Multimodal Imaging of Brain Activity and Connectivity

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Brain Activity is Spatiotemporal Process

- Brain activity is distributed in 3-dimensional space and evolves in time.
- High spatial resolution imaging modalities needed.
- High temporal resolution imaging modalities needed.
- Noninvasive imaging modalities needed for human brain imaging.

100 ms
Examples of Noninvasive Imaging

- Functional MRI
- Diffusion Tensor MRI
- PET
- EEG/MEG Imaging
Questions

• Can we non-invasively image the distributed brain activity with mm spatial resolution and ms temporal resolution?
Multimodal Neurovascular Recordings

- EEG
- Scalp EEG mapping
- Neural activation
- Neurovascular coupling
- BOLD-fMRI mapping
Imaging Neural Activity from EEG/MEG

[Diagram showing the process of imaging neural activity from EEG/MEG, involving steps such as EEG/MEG, MRI, and source imaging.]
Static fMRI-weighted Source Imaging

This solution minimizes the residual errors of fitting EEG data with a penalty term of weighted minimum norm

$$\min_{f} \left( \left\| C^{-1/2} (\Phi - LJ) \right\|^2 + \frac{1}{r} \left\| R_f^{-1/2} J \right\|^2 \right)$$

$f$: fMRI weighting factor ($f \geq 1$), determining the level of fMRI preference

- Dale et al, Neuron, 2000
Grand Challenge in Integrating fMRI with EEG
Dynamic fMRI-EEG Integrated Neuroimaging

Event-related potential

Linear regression

quantified fMRI map

fMRI-EEG integrated electrical source imaging

Covariance Analysis

Spatiotemporal Current Density Distribution

Time

Control task control task control

BOLD

Time

signal covariance noise covariance

Σ
Spatiotemporal Dynamic Multimodal Imaging in Human
Summary

- **Where - Brain Mapping and Localization**
  - BOLD fMRI mapping
  - *Neurovascular coupling mechanisms*

- **When – Electrophysiological Imaging**
  - EEG/MEG mapping
  - *EEG/MEG source imaging*

- **How - Mapping Brain Connectivity and Networks**
  - Multimodal neuroimaging integrating fMRI and EEG/MEG
  - *Reliable simultaneous fMRI/EEG recordings*
  - *Quantifying neurovascular coupling*

- **What –**
  - Better understand brain functions
  - Aid clinical diagnosis and treatment of nervous disorders
Grand Challenge

- Imaging brain connectivity and network dynamics beyond localization