Percent Change and Power Calculation

UCLA Advanced NeuroImaging
Summer School, 2007

Outline

- Calculating %-change
  - How to do it
  - What featquery does
- Power analysis
  - Why you should use power calculations
  - How to carry out power calculations

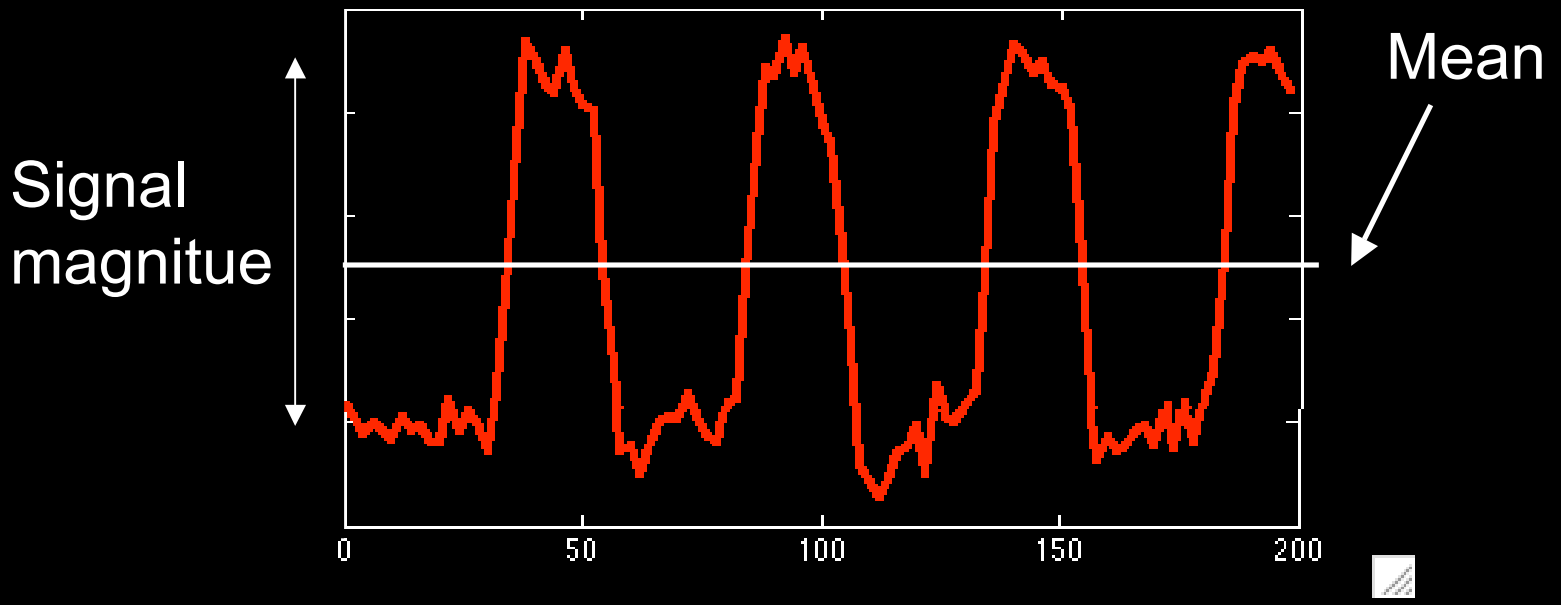
Why %-Change?

- As it is, parameter estimates do not reflect a specific unit
- T-stats are okay (they are unitless)
- What if we want to tell other people how large our activation was?
  - Convert to %-change

%-change

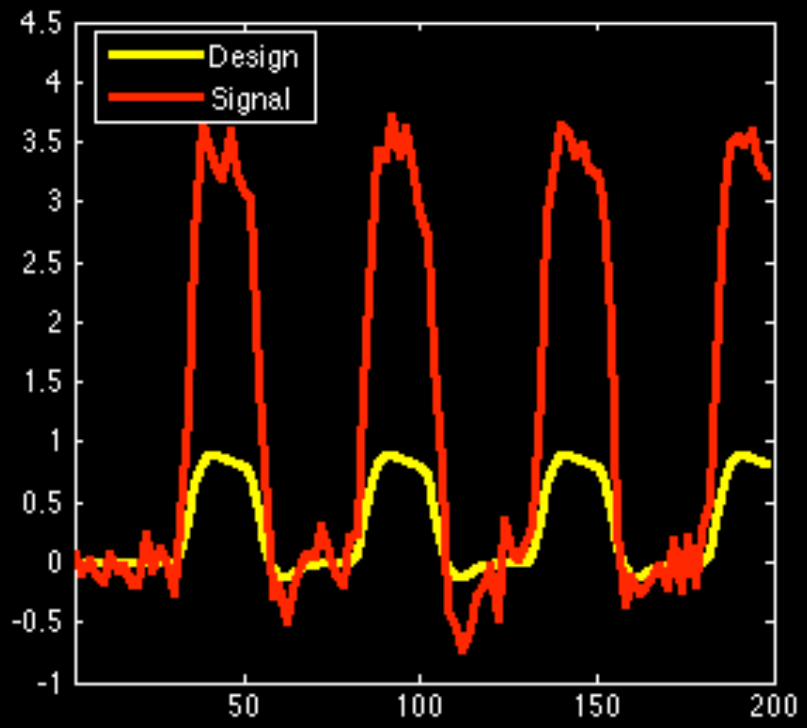
- How big is the signal magnitude relative to baseline?

$$\%\text{-change} = \frac{sig.\,magnitude}{mean} \times 100$$

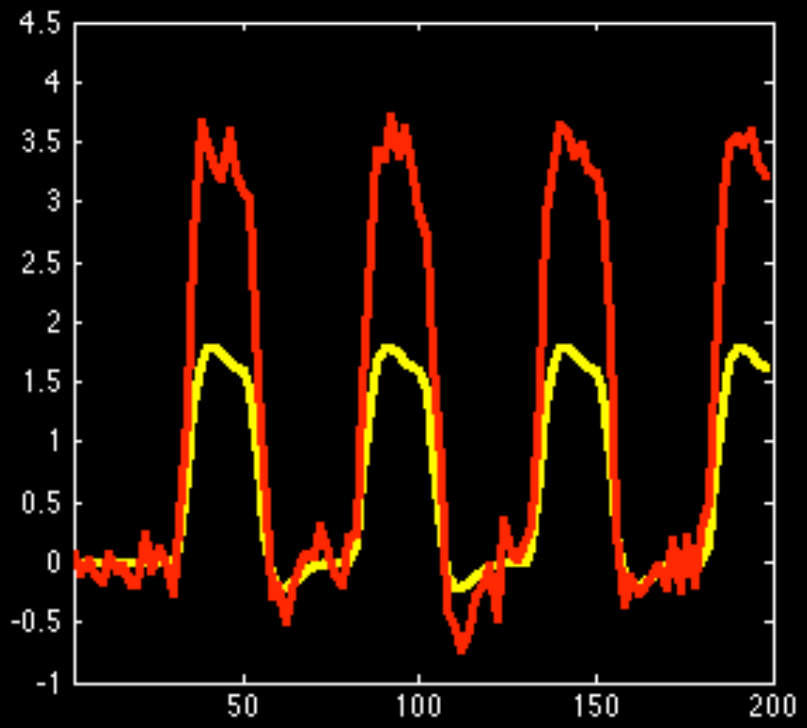


Block Design

- How to get the signal magnitude from parameter estimates…



p.e.=4, EV height=1
1x4=signal magnitude



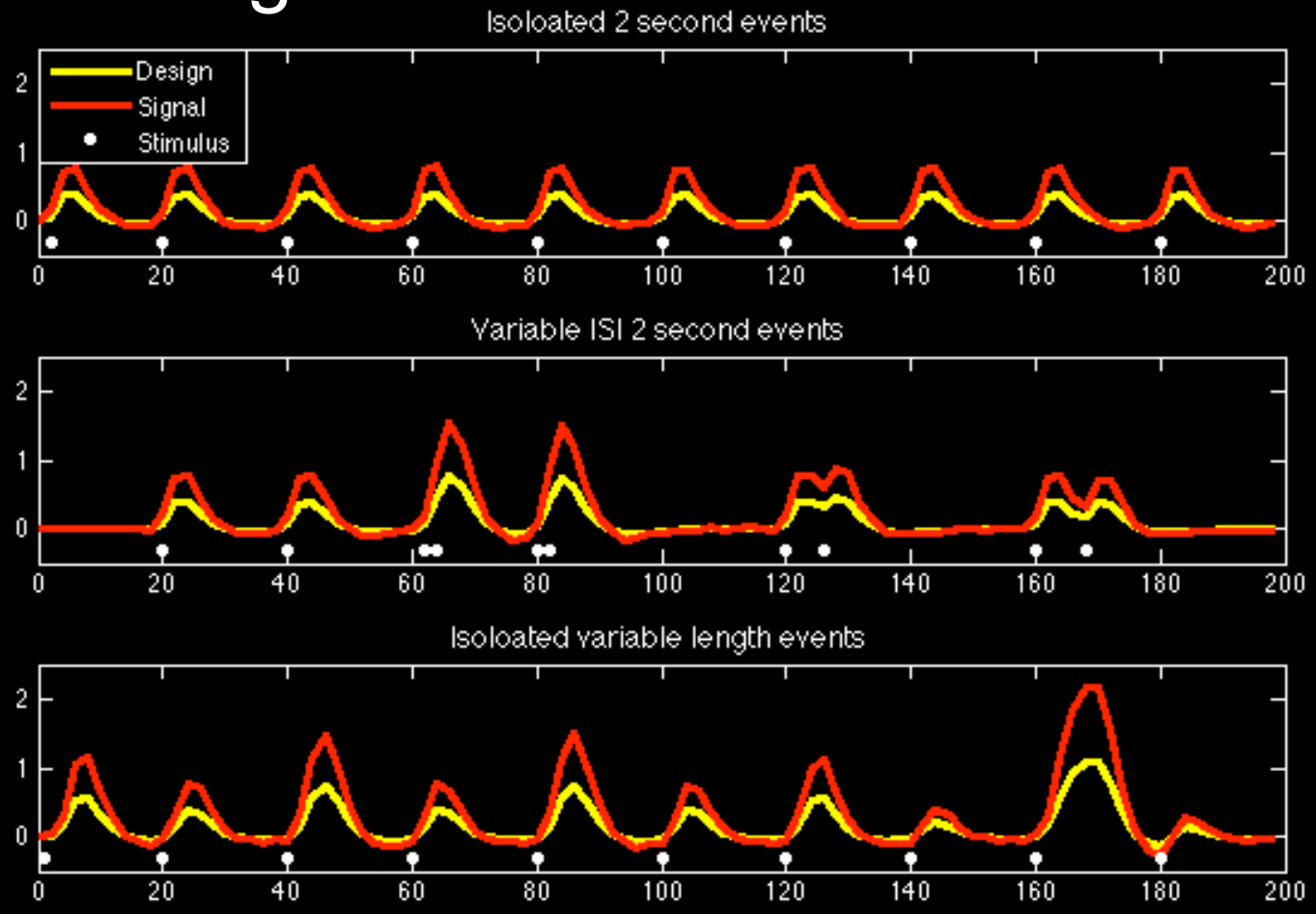
p.e.=2, EV height=2
2x2=signal magnitude

Block Design

- To make life easier, set min/max range of EV's=1!
  - In FSL the Grand Mean Scaling sets mean~100^2 in all voxels
  - PE/100=%-change! (roughly)
  - To be completely accurate you should divide by the true mean

Event Related Design

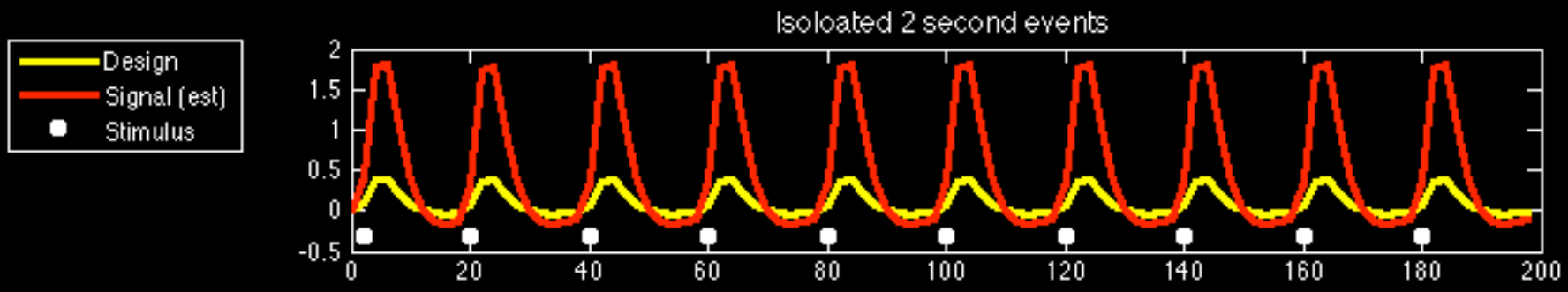
- Tricky! Proximity and length of events affects height



Event Related Design

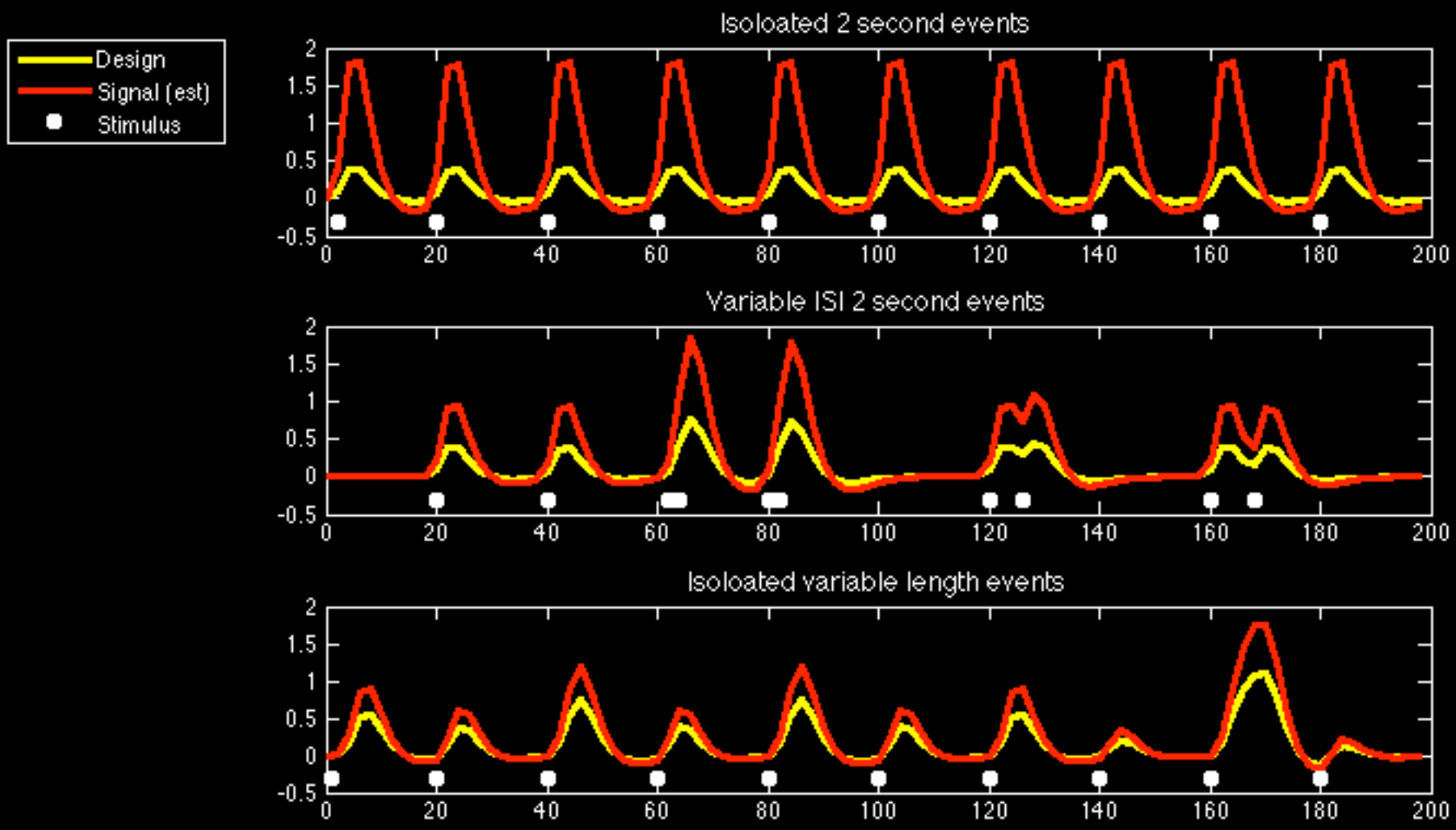
- How about using min/max range?
  - Is it interpretable?
  - I tell you I found a 2% change, calculated using the min/max range. Can you interpret this with your own design?

ER design

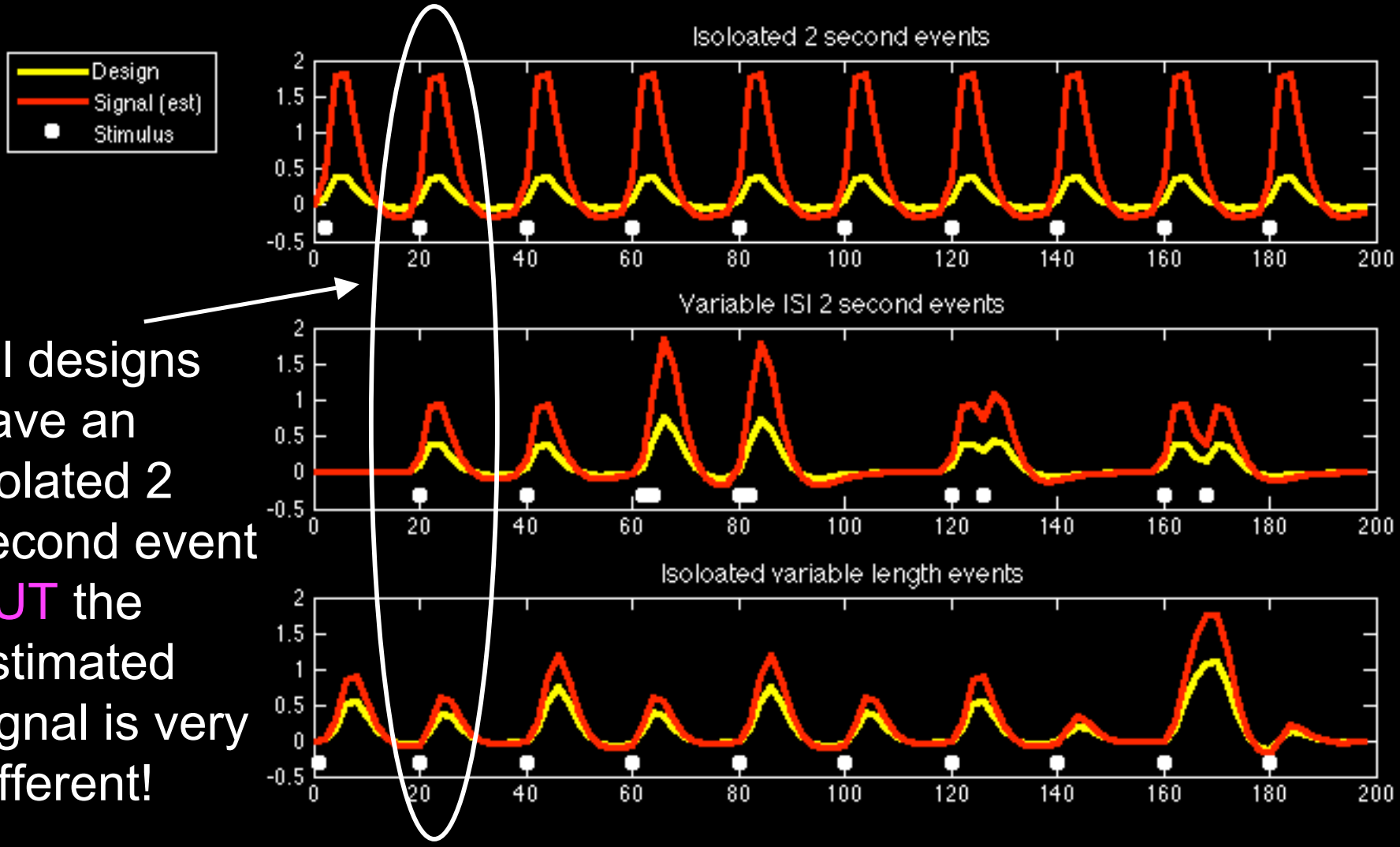


- Assume mean=100
- %-change=(PE)(Min/Max range)
- 2=PE*(0.5) ⇒PE=4

ER design


Design
Signal (est)
Stimulus
Isoloated 2 second events
Variable ISI 2 second events
Isoloated variable length events
2
1.5
1
0.5
0
-0.5
0
20
40
60
80
100
120
140
160
180
200

ER design



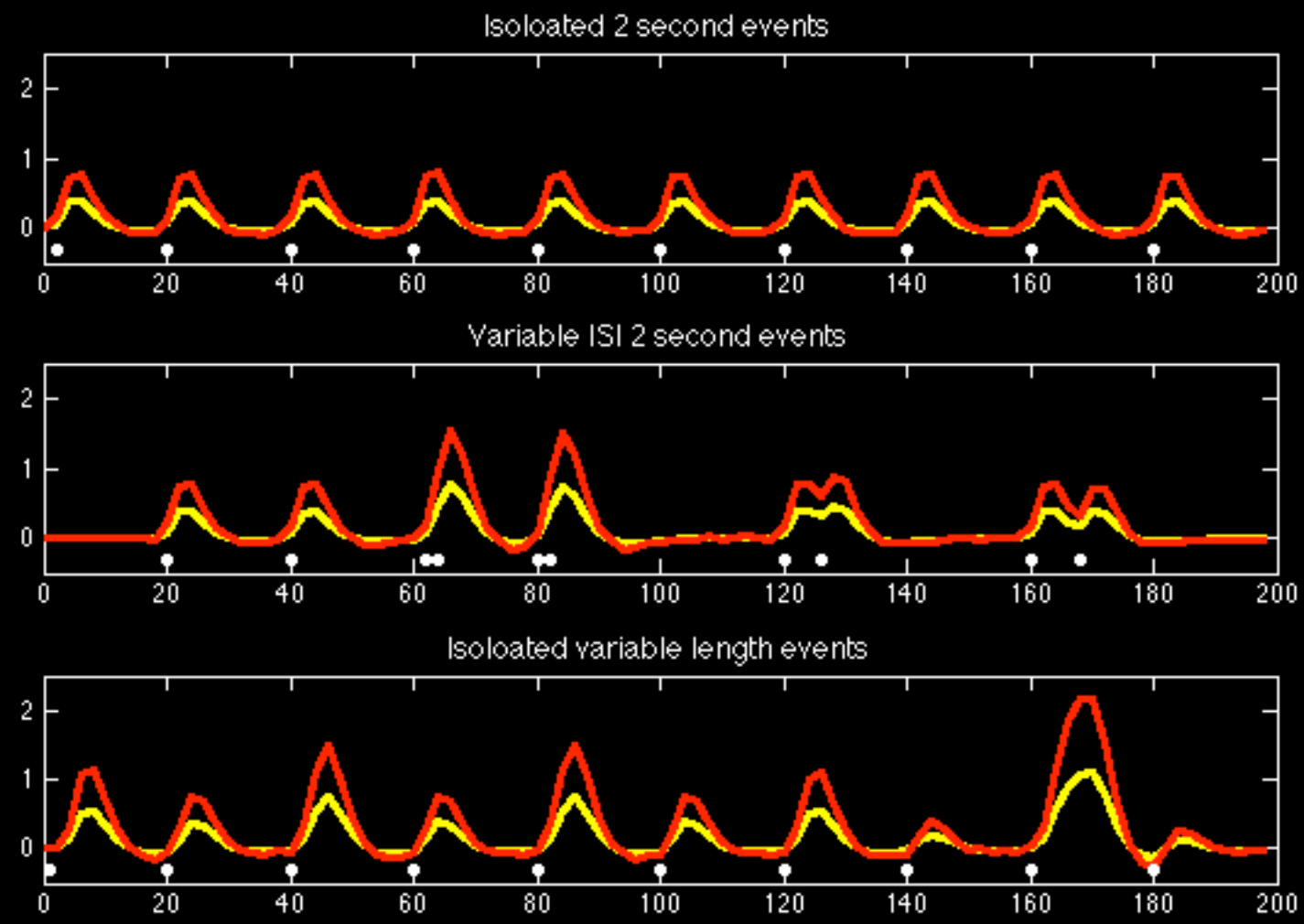
All designs have an isolated 2 second event BUT the estimated signal is very different!

ER Design

- Min/max range doesn’t work as well for event related design
  - Doesn’t translate well to other designs.
  - *warning* Featquery uses min/max range
- Instead of min/max range, choose something specific (isolated 2 second event) and make sure to report what you used!

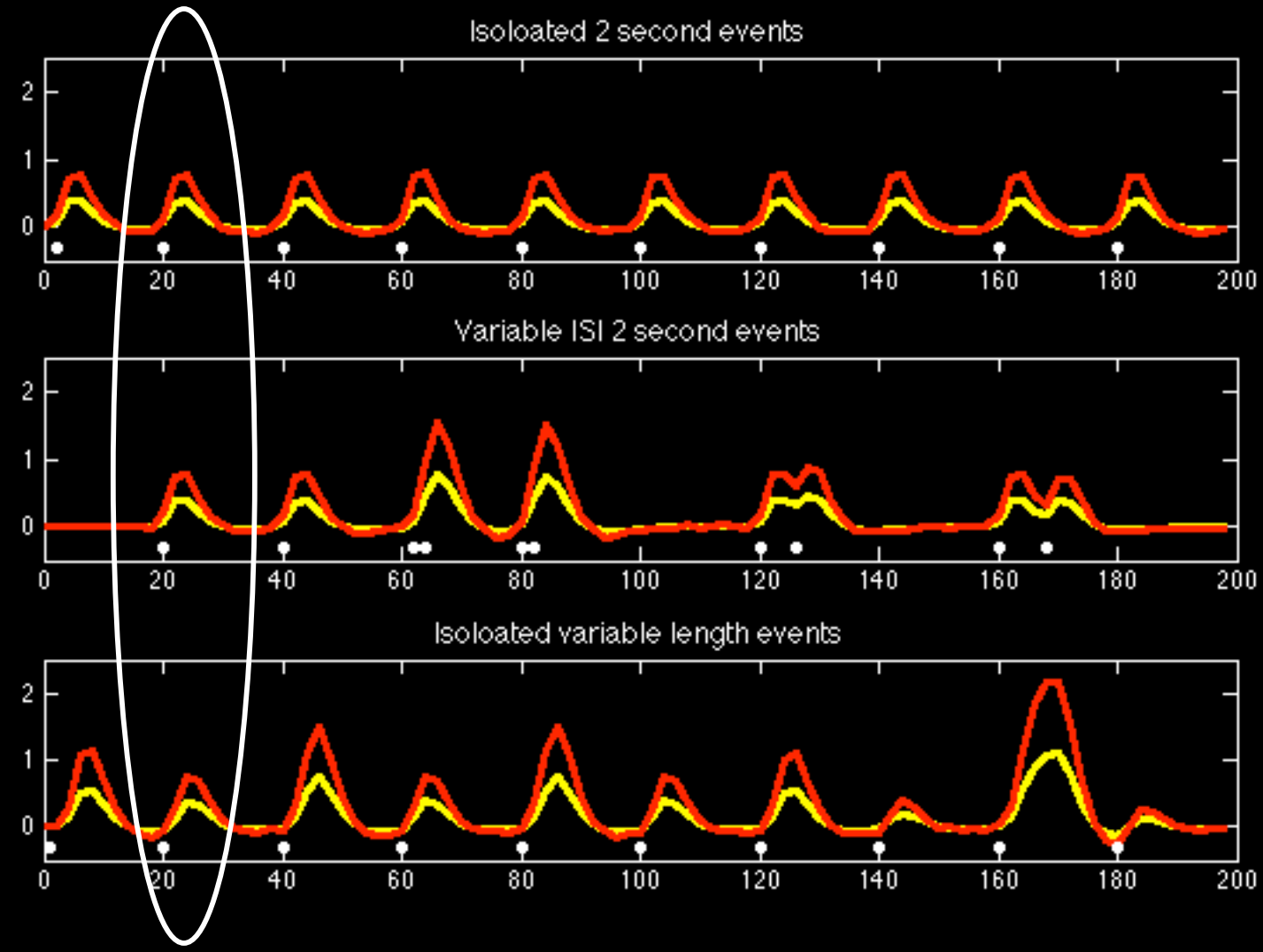
ER Design

- 1% change based on height of isolated 2-s event



ER Design

- 1% change based on height of isolated 2-s event
- Now we can compare across designs!



A note about contrasts

- What does the contrast [1 1 -1 -1] mean?
  - $(\beta_1 + \beta_2) - (\beta_3 + \beta_4)$
  - beta's are mean activations for 4 levels of subjects performing some task (beginners, some training, medium training, experts)
  - Test beginners/some training - med/experts
  - $\beta_1 = 2, \beta_2 = 2.5, \beta_3 = 5, \beta_4 = 5.2$
  - $\beta_1 + \beta_2 = 4.5 \text{ and } \beta_3 + \beta_4 = 10.2$
  - Difference is twice the mean difference!

A note about contrasts

- Although [1 1 -1 -1] implies a difference that is twice the original scale, our test statistic is okay
- Since we're interested in preserving scale, use contrast that give us means
  - Positive parts sum to 1
  - Negative parts sum to -1

Rules to get *almost* %-change in FSL

- Baseline is already ~100^2
- EV is constructed appropriately
  - Boxcar height =1
  - ER design: Specified event has height=1
    - I like to ignore the post stimulus undershoot
- Construct contrast that follow the rules
  - Positive parts sum to 1
  - Negative parts sum to -1
- PE*100~%-change

What if you didn't follow the rules

- Calculate the height of regressor as it was
  - Height of block
  - Height of specified typed of event
- Calculate contrast fix
  - Number you'd have to divide contrast by to fix it
- $$\%-change = \frac{PE(\text{EV height})}{(\text{contrast fix})(\text{baseline})} \times 100$$

Example

- Study with subjects that were beginners, some training, medium training, experts
- Level 1, isolated 2 second event (using the gamma HRF) has height=0.2917
- Level 2, I used the contrast [1 1 -1 -1]
- COPE=500 (from contrast estimate)
- $$\%-change=\frac{(500)(0.2917)}{(2)(100^2)}\times 100=0.729$$

Featquery

- Featquery calculates %-change for ROI's
- Uses min/max range of 'effective regressor height'
  - Roughly speaking effective regressor corrects violation of the contrast rule and correlation between regressors
- Probably works fine for block design
- Very bad to run separately on first level runs for ER studies!
  - Will use a different scale factor for each subject
- Min/Max range isn't best for ER design

What to do instead of featquery?

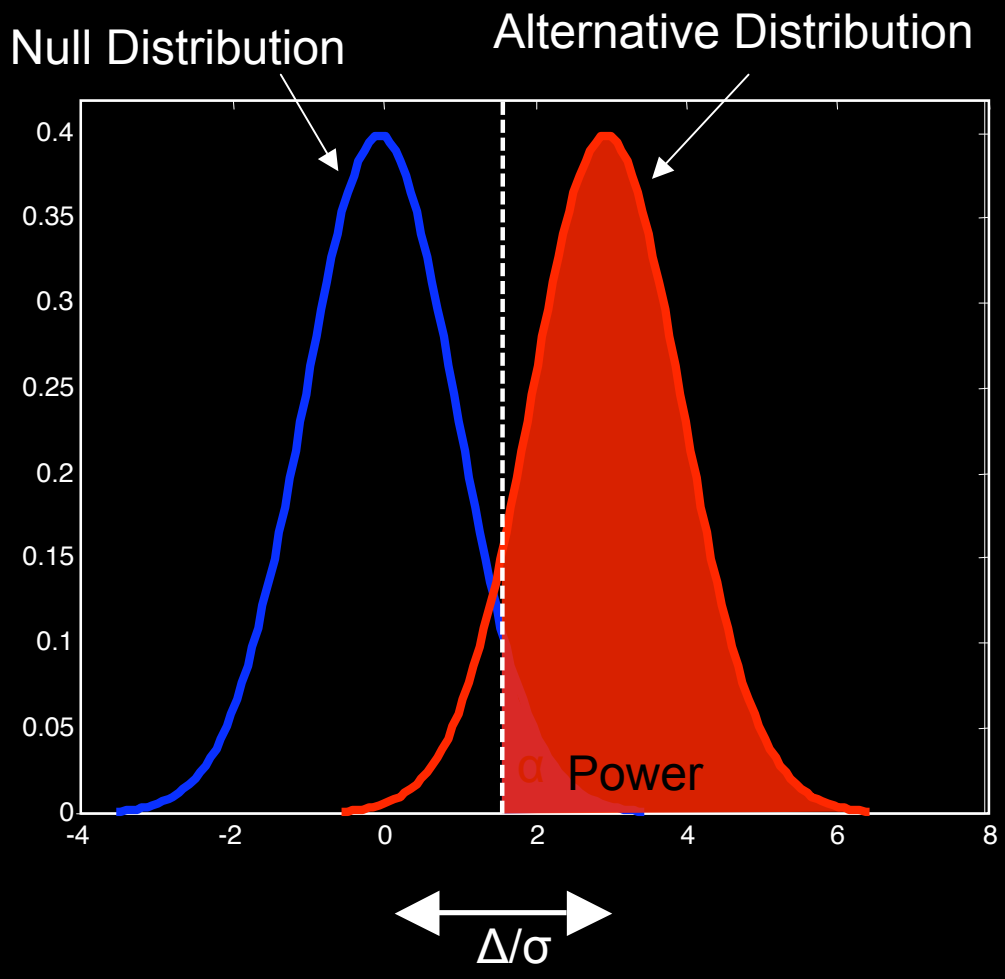
- There's a writeup with some code that uses avwstats and avwmaths located here
  - http://mumford.bol.ucla.edu/perchange_guide.pdf
- Some isloated event heights are in a table in this document
  - Isloated event height should be calculated from a design with *very* small TR for best resolution

Power Analysis-Why?

- To answer the question….
  - How many subjects do I need for my study?
  - How many runs per subject should I collect?
- To create thorough grant applications that will make reviewers happy!
  - Don’t waste money on underpowered studies OR collecting data on more subjects than you need

What is Power?

- Power: The probability of rejecting H_0 when H_A is true
- Specify your null distribution
  - Mean=0, variance=σ^2
- Specify the effect size (Δ), which leads to alternative distribution
- Specify the false positive rate, α



fMRI Power

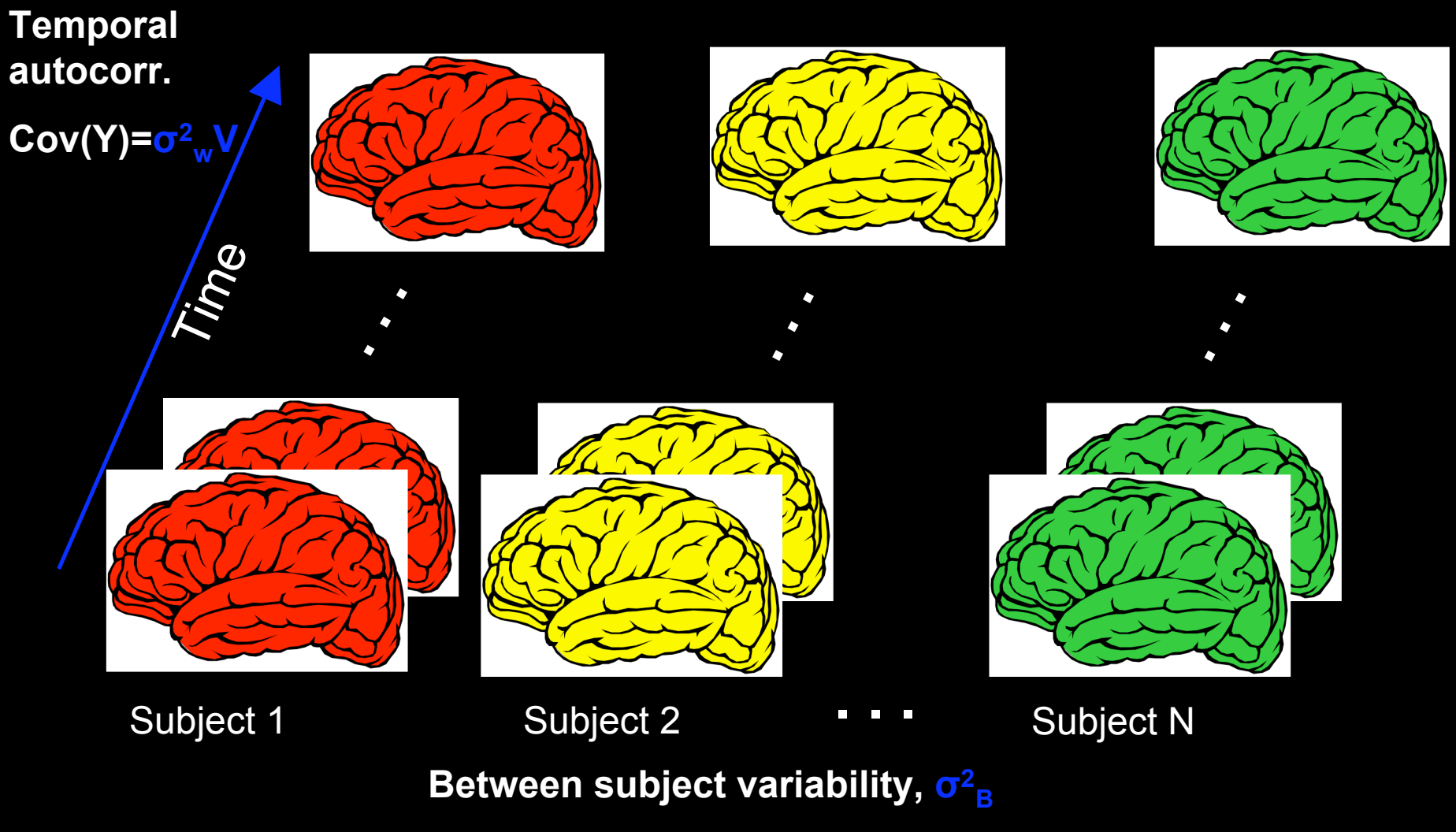
- Interpretation
  - 1100 total voxels
  - 100 voxels have β=Δ
    - A test with 50% power on average will detect 50 of these voxels with true activation
  - 1000 voxels have β=0
    - α=5% implies on average 50 null voxels will have false positives

Test Result (observed) \ Truth (unobserved)	H_0 True	H_0 False
Reject H_0	Type I Error α **50**	Power **50**
Accept H_0	Correct **950**	Type II Error **50**
	1000	**100**

Necessary information

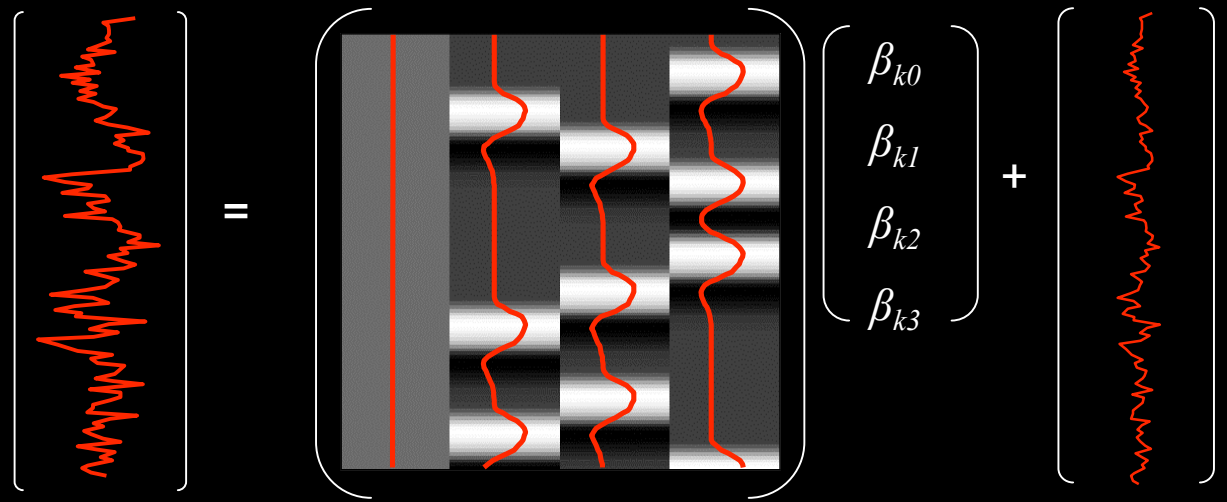
- N: Number of Subjects
  - Adjusted to achieve sufficient power
- α: The size of the test you'd like to use
  - Commonly set to 0.05 (5% false positive rate)
- Δ: The size of the effect you're interested in detecting
  - Based on intuition or similar studies
- σ^2: The variance of Δ
  - Has a complicated structure with very little intuition
  - Depends on many things …

Why is it so difficult for group fMRI?



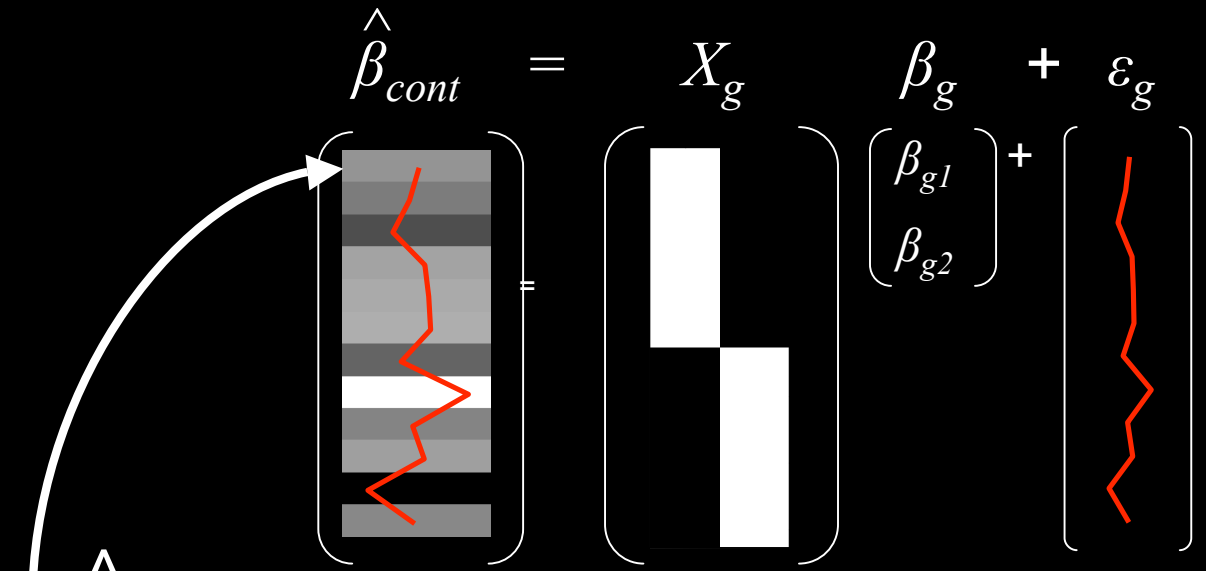
Level 1

$Y_k = X_k \beta_K + \varepsilon_k$



- Y_k : T_k-vector timeseries for subject k
- X_k : $T_k$xp design matrix
- β_k : p-vector of parameters
- ε_k : T_k-vector error term, $Cov(\varepsilon_k)=\sigma^2{}_k V_k$

Level 2

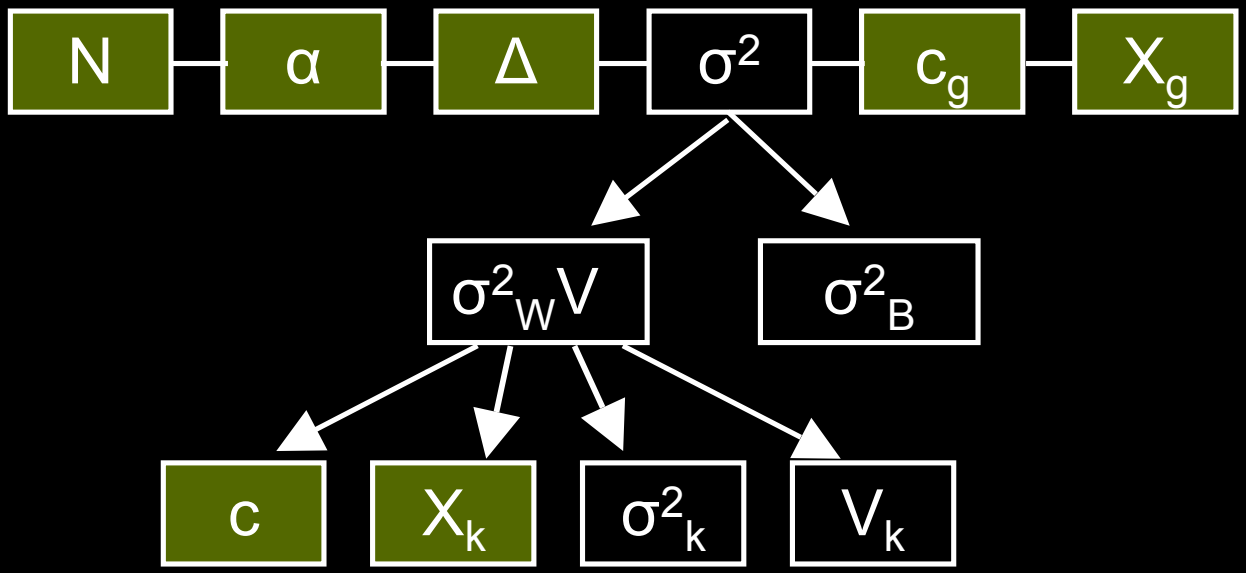


- $c\hat{\beta}_k$
- X_g : Nxp_g design matrix
- β_g : p_g-vector of parameters
- ε_g : N-vector error term
  - $Cov(\varepsilon_g)=V_g=diag\{c(X^T_k V_k^{-1} X_k)^{-1}\sigma_k^2 c^T\} + \sigma_B^2 I_N$

Within subject variability Between subject variability

Alternative distribution

- For a specific $H_A: c_g\beta_g = \Delta$
- t is distributed $T_{n\text{-}pg,\ ncp}$
  - $ncp = \Delta / c_g(X_g^T V_g^{-1} X_g) c_g^T$
- What do we need?



Estimating Parameters

- How to you estimate parameters for a future study?
  - Look at other people's study results for similar studies
  - Look at your own similar studies
- Average parameter estimates over ROIs of interest

Estimating $\sigma^2_k V_k$

- Use covariance estimate supplied by software
  - FSL uses a unstructured covariance that can have up to 13 or more parameters
  - SPM2 uses a 2 parameter AR(1) approximation
- Fit AR(1)+WN model to software estimate
  - Only 3 parameters
  - Summarize parameters over ROI's
  - Simple parameterization is easy to report and bridges covariance estimates across software
  - Assume covariance is same over all subjects (necessary to extrapolate to larger populations)

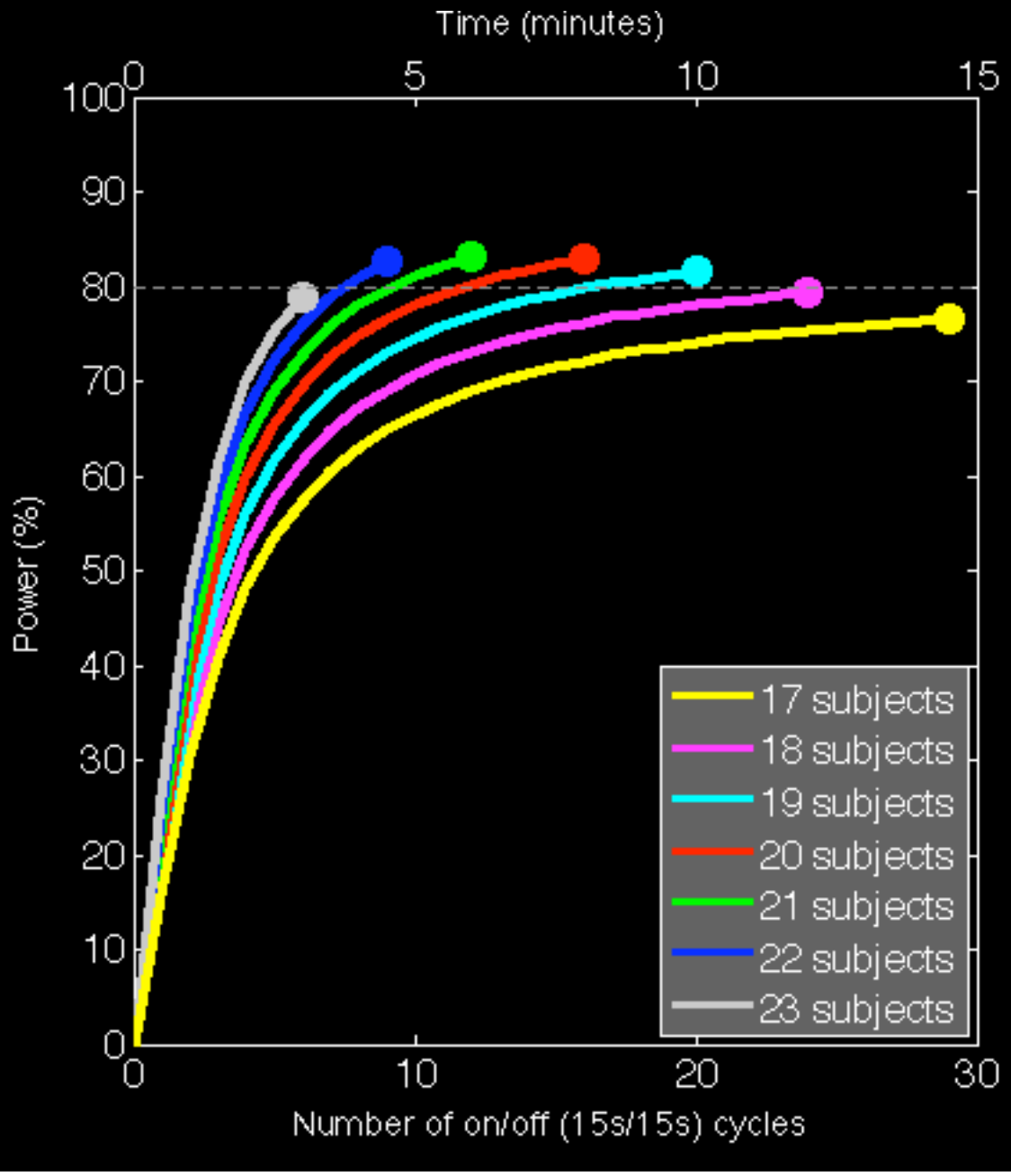
Estimating σ^2_B

- SPM2 doesn't estimate, but we still need to approximate it for the power calculation
  - You can see my paper for the details
- FSL estimates and saves this parameter in an image file
  - Average over the ROI

Model

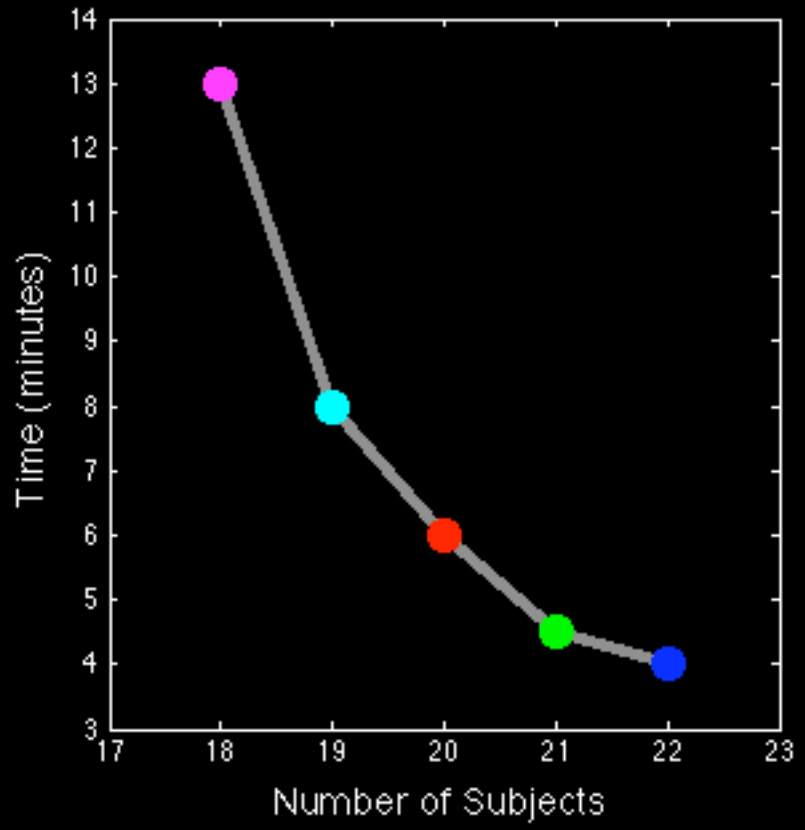
- Block design 15s on 15s off
- TR=3s
- Hrf: Gamma, sd=3
- Parameters estimated from Block study
  - FIAC single subject data
  - Read 3 little pigs
    - Same/different speaker, same/different sentence
    - Looked at blocks with same sentence same speaker

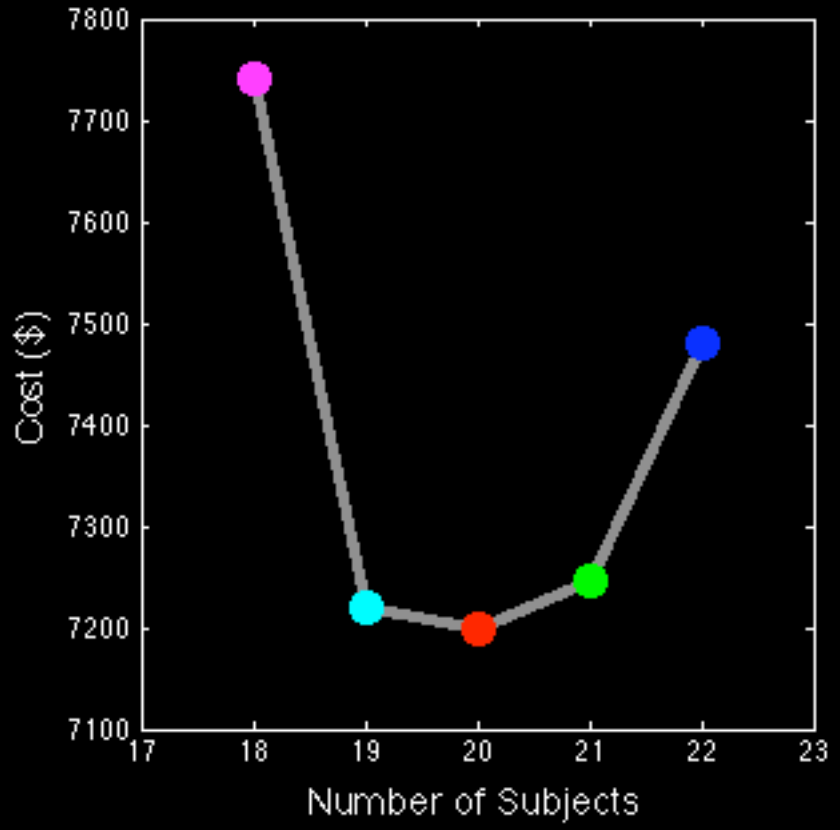
Power as a function of run length and



More importantly….cost!

- Cost to achieve 80% power
- Cost=$300 per subject+$10 per each extra minute

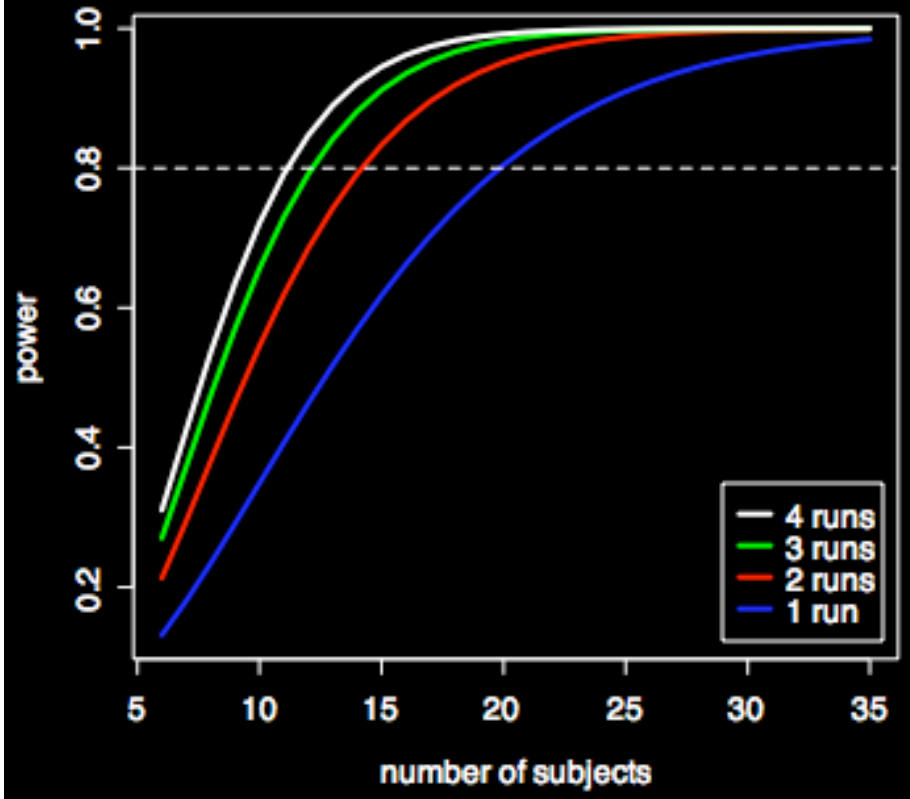


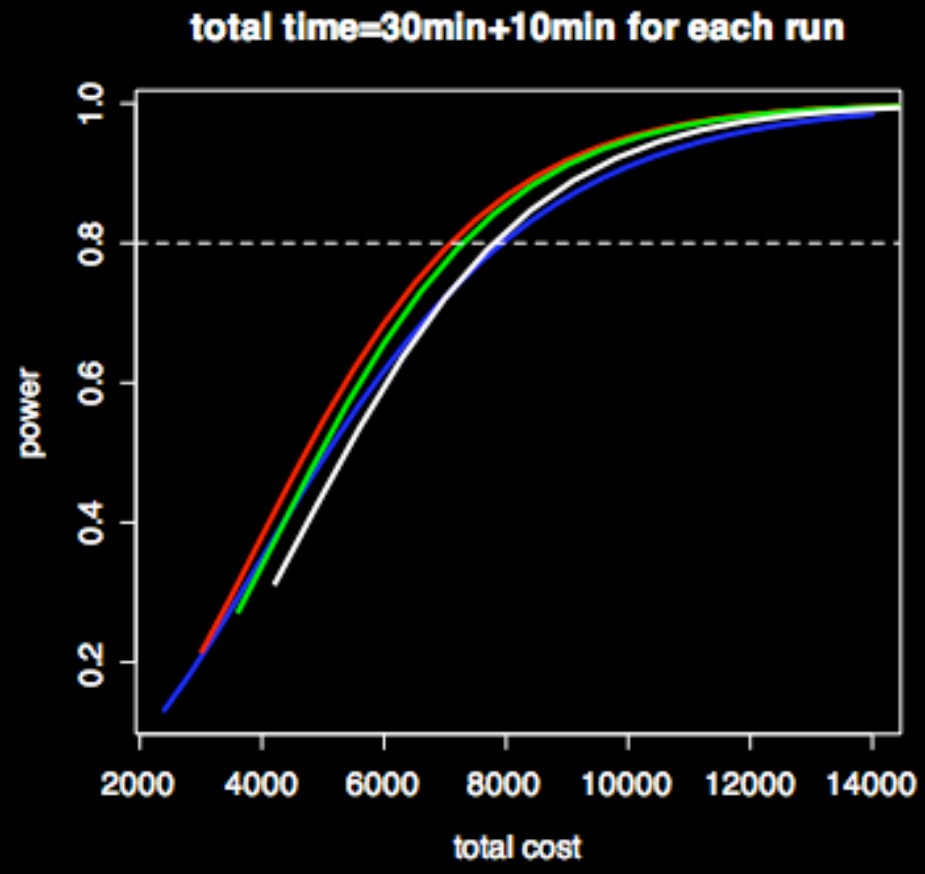


How Many Runs?

- Can also expand to a 3 level model and study impact of adding runs
- Example
  - ER study
  - Study used 3 runs per subject
  - Estimate between run variability
  - Assume within subject variability is the same across subjects
  - Assume study design is same across subjects

How many runs?



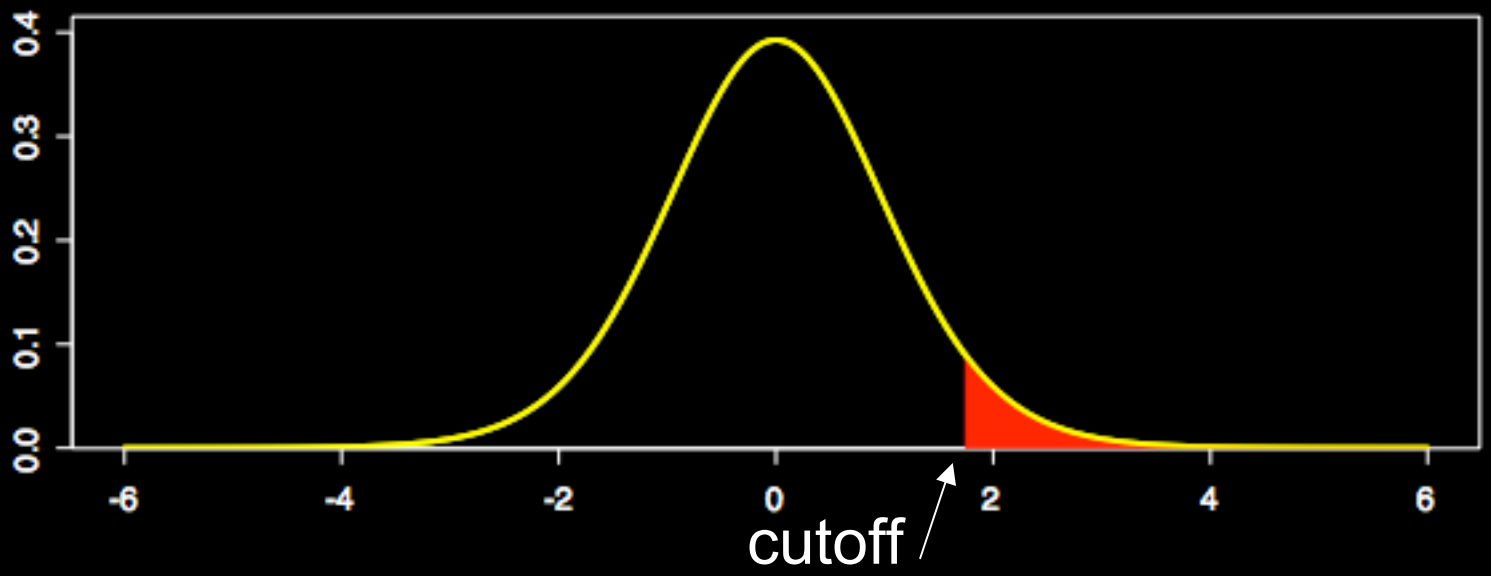


How can you calculate power?

- Only 1 tool that I know of
  - Fmripower! (created by me)
  - Beta version at fmripower.org
  - ROI based power analysis
  - Can apply to old FSL anlayses
  - Runs in Matlab
  - Current version only allows user to specify different #'s of subjects
    - Assumes # of runs for future study will be the same
    - Assumes between subject variability is same across subjects
    - Doesn't control for multiple comparisons

Can I use power post hoc?

- Please don't! It doesn't make sense
  - Power is a function of alpha
  - If you rejected your null, post hoc power is always less than 50%
  - See The Abuse of Power: The Pervasive Fallacy of Power Calculations for Data Analysis Hoenig et al, Amer. Stat. 2001
- Try percent change threshold (see Tom Nichols website)
  - Based on confidence intervals



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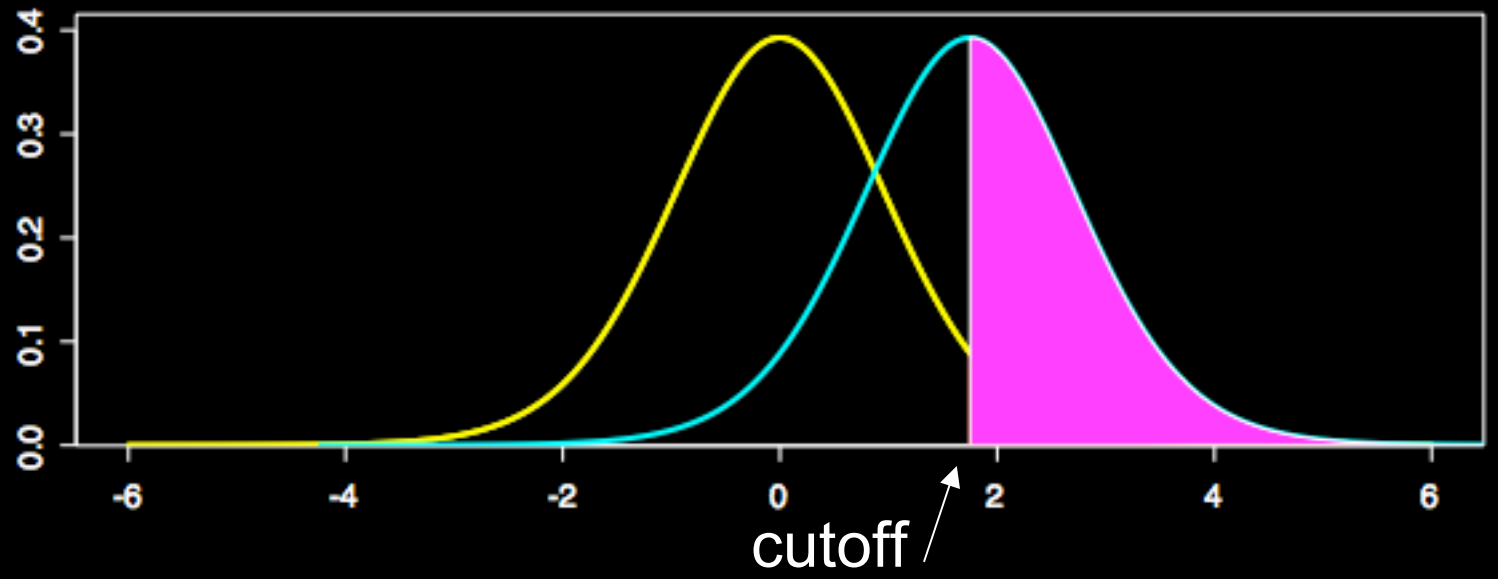
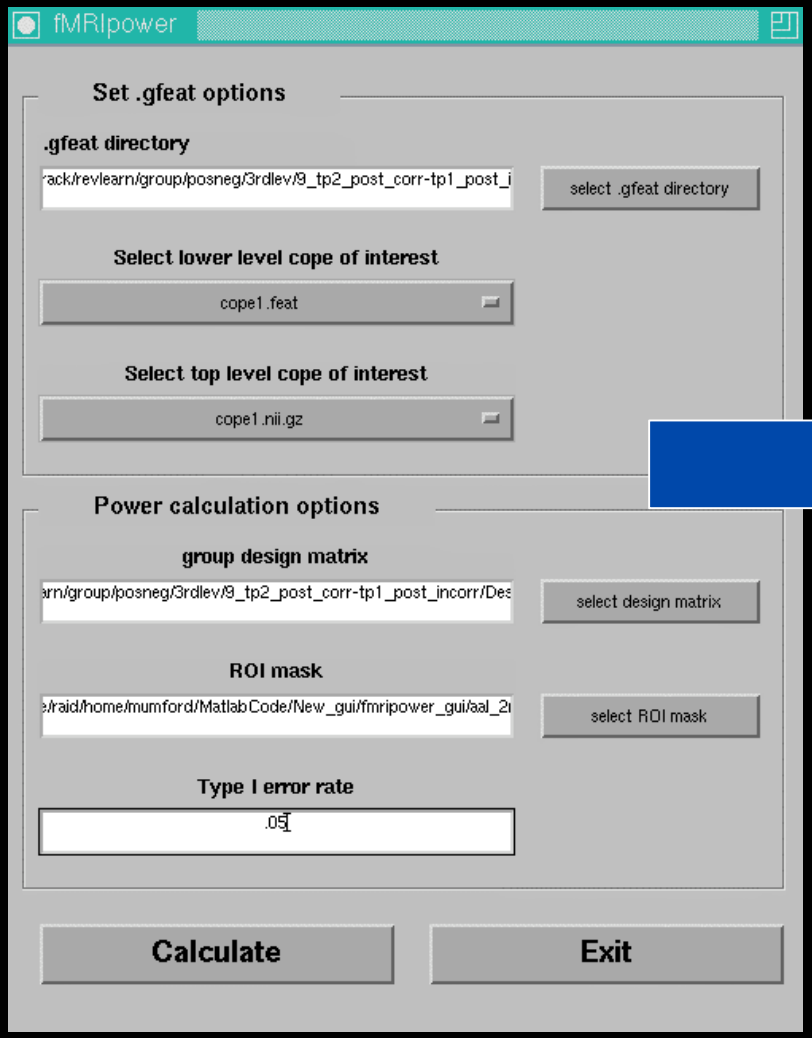


fmripower


fMRIpower
Set .gfeat options
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Select lower level cope of interest
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Select top level cope of interest
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group design matrix
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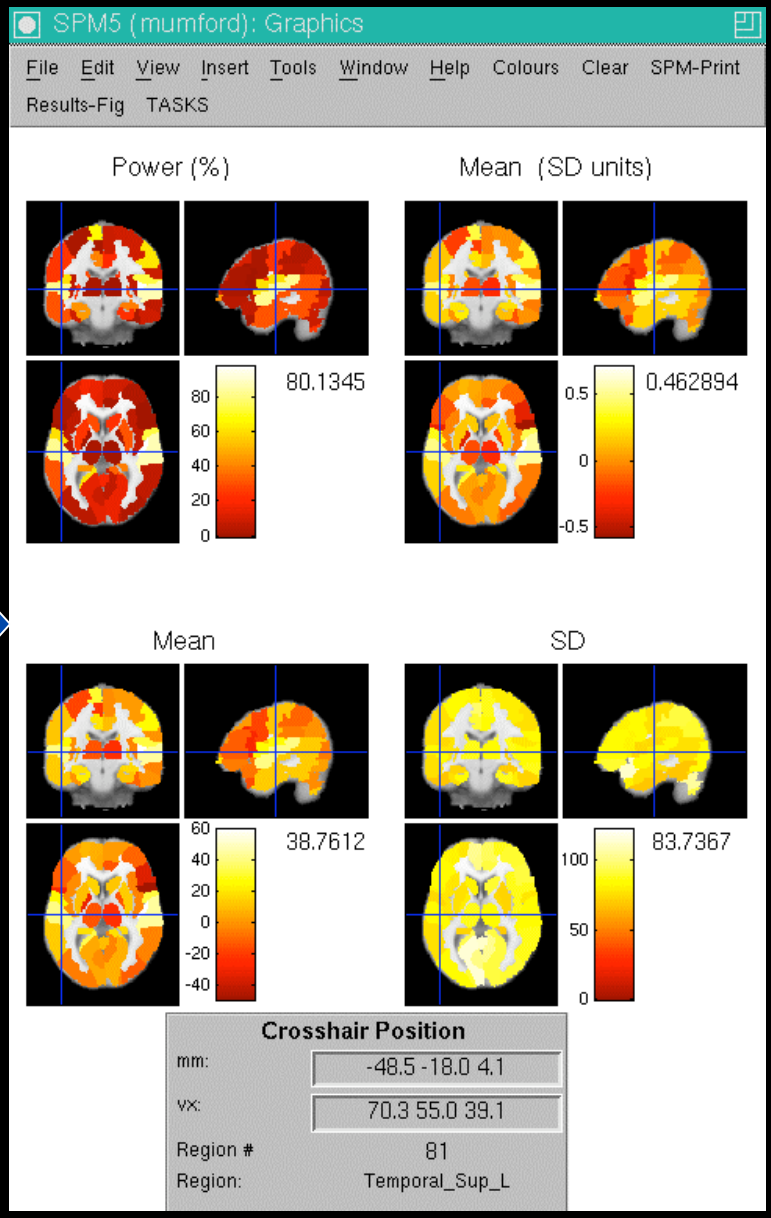
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38.7612
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Crosshair Position
mm: -48.5 -18.0 4.1
vx: 70.3 55.0 39.1
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Region: Temporal_Sup_L

Conclusion

- Percent change should be calculated in a manner that is interpretable
  - Min/max range does not lead to interpretable %-change
  - Interpretable %-change is very handy for power calculations
- Power calculations can save you time and money
  - Scan enough subjects to see an effect, don't waste time on an underpowered study
  - Don't keep subjects in the scanner too long if you don't need to