MR-Encephalography (MREG): ultra-high temporal resolution functional MRI

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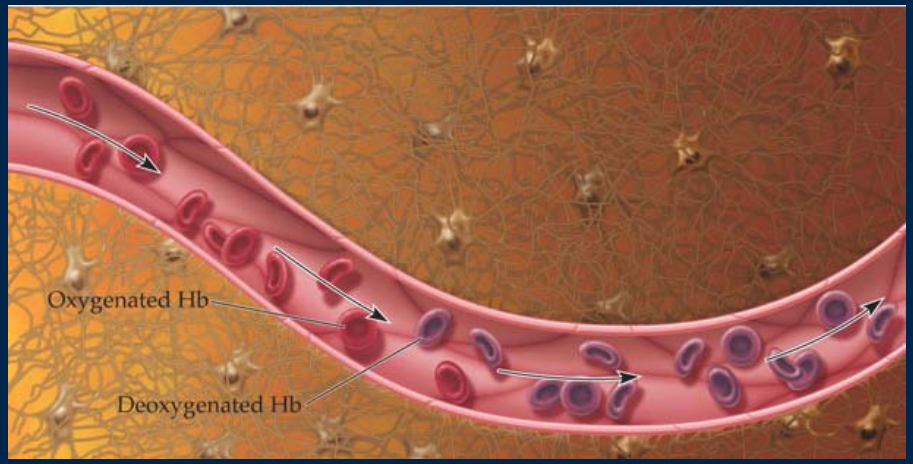
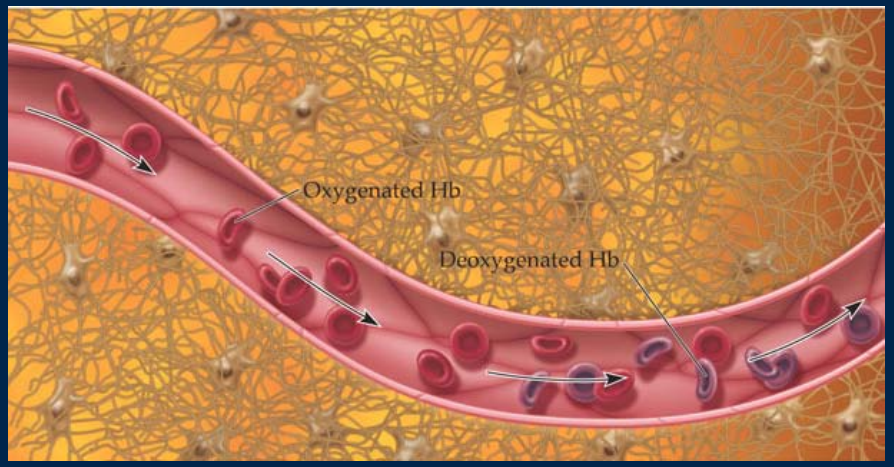
Introduction

- fMRI is based on the identification of hemodynamic changes to neuronal activity

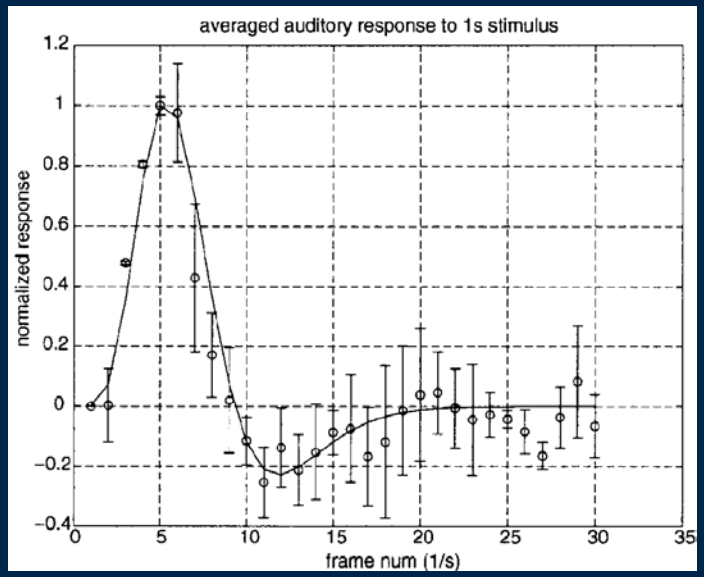




Huettel et al., 2004

Introduction

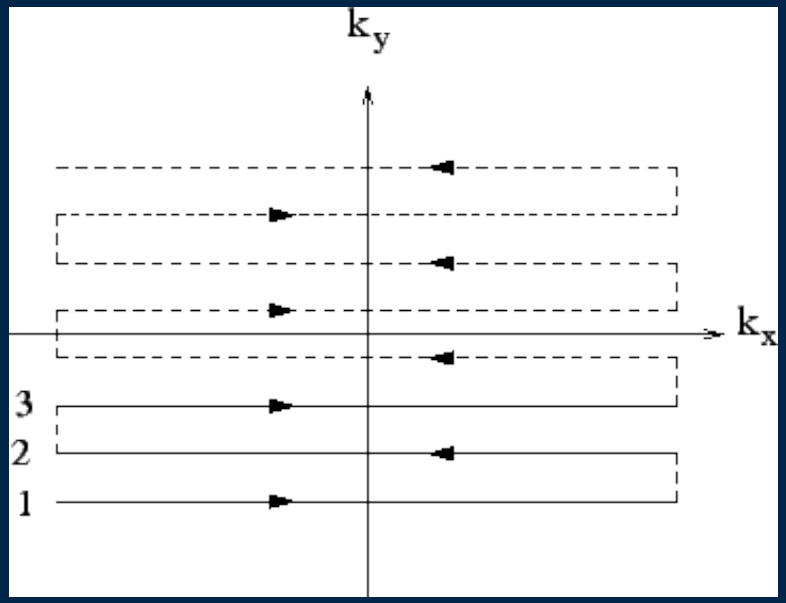
- The hemodynamic response shows changes over ~15 seconds with a percent signal change of the order of 1%

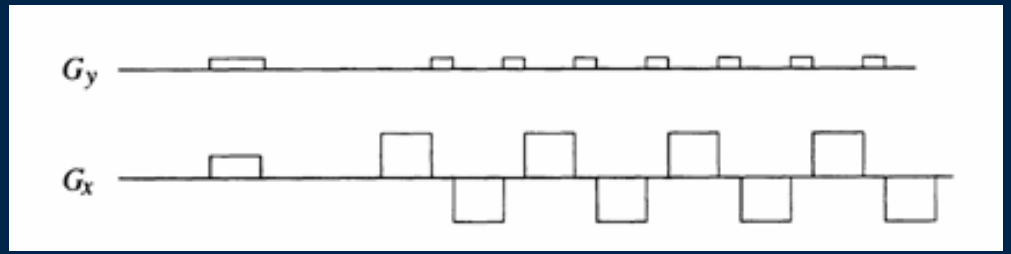


Glover et al., 1999

Introduction

- EPI provides sufficient temporal resolution to sample the HRF (~60ms per 2D slice or ~2s for whole-brain data at 3T)



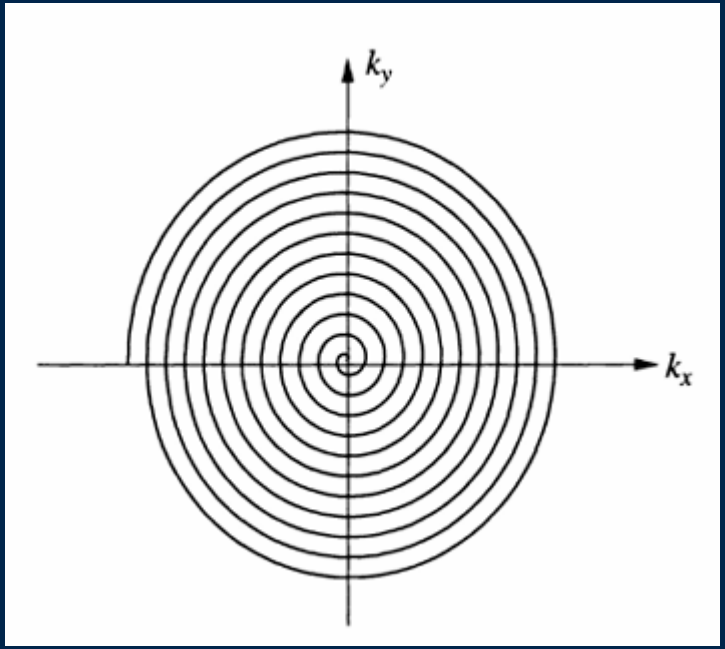


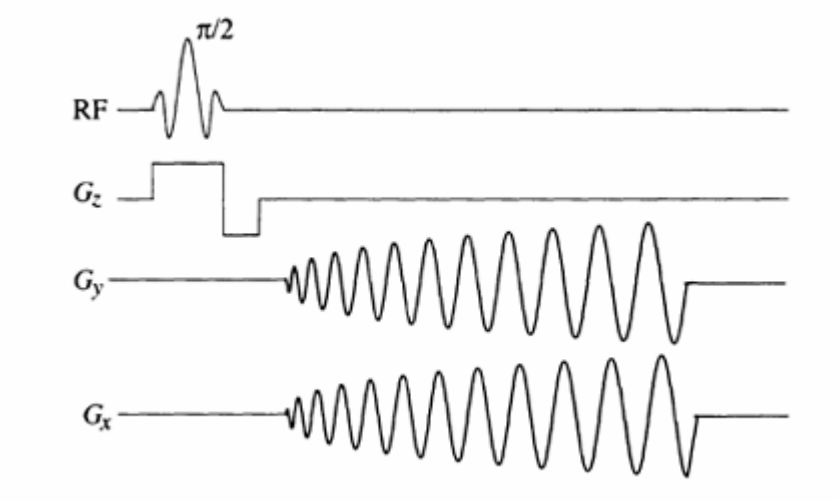
Introduction

- Two questions:
  - Can we acquire images with a higher temporal resolution?
  - Can a higher temporal resolution allow the extraction of new information from fMRI data?

Improved temporal resolution

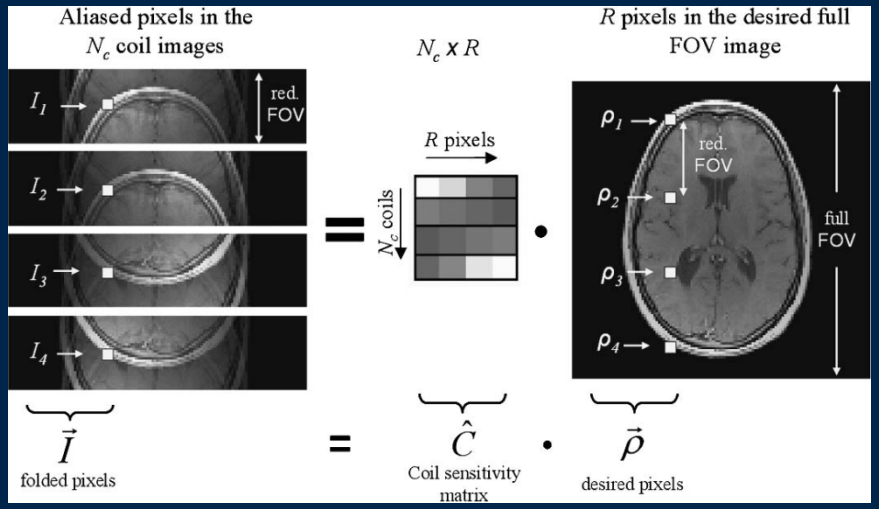
- Spiral trajectory uses gradients more efficiently, although k-space data is no longer uniformly sampled

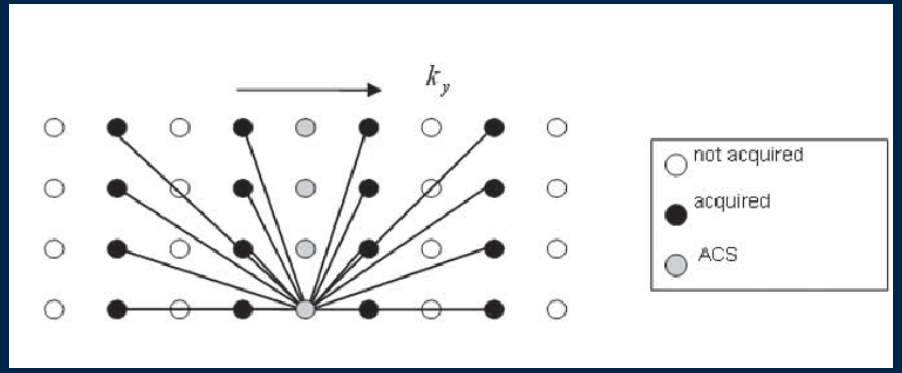




Parallel imaging

- Using multiple receiver coils, there is sufficient information to reconstruct missing k-space points





MR-encephalography (MREG)

- 3D single-shot trajectory consisting of concentric shells
- Readout time: ~60ms
- Highly undersampled trajectory (~20-fold) acquired with a 32-channel head coil

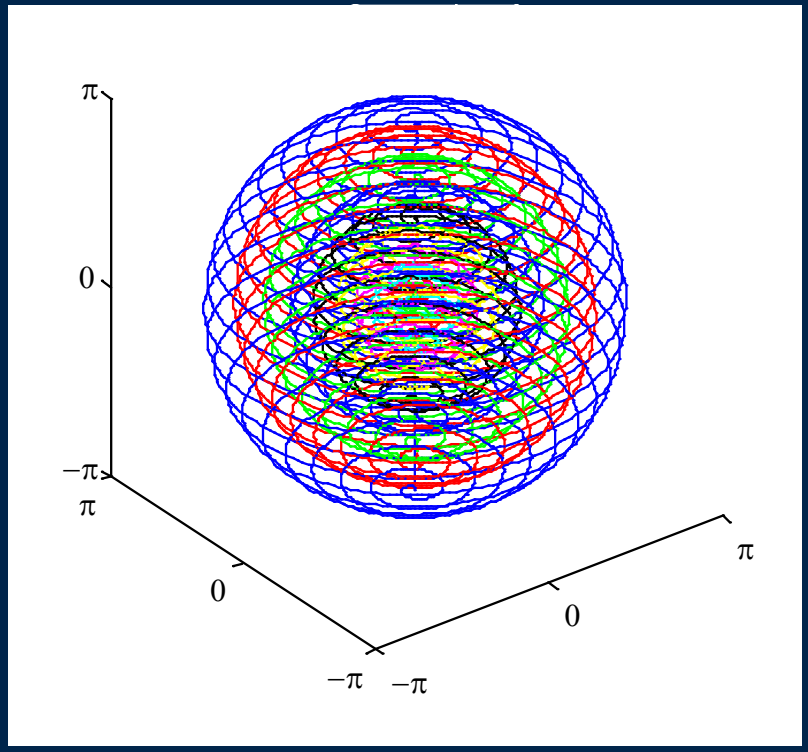
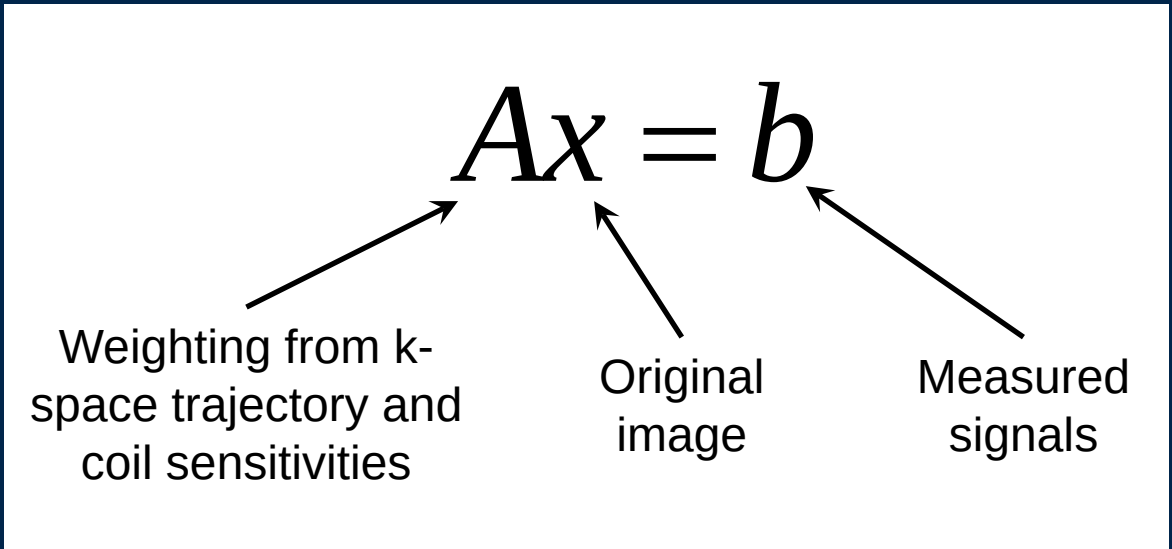


Image reconstruction

- Large, non-uniform k-space data:



- Minimize $||Ax - b||^2 + \lambda^2 ||x||^2$

Image reconstruction

- Reconstructed images without regularization

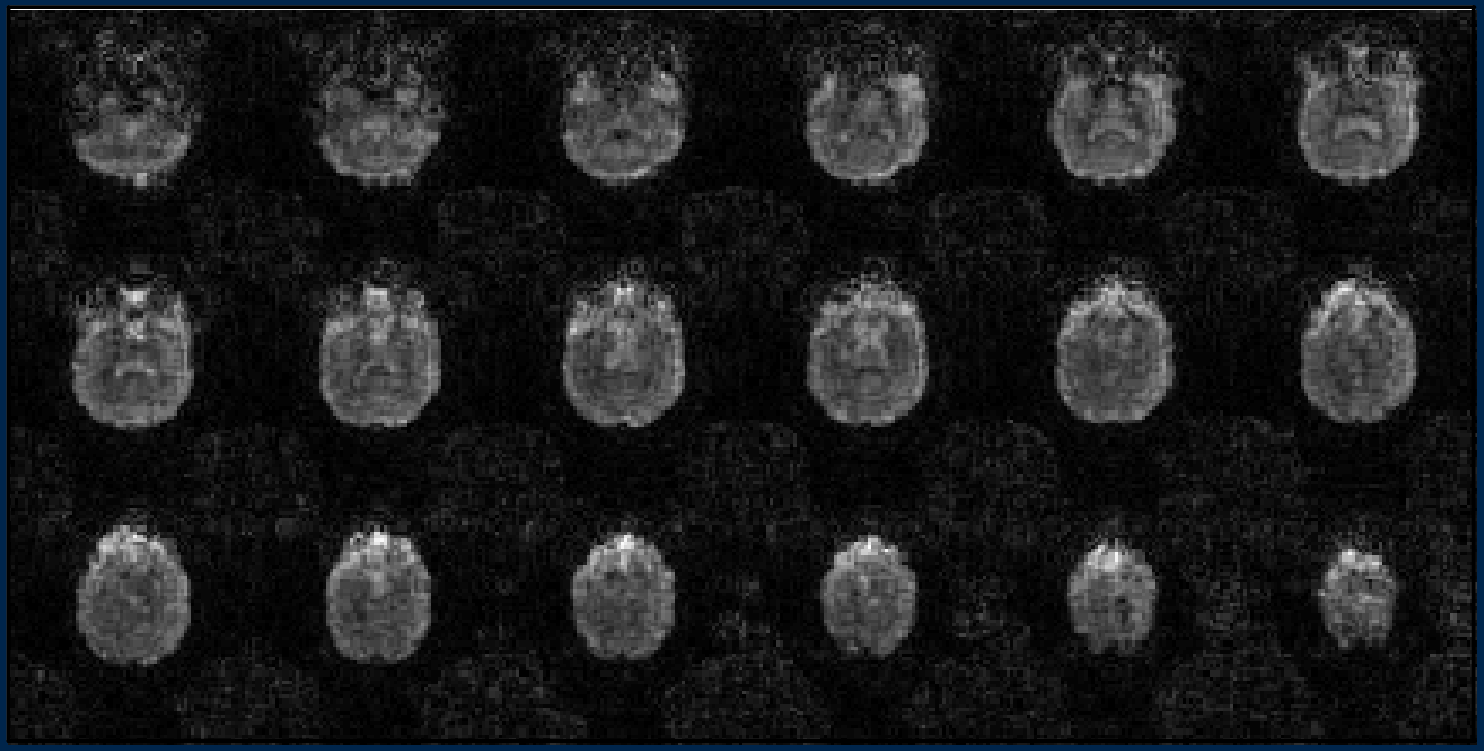


Image reconstruction

- Reconstructed images with regularization

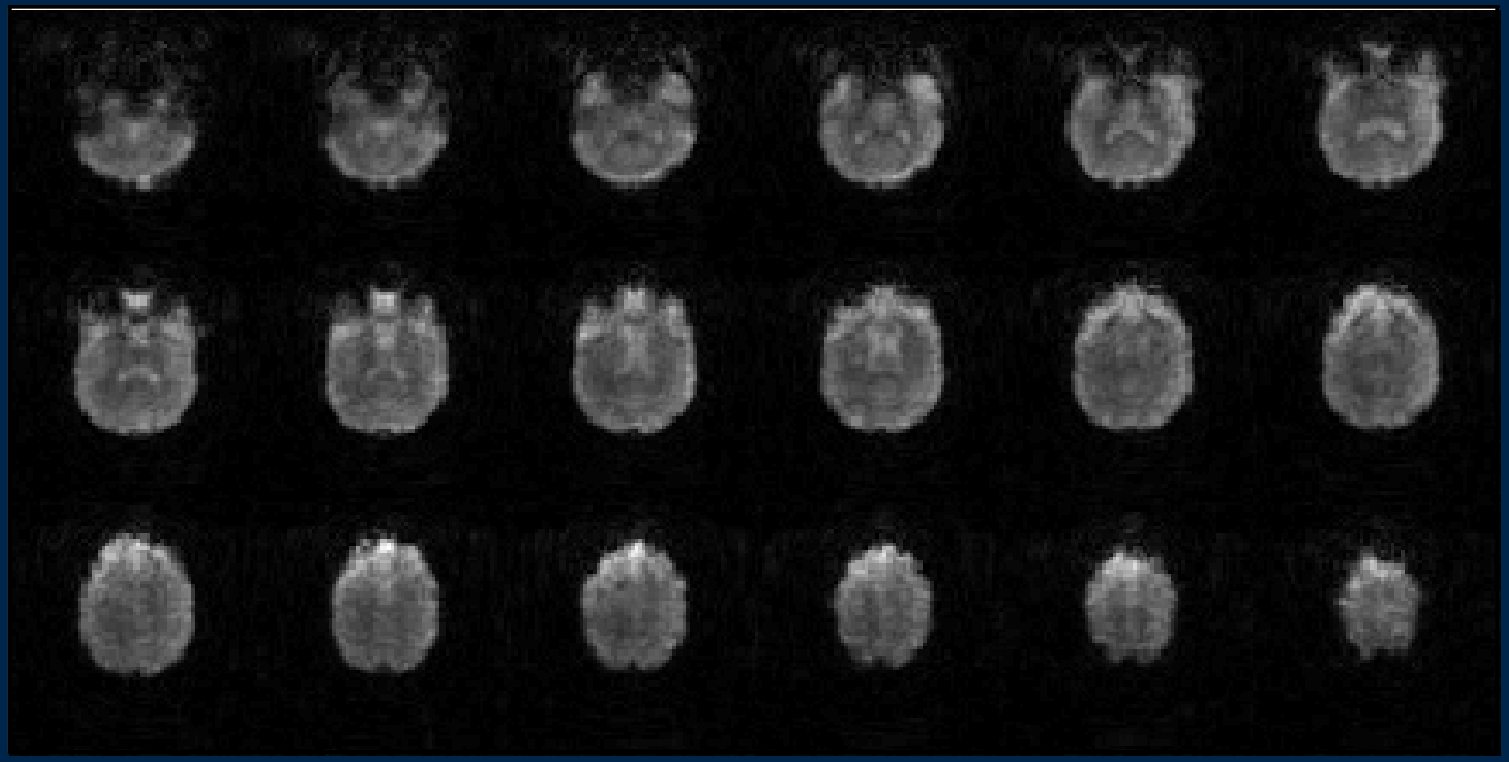


Image reconstruction

- Off-resonance correction

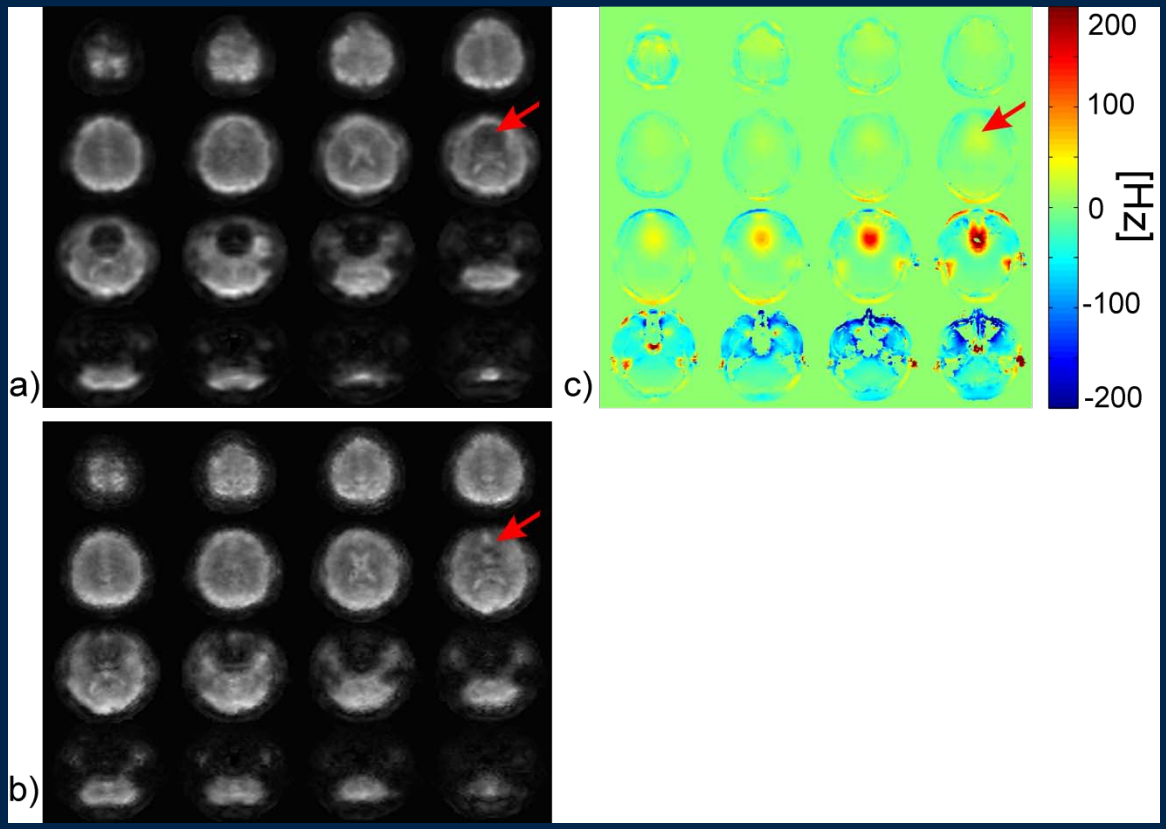
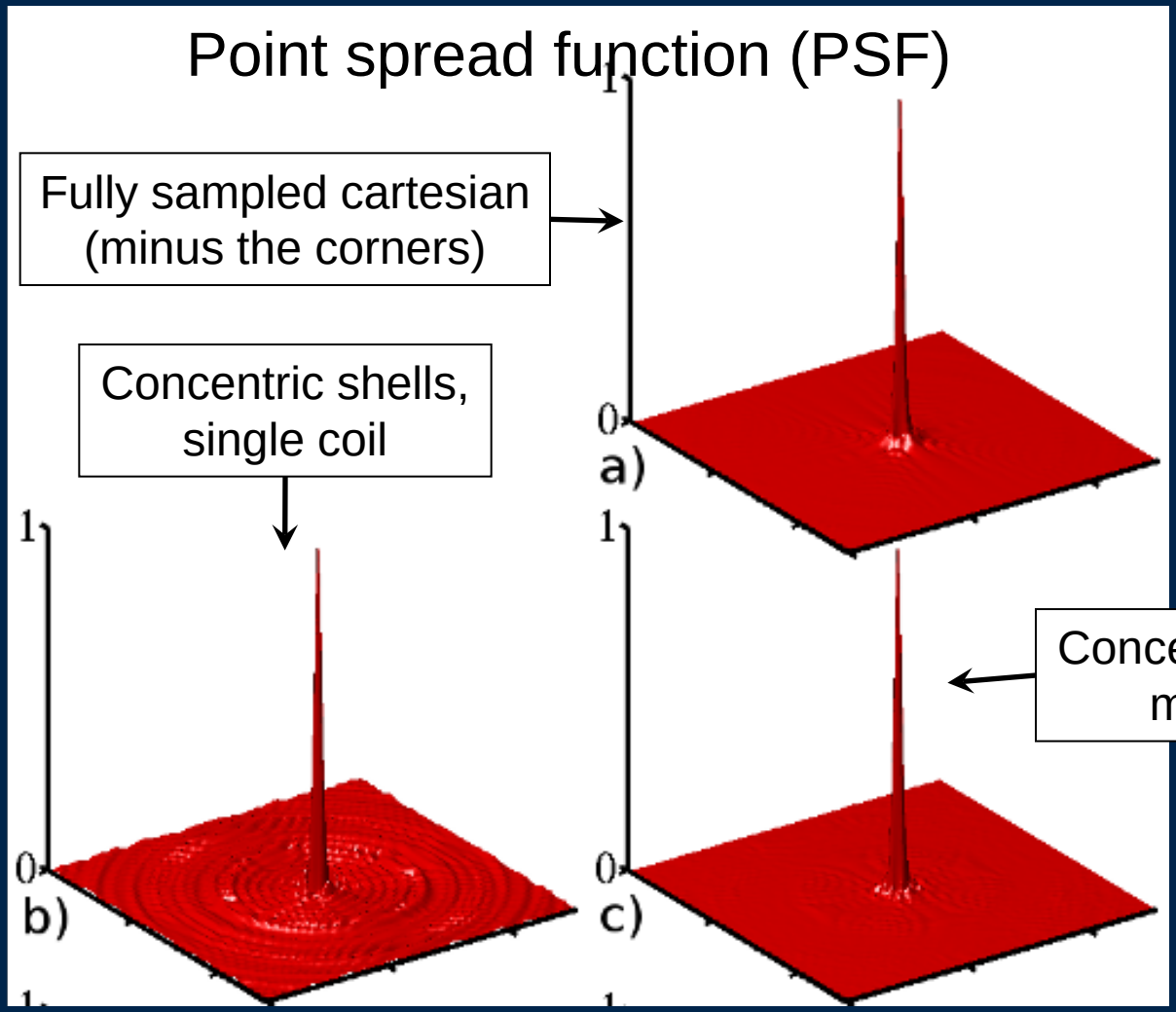
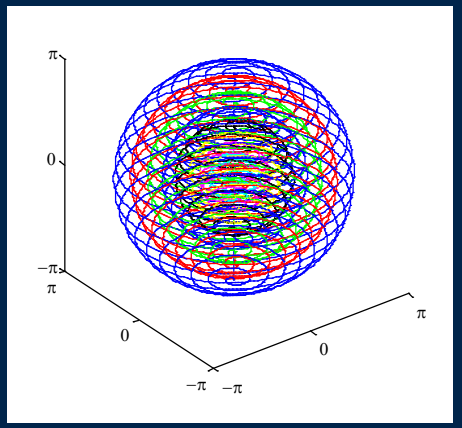


Image reconstruction

- Reconstruction of a single volume requires 10 minutes on a single CPU
  - 30 minutes of fMRI data at TR=100ms: 18000 volumes
  - Parallel reconstruction on multiple CPUs and GPU implementation

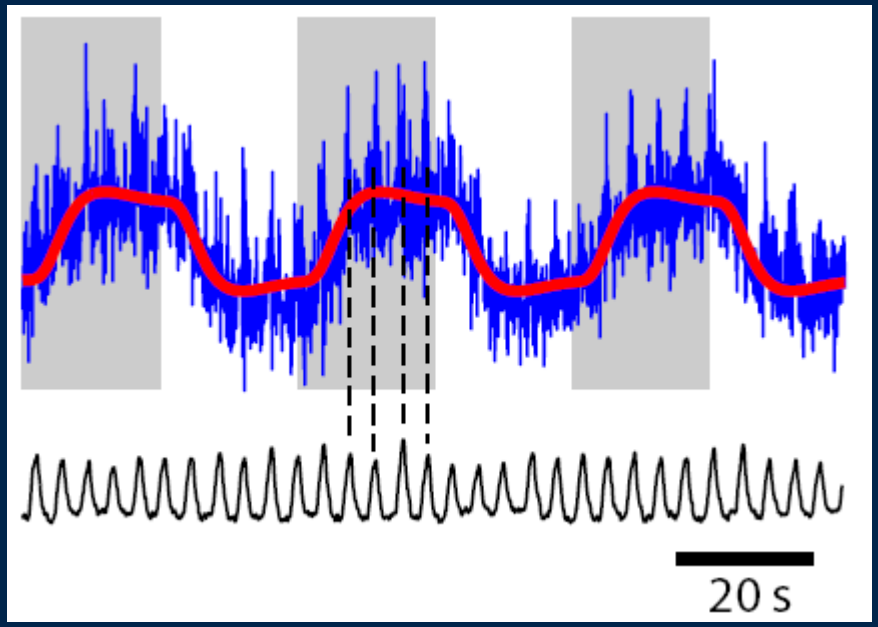
Image quality

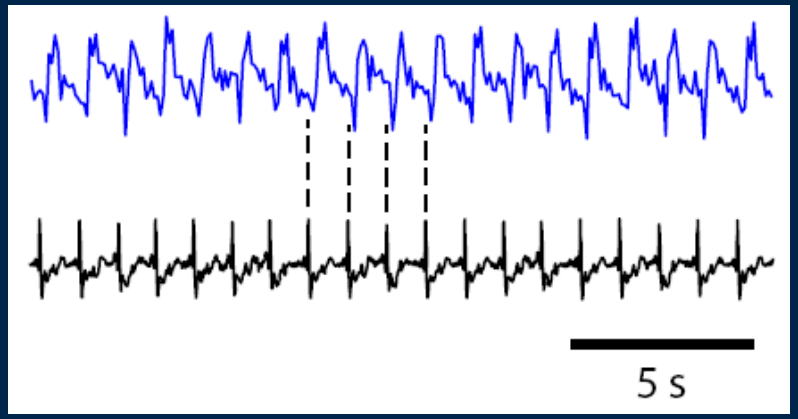




Applications

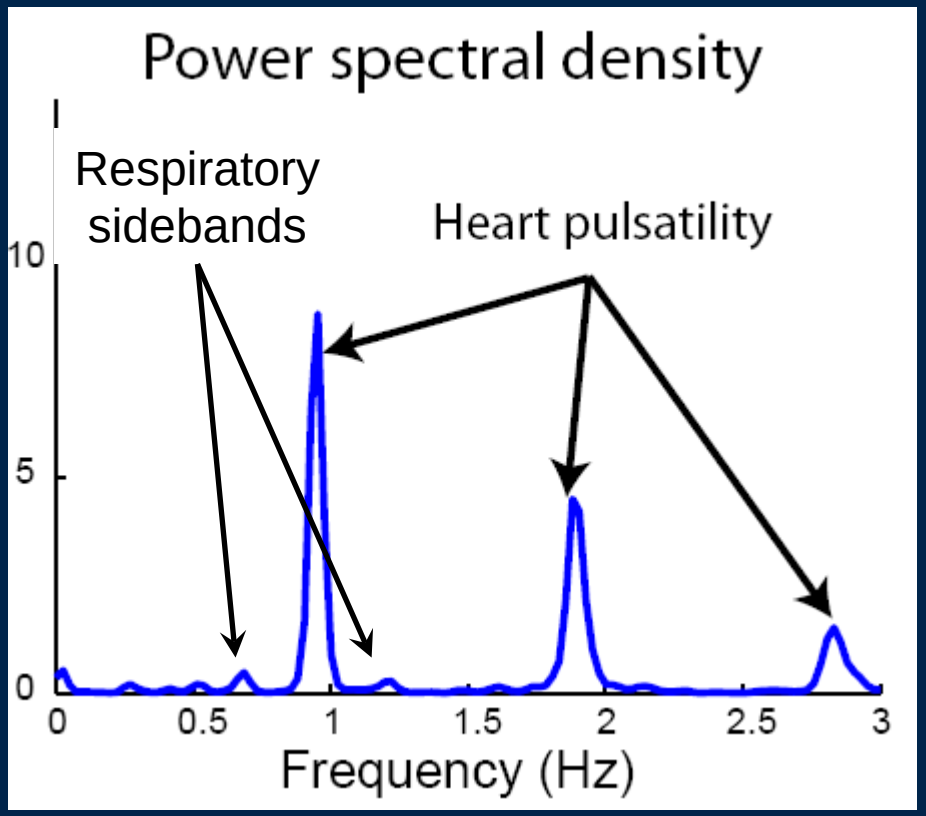
- Measurement of unaliased physiological noise





Applications

- Cardio-respiratory interactions



Applications

- High-frequency functional connectivity
  - High-pass filtered 0.5Hz
  - 30s acquisition

Application: visual evoked potentials

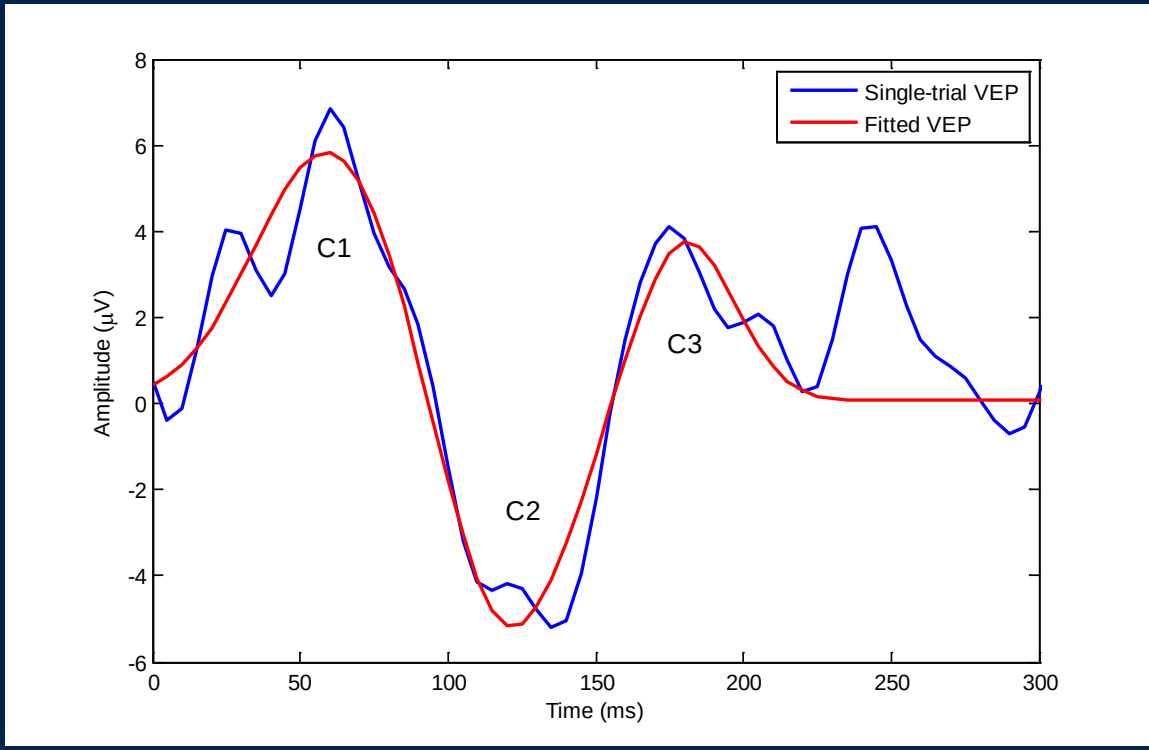
- Ten healthy subjects scanned for 10 minutes (TR=100ms) with simultaneous 64-channel EEG
- Visual paradigm consisted of a checkerboard flashing on a gray background for 1s with 20s average inter-stimulus interval

Methods

- GLM processing:
  - Regressors accounting for cardiac and respiratory fluctuations and their harmonics
  - High-order noise temporal autocorrelation model
  - Resulting statistical t-maps thresholded at $p<0.05$ (corrected)

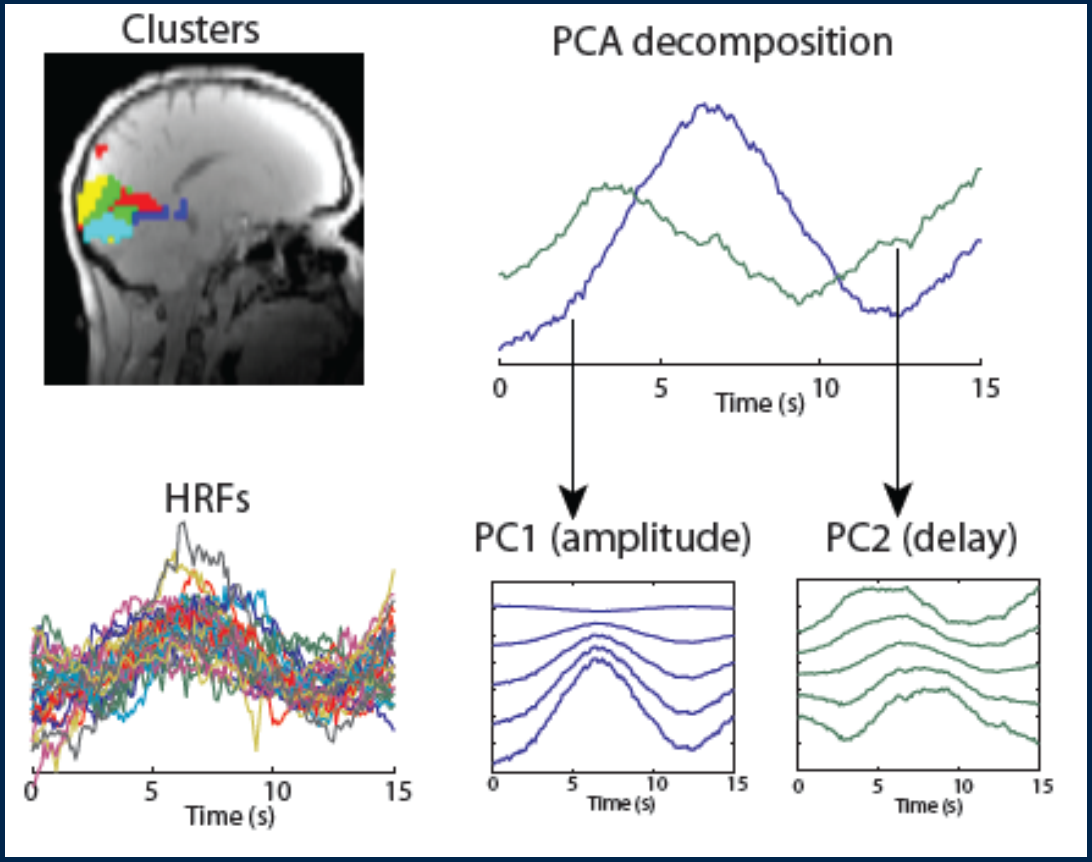
Methods

- Standard EEG artifact correction
- Detection of pattern-onset visual evoked potential



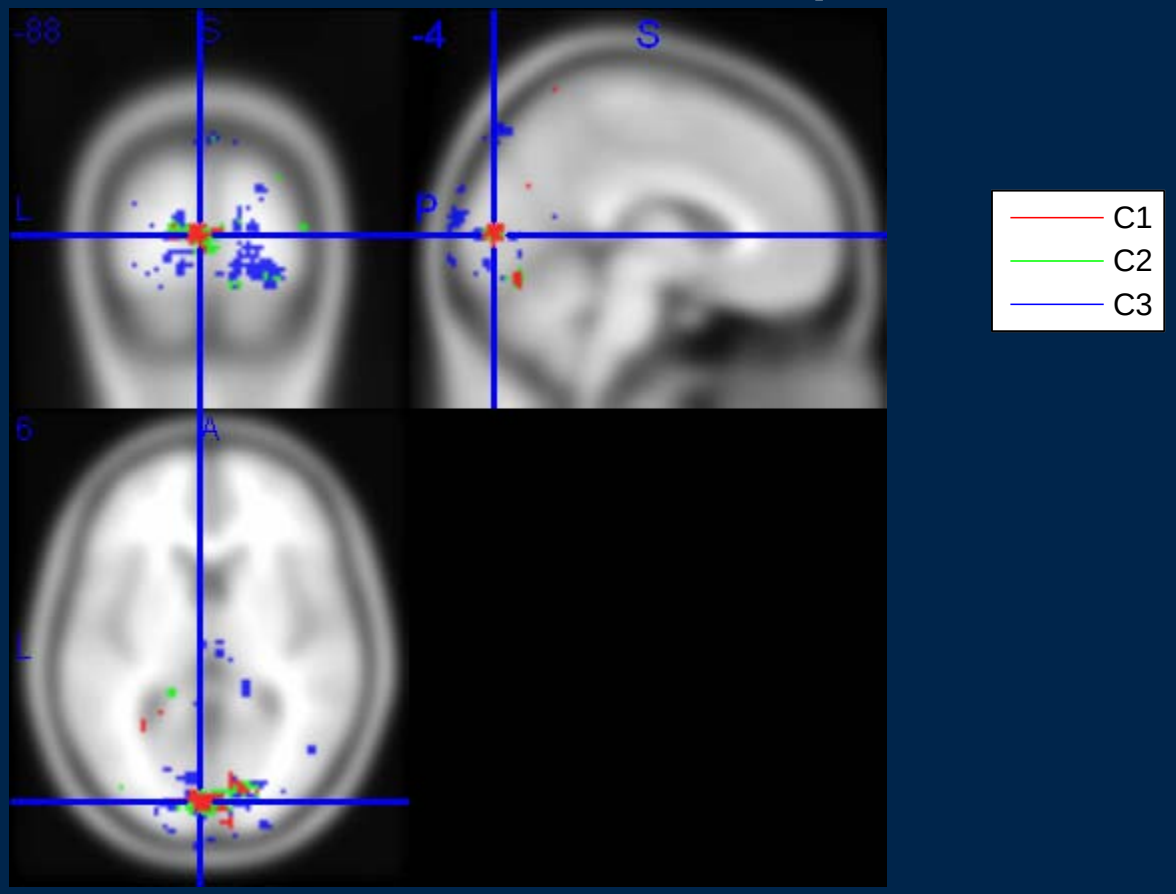
Results

- HRF trial-by-trial variability



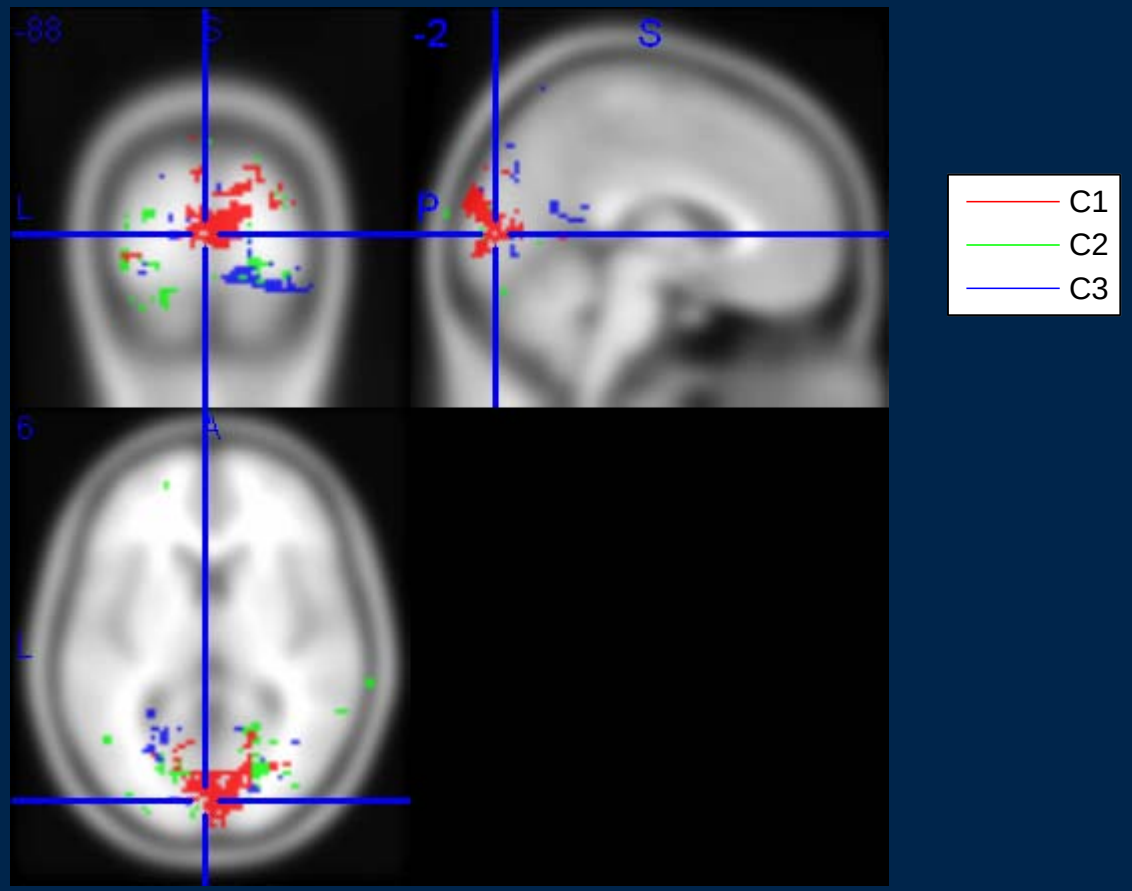
Results

- Correlation HRF vs VEP amplitudes



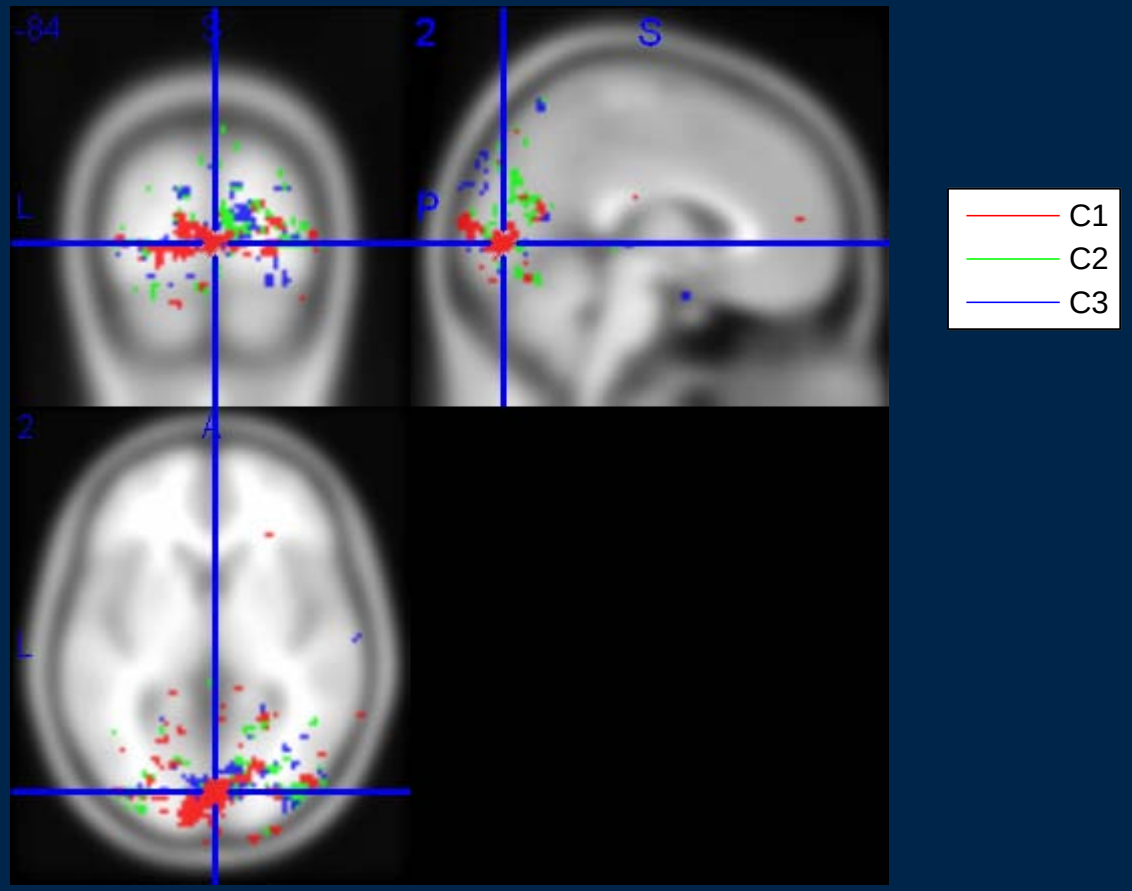
Results

- Correlation HRF vs VEP delays



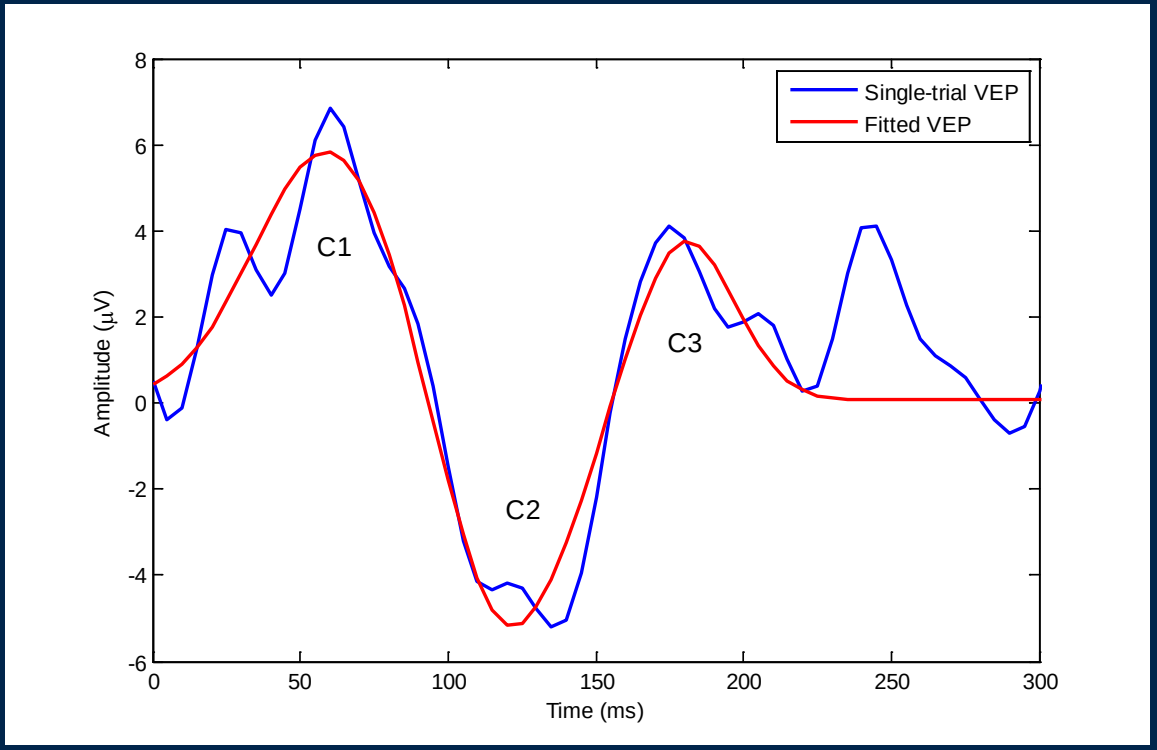
Results

- Correlation HRF width vs VEP amplitude



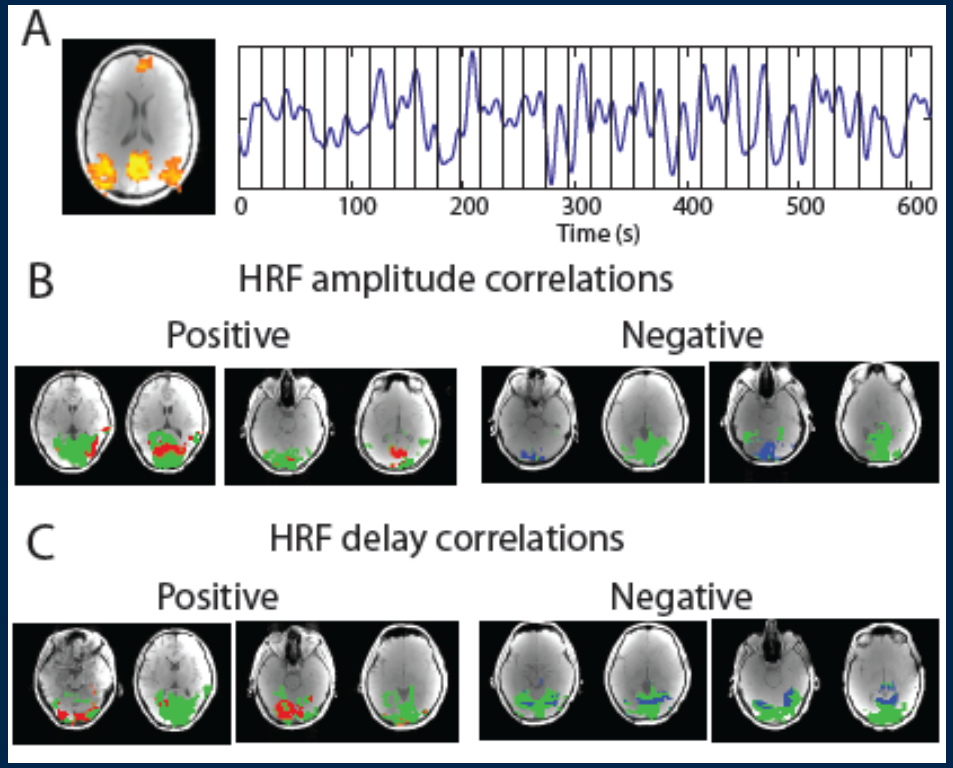
Results

- Can localize the VEP components



Results

- Correlation of HRF parameters across trials with default-mode timecourse



Conclusions

- High temporal resolution fMRI data allows the accurate measurement of HRF parameters at the single-trial level
- Trial-by-trial fluctuations of HRF parameters follow consistent spatial patterns and are correlated with EEG parameter and default-mode signal fluctuations

Acknowledgements

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