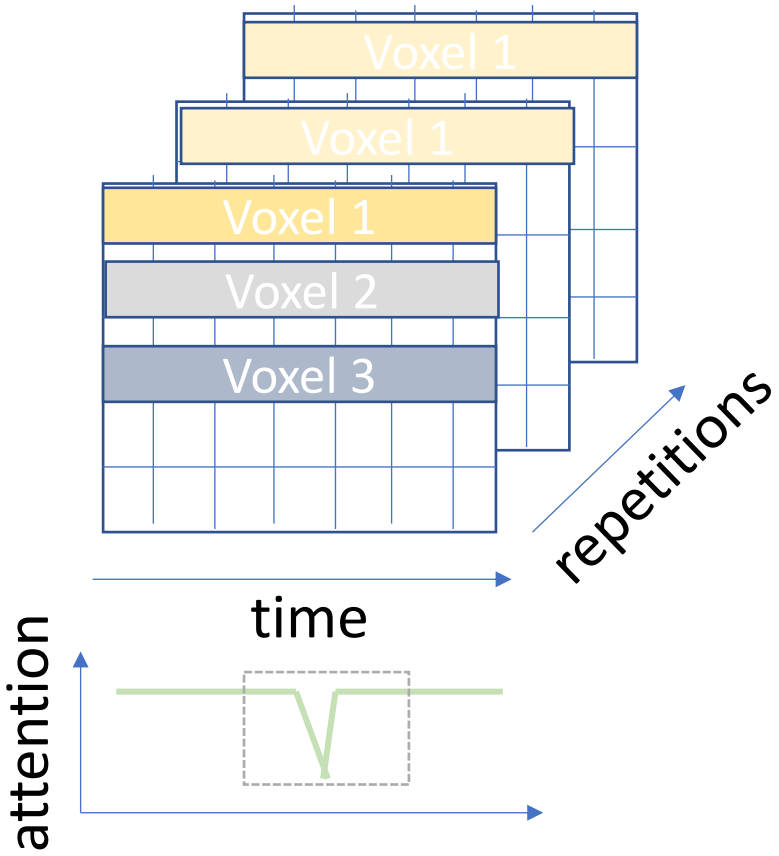
Denoise brain responses for repeated stories dataset

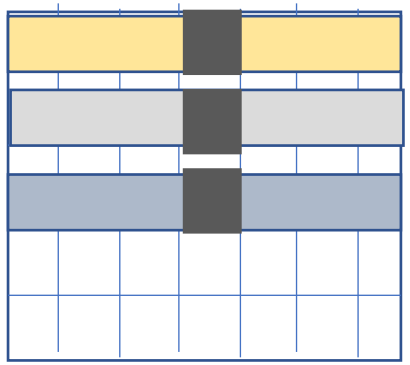
Motivation

- Subject is not attentive towards the story at some instant *t*
  - ➢ Response is not ideal response – need to detect this

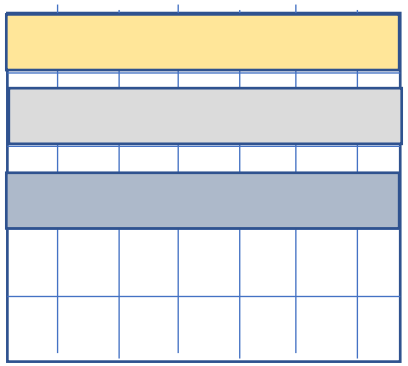


Idea

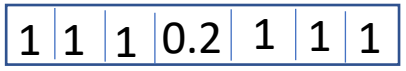
- Assume that brain response with full attention as R_{ideal}
- Multiplicative noise $\boldsymbol{\gamma}$ – dampens the ideal response at instants when subject is not attentive



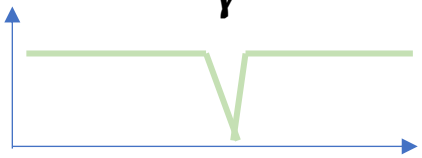
$R_{observed}$



R_{ideal}



$\boldsymbol{\gamma}$



$$R_{observed} = \gamma R_{ideal} + \varepsilon$$

$R_{observed}$ – FMRI data

R_{ideal} and $\boldsymbol{\gamma}$ – UNKNOWN

ε – Noise

$$R_{ideal} \sim N\,(0, \sigma_*^2),$$
$$\varepsilon \sim N\,(0, \sigma_\varepsilon^2)$$

$\boldsymbol{\gamma}$ – noise vector over time

– take values between 0 and 1

– same for all voxels at a given time t

Estimation of R_{ideal} and γ from $R_{observed}$

- For each repetition *r* : $R_{obs,r} = \gamma_r R_{ideal} + \varepsilon_r$
- Factorize $R_{observed}$ into R_{ideal} and γ_r by minimizing error for each repetition

$$MSE = \Sigma_r \left(R_{obs,r} - \frac{\gamma_r R_{ideal}}{\sqrt{1+var(\gamma_r R_{ideal})}}\right)^2$$

Note: R_{ideal} is common across all repetitions, only noise varies across them

- Normalization term: $\sqrt{1 + var(\gamma_r R_{ideal})}$ - since R_{obs} is normalized for each voxel

- Assumption on noise vector γ_r :
  - Different for each repetition r
  - Independent samples over time, sampled from **beta distribution** with parameters (α, β)

- Maximizing likelihood of the noise samples:

$$\alpha - 1 * \log(\gamma) + \beta - 1 * \log(1 - \gamma)$$

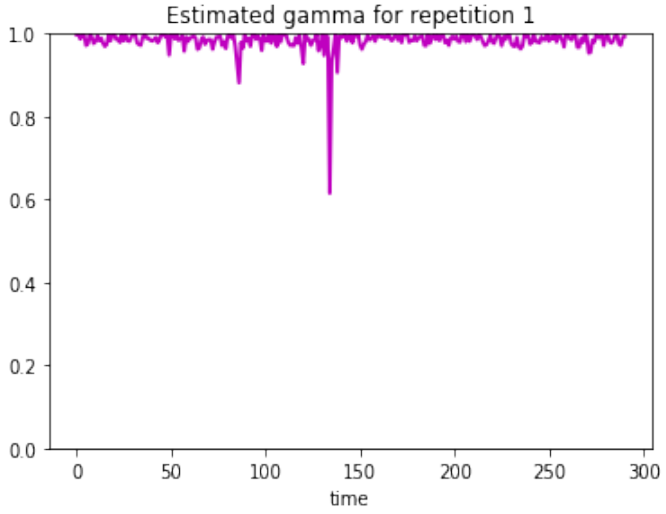
- Final loss function:

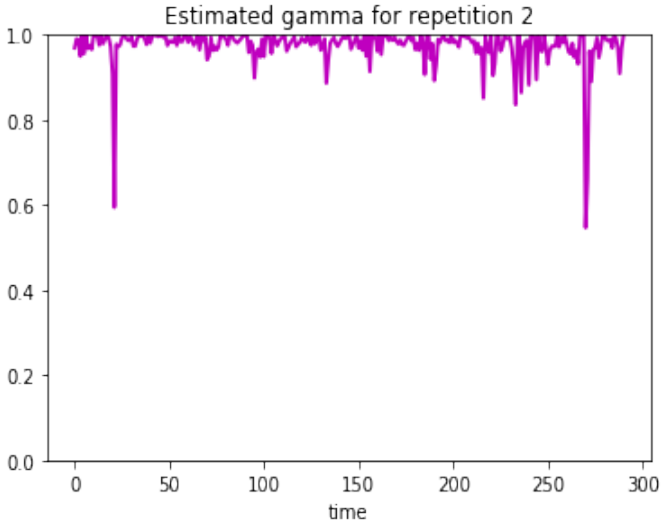
$$\Sigma_r \left(R_{obs,r} - \frac{\gamma_r R_{ideal}}{\sqrt{1 + var(\gamma_r R_{ideal})}}\right)^2 + \lambda(\alpha - 1 * \log(\gamma) + \beta - 1 * \log(1 - \gamma))$$

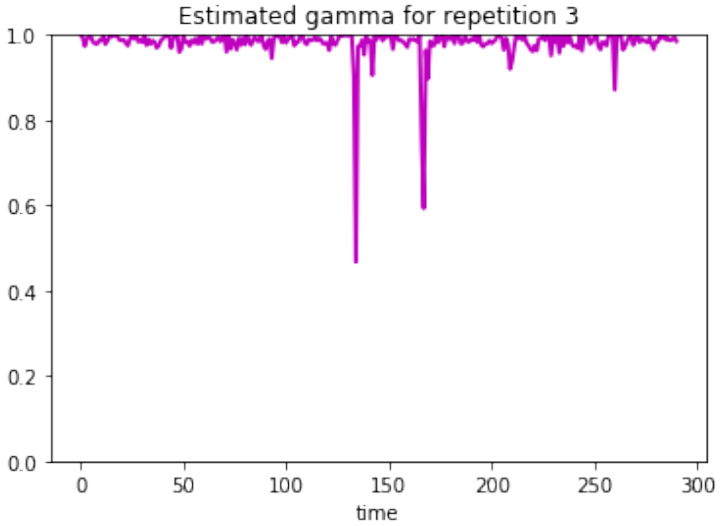
Experiments

- Dataset: 10-times repeated ‘wheretheresmoke’ and subject - AA, AHfs, SJ
  - Divide into two parts: **training set** (data for any 9 repetitions), **test set** (left 1 repetition)

- Estimated R_{ideal} and γ by minimizing loss function over training set
- For AA dataset: 10 repetitions x 291 time x 95556 voxels







$\lambda = 1e-4, \alpha = 8, \beta = 1$

Evaluation

How do we evaluate? – don't have ground truth values for Rideal or noise γ

- Take test set response: R_{test}
- Compare correlation of R_{test} with estimated Rideal and Robs averaged over training data:

$$Diff = corr(R_{test}, R_{ideal}) - corr(R_{test}, \Sigma R_{train\_avg}) \rightarrow \text{expected a positive value}$$

- For $\lambda = 1e-4, \alpha = 8, \beta = 1$, we averaged Diff over all possible train test combination: small +ve value in order 1e-4

- In place of R_{test}, tried prediction of encoding model: Small +ve value

Next…

- How responses varying over repetitions
  - analyzing correlation functions in time
- Training LM over test repetitions -