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Lecture 11 – Functional Brain Imaging – Hirsch

A. Hypothesis of functional specificity
   Key question: What is the fundamental neurophysiological unit of behavior?

   1. Specialization of single brain areas
   2. Specialization of networks of brain areas

B. Brain Mapping Techniques
   1. Functional Magnetic Resonance Imaging, fMRI
      a. Source of signal
         - A change in magnetic susceptibility occurs in a neurally active region of the brain due to the increase of oxygenated blood flow to that area.
         - Signals are relative to baseline (resting) levels and are acquired on a single "voxel" basis.
         - The size of a voxel (resolution) usually varies from 1 to 3 mm in-plane with a slice thickness of 3 to 5 mm.
      b. Measurement techniques
         - Block design
         - Event-related design
      c. Computation for analysis
         - Statistical comparisons of signal amplitudes
         - Signal averaging and time-course analyses
         - Statistical parametric mapping
      d. Individual maps of brain function
         - Applications for neurosurgery
         - Applications for neurology

   2. Somatosensory Evoke Potentials, SSEP
      a. Source of signal
         - Neural activity is induced by stimulation of a peripheral nerve
         - Output signals are acquired from a strip of surface electrodes located on the exposed brain following a craniotomy.
      b. Measurement techniques
         - A reversal of signal polarity indicated the margin of the Central Sulcus
      c. Applications for neurosurgery
         - Location of Central Sulcus

   3. Direct Cortical Stimulation
      a. Source of Signal
         - Neural activity induced by direct stimulation of cortical neurons
      b. Measurement techniques
         - Behavioral report or observation of movement of an extremity.
      c. Applications for Neurosurgery
         - Cortical maps (motor, language function)

4. Position Emission Tomography, PET
   a. Source of signal
      - Radionuclides that emit positrons (^{15}O, ^{18}F) are injected into arterial system.
      - Positron collides with free electron. Annihilation event results in gamma ray emission.
      - Site of origin of the annihilation event is computed by coincidence detection.
   b. Measurement techniques
      - Radioactive-labeled water is injected prior to scanning procedure
      - Blood flow increments are detected by comparison of gamma ray counts during baseline and during task performance.
   c. Computation for analysis
      - Multiple subjects are usually combined for statistically meaningful results.

5. Magnetoencephalography, MEG
   a. Source of signal
      - Electrical currents resulting from neural activity result in a current flow within the brain.
      - Current flow produces a magnetic field that can be measured outside of the brain.
   b. Measurement techniques
      - The detector is a Super Conducting Quantum Interference Device, SQUID.
      - Stimulus evoked magnetic signals are recorded by an array of detectors within the SQUID.
   c. Computation for analysis
      - The spatial location of the source is inferred by mathematical modeling of the pattern of magnetic fields.
      - Temporal profiles of signals indicate temporal properties of nerve firing.

6. Electroencephalography, EEG
   a. Source of signal
      - Electrical currents produce a current flow within the brain that is measured as a potential difference by surface electrodes placed on the scalp.
   b. Measurement techniques
      - Stimulus evoked electro-magnetic signals are recorded by the array of electrodes.
   c. Computation for analysis
      - Signal averaging yields temporal properties of neural activity
      - Signal source is computed based on models of global patterns of activity.

C. Integration of Brain Mapping Strategies
1. Task specificity and definitions
   a. Conjunction paradigms
   b. Subtraction paradigms

2. Labels of functional areas
   a. Atlas-based comparisons
   b. Registration methods

3. Connectivity computations
   a. Variance based
   b. "Coincidence based"

4. Models of Long-Range Connectivity

References:

1. Toga, A.W. and Mazziotta, J.C. Brain Mapping: The Systems. Academic Press, San Diego, 2000.Chapter 2: A Brief History of Human Functional Brain Mapping by Marcus E. Raichle, pages 33-75
Note: This chapter covers the main scientific events, theories and ideas that bring us to current imaging practices. PET and fMRI are compared and contrasted.

2. Damasio, H., Grabowski, T., Frank, R., Galaburda, A. M., Damasio, A. R. The Return of Phineas Gage: Clues About the Brain from the Skull of a Famous Patient. *Science*, 264, 1102-1105, 1994.
Note:. This article illustrates significant developments in understanding brain function that have emerged within the last century

3. Price, C.J., Moore, C.J., Friston, K.J. Subtractions, Conjunctions, and Interactions in Experimental Design of Activation Studies. *Human BrainMapping*, 5: 264–272, 1997.

4. Moonen, C. T. W. and Bandettini, P.A. (eds), 1999. Functional MRI Springer-Verlog, Berlin

   Chapter 10: Principles of **functional MRI**
   by W. Chen and S. Ogawa
   pages 103 - 114
   Chapter 29: Psychophysical Laboratory in the Magnet: Stimulus Delivery, Response Recording and Safety
   by R. L. Savoy, M.E. Ravicz & R.Gollub
   pages 347 – 366
   Chapter 30: Experimental Design for Brain fMRI
   by A. K. Aguirre and M. D. Esposito
   pages 369 – 380

Note: This entire book is an excellent reference for both an overview and specific issues related to neuroimaging with MRI. These three chapters highlight fundamental issues of fMRI.

5. Orrison, W. M., Levine, J. D., Sanders, J. A. and Hartshorne, F. Functional Brain Imaging. Mosby, St. Louis, 1995.

   Chapter 5: Position Emission Tomography by Michael F. Hartshorne
   pages 187 – 238

   Note: This chapter provides a comprehensive overview of neuroimaging with PET as well as specific applications for a variety of clinical conditions including ischemia, dementia, psychiatric disorders, epilepsy, drug addiction and malignancy

6. www.fmri.org