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NATIONAL RESEARCH COUNCIL CANADA

Functional Neuroimaging

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Outline of Presentation

- **Functional Neuroimaging**
  - **fMRI**
  - **EEG**
- **Time-Aware Data acquisition and Real-time fMRI**
- **Combining fMRI and EEG**
- **Neurofeedback**
- **Machine/Human interfaces and Functional Neuroimaging**

Functional Neuroimaging

- **ElectroEncephaloGraphy**
  - **Evoked potentials**
  - **Localized EEG**
- **Positron Emission Tomography**
  - **Fluorodeoxyglucose - metabolism**
  - **O15 water - blood flow**
- **Magnetic Resonance Imaging**
  - **Diffusion**
  - **Perfusion**
  - **BOLD-contrast fMRI**

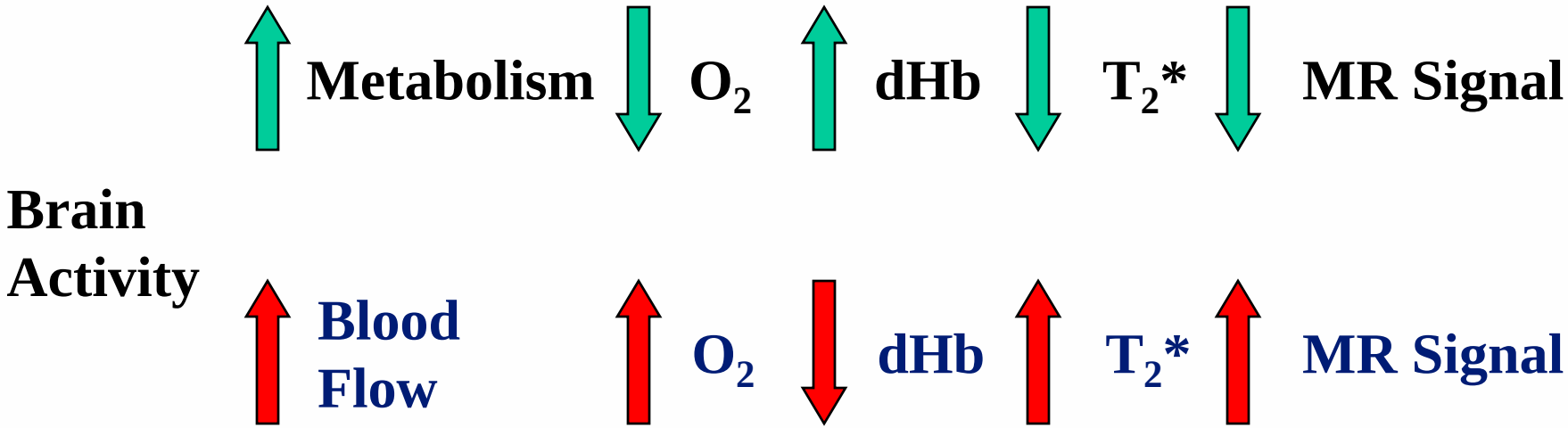
Functional Neuroimaging

- **Diagnostic use**
  - **Epiletic seizures**
  - **Tumor localization**
- **Treatment planning**
  - **Surgical planning**
  - **Radiation treatment**
- **Clinical Research populations**
  - **Supplement classic lesion studies**
  - **Neurorehabilitation**

Functional Magnetic Resonance Imaging

- **Measurement of altered neural activity by using the property of nuclear spin in the tissue water**
- **Neural activity indirectly affects the MR properties of tissue water through alteration of blood flow and blood oxygenation state by metabolism and blood flow**

What do we measure with fMRI



Take home message:
What we see with fMRI is far removed from neuroactivity!

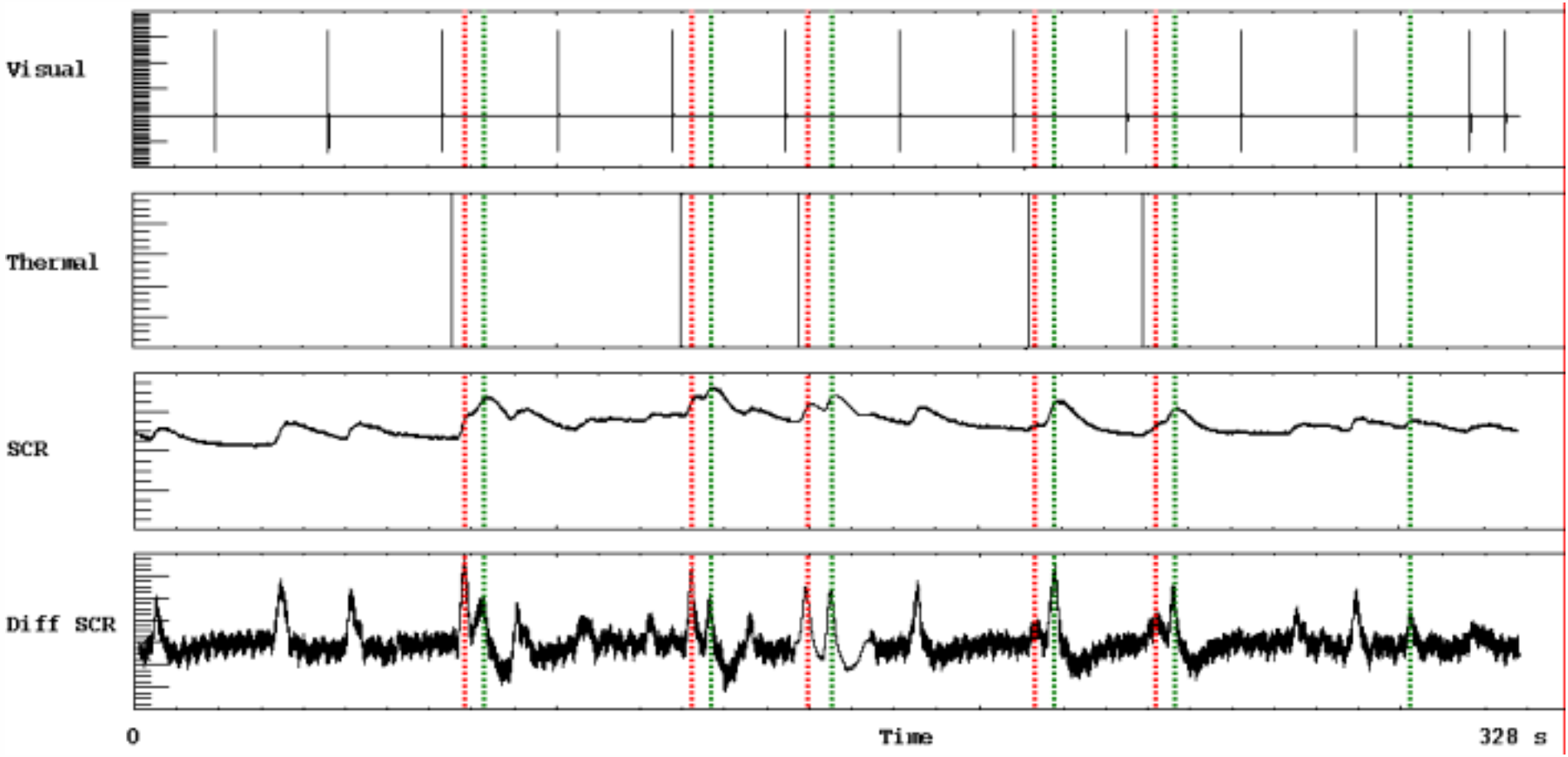
Electroencephalography - EEG

- **Measures electrical activity of the brain**
- **Usually measuring “large” electrical circuits**
- **Signal generated by brain activity directly**
- **Close in time and physical response to neural event**

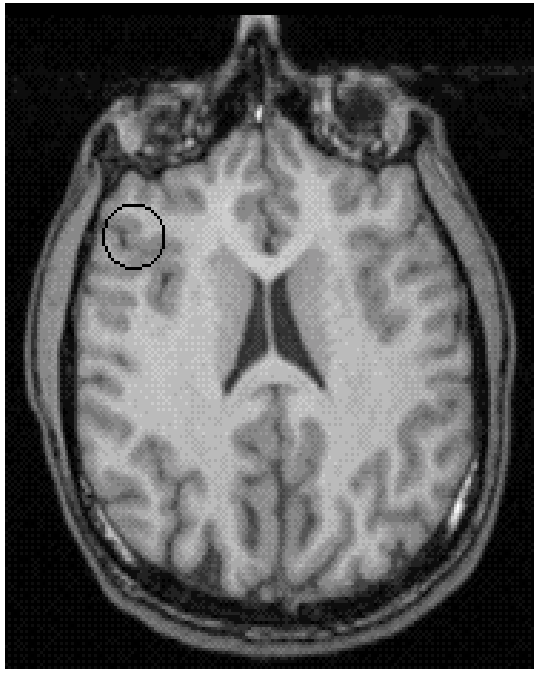
Time-Aware Data Acquisition

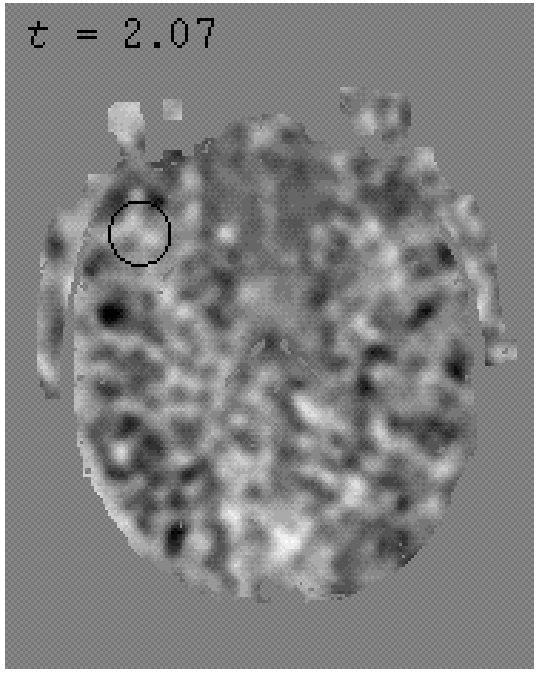
- **Every data point on every data channel has a time of acquisition assigned to it. Therefore, we can know relative timings.**
  - **Stimulus**
  - **ECG or pulse oximetry**
  - **Respiration**
  - **Image Acquisition**
    - **Speech**
    - **Skin Conductance**
    - **Button Responses or data glove**
    - **EEG**

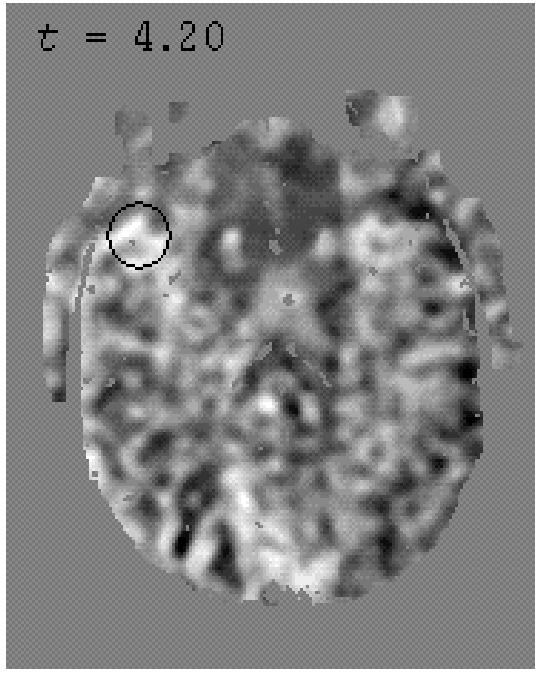
Skin Conductance



Skin Conductance







Overt Speech Responses

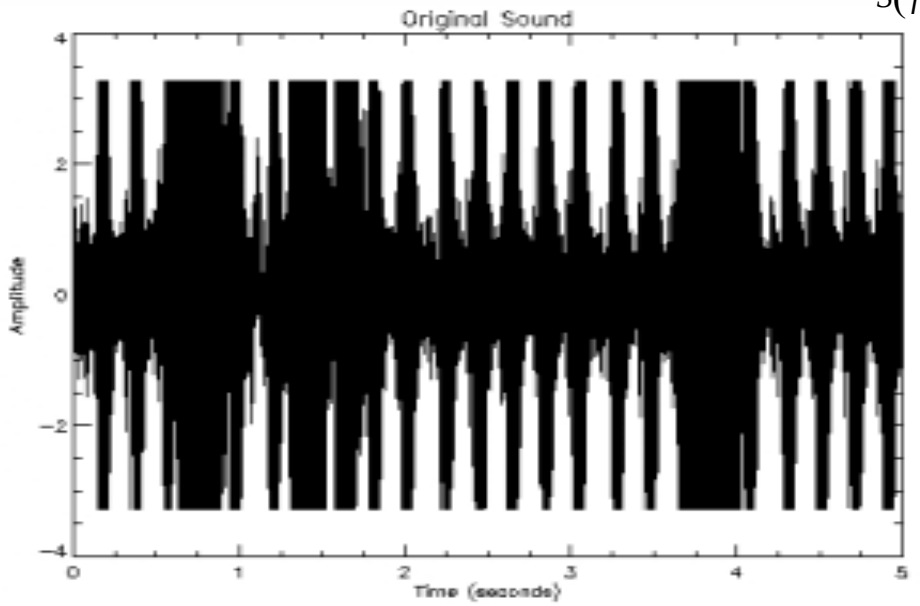
- **Subjects are more diligent doing the task if they know they are being monitored**
- **Separate analysis of successful and unsuccessful events**
- **Analysis based on latency of response**

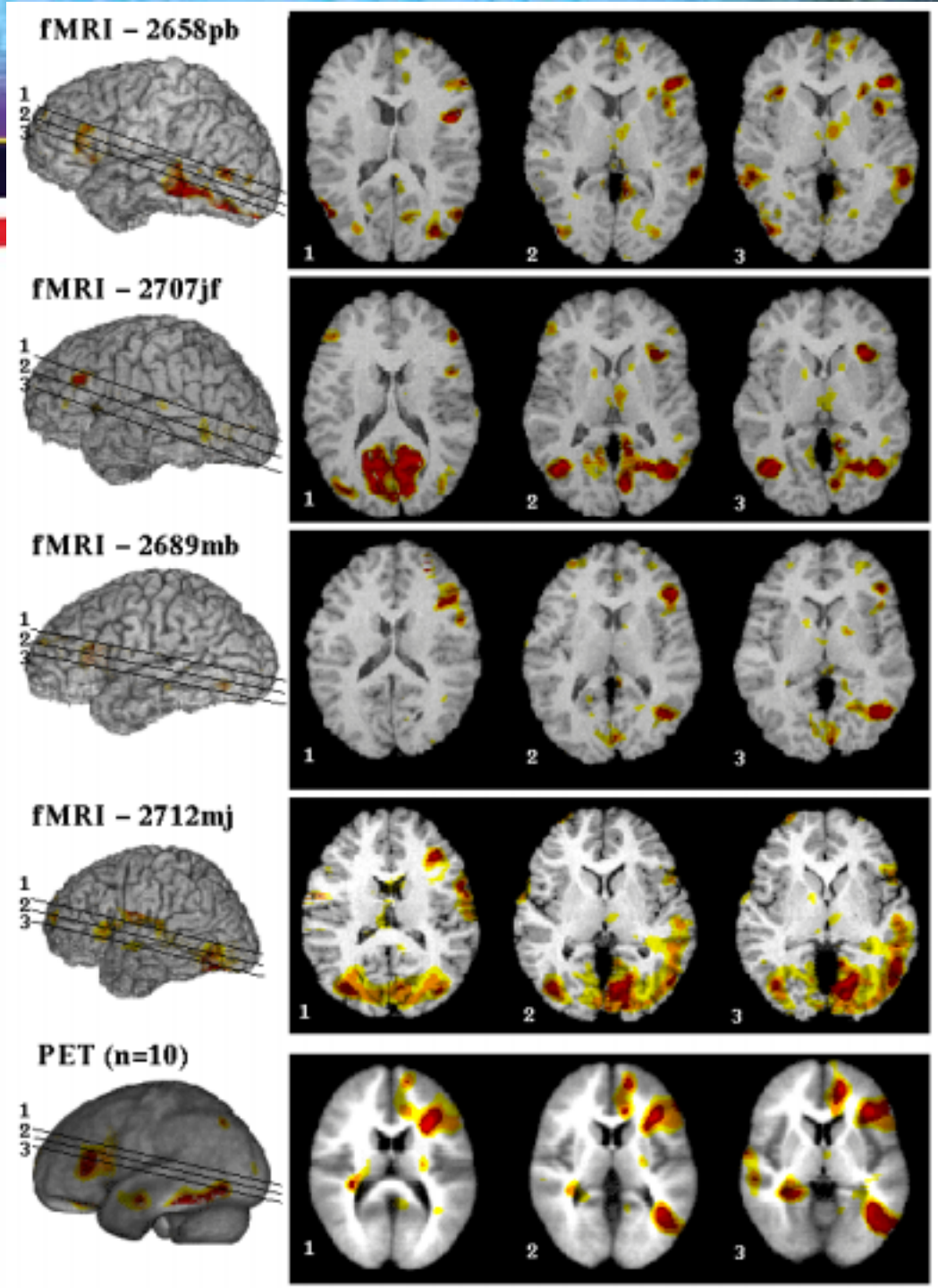
Speech

Weiner Filter

$$H[f] = \frac{S[f]^2}{S[f]^2 + N[f]^2}$$

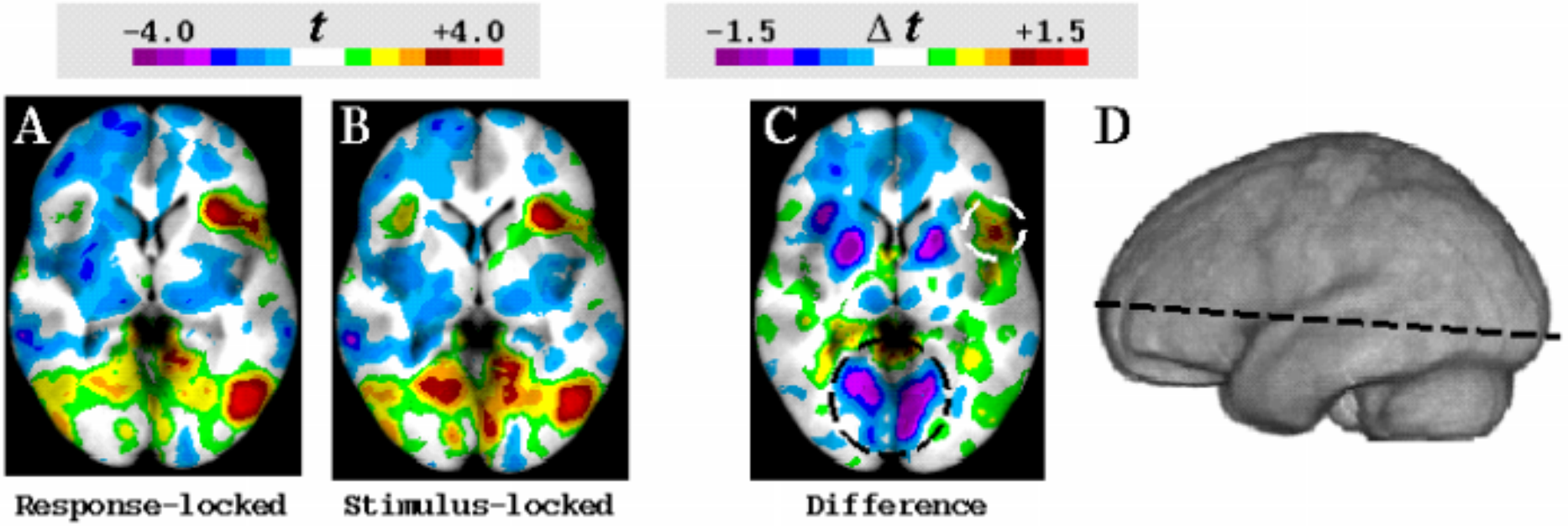
$$H(f) = \frac{S(f)}{S(f)^2 + N(f)^2}$$





The top four tiers show fMRI data for four of the seven subjects rendered with their 3D and 2D structural MRI data. The color data represent the *t* statistic contrasting the object naming task with the baseline task. The bottom tier shows PET data averaged across 10 normal subjects, analyzed in Talairach space and corendered on average Talairach-transformed structural MRI data. Both analyses show consistent left posterior temporal and left inferior frontal activation.

Time-Aware Data Acquisition



Real-Time fMRI Analysis

- **Provides statistical map of brain activation**
- **Performs calculation faster than data acquisition (> than 10 images per second)**
- **Provides same analysis that would be obtained offline**
  - **Image alignment**
  - **Multiple linear regression**
  - ***t*-statistic, F-statistic**
- **Sliding window analysis - analysis over a portion of time instead of all data acquired**

Combining fMRI and EEG

- **Relate fMRI signal back to neural event**
- **Gain better understanding of neural circuitry**
- **Better localize EEG signal**
- **Understand EEG signals associated with specific areas of brain localization**
- **Combined results allow neurofeedback protocols to be developed**

Imagined finger-tapping

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

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From: “Learned regulation of spatially localized brain activation using real-time fMRI”
deCharms, et al, NeuroImage 21: 436, 2004

Neurofeedback

- **For rehabilitation of damaged brain**
  - **Post-surgical intervention**
  - **Stem cell replacement**
  - **Post-stroke recovery**
  - **Cognitive behaviorial modification**
- **Train to control areas of brain activated by thought**

Human-Computer Interface

- **Use combined fMRI/EEG to understand EEG signals associated with specific thought tasks**
- **Use real-time fMRI to better train subjects to activate specific areas of brain**
- **Use EEG signal - transmitted wirelessly - to interface to machines**

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