Module 13:
Model Building II

General Linear Model

A standard GLM can be written:

$$\mathbf{Y} = \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon} \qquad \boldsymbol{\varepsilon} \sim N(\mathbf{0}, \mathbf{V})$$

where

$$\begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_n \end{bmatrix} = \begin{bmatrix} 1 & X_{11} & \cdots & X_{1p} \\ 1 & X_{21} & \cdots & X_{2p} \\ \vdots & \vdots & & \vdots \\ 1 & X_{np} & \cdots & X_{np} \end{bmatrix} \times \begin{bmatrix} \beta_0 \\ \beta_1 \\ \vdots \\ \beta_p \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_n \end{bmatrix}$$

fMRI Data

Design matrix

Model parameters

Noise

V is the covariance matrix whose format depends on the noise model.

The quality of the model depends on our choice of X and V.

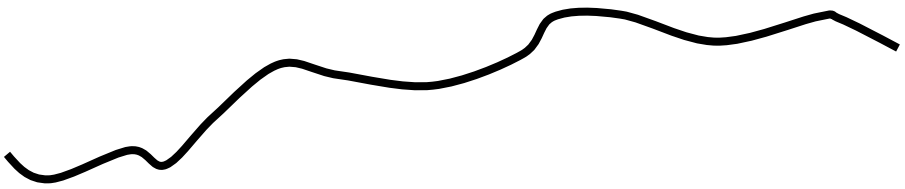
Nuisance Covariates

- Often model factors associated with known sources of variability, but that are not related to the experimental hypothesis, need to be included in the GLM.

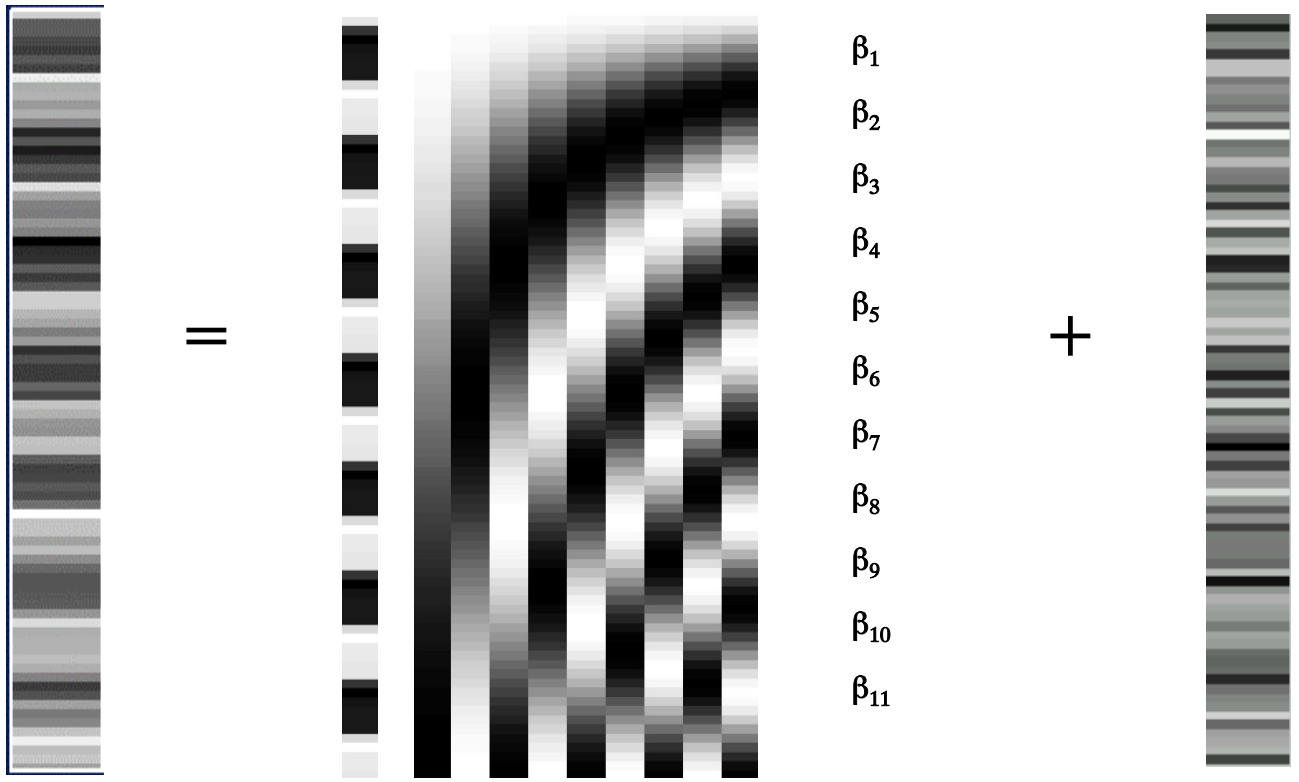
- Examples of possible ‘nuisance regressors’:
  - Signal drift
  - Physiological (e.g., respiration) artifacts
  - Head motion, e.g. six regressors comprising of three translations and three rotations.
    - Sometimes transformations of the six regressors also included.

Drift

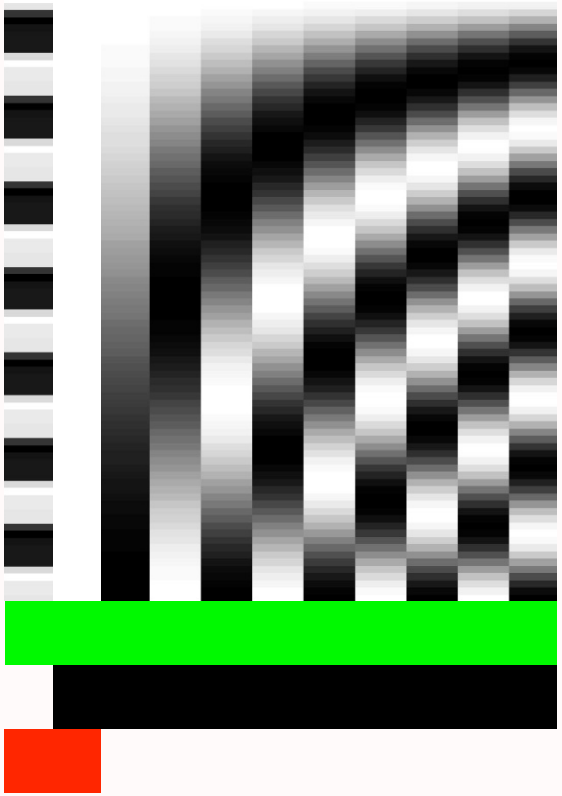
- Slow changes in voxel intensity over time (low-frequency noise) is present in the fMRI signal.
- Scanner instabilities and not motion or physiological noise may be the main cause of the drift, as drift has been seen in cadavers.
- Need to include drift parameters in our models.
  - Use splines, polynomial basis or discrete cosine basis

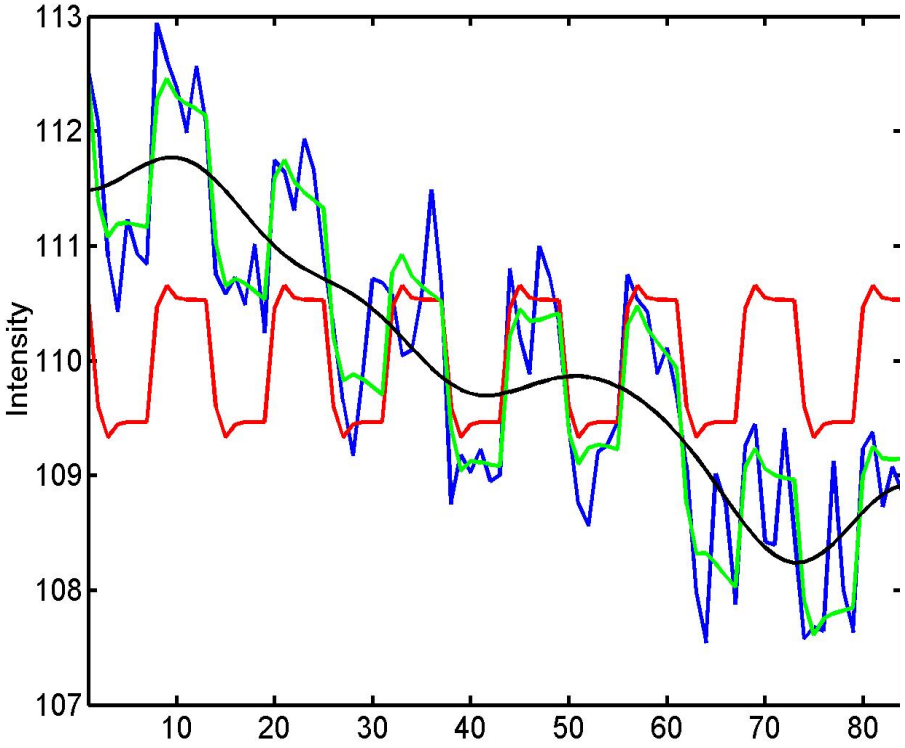


Model with Drift



High Pass Filtering





blue = data

black = mean + low-frequency drift

green = predicted response, taking into account low-frequency drift

red = predicted response (with low-frequency drift explained away)

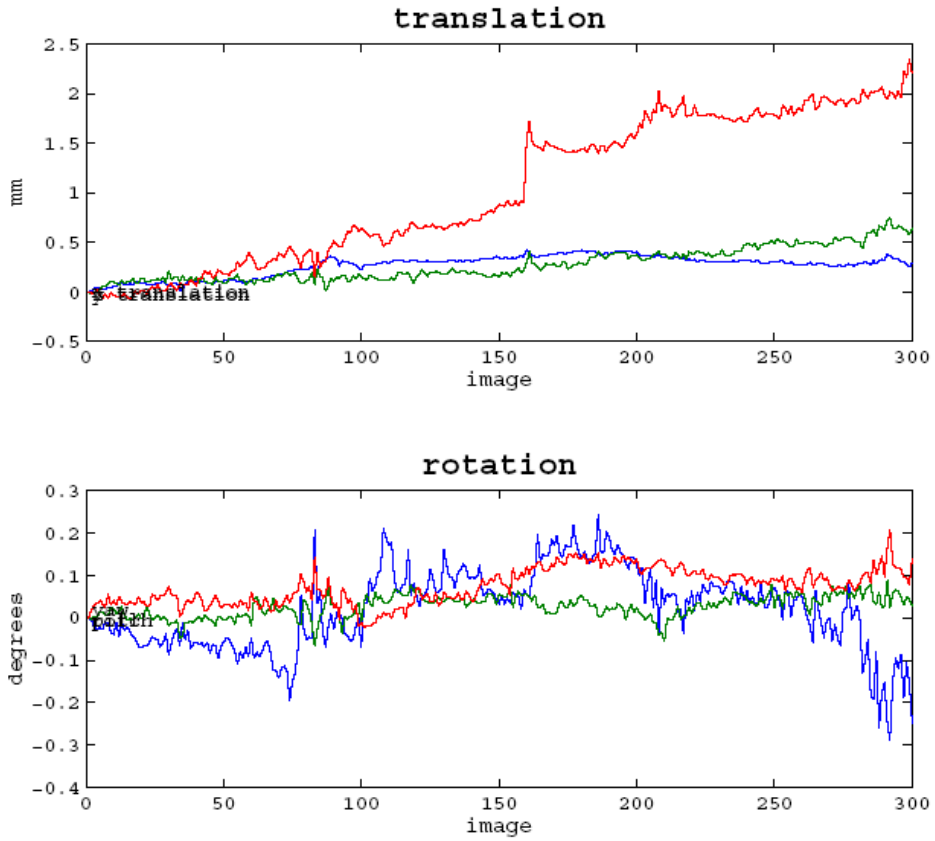
Physiological Noise

- Respiration and heart beat give rise to high-frequency noise.
- It can potentially be modeled, but if the TR is too low there will be problems with aliasing.
  - Sampling rate must be at least twice as big as the frequency of the curve you seek to model.
- Hence, this type of noise is difficult to remove and is often left in the data giving rise to temporal autocorrelations.

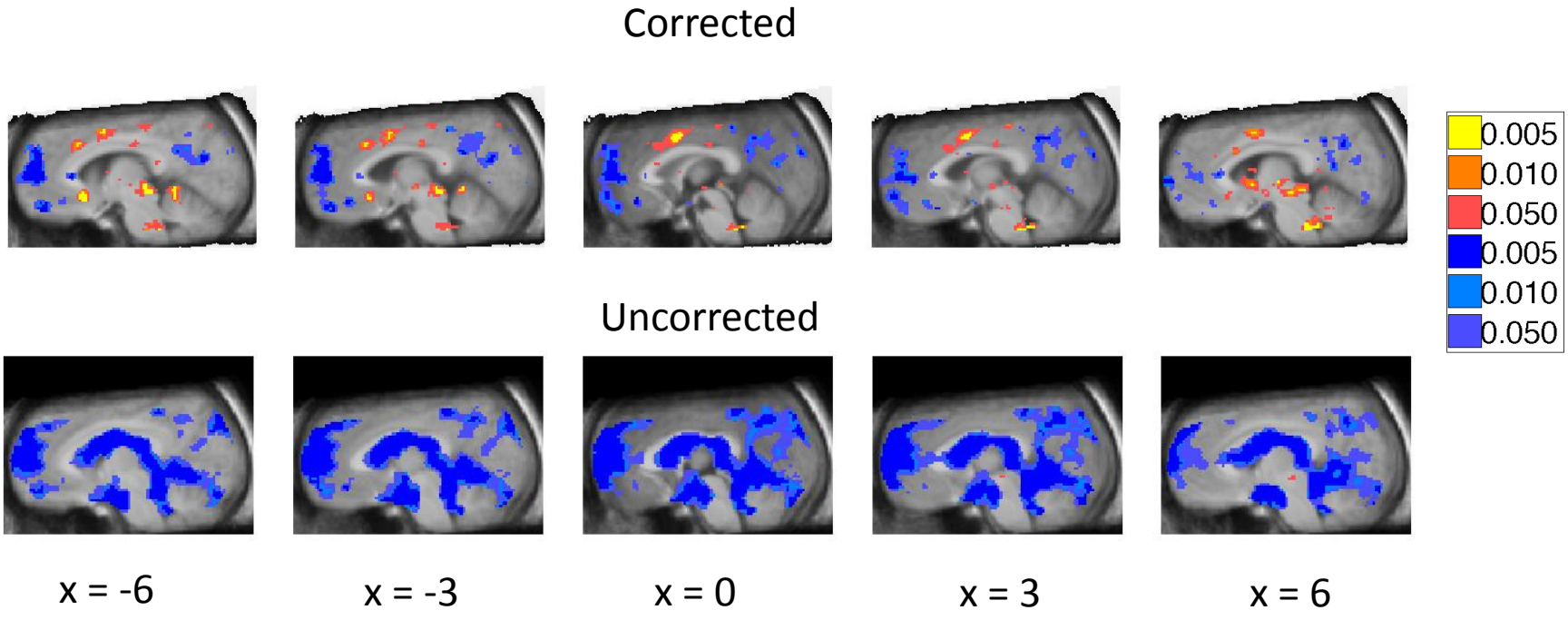
Motion

- Subject motion during the experiment can also give rise to serious problems.
- Typically motion correction is performed in the pre-processing stages of the analysis.
- However, ‘spin-history’ artifacts may remain that cannot be removed.
  - This is caused by through-plane motion.
  - Head motion parameters often included in GLM.

Head Motion


translation
mm
2.5
2
1.5
1
0.5
0
-0.5
0
50
100
150
200
250
300
image
translation
rotation
degrees
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
0
50
100
150
200
250
300
image

Head Motion Example



End of Module

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