** **After Surgery**

Tumor Tumor

R

Left Hand: Sensory/Motor

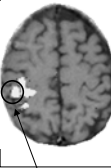
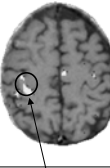
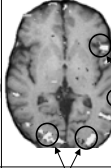
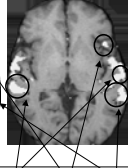
Left Hand Movement

QuickTime FICT

CC 23 (AB)

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Standard Brain Mapping Tasks

SENSORY	MOTOR	LANGUAGE	
Touch (passive)	Finger Thumb Tapping (active)	Picture Naming (active)	Listening to Words (passive)
			
GPoC	GPrC	GOi	GTT GFi GTs

From Hirsch, J., et al. Neurosurgery 47: 711-722, 2007

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Functional Organization of Visual Cortex

QuickTime™ and a Video decompressor are needed to see this picture.

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B. Brain Mapping Techniques

1. Functional Magnetic Resonance Imaging, fMRI
2. Somatosensory Evoked Potential, SSEP
3. Direct Cortical Stimulation

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Conventional functional mapping in the OR

**SSEP - SomatoSensory Evoked Potentials
Cortical Stimulation**

Based on Electrical Activity of Neurons Induced by External Stimulation

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Sensory Motor Mapping

Craniotomy	SSEP	Direct Cortical Stimulation	Localization fMRI
		<p>“Twitching of hand, focal seizure involving arm”</p>	
		<p>“Twitching in 1st three digits”</p>	

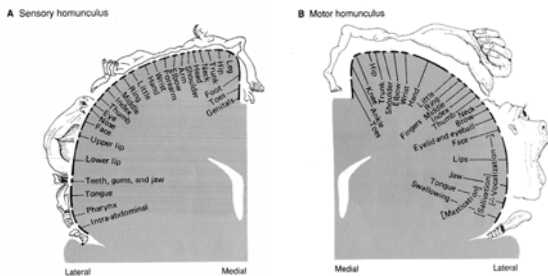
From Hirsch, J., et al. An Integrated Functional Magnetic Resonance Imaging Procedure for Preoperative Mapping of Cortical Areas Associated with Tactile, Motor, Language, and Visual Functions, *Neurosurgery* 47: 711-722, 2000.

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Homunculus


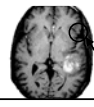




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Language Mapping

fMRI	Intraoperative Stimulation	Response
Broca's Area 		Speech Arrest During Counting
Wernicke's Area 		Literal paraphasic speech error during picture naming

From Hirsch, J., et al. An Integrated Functional Magnetic Resonance Imaging Procedure for Preoperative Mapping of Cortical Areas Associated with Tactile, Motor, Language, and Visual Functions, *Neurosurgery* 47: 711-722, 2000.

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B. Brain Mapping Techniques

1. Functional Magnetic Resonance Imaging, fMRI
2. Somatosensory Evoked Potential, SSEP
3. Direct Cortical Stimulation
4. Positron Emission Tomography, PET
 - a. Source of signal

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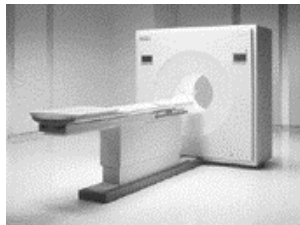


Positron Emission Tomography

Radionuclides that emit positrons such as ^{15}O and ^{18}F are introduced into the brain.

H_2^{15}O behaves like H_2^{16}O and indicates blood flow (rCBF) (half life = 123 seconds) integration time \approx 60 seconds.

^{18}F - deoxyglucose behaves like deoxyglucose and indicates metabolic activity (half-life = 110 minutes) integration time \approx 20 minutes



PET SCANNER

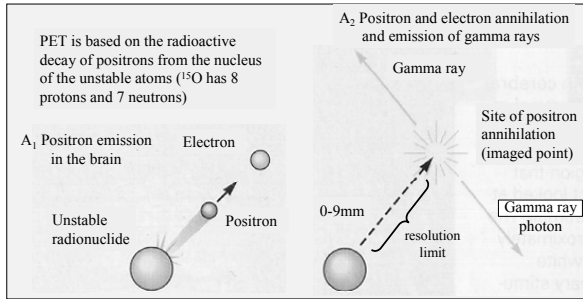
From: www.epub.org.br/cm/n011pet/pet.htm

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Principle of PET



From: Principles of Neural Science (4th. Ed.) Kandel, Schwartz, & Jessell, p. 377.

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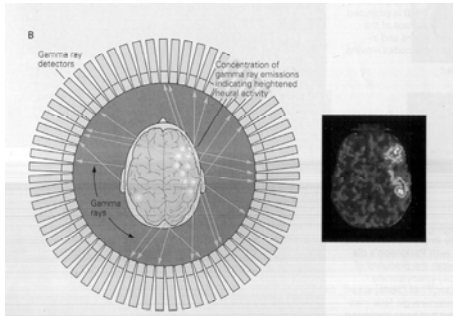
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 - a. Source of signal
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Gamma Ray Detections to Location of Function



From: Principles of Neural Science (4th. Ed.) Kandel, Schwartz, & Jessell, p. 377.

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Injection of radioactive-labeled water for PET scanning



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B. Brain Mapping Techniques

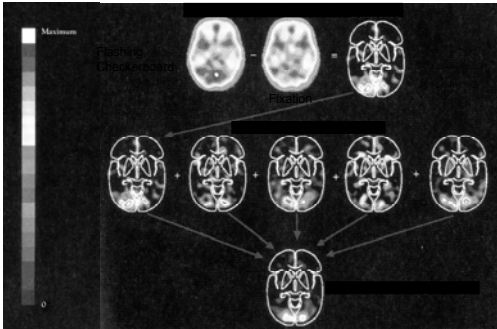
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Analysis of PET Results



From: Images of Mind by Posner, M. and Raichle, M. Scientific American Library, 1994, p. 24

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B. Brain Mapping Techniques

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Measurement of Electromagnetic Activity

MEG: MagnetoEncephaloGraphy
EEG: ElectroEncephaloGraphy

**Provides Information of
temporal interactions**

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B. Brain Mapping Techniques

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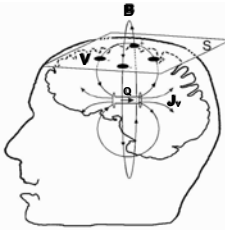
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Relationship between currents in the brain and the magnetic field outside the head.

- Based on the discovery that electrical currents generate magnetic fields: Hans Christian Oersted, a Danish physicist (early 19th. century)
- A current source with strength Q causes a current flow J_v within the brain.



- The current flow produces a potential difference V on the scalp: (measured by EEG)
- And a magnetic field B outside of the head: (measured by MEG)

from:
www.Aston.ac.uk/psychology/meg/meg/intro/magfield.htm

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B. Brain Mapping Techniques

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Magnetoencephalography, MEG

Tiny magnetic fields produced by brain activity (10^{-13} Teslas) can be measured using Superconducting Quantum Interference Devices (SQUIDS).



SQUIDS operate at superconducting temperatures (-269°C). Sensors are placed in a dewar containing liquid helium.

Stimulus – evoked neuromagnetic signals are recorded by an array of detectors.

The spatial location of the source is inferred by mathematical modeling of the magnetic field pattern.

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B. Brain Mapping Techniques

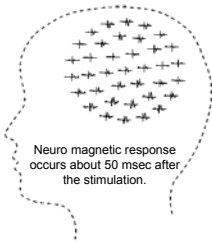
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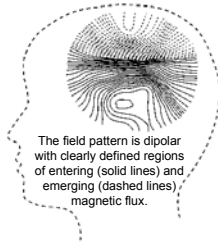
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Somatosensory evoked magnetic signals in response to tactile stimulation of the contralateral index finger



Isofield contour maps at the time of maximal response (50 msec) to the tactile stimulation



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B. Brain Mapping Techniques

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Electroencephalography



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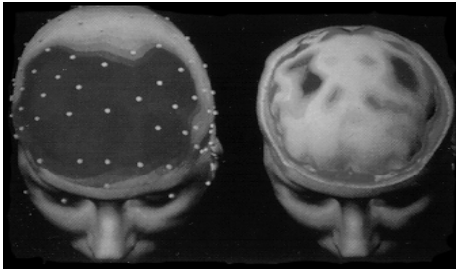
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Electroencephalography

Electrode Array
for EEG

Averaged Activity profiles during
bilateral finger movement



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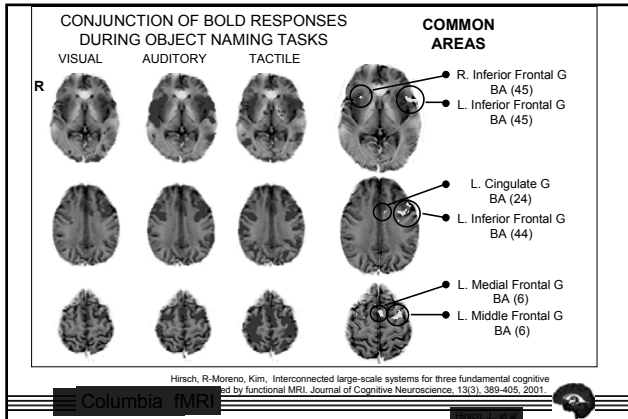
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C. Integration of Brain Mapping Techniques

1. Task of specificity and conjunctions





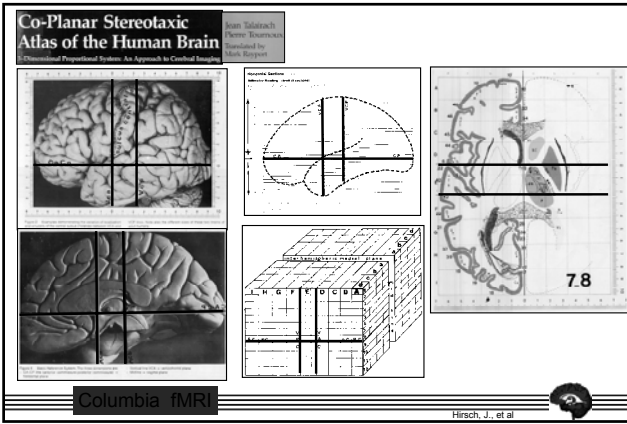
C. Integration of Brain Mapping Techniques

1. Task of specificity and conjunctions

2. Labels of functional areas

a. Atlas-Based





C. Integration of Brain Mapping Techniques

1. Task of specificity and conjunctions
2. Labels of functional areas
 - a. Atlas-Based
 - b. Registration methods

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Labeling of Active Brain Areas

Functional Brain Atlas Brain

Name	BA	Sector
GPrC	4	c,E
GFs	6	b,E
GFd	6	a,E,60,-a
GFs	6	b,E,60
GRC	4	c,E,60
LPs	7	b,G,60

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C. Integration of Brain Mapping Techniques

1. Task of specificity and conjunctions
2. Labels of functional areas
3. Connectivity computations





Anatomical Region	BA	Center of mass		
		x	y	z
Medial Frontal Gyrus	6	9	-6	53
Superior Temporal Gyrus	22	57	-26	9
Inferior Frontal Gyrus	44	49	10	25
Inferior Frontal Gyrus	45	40	25	8

Hirsch, R-Moreno, Kim. Interconnected large-scale systems for three fundamental cognitive tasks revealed by functional MRI. *Journal of Cognitive Neuroscience*, 13(3), 389-405, 2001.



QuickTime™ and a Video decompressor are needed to see this picture.



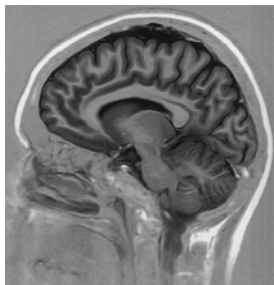
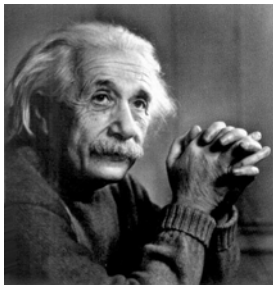
C. Integration of Brain Mapping Techniques

1. Task of specificity and conjunctions
2. Labels of functional areas
3. Connectivity computation
4. Models of long-range connectivity





The Astonishing Hypothesis Cognitive Events *are caused by* Neural Events





Functional MRI Research Center

Department of Radiology
Center for Neurobiology and Behavior
Columbia University
College of Physicians and Surgeons

Mission

To establish a collaborative and multi-investigator neuroimaging research environment focused on education, medical applications, and the study of brain, behavior, and therapy-induced cortical effects aimed at the systems of the brain that underlie cognition, perception, and action.

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