FMRI Analysis

Experiment Design

↓

Scanning

↓

Pre-Processing

↓

Individual Subject Analysis

↓

Group Analysis

↓

Post-Processing

Scheme of the Talk

- Players in Experiment Design
- Intuitive Thinking

  → Useful bandwidth for FMRI data
- Statistical Theory

  → Efficiency
- Experiment Design in AFNI

  → AlphaSim and 3dDeconvolve
- Miscellaneous

Players in Experiment Design

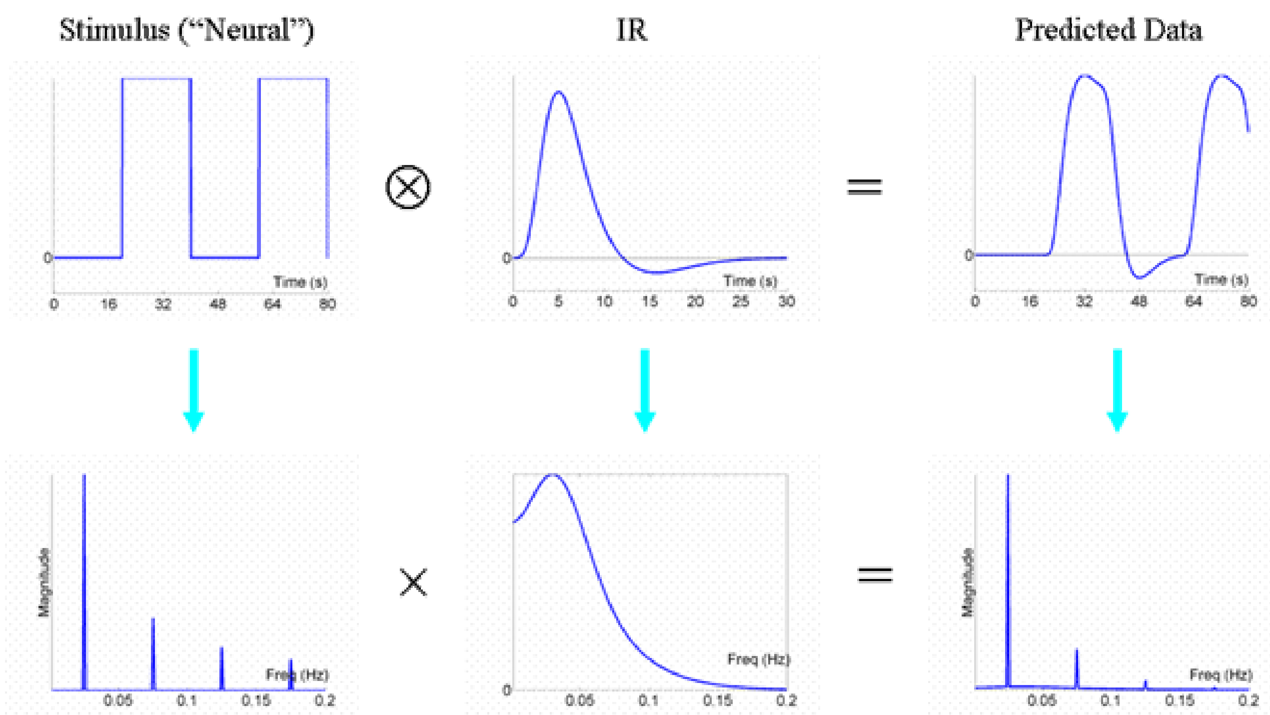
- Number of subjects (*n*)
  - Important for group analysis: inter-subject vs. intra-subject variation
  - Power roughly proportional to sqrt(*n*)
  - Recommended: 20+; Current practice: 12 – 20
- Number of time points
  - Important for individual subject analysis
  - Power proportional to sqrt(*DF*)
  - *N* limited by subject's tolerance in scanner: 30-90 min per session
- TR length
  - Shorter TR yields more time points (and potentially more power)
  - Power improvement limited by stronger temporal correlation and weaker MR signal
  - Usually limited by hardware considerations

Players in Experiment Design

- Study design
  - Complexity: factors, levels, contrasts of interest, balance of events/levels/subjects…
  - Design choices may limit statistical analysis options
- Number of events per class
  - The more the better (20+), but no magic number
- HRF modeling
  - Different regions may have different response curves
- **Event arrangement** (☼focus of this talk)
  - How to design? How to define 'best'?
  - Efficiency: achieve highest power within fixed scanning time

Intuitive Thinking

- Classical IRF



Intuitive Thinking

- Event frequency
  - Optimal freq: 0.03 Hz (period 30 s)
    - Implication for block designs: optimal duration – about 15s
  - Upper bound: 0.15 Hz (6.7 s)
    - Submerged in the sea of white noise
    - Implication for event-related designs: average ISI > 3 ~ 4 s
  - Lower bound? 0.01 Hz (100 s)
    - Confounded with trend or removed by high-pass filtering
    - Implication for block designs: maximum duration about 50s*

      *Longer blocks could still be analyzed (see last slide)
  - Bandwidth: 0.15 – 0.01 Hz
    - Spread events within the frequency window

Statistical Theory

- <u>Regression Model (GLS)</u>
  - Y (one column of data @ each voxel) = $X\beta + \varepsilon$
  - X: design matrix with columns of regressors
- General Linear testing
  - H_0: $c'\beta = 0$ with $c = (c_0, c_1, \ldots, c_p)$
    - $t = c'\beta / \text{sqrt}(c' (X'X)^{-1} c\ MSE)$ (MSE: unknown but same across tests)
    - sqrt($c' (X'X)^{-1} c$): normalized standard deviation of $c'\beta$
      - Efficiency = 1/sqrt($c' (X'X)^{-1} c$): Smaller → more powerful (and more efficient)
      - X'X measures the co-variation among the regressors
      - Less correlated regressors are more efficient and easier to tease apart
      - Goal: find X that would give lowest sqrt($c' (X'X)^{-1} c$)
  - Multiple tests: Efficiency in AFNI = sum of individual test efficiencies
    - A relative value

Experiment Design in AFNI

- AFNI programs for experiment design
  - **RSFgen**: Design X by generating randomized events

```
RSFgen -nt 300 -num_stimts 3                        \
          -nreps 1 50 -nreps 2 50 -nreps 3 50  \
          -seed 103859 -prefix RSF.stim.001.
```

  - **3dDeconvolve -nodata**: calculate efficiency
  - May have a more user-friendly Python script in the future
- Detailed scripts and help
  - HowTo#3: http://afni.nimh.nih.gov/pub/dist/HOWTO//howto/ht03_stim/html/AFNI_howto.shtml

Miscellaneous

- Nothing is best in absolute sense
  - Modeling approach
    - Pre-fixed HRF or basis function modeling?
  - Specific statistical test
    - Good design for one test is not necessary ideal for another
- Sequence randomization always good?
  - Experiment constraint
  - May not change efficiency much
  - Good from other perspectives: Efficiency is not everything!
    - Neurological consideration: saturation, habituation, expectation/predictability

Miscellaneous

- Dealing with low frequencies
  - Modeling drifting with polynomials (additive effect)
  - High-pass filtering (additive effect): 3dFourier –highpass
  - Global mean scaling (multiplicative or amplifying effect)
- Control condition
  - Baseline rarely meaningful especially for higher cognitive regions?
  - If interest is on contrasts, null events are not absolutely necessary
  - High-pass filtering (additive effect)
  - Scaling by and regressing out ventricular signal