

# Report - Daehyun Cho

In advance, every work about this assignment is uploaded on github.

[0] Data Preparation

[1] Deconvolution approach

[2] Using a flexible mathematical model of HRF (one gamma function)

[3] Using a flexible model of HRF (two gamma functions)

[4] Based on the model with three fixed gamma functions (Friston et al., 1998) using least-squares (LS) algorithm

[5] Discuss overall results obtained from [1] to [4].

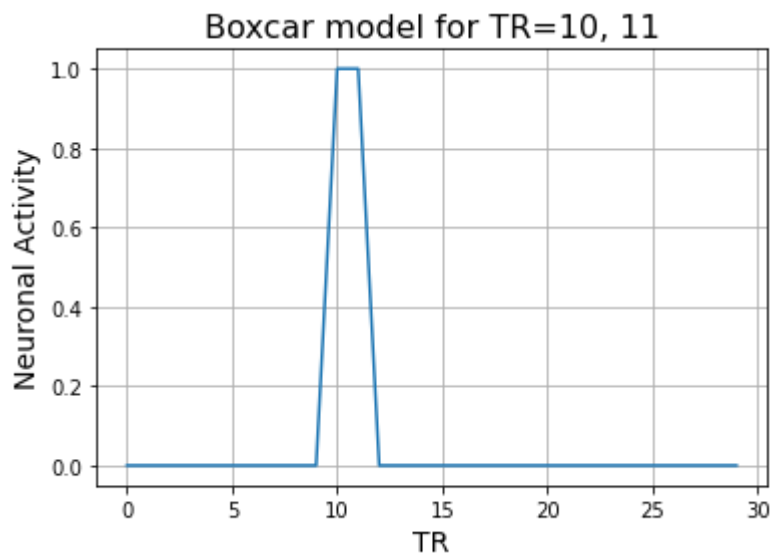
[Note] Common to all of the problems

## [0] Data Preparation

**Let's suppose the following for the measured BOLD signal ( $TR = 2$  s).**

**(a) Each of the task was performed at 20 s during 4 s (i.e., 10th and 11th TRs). Please use the boxcar model for neural activity**

I made boxcar  $N(t)$  for this



**(b) Consider the 0 – 20 s (i.e., 0th – 9th TRs) and 40 s – 60 s (i.e., 20th – 29th TRs) as baseline period**

**(c) Calculate the percentage (%) BOLD (pBOLD) signal based on (b)**

**(d) Conduct the estimation of the HRFs using the pBOLD signals calculated in (c) by applying each of the following methods [1] - [4].**

**When estimating HRFs, please use the pBOLD signal between 18 s – 52 s (i.e., 8th to 25th TRs) which includes a task-related period in between the baseline periods**

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## **[1] Deconvolution approach**

### **(a) Set the reasonable number of Fast Fourier transform (FFT) points**

I couldn't understand *reasonable number* of FFT because there is no way of giving hyperparameters on FFT. I attach some of the research that I endeavored.

I set below intervals as number of points.

- TR=8 ~ 25
- TR=8 ~ 16
- TR=10 ~ 16

Re: Deconvolution

Is it a reasonable approach to remove a hemodynamic response function from a timeseries of EPI data with deconvolution? That is, converting both the HRF and the time series into frequency space, dividing the data by the HRF, and then converting it back?

<https://afni.nimh.nih.gov/afni/community/board/read.php?1,74554,74555>

### **(b) Perform the FFT and inverse FFT to estimate the HRF in the time domain for each of the voxels in the ROI**

→  $\text{IFFT}(\text{FFT}(\text{bold}) / \text{FFT}(\text{Nt}))$  로 구하는 것 같은데...

### **(c) Check the estimated HRFs across the voxels and average the estimated HRFs**

→ ....? 이것도 뭐하라는건지 잘모르겠네. 그냥 전체 voxel 전체에 대해서 구하라는 건가...?

### **(d) Evaluate your results by comparing the average estimated HRF and average pBOLD signal**

→  $\text{HRF}(\text{pred})$ 랑  $\text{pBOLD}(\text{true})$ 를 비교하라는 것 같음. 근데 HRF를

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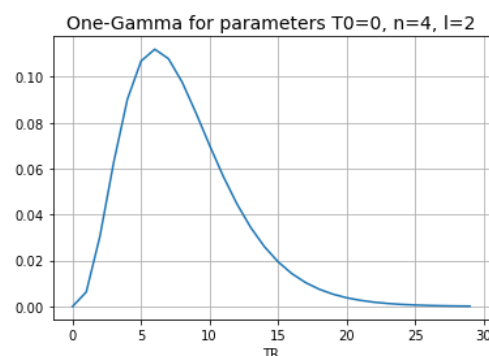
## **[2] Using a flexible mathematical model of HRF (one gamma function)**

(a) **Set the reasonable range of values as a grid for each of the parameters (i.e.,  $T_0$ ,  $n$ , and  $l$ )**

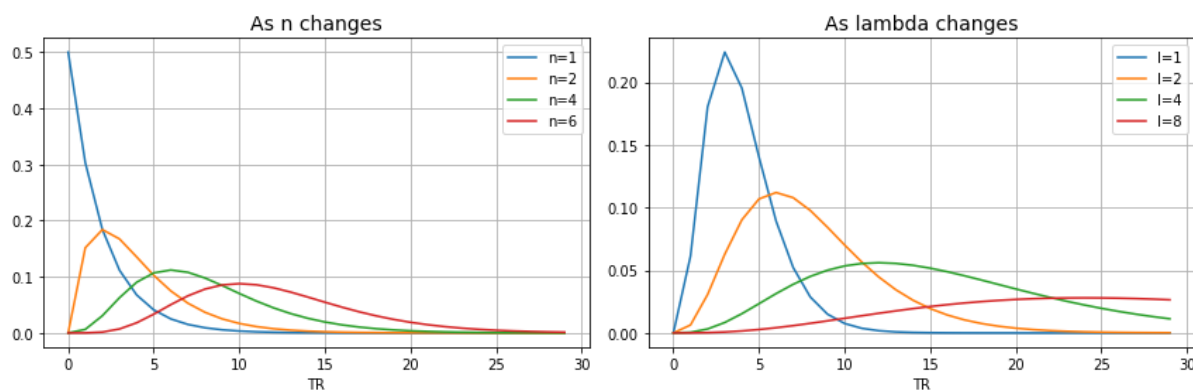
With  $T_0$ , I didn't set a range for this — I just set this to 0.

Since one-gamma function looks like below formula, and it's shape with a given parameters,  $T_0$  only cares about the onset. Therefore I didn't modify any of

$$\Gamma_1(t; T_0, n, \lambda) = \frac{(t - T_0)^{n-1}}{\lambda^n (n-1)!}$$



We know that  $n$  takes a role of the shape, while  $\lambda$  takes a role of scale. With different parameters



I aimed to find the one that has similar peak. So I set  $n$  around 2 ~ 5,  $\lambda$  around 2 ~ 7.

(b) **Calculate Pearson's correlation coefficients (CC) between the pBOLD signal and estimated pBOLD from the modeled HRF across all combinatorial sets of model parameters for each voxel.**

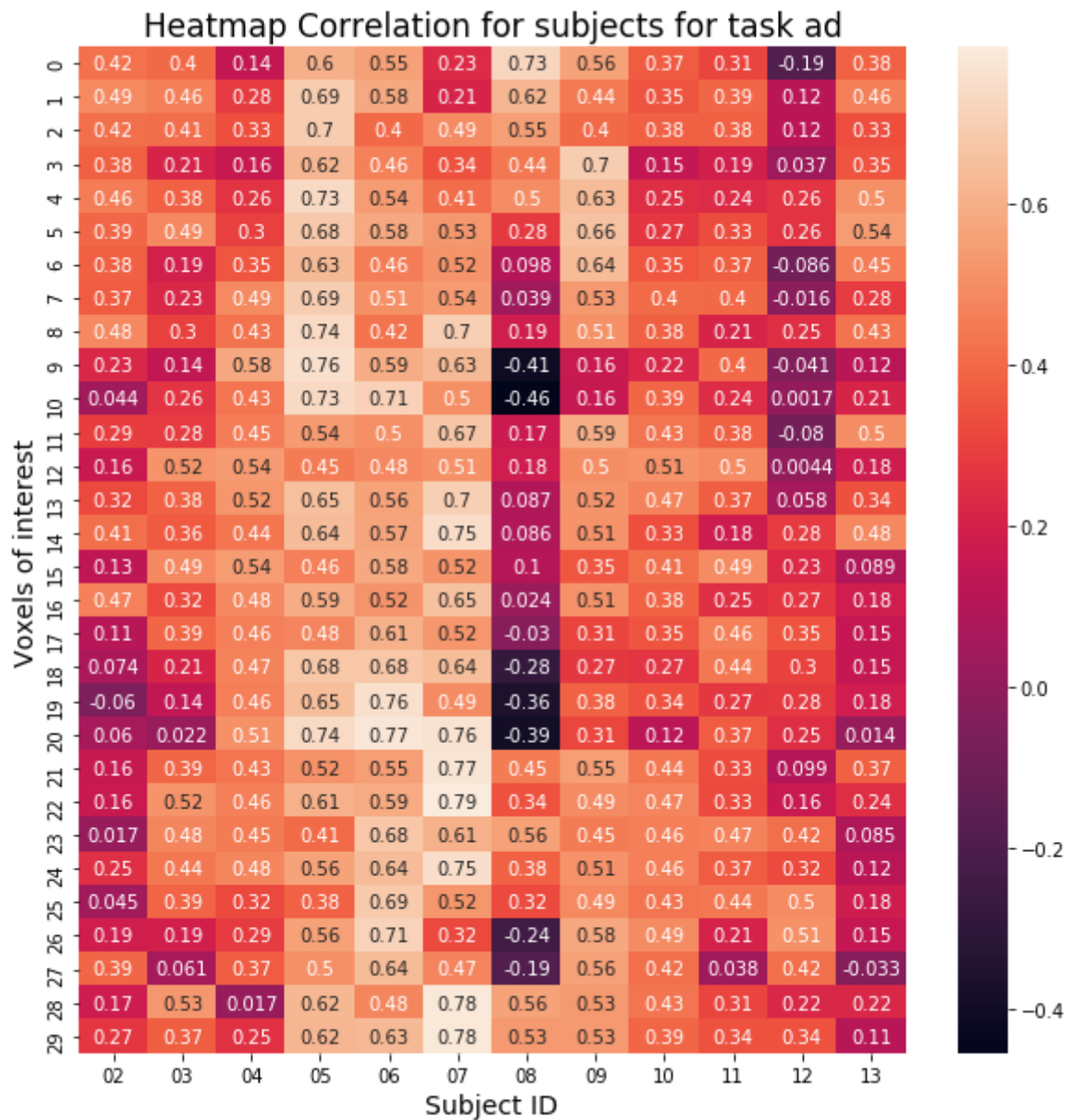
(c). **Calculate the average CC across all voxels within an ROI for each of the parameter set and choose the optimal parameter set that showed the maximum average CC. The HRF obtained from the optimal parameter set is the estimated HRF of the pBOLD signal.**

With mean value among ROI voxel and subjects, I found that  $n = 3.7$ ,  $\lambda = 1.6$  has the highest CC around 0.58.

### One-gamma Correlation set

<u>Aa</u> Task	# Correlatoin	# n1	# l1
<u>Auditory</u>			
<u>Left hand</u>			
<u>Right hand</u>			
<u>Visual</u>			

Below figure is a heatmap of estimated HRF and pBOLD among voxels of interest and subjects. Since the figure is too big, I didn't attach them here, but you can see them on codes.



(d) **Evaluate your results by comparing the estimated HRFs, estimated pBOLD signal, and average measured pBOLD signal**

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### [3] Using a flexible model of HRF (two gamma functions)

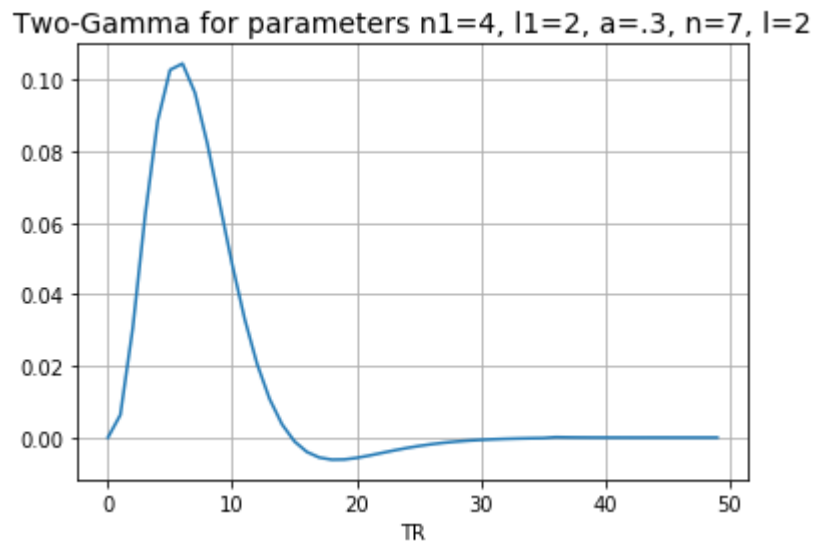
**Follow the similar steps in [2] with difference in the adjustable parameters for the two gamma functions (i.e.,  $T_0$ ,  $n_1$ ,  $\lambda_1$ ,  $a$ ,  $n_2$ ,  $\lambda_2$ )**

a. **Set parameter sets.**

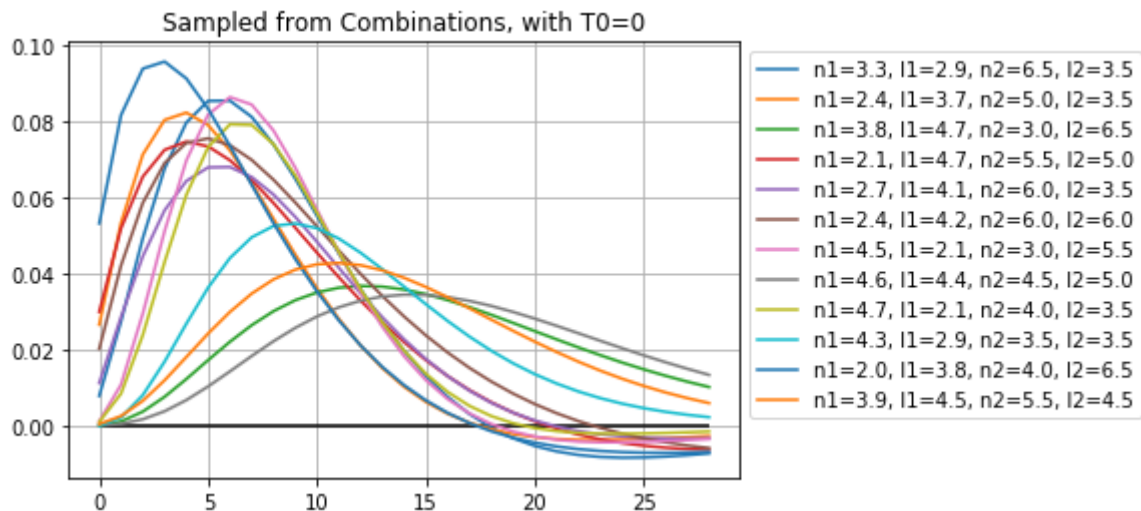
For  $T_0$  and  $a$ , I fixed them with 0 and 0.3 respectively since our onset is fixed and damping is better dealt with  $n_2$  and  $\lambda_2$ .

$$\Gamma_2(t; T_0, n_1, \lambda_1, a, n_2, \lambda_2) = \frac{(t - T_0)^{n_1-1}}{\lambda^{n_1}(n_1 - 1)!} - a \frac{(t - T_0)^{n_2-1}}{\lambda^{n_2}(n_2 - 1)!}$$

Since second term(undershoot) should have its peak on larger TR, I find  $n_2, \lambda_2$  bigger. Therefore I set the candidates around —  $n_1$  from 2 ~ 5,  $\lambda_1$  from 2 ~ 5,  $n_2$  from 3 ~ 7,  $\lambda_2$  from 3 ~ 7.



As we



b, c **Calculate Pearson Correlation Coefficients and choose the best one.**

**Two-gamma Correlation set**

<u>Aa</u> Task	# Correlatoin	# n1	# lambda1	# n2	# lambda2
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<u>Aa</u> Task	# Correlatoin	# n1	# lambda1	# n2	# lambda2
<u>Auditory</u>	0.3429	3	2	5	6.5
<u>Left hand</u>	0.5687	3	2	4	4
<u>Right hand</u>	0.489	3	2	4	4
<u>Visual</u>	0.5907	3.5	2	4	4

#### **[4] Based on the model with three fixed gamma functions (Friston et al., 1998) using least-squares (LS) algorithm**

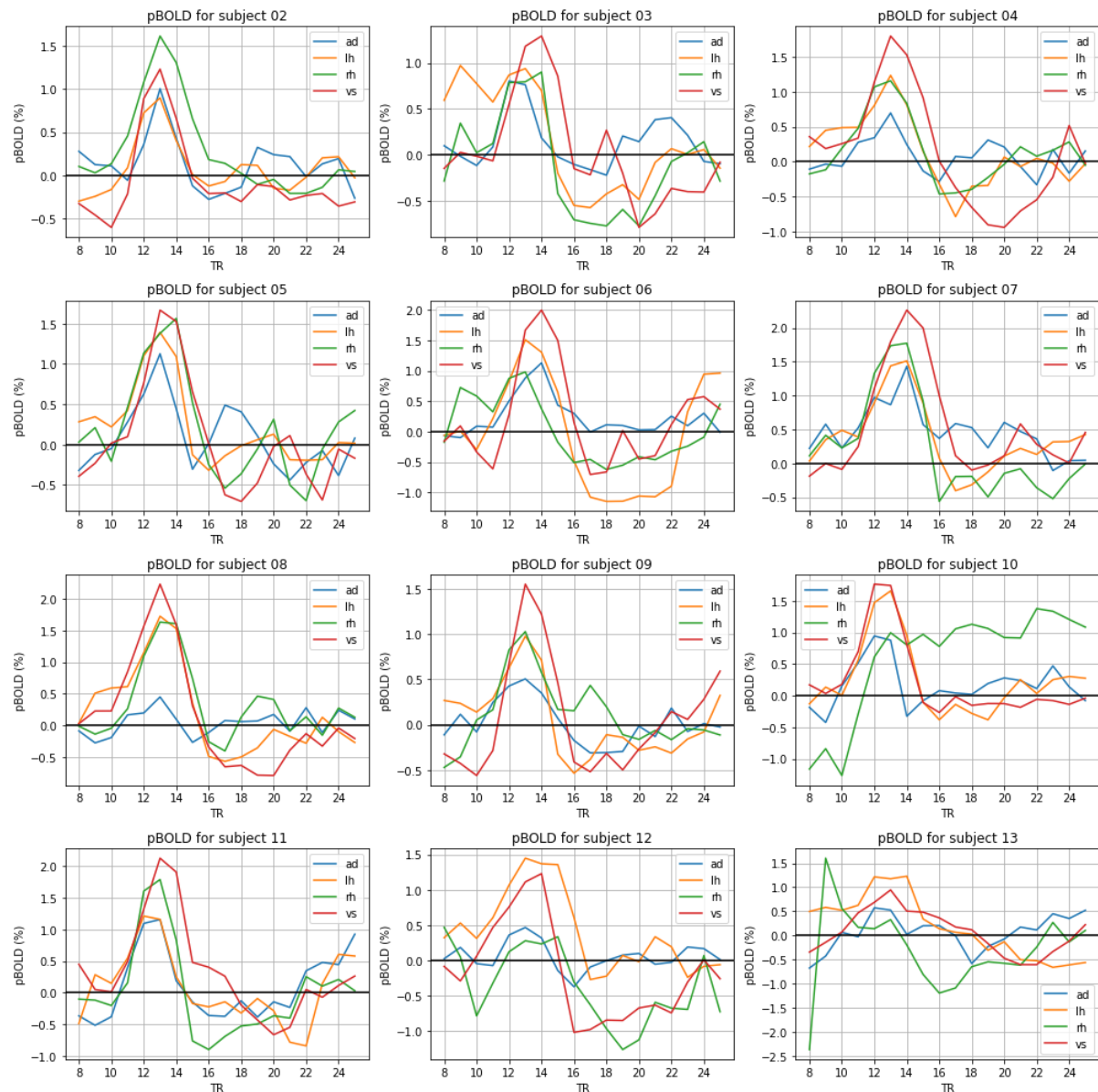
##### **(a) Study the LS algorithm and show your work**

So-called LS algorithm is to use Squared error as a loss or reference of direction to where parameters should head to. We can either take this squared error as — 1. Checking all of combinations' SSE and choose the lowest one or 2. Take Gradient descent method using SSE as a loss function.

I chose Gradient descent method to find the best parameters.

##### **(b) Calculate average pBOLD signal across all the voxels ('avg\_pBOLD')**

There is a bigger picture for this on the script(.ipynb) or the github.



**(c) Apply the LS algorithm to this 'avg\_pBOLD' signal and estimate the  $q$  parameters of this model**

I have no idea what  $q$ -parameters are.

**[5] Discuss overall results obtained from [1] to [4].**

***Too many things to be considered...***

**No AFNI**

It would be better to use AFNI command while doing the assignment but I couldn't. First, I couldn't find command that I should use here(maybe there was



but it was just me who couldn't find the right command). Second, I was using Windows so I installed it with WSL on my desktop but since COVID19 is swarming again, I couldn't use my desktop anymore...

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### **[Note] Common to all of the problems**

- Note that  $TR = 2$  s, so measured BOLD signals were acquired in every 2 s
- Perform the analyses for each of the four tasks
- Summarize the estimated parameters of the HRFs: e.g., for each of the four tasks across the subjects and/or for each subject across the four tasks preferably using some kinds of graphs for visualization
- Visualize the estimated HRFs for each of the four tasks and for each of the subjects (e.g., refer to p.17 of the lecture note, "*CH. 8 Signal, Noise, and Preprocessing of fMRI Data*")
- Discuss your results/figures at least with a few lines of text
- Use AFNI and MATLAB/Python to perform the analyses