Imaging the Brain

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Functional magnetic resonance imaging (fMRI)
- Measures blood-oxygenation levels (BOLD signal)

Positron emission tomography (PET)
- Measures brain metabolism

Electroencephalogram (EEG)
- Detects electrical activity at the surface of the brain
fMRI

• Measuring brain activity → oxygen is a marker for activity

• Timescale: slow but spatially accurate

http://fmri.ucsd.edu/Research/whatisfmri.html
A Bug in fMRI Software Could Invalidate 15 Years of Brain Research

This is huge.

www.sciencealert.com
PET imaging measuring metabolism
Positron emission Tomography measuring energy consumption in the brain.
PET-scans → look at bodily processes

1. detect the decay products of radioactive tracers

2. when tracers decay, they emit positrons → γ rays
$^{18}$FDG \[ \text{OH} + ^{18}F \rightarrow \text{OH} + ^{18}F \]

$^{18}$FDG ($^{18}$-2-fluoro-2-deoxy-D-glucose)
FDG is not used in glycolysis and is metabolically trapped inside the cells. FDG is excreted by the kidneys.
function PET + CT anatomy → way better
Combined PET/CT: the historical perspective

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The proposal to combine PET with CT was made in the early 1990s by Townsend, Nutt and co-workers. The concept originated from an earlier low-cost PET scanner design (Figure 1a) that comprised rotating banks of bismuth germinate (BGO) block detectors that was developed by Townsend and coworkers at the University of Geneva in 1991. The gaps between the banks of BGO detectors (Figure 1b, arrow) offered the possibility to incorporate a different imaging modality within the PET scanner. A Swiss oncology surgeon, Dr Rudi Egeli, suggested adding something useful such as a CT scanner in the gaps that would provide anatomical information more familiar to surgeons at that time. Thus, the concept of PET/CT was born in 1991, in which the components of a CT scanner would be mounted in the gaps between the banks of BGO block detectors (Figure 1c). However, it was soon evident from the inspection of a typical CT scanner (Figure 1d) that such a concept would not be feasible owing to the density of x-ray components mounted on the rotating support. Thus, it was to be seven years before the first prototype combined PET/CT scanner was completed and installed in the University of Pittsburgh Medical Center. In 1993, Townsend moved to the University of Pittsburgh where, in collaboration with Dr Ron Nutt, then President of CTI PET Systems (CPS) in Knoxville, Tennessee, received NIH funding to begin the development of the first PET/CT prototype. This work followed the pioneering work of the late Bruce Hasegawa and colleagues at the University of California, San Francisco in the early 1990s where they developed the first combined clinical CT and SPECT prototype scanner.
PET/CT SCAN

The combination of PET and CT – hybrid or fusion imaging – provides remarkable accuracy.
1. good functional info

2. great anatomical details
One can measure the electrical activity at the surface of the brain. Electrodes are placed on the scalp. Activity of many neurons under the scalp can be detected. Fast, but can be spatially ambiguous.
Hans Berger
Father of EEG
Discovered alpha rhythm in 1928
“The naive view of EEG is that the signal flows straight up from the cortical surface to the electrodes.”
For brain electrical activity to be detectable through skull, must be strong signal summed over many neurons
- All behaving similarly at same time
- All oriented in same way
- So negative and positive don’t cancel each other out when summed

**Pyramidal Cells**

in the cortex have the right properties

*Single pyramidal cell in cortex*
Neural Activity

Figures adapted from S. Makeig (2007)
Each scalp EEG data channel sums the projected activities of multiple brain (and non-brain) source processes.
ICA
(independent component analysis):

- ICA
  - Any ERP at the scalp and see which sources that contribute.
  - (Eg: Sources that give rise to P3)

S. Makeig (2007, 2011)
Event Related Brain Potentials

- Time-locked electrophysiological responses to stimuli
- Time-locked responses are averaged to reduce noise
EEG era:
1926 – 1938 Human EEG recording and spectral analysis

ERP era:
1962 - Computer ERP averaging (CAT)
1972 - Magnetoencephalogram (MEG)

fMRI era:
1993 - fMRI BOLD recordings

fEEG/BCIMoBI era:
2009 - EEG dry electrodes
2011 - MoBI Laboratory
Mining event-related brain dynamics

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This article provides a new, more comprehensive view of event-related brain dynamics founded on an information-based approach to modeling electroencephalographic (EEG) dynamics. Most EEG research focuses either on peaks ‘evoked’ in average event-related potentials (ERPs) or on changes ‘induced’ in the EEG power spectrum by experimental events. Although these measures are nearly complementary, they do not fully model the event-related dynamics in the data, and cannot isolate the signals of the contributing cortical areas. We propose that many ERPs and other EEG features are better viewed as time/frequency perturbations of underlying field potential processes. The new approach combines independent component analysis (ICA), time/frequency analysis, and trial-by-trial visualization that measures EEG source dynamics without requiring an explicit head model.
Cognition in action: imaging brain/body dynamics in mobile humans

Abstract

We have recently developed a mobile brain imaging method (MoBI), that allows for simultaneous recording of brain and body dynamics of humans actively behaving in and interacting with their environment. A mobile imaging approach was needed to study cognitive processes that are inherently based on the use of human physical structure to obtain behavioral goals. This review gives examples of the tight coupling between human physical structure with cognitive processing and the role of supraspinal activity during control of human stance and locomotion. Existing brain imaging methods for actively behaving participants are described and new sensor technology allowing for mobile recordings of different behavioral states in humans is introduced. Finally, we review recent work demonstrating the feasibility of a MoBI system that was developed at the Swartz Center for Computational Neuroscience at the University of California, San Diego, demonstrating the range of behavior that can be investigated with this method.