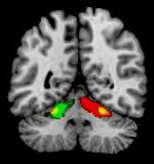
SPM8 for Basic and Clinical Investigators

First-Level Design and Analysis

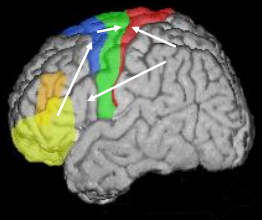


theory

inference design

estimation

regional specialization



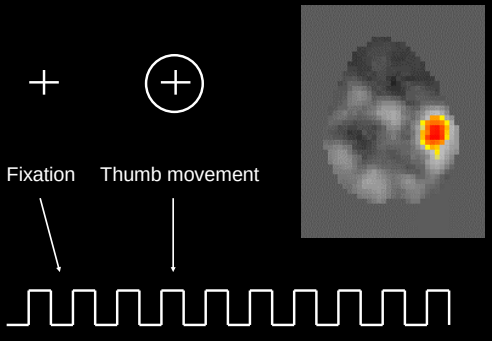
regional integration

effects of interest

error variance

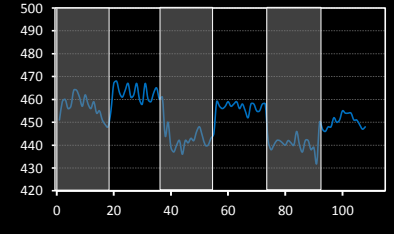
effects of no interest

$$\text{statistic} = \frac{\text{effects of interest}}{\text{error variance}}$$



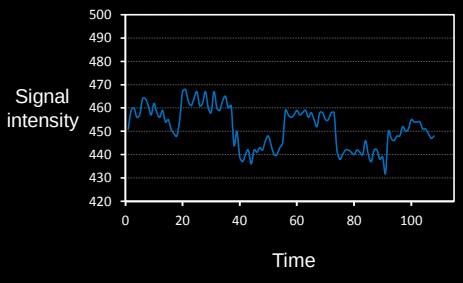
Effect Size

mean (Move) - mean (Rest) / std dev (Rest)

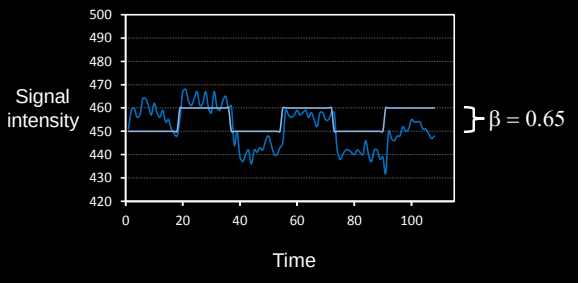


Rest Move Rest Move Rest Move

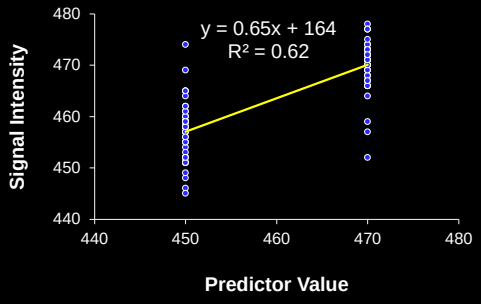
Effect Size



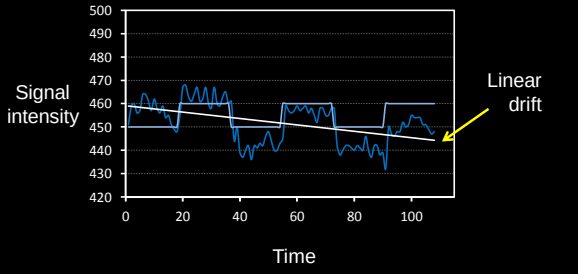
Effect Size



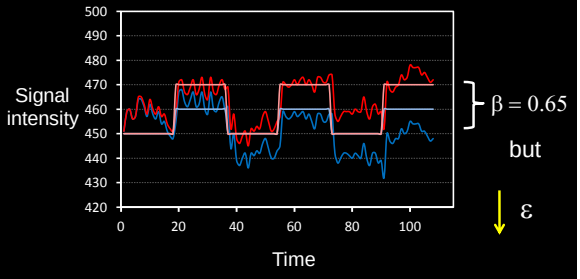
Regression representation



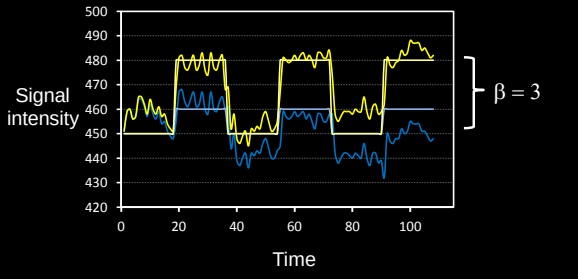
Statistical Control



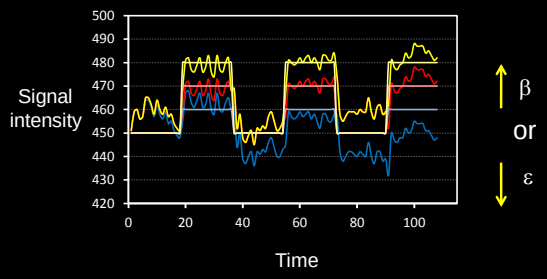
Statistical Control



Experimental Control

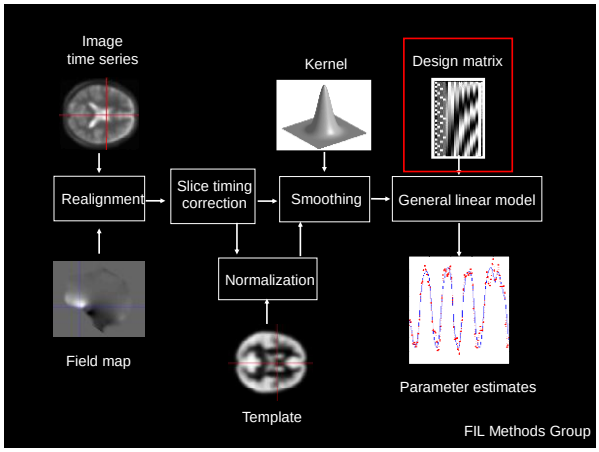


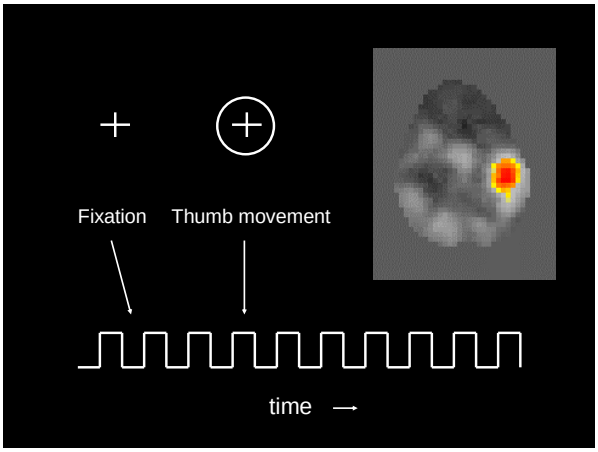
Sensitivity Enhancement



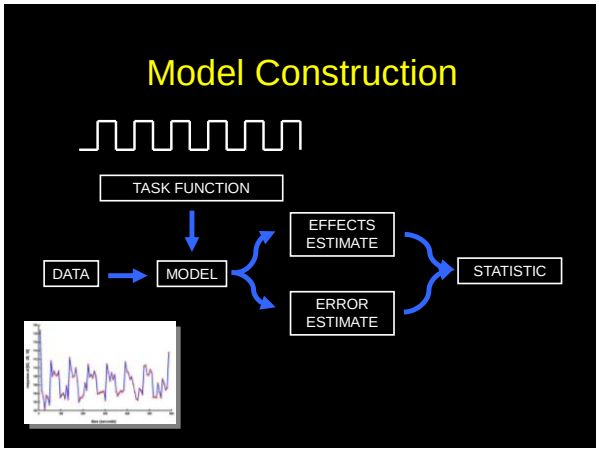
Detection sensitivity

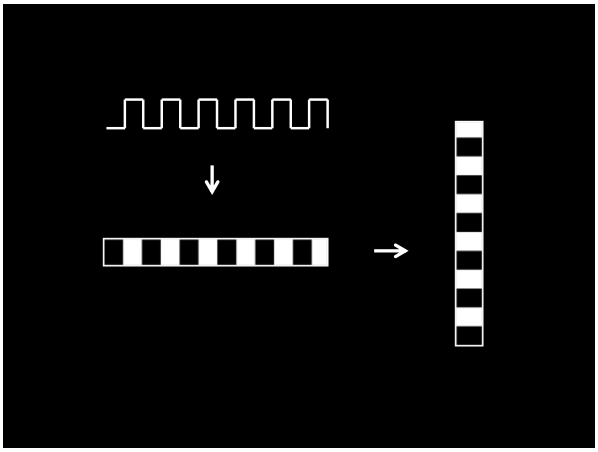
- Experimental control
  - Task type
  - Task timing
  - Participant selection
  - Image acquisition parameters
- Statistical control
  - Task effects model
  - Physiological noise
  - Instrumental noise



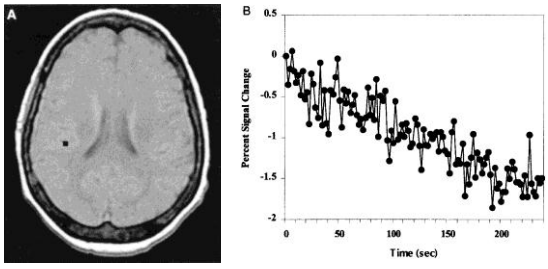


Model Construction



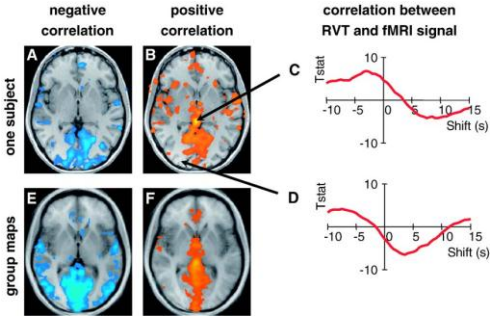


Low-Frequency Signal Drift

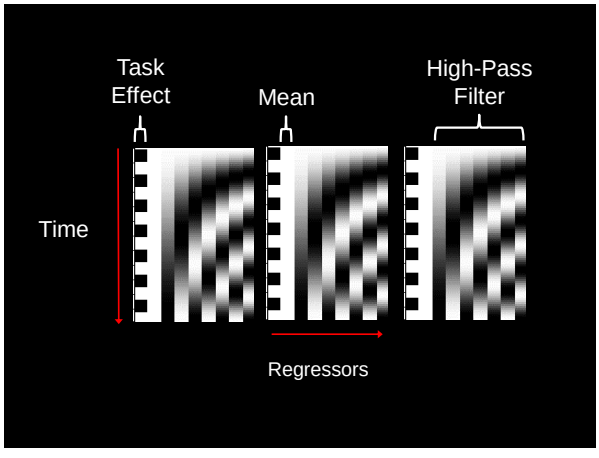


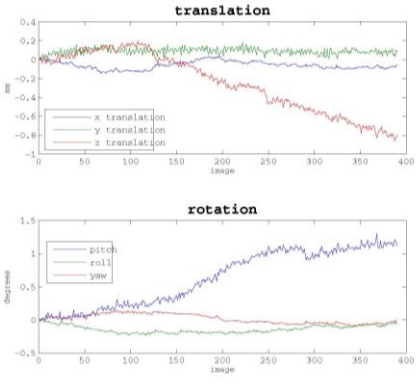
Smith et al., Neuroimage (1999)

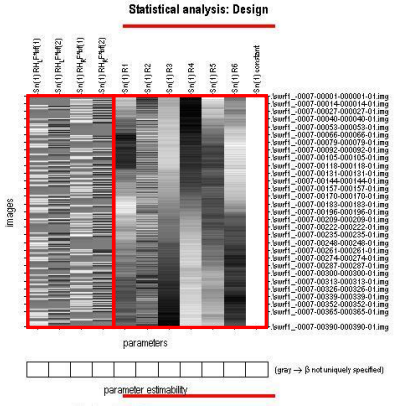
Respiration Modulates BOLD Contrast at Rest



Birn et al., Neuroimage (2006)







General Linear Model

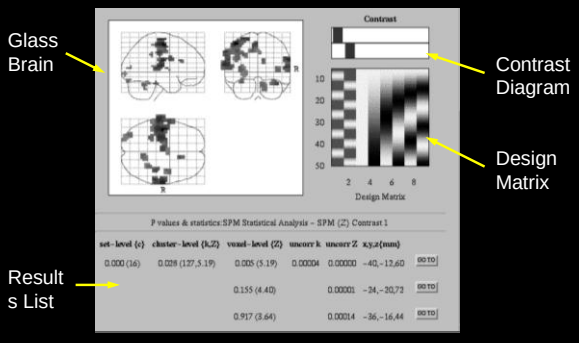
- **Observed data = predictors*weights + error**
- Basic concept
  - The model predicts the observed data using a combination of **predictors** (which we will call basis functions) that are weighted by a set of **weights** (which we will call parameters)
  - Whatever part of the data are not modeled goes into the **error**
- Results of the model:
  - Estimates of the true value of parameters
  - Statistical tests of whether parameters are non-zero

Holmes

Estimation and Inference Components

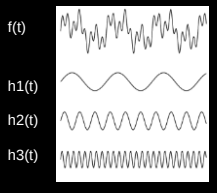
- Design matrix
- Contrast diagram
- Statistical parametric map
- Results table

$$Y = X\beta + \varepsilon$$



Basis functions

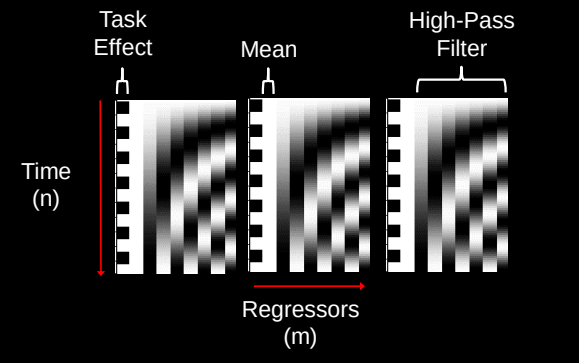
- Used to model the hemodynamic time course
- A basis function set combines a number of functions to describe a more complex function.

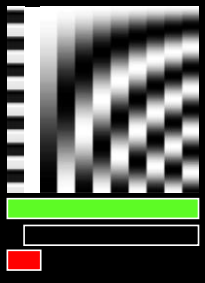


Fourier analysis

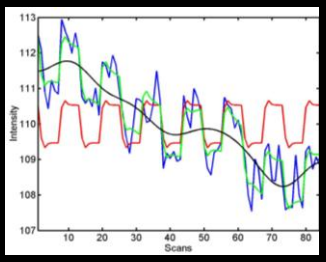
The complex wave at the top can be decomposed into the sum of the three simpler waves shown below.

f(t)=h1(t)+h2(t)+h3(t)

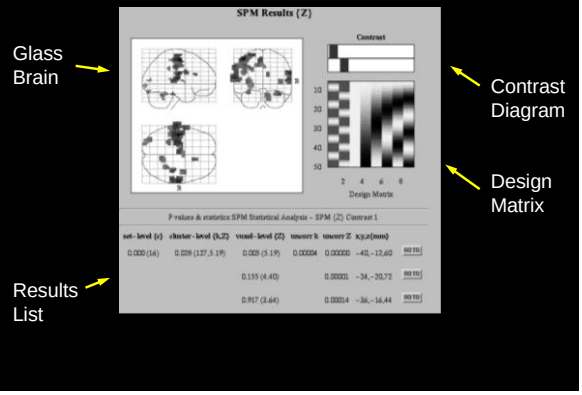




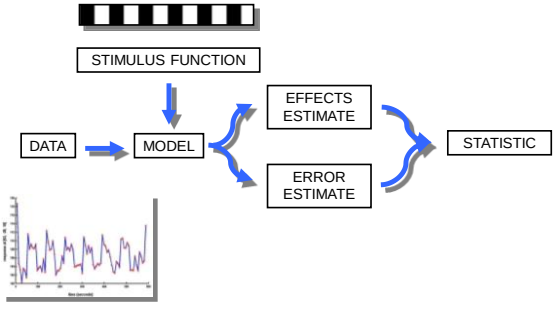
$$Y = X\beta + \varepsilon$$

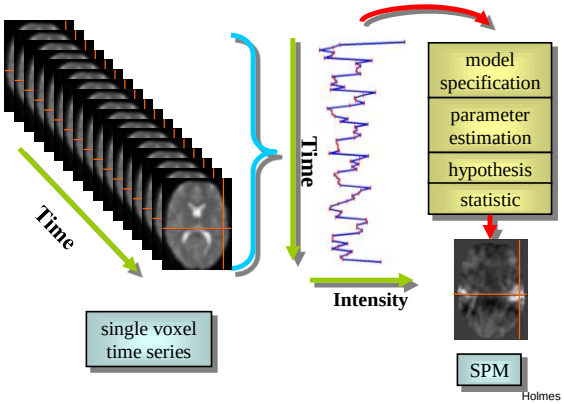


data and three different models

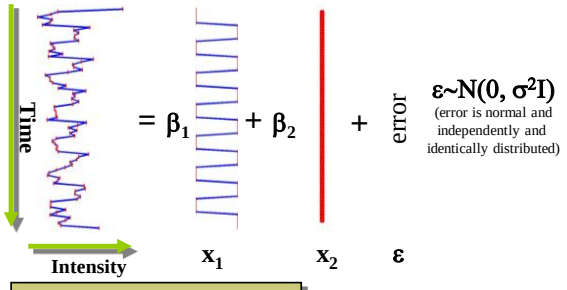


Statistical Modeling

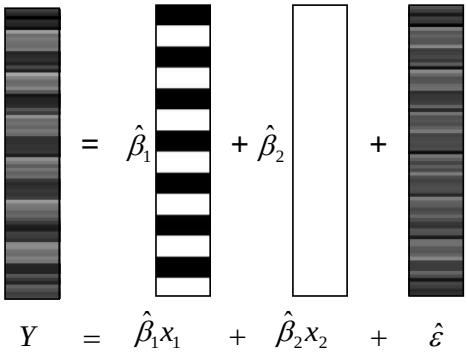




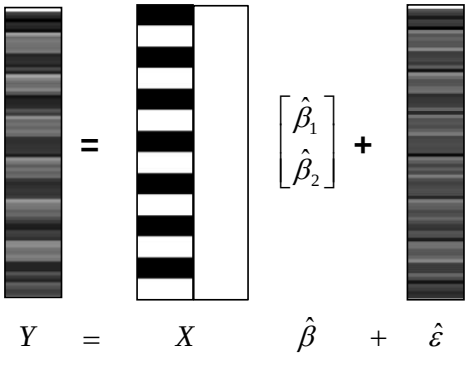
Holmes



Holmes



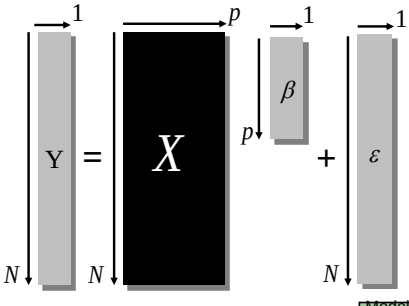
Holmes



Holmes

General Linear Model

$Y = X\beta + \varepsilon$



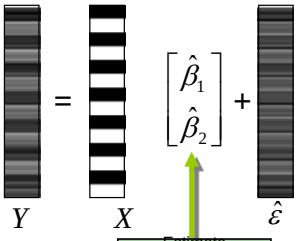
N: number of scans
p: number of regressors

Model is specified by
1. Design matrix X
2. Assumptions about e

Parameter Estimation

$Y = X\beta + \varepsilon$

Assume iid error



$\hat{\varepsilon} = Y - X\hat{\beta}$

residuals

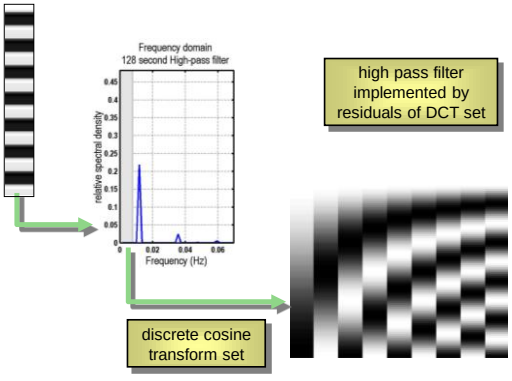
$\hat{\beta} = (X^T X)^{-1} X^T Y$

such that $\sum_{t=1}^{N} \hat{\varepsilon}_t^2$ minimal

Least squares parameter estimate

Holmes

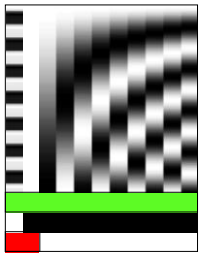
High-Pass Filter



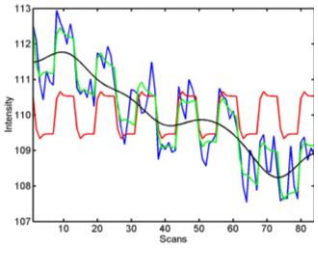
high pass filter implemented by residuals of DCT set

discrete cosine transform set

High-Pass Filter



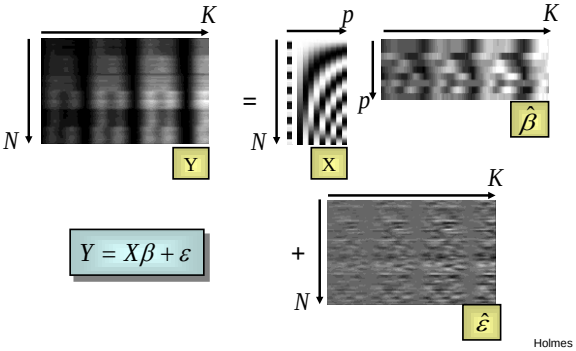
$Y = X\beta + \varepsilon$



data and three different models

Holmes

Mass Univariate Analysis



$Y = X\beta + \varepsilon$

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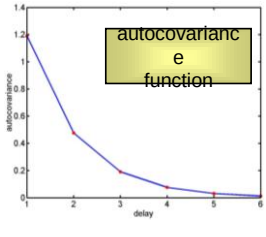
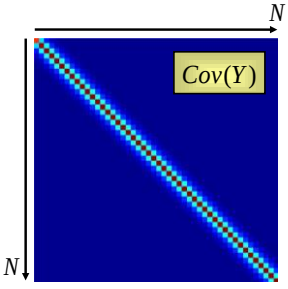
Serial Correlation

$Y_t = aY_{t-1} + \varepsilon_t$ with $\varepsilon_t \sim N(0, \sigma^2)$

autoregressive process of order 1 (AR(1))

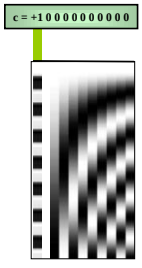


autocovariance function



t-statistic Inference

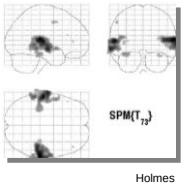
$Y = X\beta + \varepsilon$



boxcar parameter > 0 ?

Null hypothesis: $\beta_1 = 0$

$t = \frac{c^T \hat{\beta}}{S\hat{t}d(c^T \hat{\beta})}$



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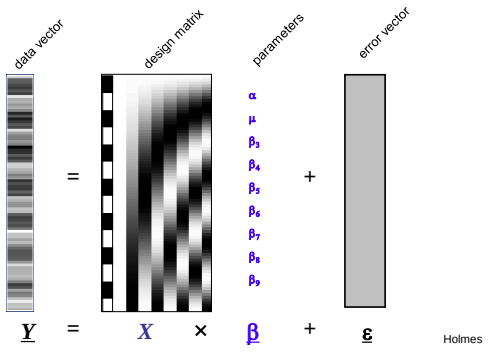
Full Block Design Model



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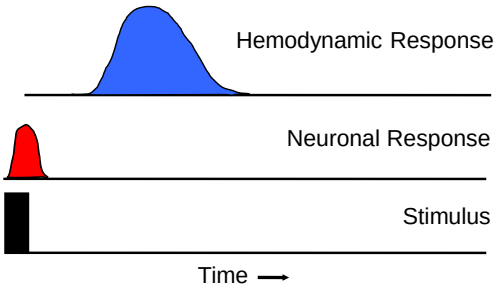
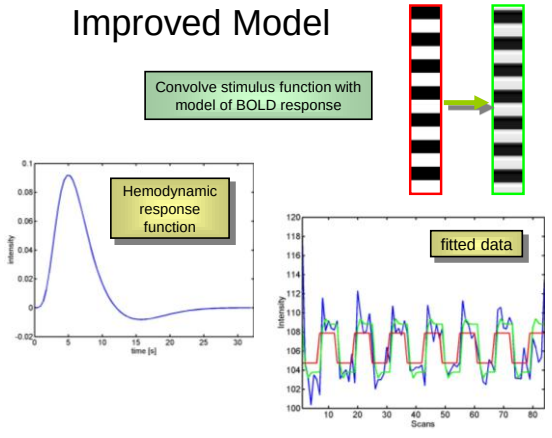
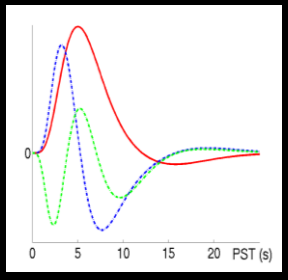
Hemodynamic Delay and Dispersion



Improved Model



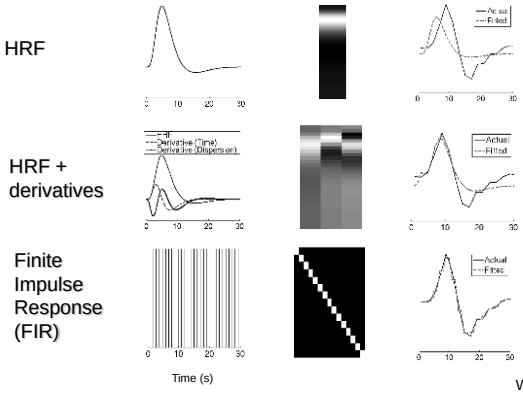
"Informed" Basis Set (Friston et al. 1998)



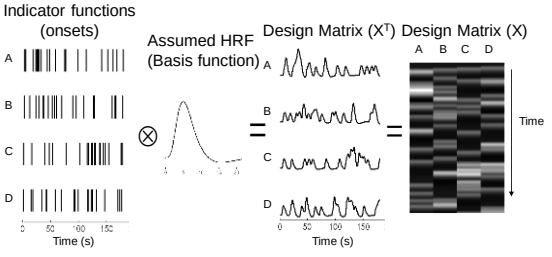
Canonical HRF (2 gamma functions)
plus Multivariate Taylor expansion in:
time (*Temporal Derivative*)
width (*Dispersion Derivative*)

The temporal derivative can model (small) differences in the latency of the peak response.

The dispersion derivative can model (small) differences in the duration of the peak response.

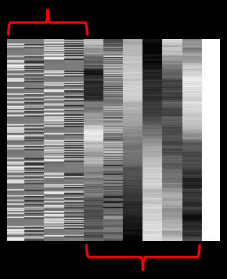


Wager



Wager

Conditions are convolved with the canonical hemodynamic response function.



Regressors are not.

Specifying multiple conditions

Create a text file of this type:

```
names{1} = 'LeftHand';
names{2} = 'RightHand';
onsets{1} = [ 10 22.3  42.1  85.4  ];
onsets{2} = [ 30 50.3  70.1  120.4  ];
durations{1} = [ 8 8 8 8 ];
durations{2} = [ 8 8 8 8 ];
save('Hand_conditions.mat','names','onsets','durations');
```

Execute the file at the MATLAB prompt:

```
>>Hand_conditions
```

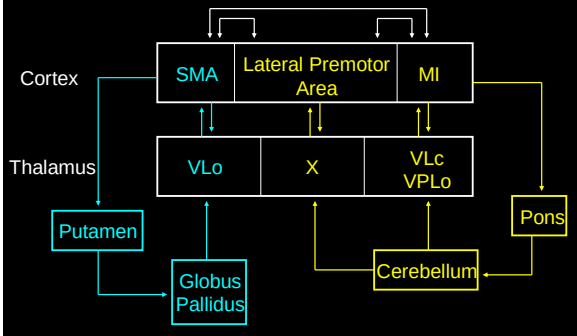
Load the resulting Hand_conditions.mat file under multiple conditions.

theory

inference  design

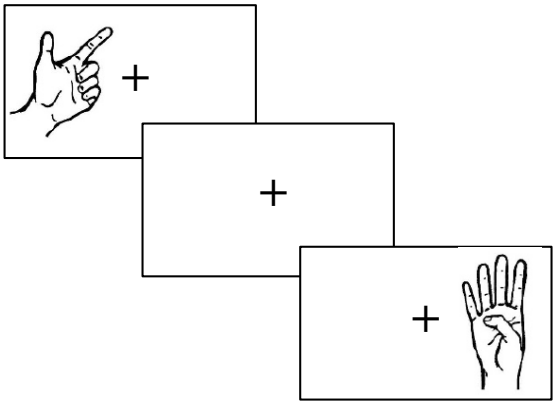
estimation

Motor Systems



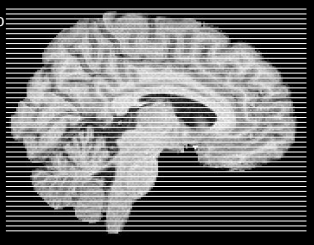
Gesture imitation

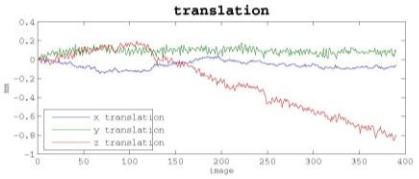
- Single subject – multiple session design
- Fixed length epoch timing
- Univariate estimation
- HRF + time derivative basis function
- Task contrasts
- Task conjunctions

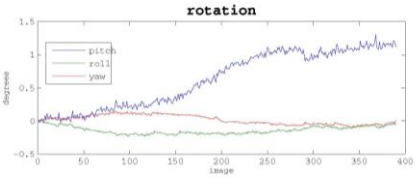


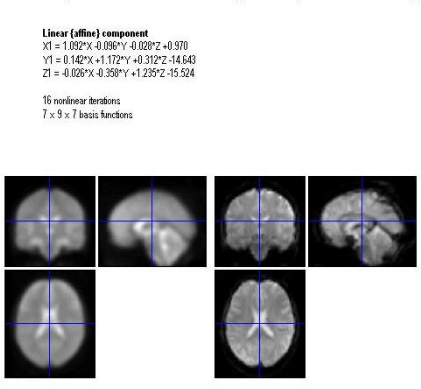
Data Acquisition Details

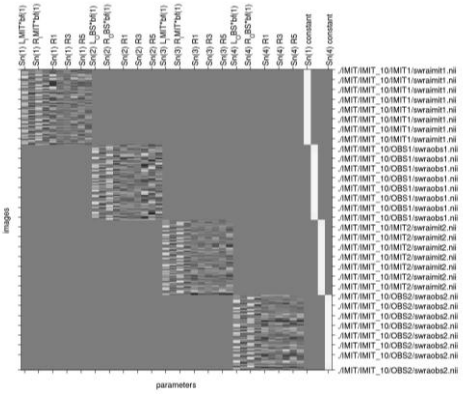
- BOLD-contrast using echo planar imaging
- 3.0 T system
- 32 channel head coil
- GRAPPA acceleration
- 58 axial slices per volume
- TE 30 ms
- TR 3510 ms
- 2.5 mm^3 voxels

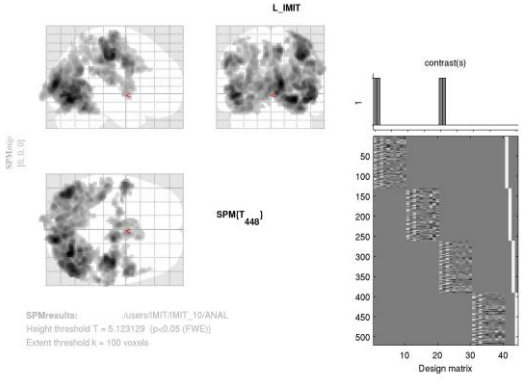


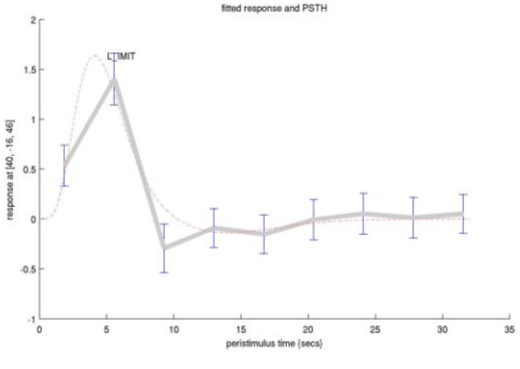


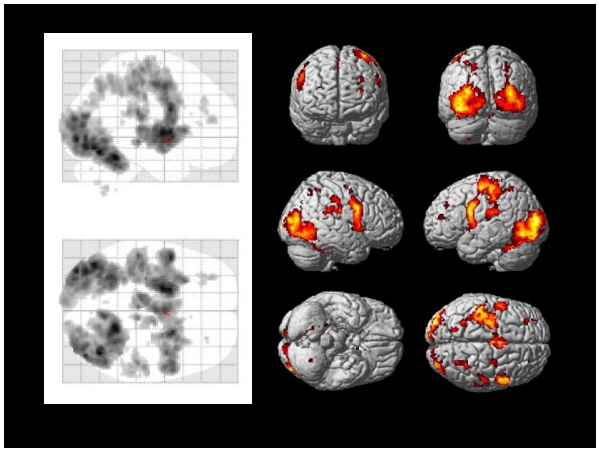


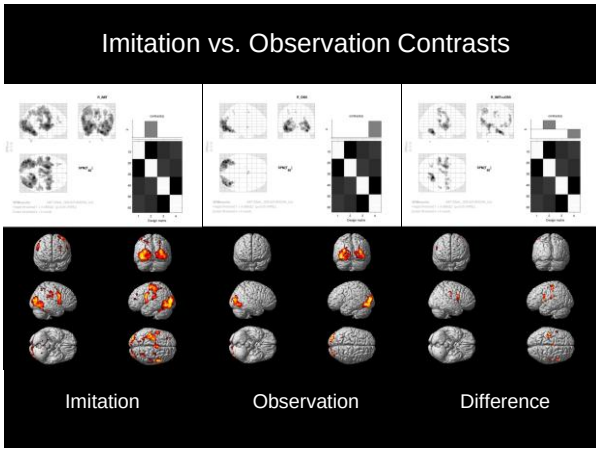











Imitation vs. Observation Contrasts
Imitation
Observation
Difference