A Guide to Calculating Percent Change with Featquery

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1 Introduction

A unit change in a parameter estimate from an fMRI model doesn't necessarily reflect a unit change in the response, so we convert to % signal change in order to help interpret the results from a study and compare to the findings in other studies. It is popular for users of the FMRIB Software Library (FSL) to use the featquery tool, choosing the "Convert PE/COPE values to %", although there are also cases where the featquery result is difficult to interpret. This is an outline of how % change is calculated in general, what featquery does and how to ensure you are interpreting the % correctly. Just a quick note, if you are comparing experiments with different densities of events, then this approach still may not be correct due to the nonlinearities in the BOLD signal differing.

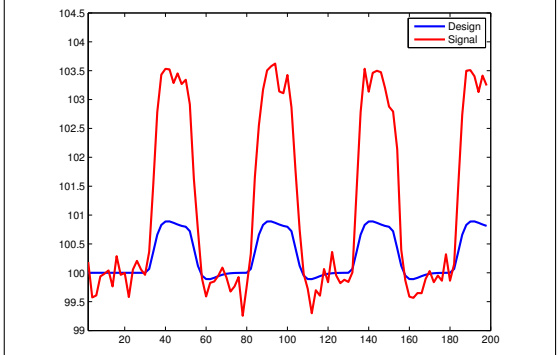
2 Calculating percent change

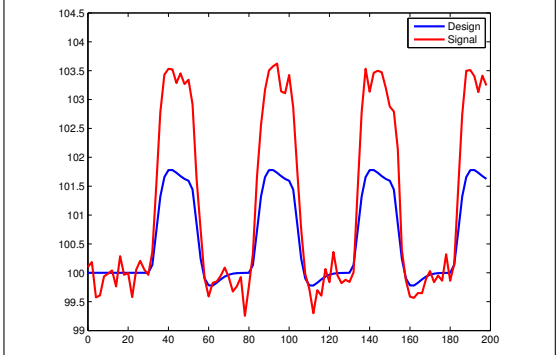
2.1 Block Design

- Assume the mean of the initial fMRI time series is 100.
  - In FSL grand mean scaling is carried out for all analysis so each voxel has a mean around 100^2 (can check by looking at mean_func image).
- Take PE times regressor height to obtain % signal change.
  - Figure 1 left panel, regressor height =1, so PE is percent signal change.
  - Figure 1 right panel, regressor height=2, so PE must be scaled by 2 to obtain percent signal change.

2.2 Event Related Design

- What do we use as a scale factor?
  - Regressor (EV) height is a function of proximity of events (Figure 2 top and middle panels).
  - EV height is a function of length of each event (Figure 2 bottom panel).
- **Q:** Is min/max range a useful scale factor? I tell you I had a 2% signal change for an event related design where I used the min/max range as my scale factor. 3 people did similar studies and want to compare my signal to theirs, so they try to recreate a version of my signal based on their designs.
  - Person 1 had a design with isolated 2 second events, person 2 had variable ISI with 2 second events, person 3 had isolated events with different durations. Estimated signals are in Figure 3.





Sig ht	EV ht	PE	%=EV ht*PE
4	1	4	4%

Sig ht	EV ht	PE	%=EV ht*PE
4	2	2	4%

Figure 1: Calculating % change for block design is as simple as multiplying the EV's height times the parameter estimate for that EV. The left panel shows an EV that is scaled to have a height of 1 actually has PE's that are in % units, while the right panel shows that if the EV had a height of 2, multiplying the PE*2 results in % change.

  - We can compare all 3 designs because they have a common isolated 2 second stimulus, which is marked by an arrow at 20 seconds (Figure 3). The signal at this point should be the same across all 3 designs, but signal ranges between 0.5 and 2.
  - **A:** No, using the min/max range does not lead to interpretable results since you can't relate the results from one study to another.

- Solution: Choose an isolated event with a particular duration, e.g. An isolated 2 second event. I tell you I had a 2% signal change for an event related design where I scaled using the baseline/max range of an isolated 2 second event and used a double gamma HRF.
  - The signals in Figure 2 correspond to this % change and at the common point (20 seconds) where all designs have an isolated 2 second event, the signal has the same height for all 3 designs.

3 How featquery works

- % change of PE (from the first level anlaysis).
  - Scales using the min/max range of the EV.
  - Uses the PPheight located in the design.mat file. This is the min/max range of the non-highpass filtered design. If you used a highpass filter then it **isn't** the min/max range of the design in the design.mat file.
  - May be okay for a block related design.
- % change of copes (from the first level anlaysis).
  - Uses the "effective regressor" min/max range.

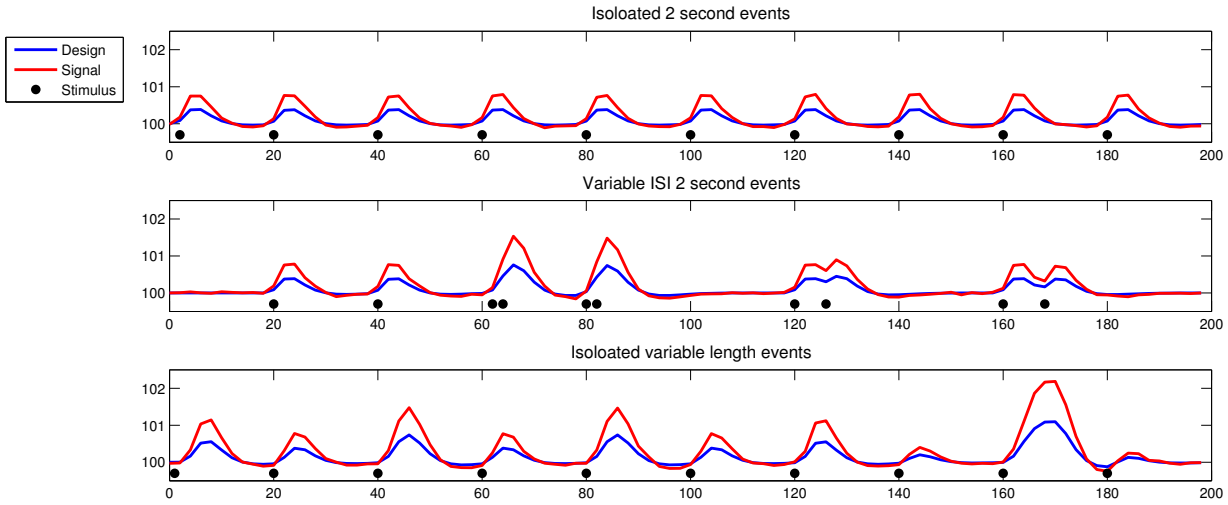


Figure 2: The blue lines represent the EV's (the model regressors) the red line the fMRI response and the black dots indicate when the stimuli occurred.

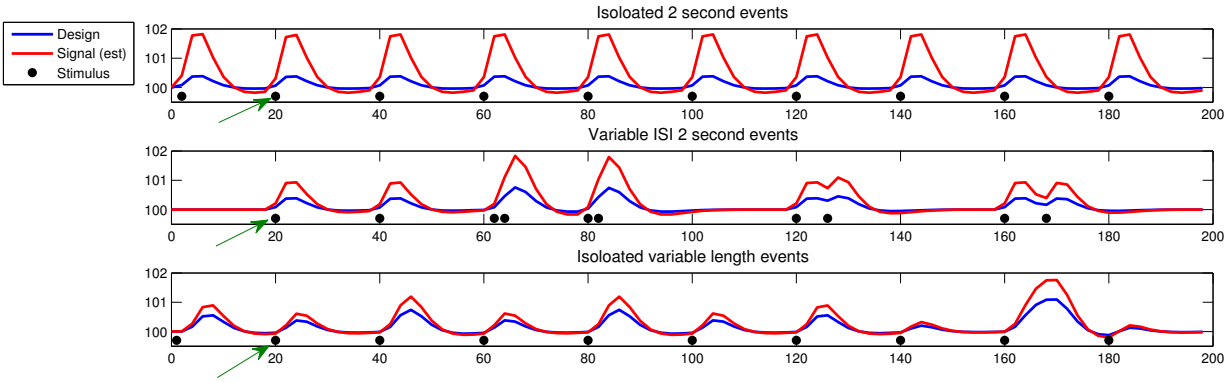


Figure 3: An illustration of inconsistencies that occur if the min/max range of the EV is used as a scale factor. The estimated responses in the 3 graphs above were all constructed based on an 8% change estimated using the min/max range as the scale factor. Note that at 20 seconds (marked by arrow) all 3 designs have an isolated 2 second event, but due to the variable scaling across designs, the estimated response varies between 0.5 and 2.

  - Effective regressor: Using matrix algebra it is possible to create a single regressor, orthogonal to the rest of the design, that will have a PE that is exactly the same as your contrast estimate.

- % change at higher level analyses.
  - Not quite sure actually (sorry). I haven't been able to figure it out exactly.
  - **Good:** It will use the same scale factor for all copes within that design. So, if it is at the second level of a 3 level design, all subjects are scaled the same.
  - **Bad:** Even though it is using the same scale factor across copes, who knows what the scale factor is referring to? For example, running featquery on 16 copes of the second level analysis used a scale factor of 1.4183, when in reality if I wanted to scale according to an isolated 2 second event, I'd use 0.4073 (note I took into account the rules of contrast and design matrix construction mentioned below).

- **A really bad thing to do:** Running featquery on multiple first level designs from an event related and then combining results.
  - Different scale factors may be used for each run, leading to completely incomparable things.
  - Especially a problem if the design varies greatly across runs; for example, looking at correct trials per run.

- Why doesn't featquery work great for all types of models?
  - All black boxes have their limitations, but for block designs (with blocks of the same length) and ER designs where the events are not dense, Featquery is doing fine.
  - Probably works for a block design study.
  - The effective regressor height is actually really neat since it can fix problems that turn up due contrast construction (see rules of building contrasts and designs below).
  - The correct scale factor may be a personal preference and featquery can't read your mind.

4 How to calculate % change

- If you follow these **Rules for Design and contrast construction:** Your parameter estimates/100 will (almost) automatically be in % change. Not exactly, since grand mean scaling sets mean to approximately 100^2. Also, I should note that the contrast contruction rules don't always work (e.g. ANOVA models), but you'll have to be vigilant about understanding your model and contrasts to be sure units are preserved.
  - **Design Matrix:** Start of with a design where the event you are going to use as your scale factor already has a baseline/max range of 1. I don't use min/max in order to avoid the poststimulus undershoot. The design matrix rule sort of a pain to do, so don't hassle with it since it is easy to fix later.
  - **Contrasts:**

1. In most cases your contrasts should sum to 0 (if you have positive *and* negative numbers in your contrast). There are exceptions for some ANOVA models. If your contrast only has positive numbers or negative numbers, they should sum to 1 (or -1), except for some ANOVA models.
   * Instead of [1 1 -1 -1], use [.5 .5 -.5 -.5].
   * Instead of [1 1 0 0], use [.5 .5 0 0].
2. If you didn't originally do this, you can still fix it in the % change calculation. See *contrast fix* below.

- If you couldn't follow the rules you can calculate the appropriate scale factor and use these steps to get your ROI average % change.

  1. Figure out your scale factor.
     - scale factor = $\frac{100*(\text{baseline-to-max range})}{(\text{contrast fix})}$
     - e.g. Contrast from a first level design. I'm using an isolated 1 second long event where the double-gamma HRF was used, and a contrast [1 1 -1 -1] was used.
       * baseline/max range= 0.2088.
       * number I'd divide my contrast by to make positive parts sum to 1 and negative parts sum to -1 (if present) =contrast fix =2.
       * scale factor = (100)(0.2088)/2=10.44.
     - For second level,
       scale factor = $\frac{100*(\text{baseline-to-max range lev1})(\text{baseline-to-max range lev2})}{(\text{contrast fix lev1})(\text{contrast fix lev2})}$
  2. let cope_img be the cope or pe that you're working with, mean_func is the mean_func image in the .feat directory, and mask_image is your ROI mask (I'm assuming it is 1's and 0's)
     `fslmaths cope_img -mul scale_factor -div mean_func -mul mask_image output_image`
     creates an image of % changes called output_image. The mean_func is the reference, so that's why we divide by it.
     `fslstats -M output_image` calculates the mean within the ROI.
  3. **Alternatively** you might be obtaining percent signal change values for all of your subjects by using the `filtered_func_data.nii.gz` in the appropriate `cope.feat` directory within your *group* analysis directory. The fslmaths command is the same

     ```
     fslmaths filtered_func_data -mul scale_factor -div mean_func
              -mul mask_image output_image
     ```

     but in this case you would replace the call in the previous step to use
     `fslmeants -i output_image -m mask`.

- You'll probably find that this is super fast, especially if you've been using the featquery gui, since the gui runs tsplot.

- How do you get the height of an isolated event?

  - Due to the poor temporal resolution of your EV, it is hard to get the true baseline/max range from the design you used.
  - You don't want to use a highpass filtered design.
  - Use Table 1 or create your own dummy model with the event you want and a really small TR (I used 0.1 in the table).

Stimulus Length (s)	Height with Gamma HRF	Height with double Gamma
0.1	0.0149	0.0211
1	0.1485	0.2088
2	0.2917	0.4075
3	0.4247	0.5872
4	0.5439	0.7421
5	0.6471	0.8689

Table 1: Height of isolated events for gamma and double gamma HRF's from FSL. Height is taken to be from the baseline to the peak, ignoring the post stimulus undershoot.