DIPF
Leibniz-Institut für Bildungsforschung und Bildungsinformation

IDeA
Individual Development and Adaptive Education

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

Session 2: Introduction into fMRI analysis

Dr. Elena Galeano Weber

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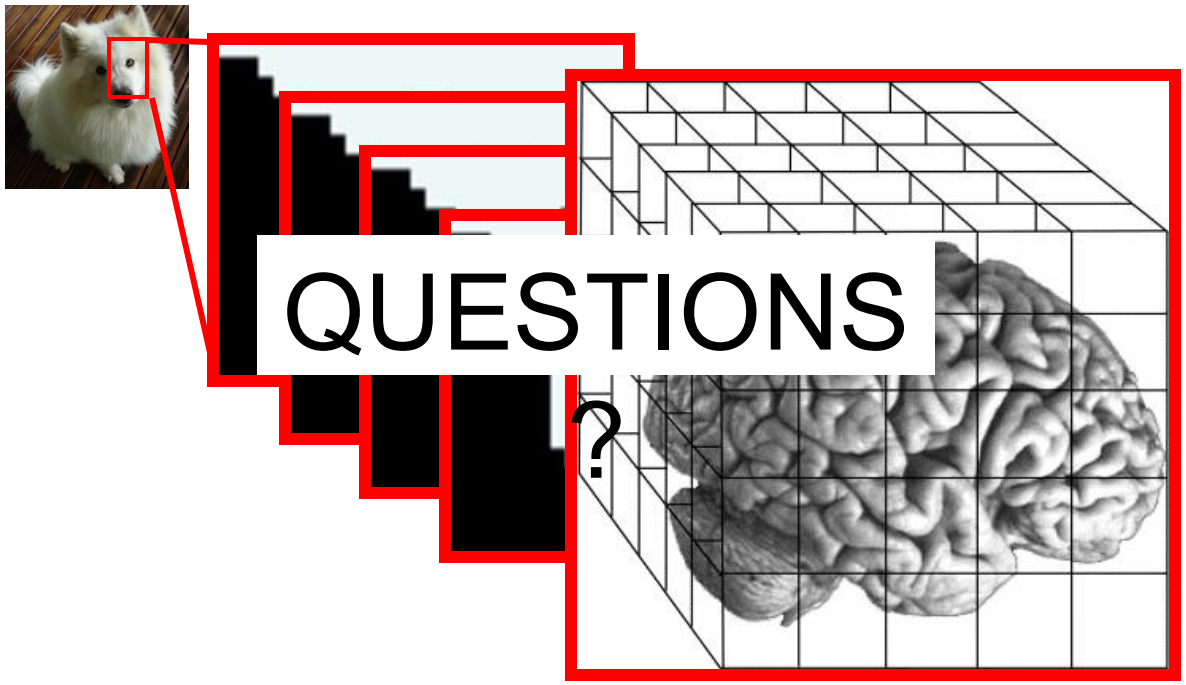
Education and Human Development & Individualized Learning Laboratory, DIPF | Leibniz Institute for Research and Information in Education

Recap of last session



MR basics:

- Scanner = magnet + RF transmitter
- MRI relies on the magnetic properties of the tissue
- MR images are 3D “pictures” composed of voxels with one value per voxel
- Most common 3D files: NifTi (.nii) and compressed NifTi (nii.gz).
- Spatial resolution depends on scanner strength

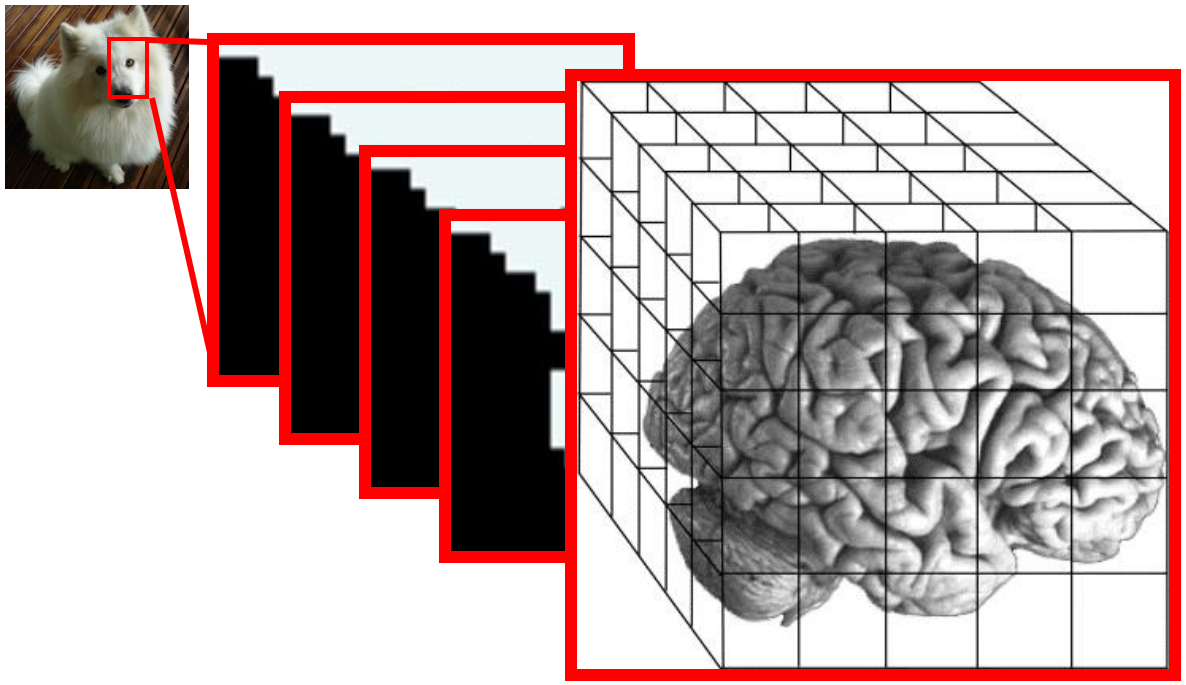
Type of images:

- MR images can be roughly grouped into anatomical and functional images
- Anatomical images (usually one volume) have higher spatial resolution than functional images (usually several volumes).
- TR = time to collect one brain volume.
- Runs = acquisition windows.

Preprocessing:

- Slice-time correction
- Magnetic field distortions
- Intensity inhomogeneities
- Motion correction
- Registration
- Normalization

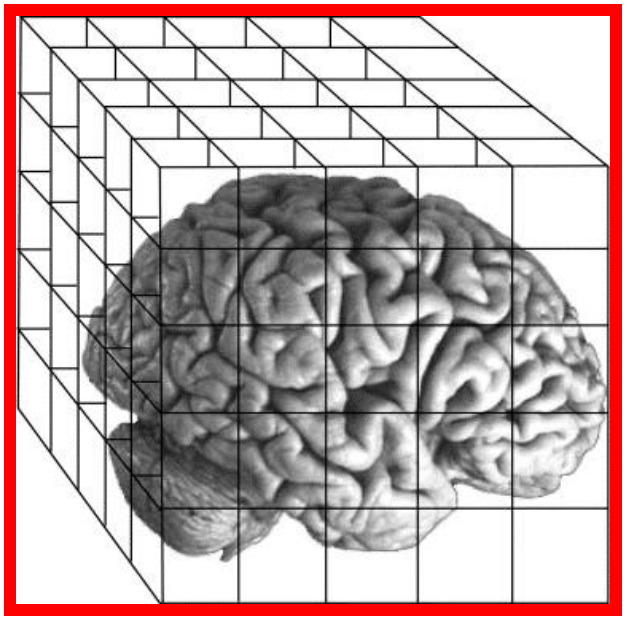
Recap of last session



MR images are a collection of voxels (3D matrix) with a value (a number) in each cell.

The value represents a different thing for anatomical and functional images.

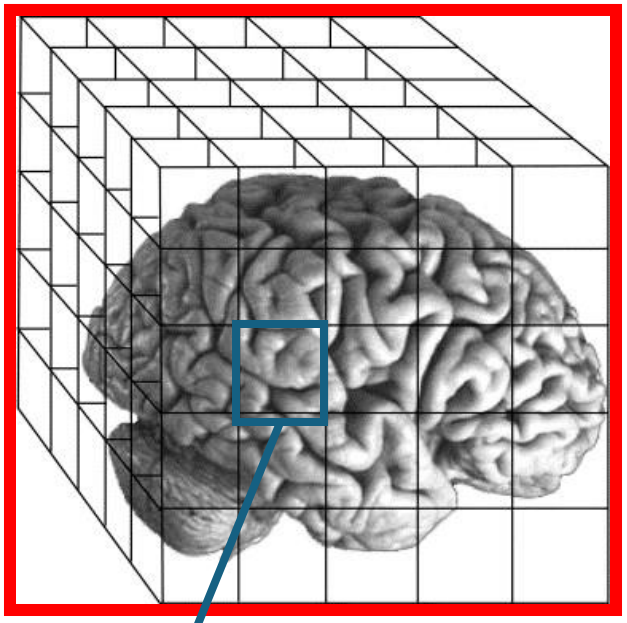
Functional MRI. BOLD signal.



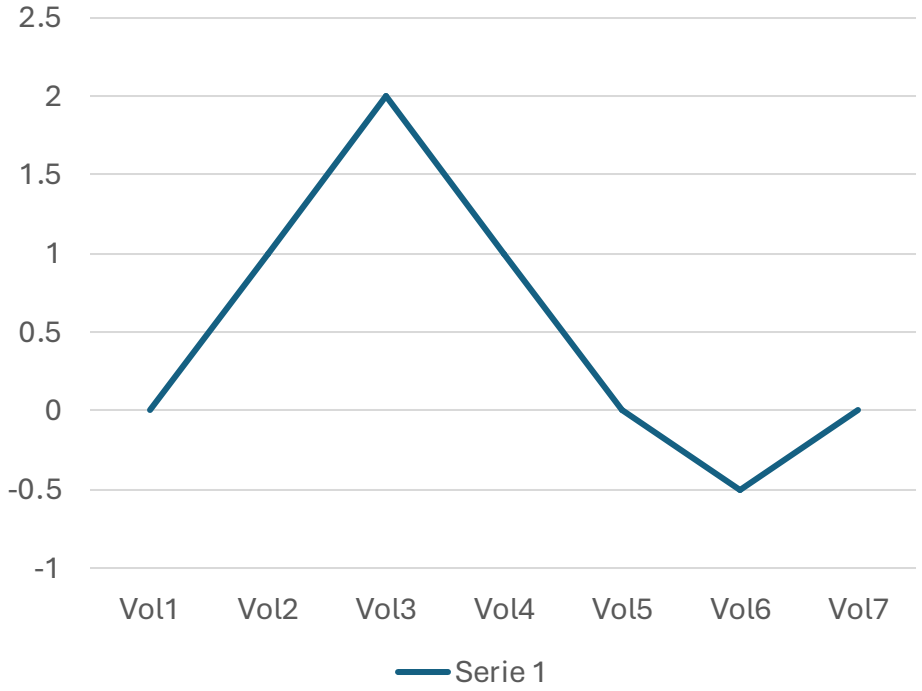
Functional images are used to study brain activity.

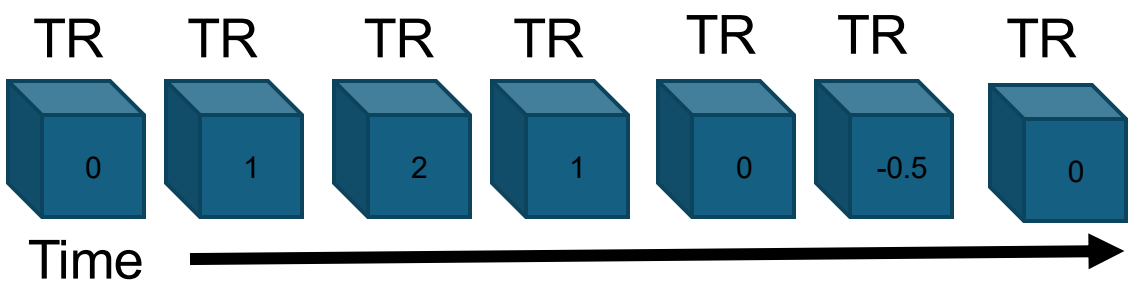
But what does brain activity look like when looked through a MR scanner?

Functional MRI. BOLD signal.



If we plot the voxels values over time…





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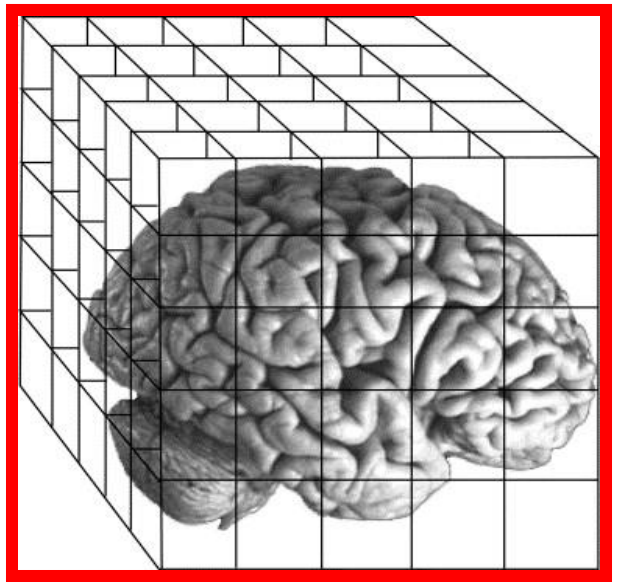
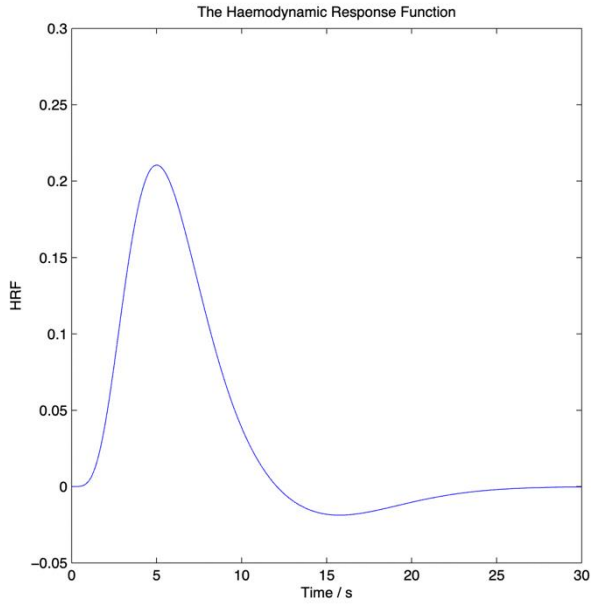


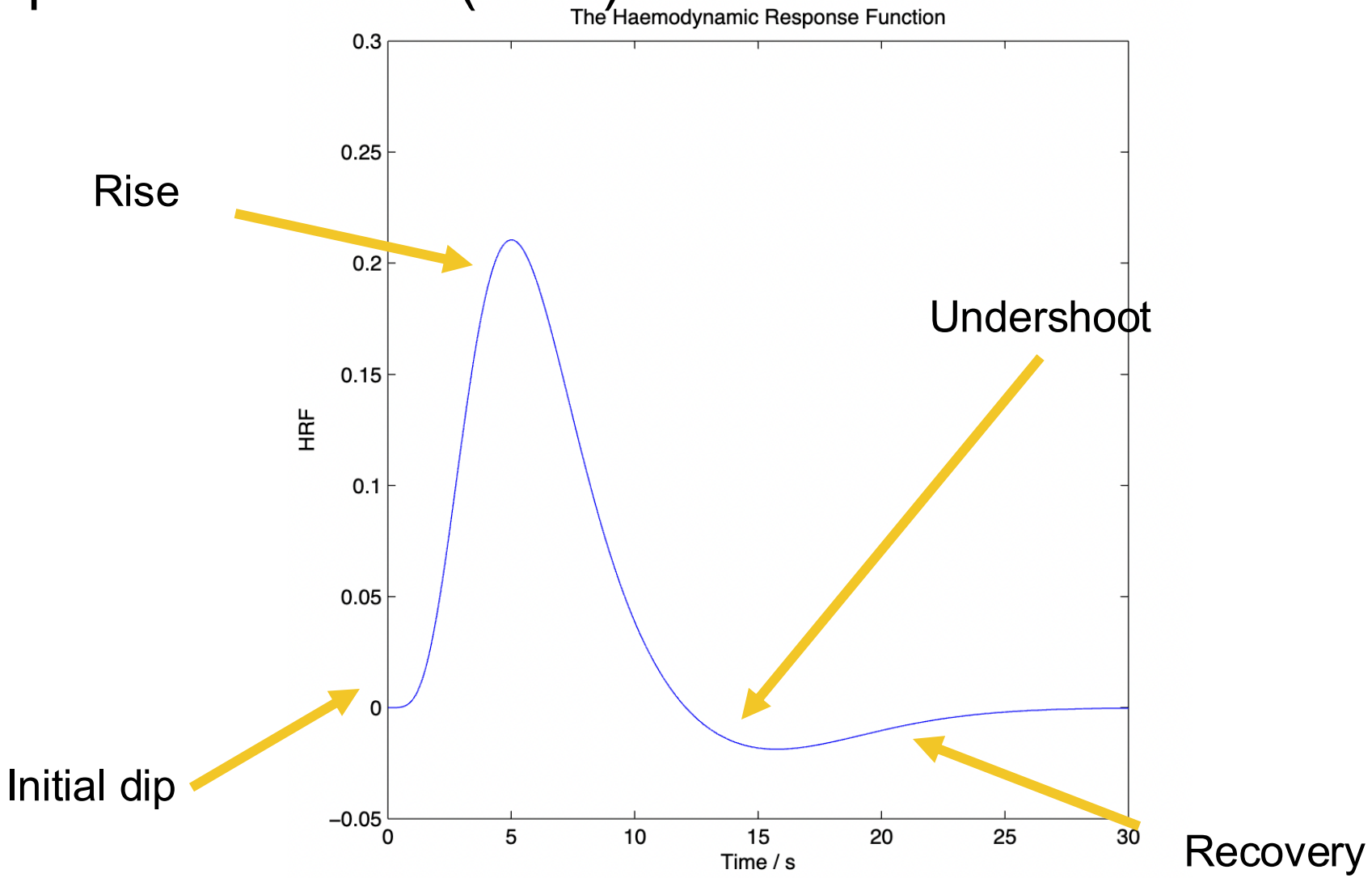
Functional images are used to study brain activity.

What we are recording in our functional sequences is actually blood oxygen level dependent (BOLD) signal.

But what does brain activity (BOLD) look like when looked through a MR scanner?

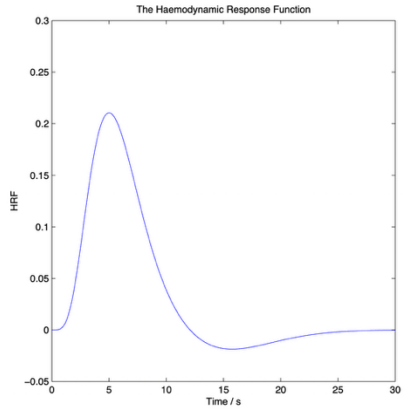


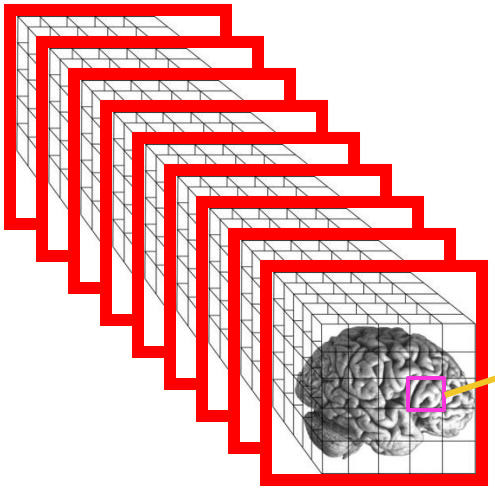
Functional MRI. BOLD signal. The Hemodynamic Response Function (HRF)



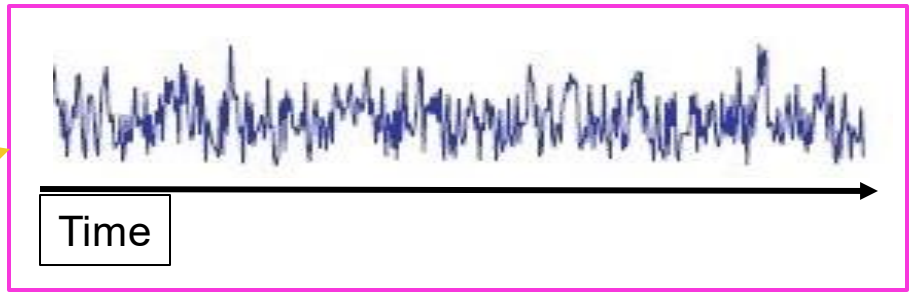
Functional MRI. BOLD signal.

This is the ‘ideal’ response to stimulation but, of course, the measured signal is noisier.



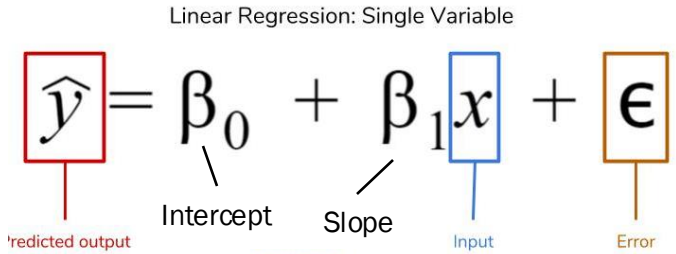


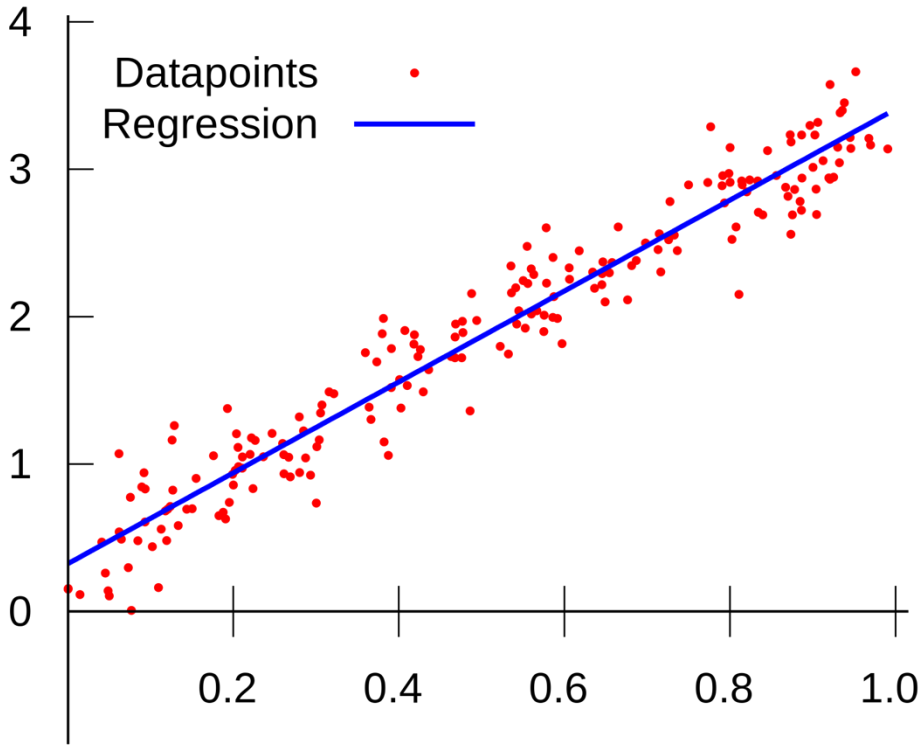
Measured signal in 1 voxel over many volumes



GLM. Generalized Linear Models

If you remember your stats class…





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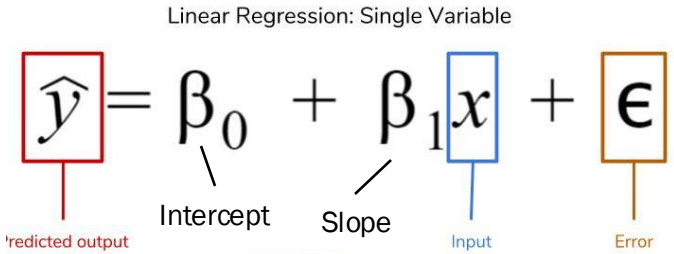

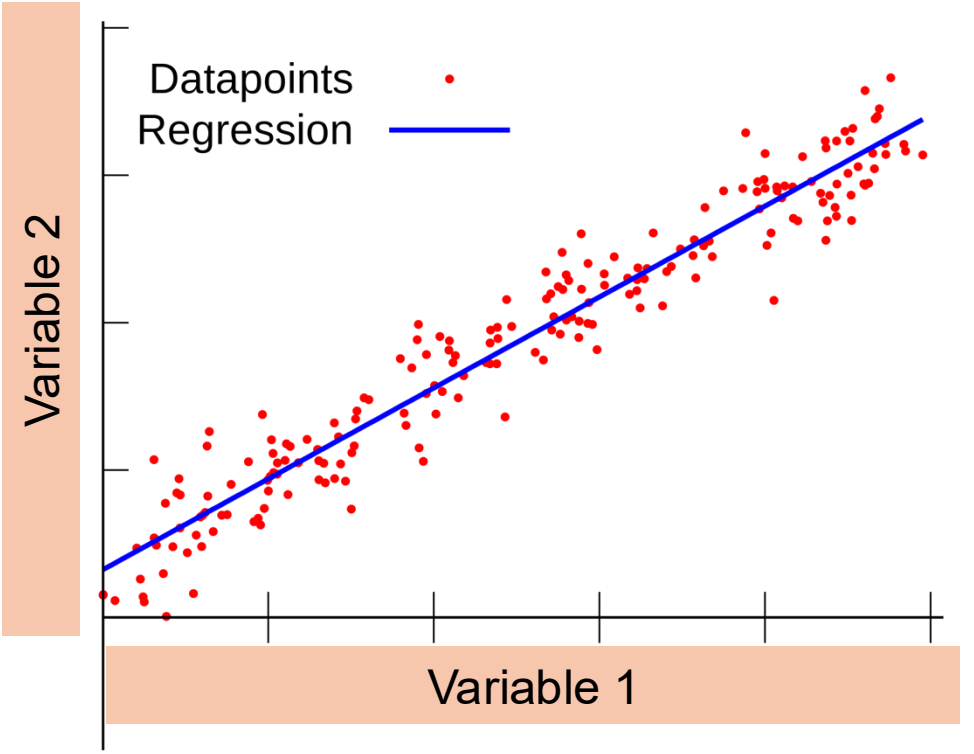

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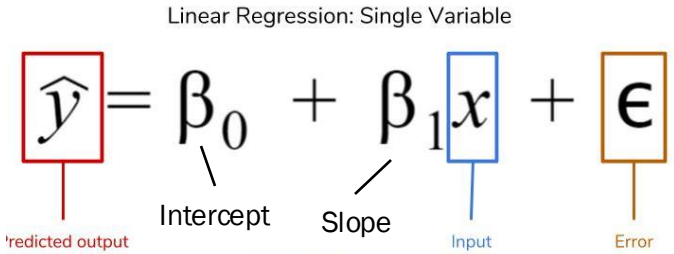

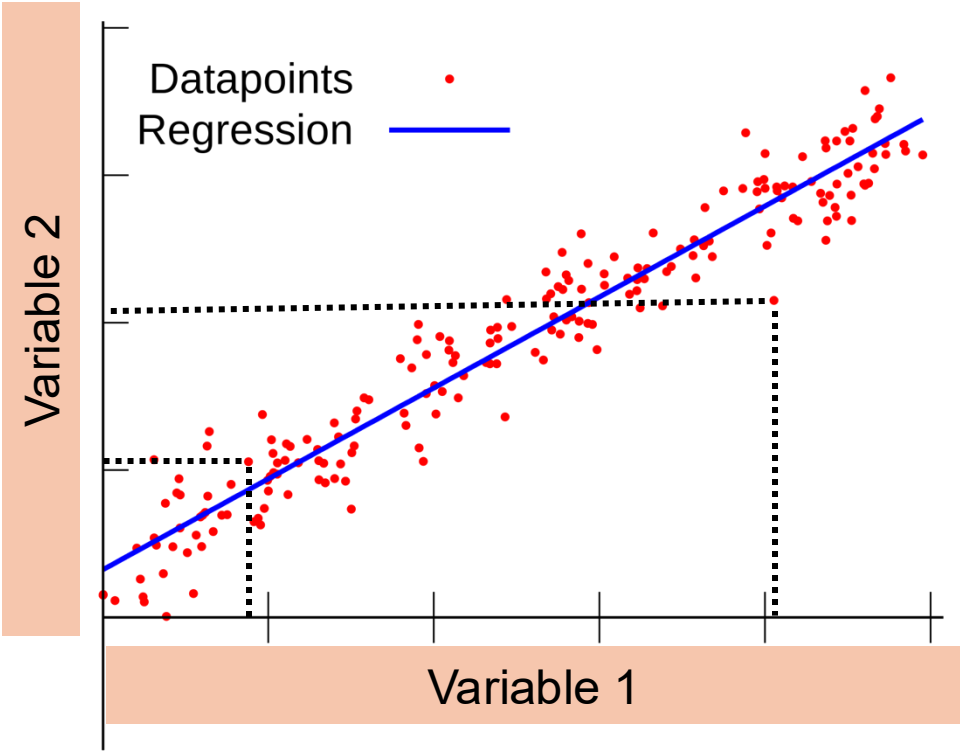

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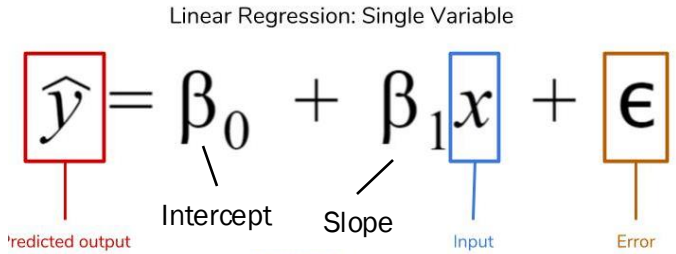

QUESTION:
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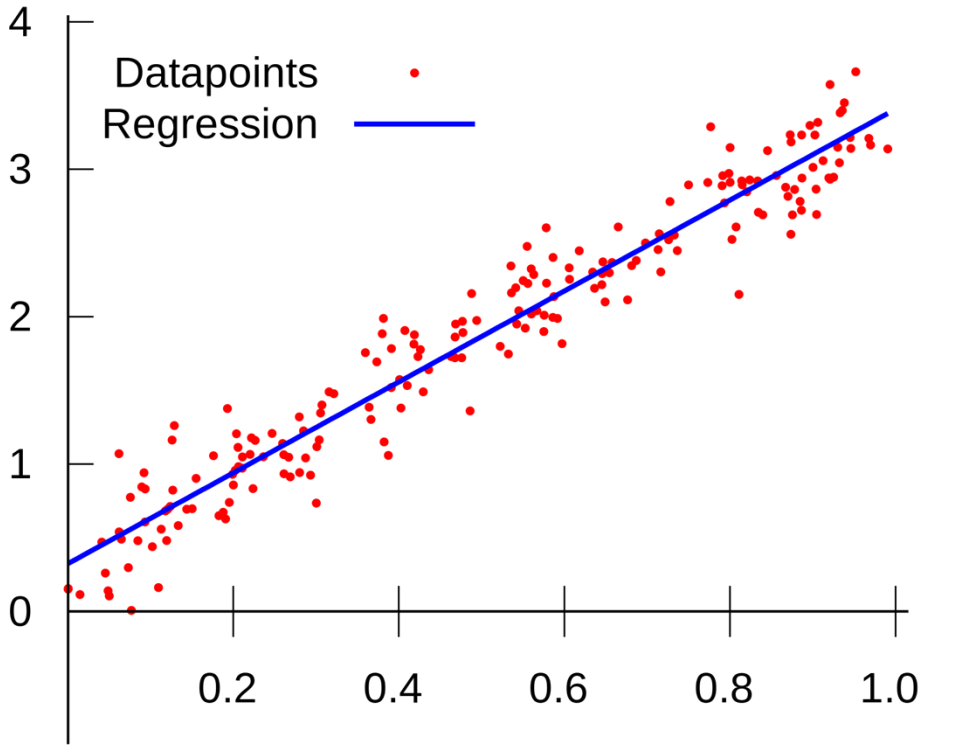

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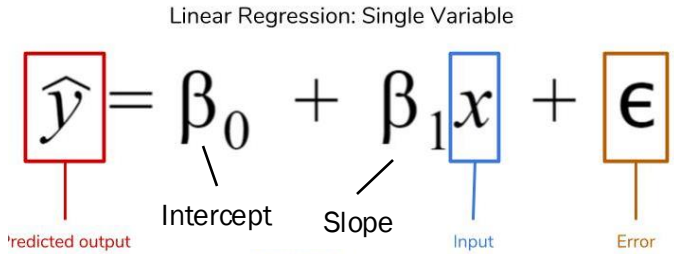

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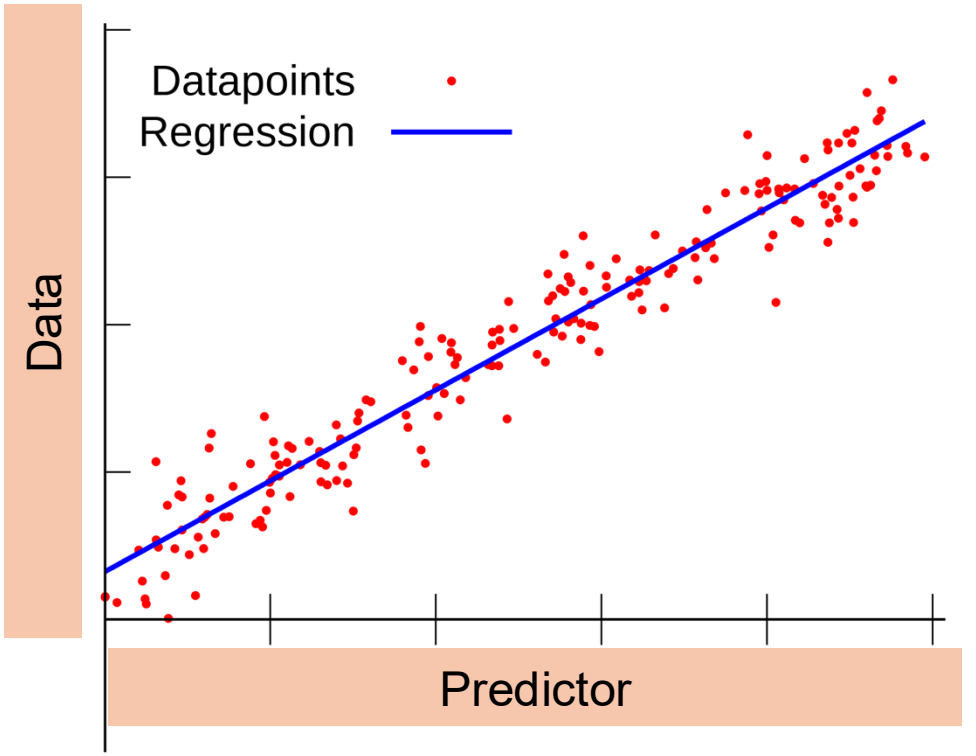

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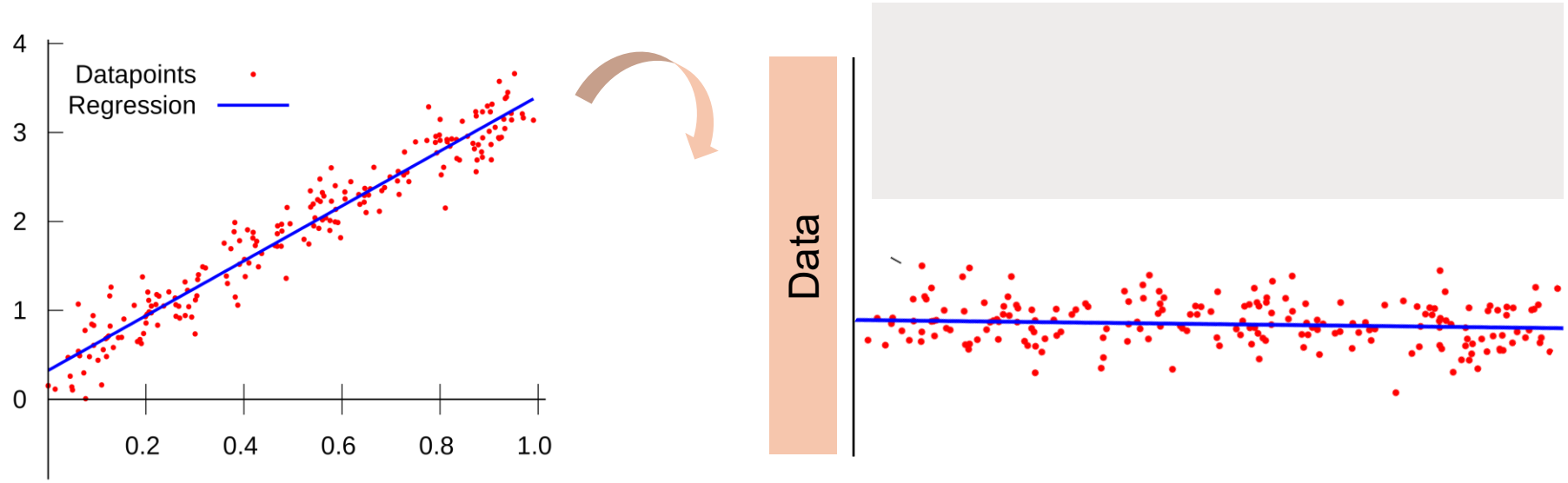
GLM. Generalized Linear Models

Regression is the usual approach for analysis of fMRI signals.



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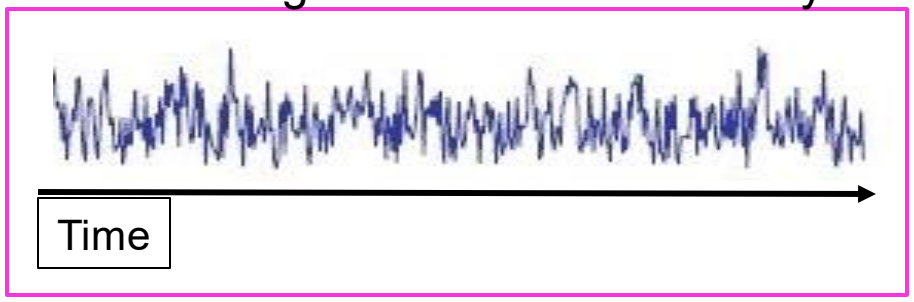
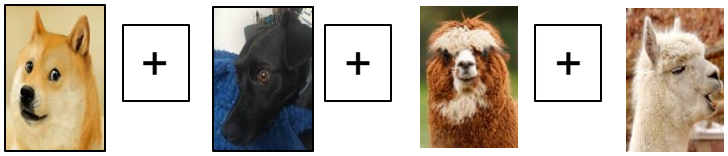


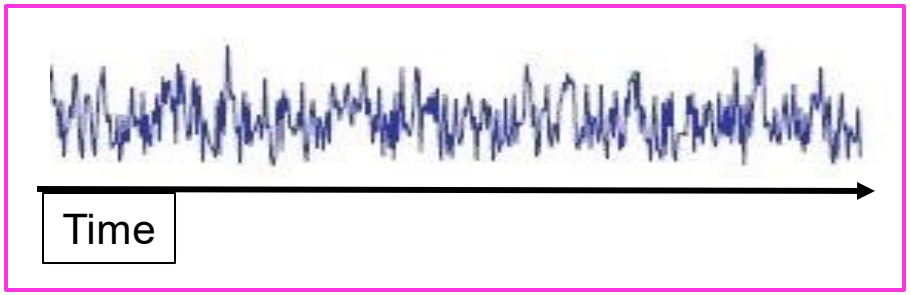
GLM

A practical example. Can we find voxels that respond to ANIMAL FACES?

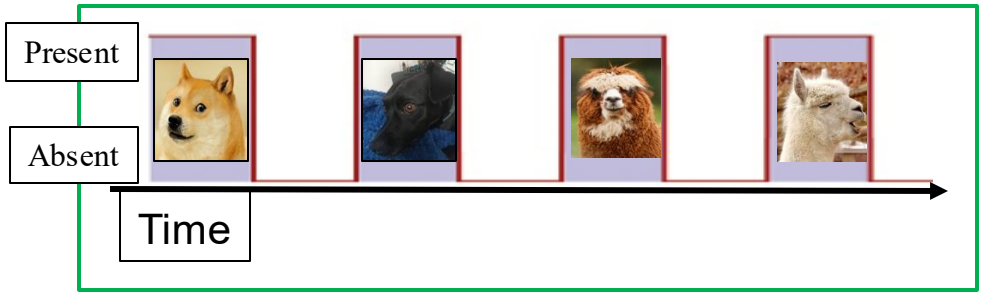
Task
(visual stim.)



Voxel
activity



Task
model



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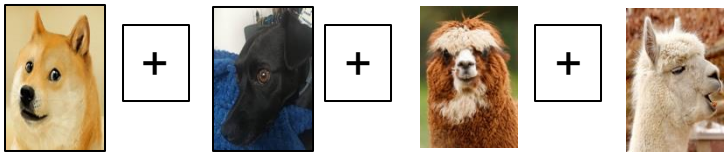

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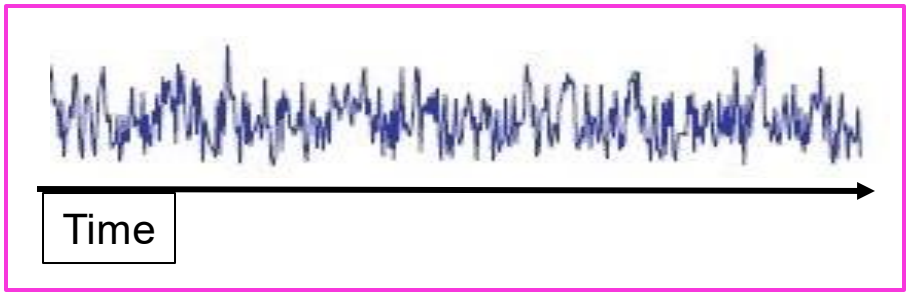

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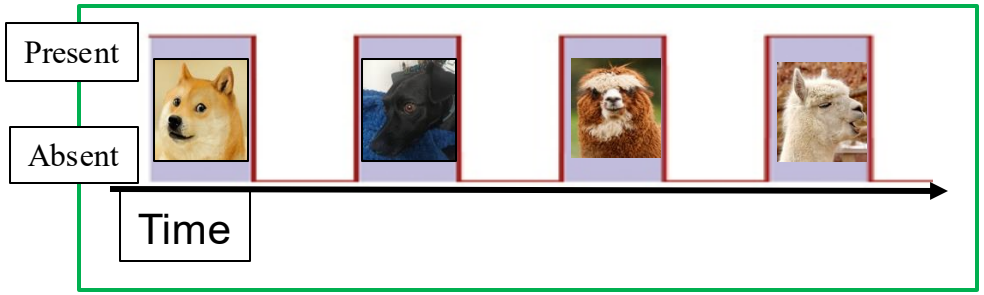

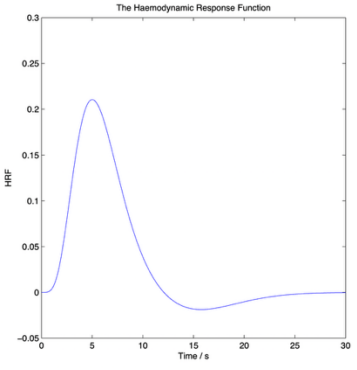

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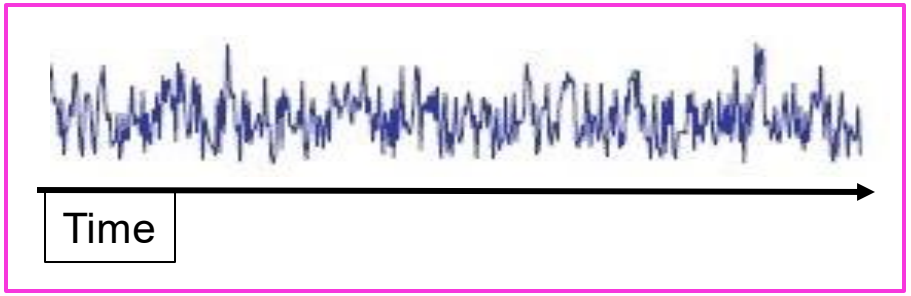
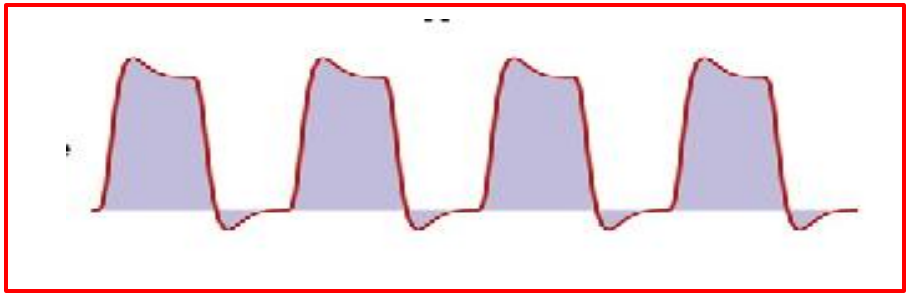
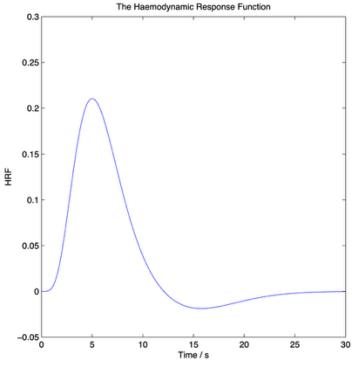


Task model

Response model





GLM

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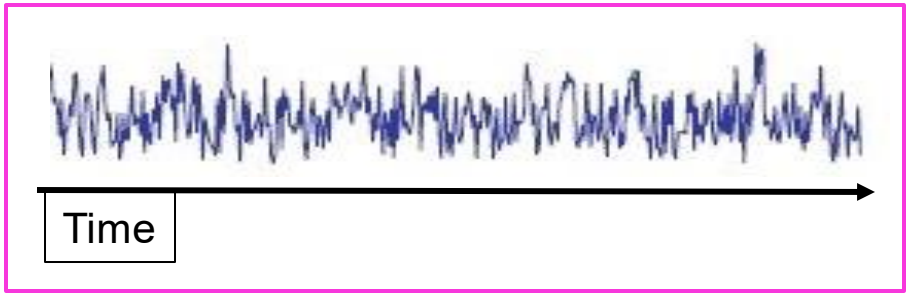
Voxel activity



Task model

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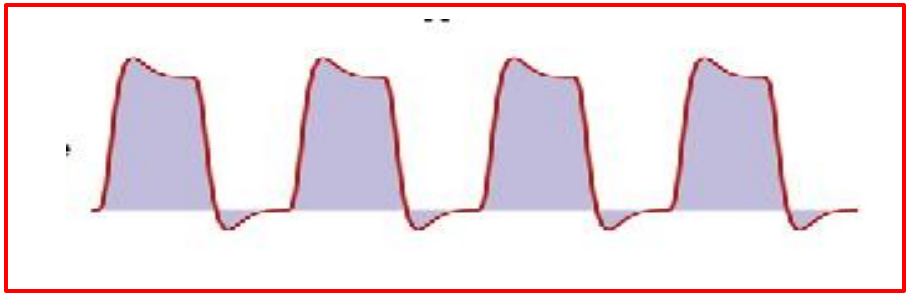
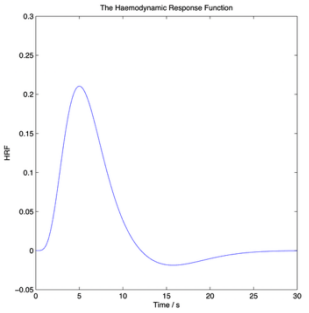


Now we can use regression to obtain an estimate (**beta**) of how much our response model explains our BOLD signal in our **voxel**.



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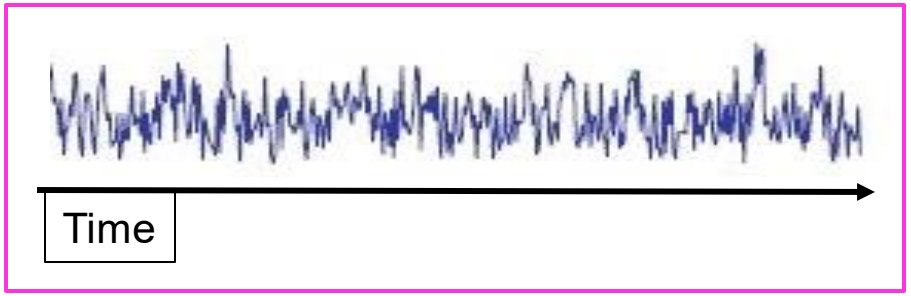

Task model

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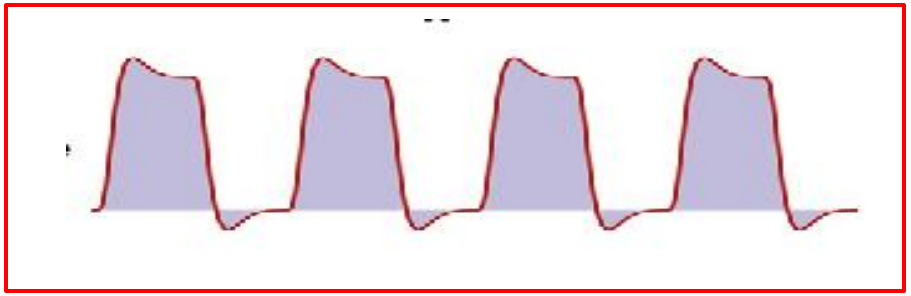
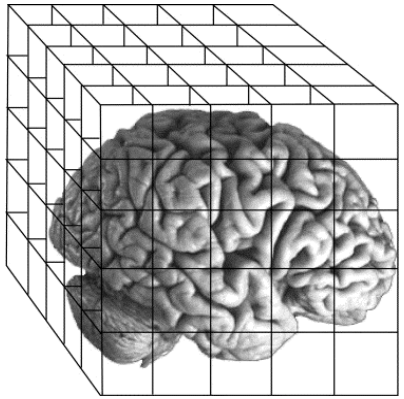
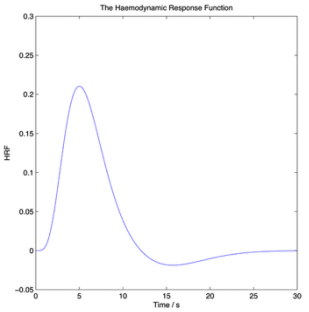


If run for every voxel, we will get one beta estimate per voxel, i.e., a beta map





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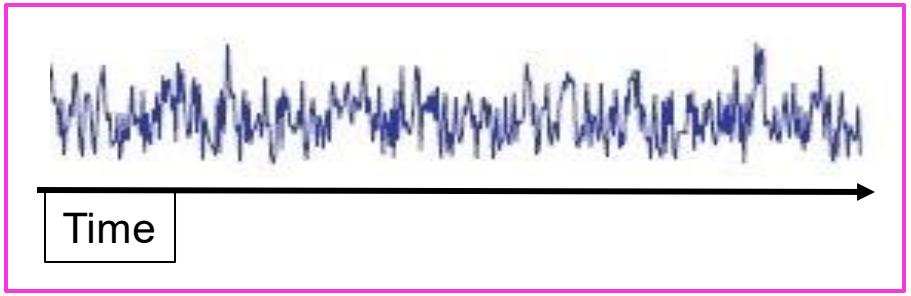

Task model

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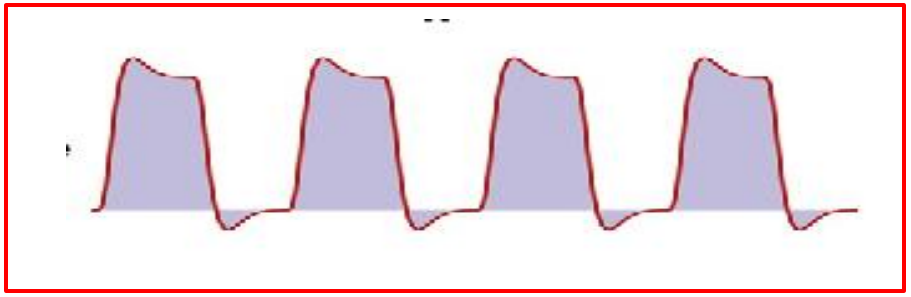
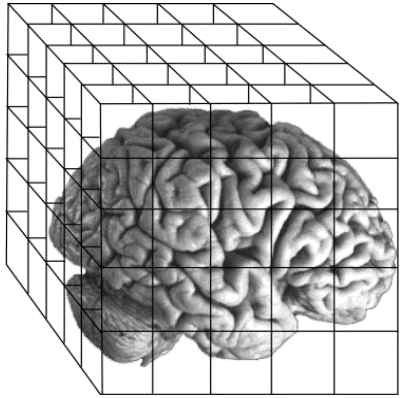
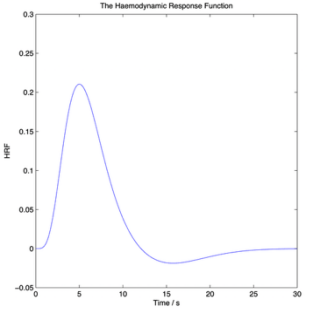


QUESTION: What would the value in each voxel of the beta map represent?

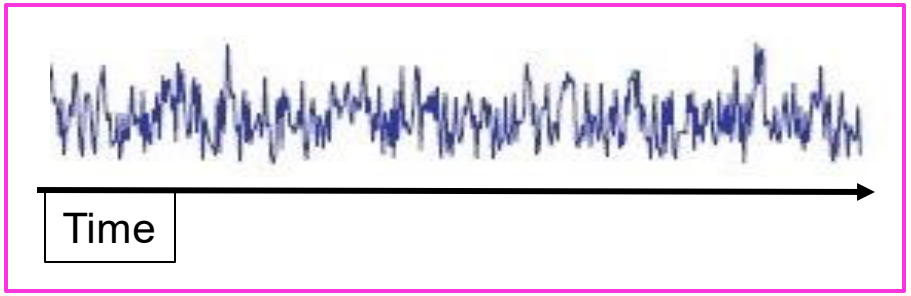




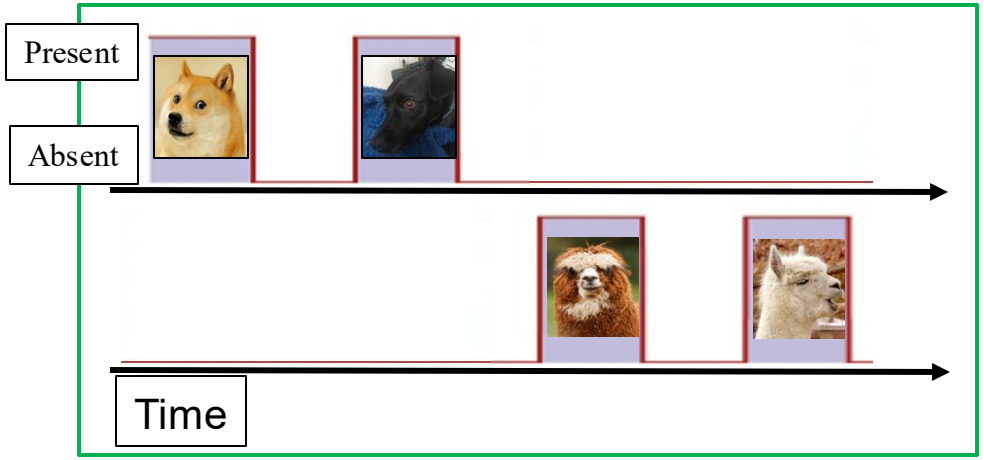
GLM

A practical example. Can we find voxels that distinguish to DOGS FACES from ALPACAS FACES?

Voxel activity



Task model



Regressor 1

Regressor 2

GLM

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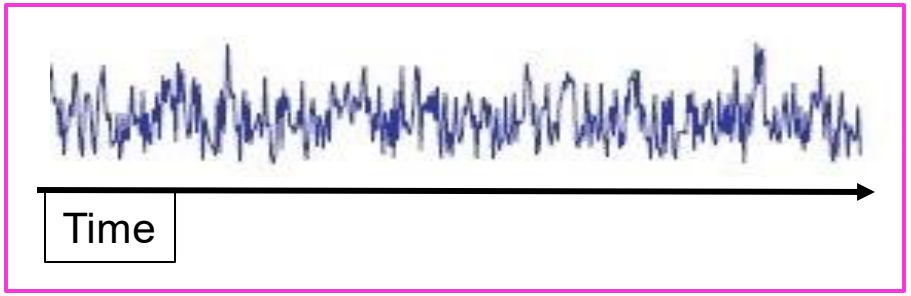

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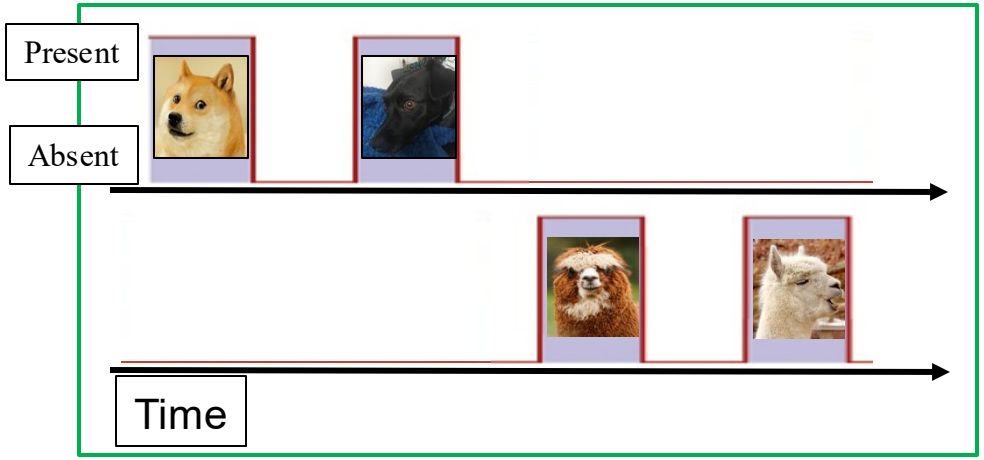

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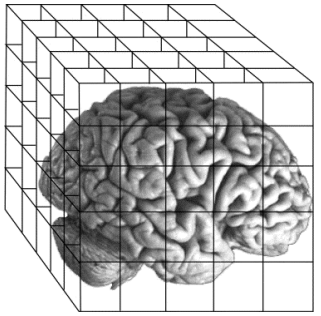
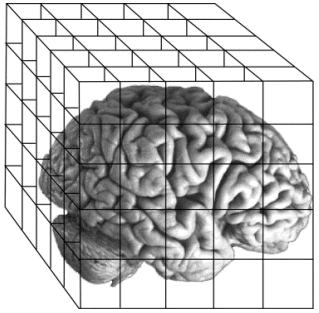


Regressor 2



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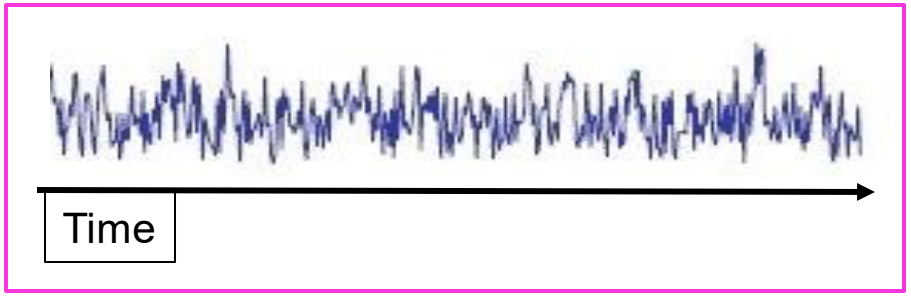

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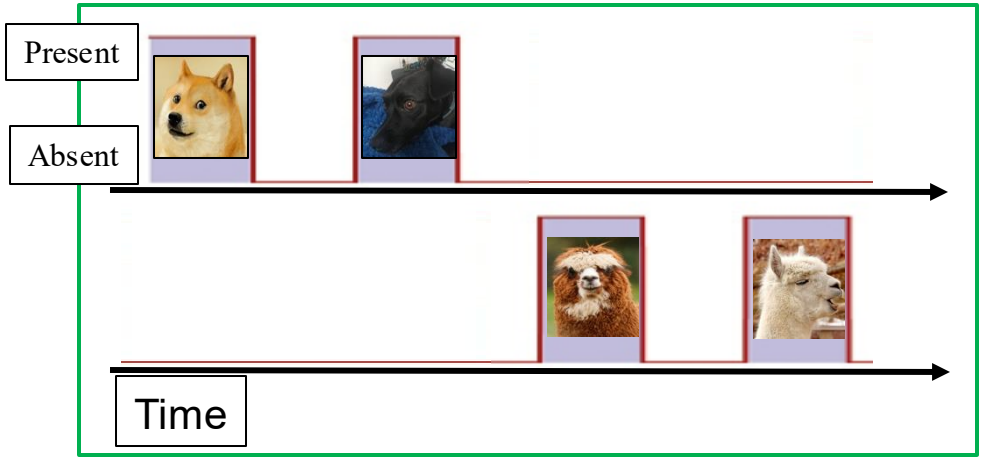

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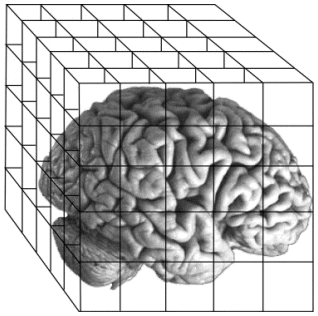
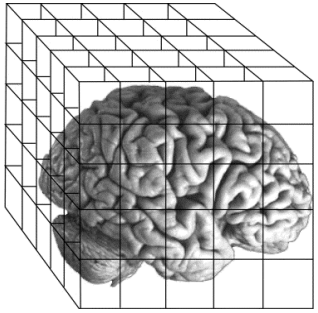


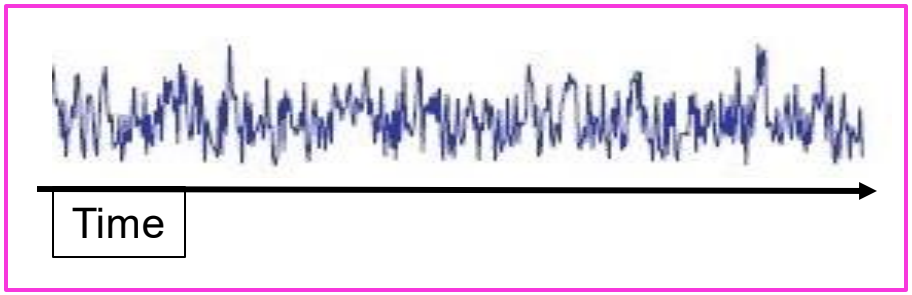
Regressor 2



GLM

Another practical example. Can we find voxels that distinguish each CHARACTER?

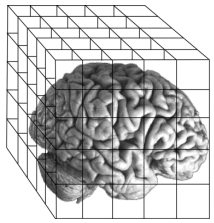
Voxel activity



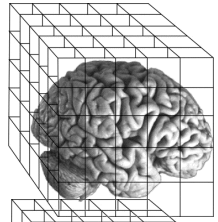
Task model

We can have a regressor and, therefore, a beta for **every** trial.

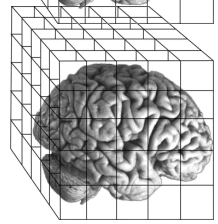
Beta1



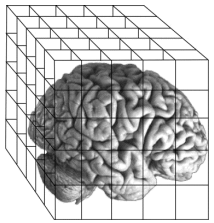
Beta2



Beta3



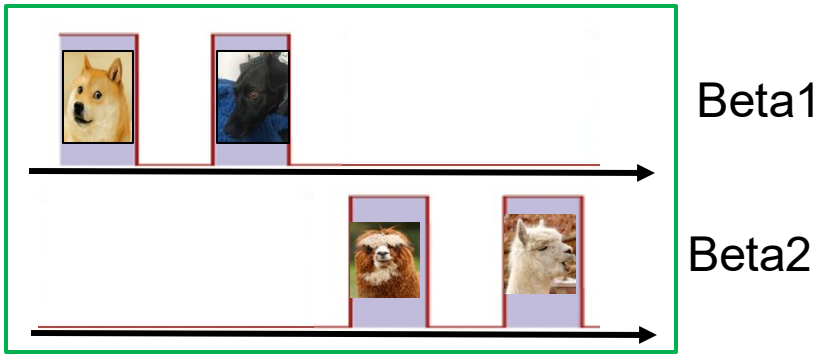
Beta4



GLM

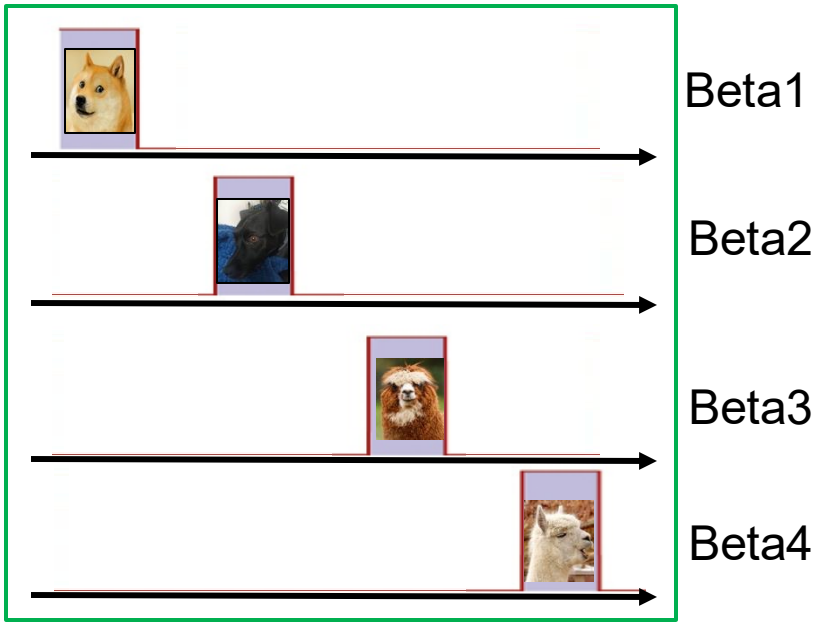
Different GLM (task) models. LSU is widely used for **univariate** analysis while LSA (or more complex models) are often used for **multivariate** analysis.

Least-Squares Unitary (LSU)



"One beta per condition is estimated"

Least-Squares All (LSA)



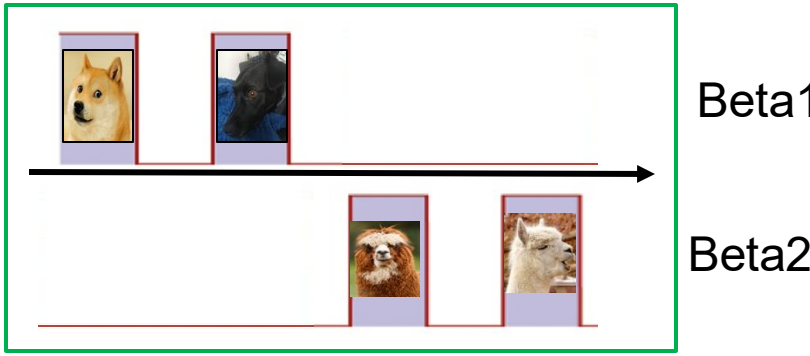
"One beta per trials is estimated"

There are also more complex models: Least-Squares Separate (LSS), LS-1, LS-2...

GLM

Interim recap.

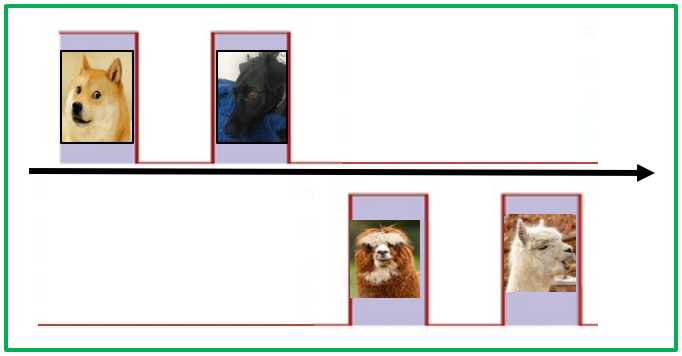
- fMRI sequences measure BOLD signal.
- Regression is the usual approach to analyze BOLD signal change.
- We use the condition (or stimulus) time course to model BOLD time course in each voxel.
- Regression will give us beta estimates for each voxel.
- The number (and meaning) of each beta estimates depends on the task model that we use.



GLM

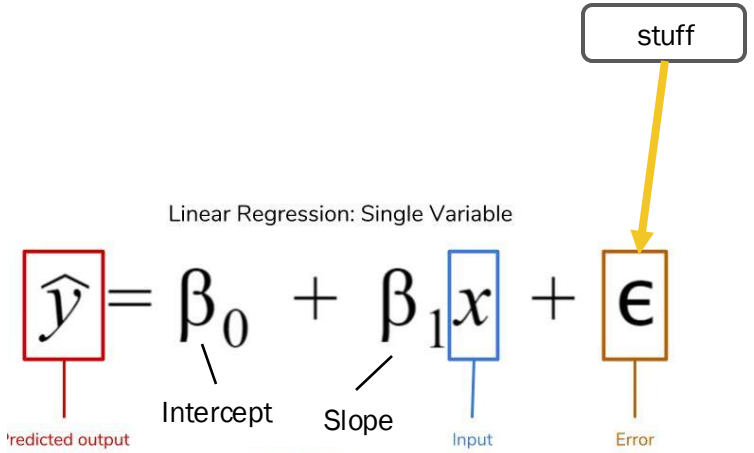
Back to theory.

We have seen that (task) regressors can be used to check if the time course of our variables correlates with signal change in the brain.



But the BOLD signal can also change with *stuff* other than our variables.

We do not want our results to be driven by (confounded with) other *stuff*.



GLM

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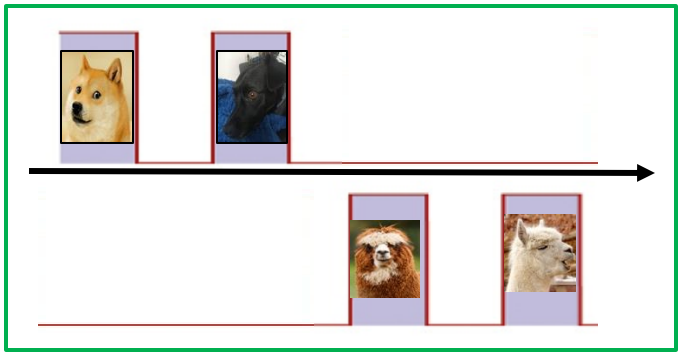
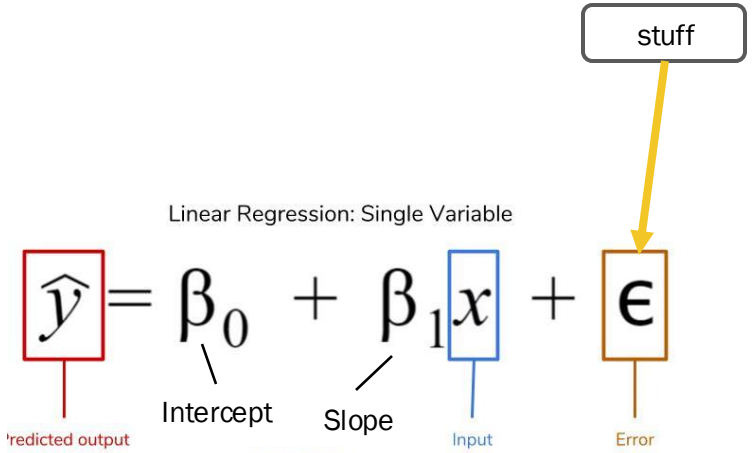


But the BOLD signal can also change with *stuff* other than our variables.

Enter: Nuisance/confound regressors.

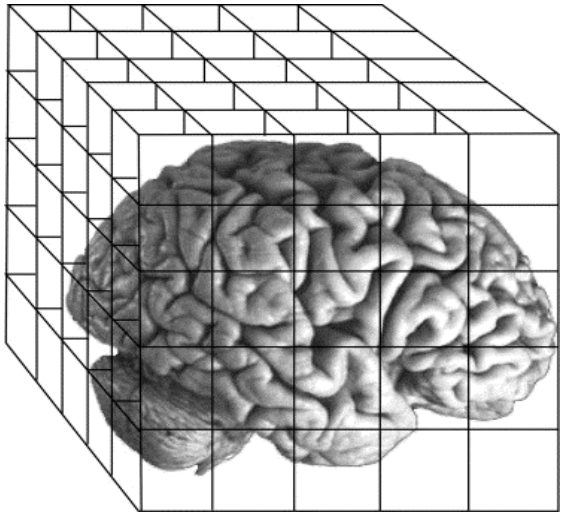


GLM

Nuisance regressors.

What can affect signal *change* in a given voxel?

- Head motion.
- Breathing.
- Heart rate.
- Scanner drift.
- …



GLM

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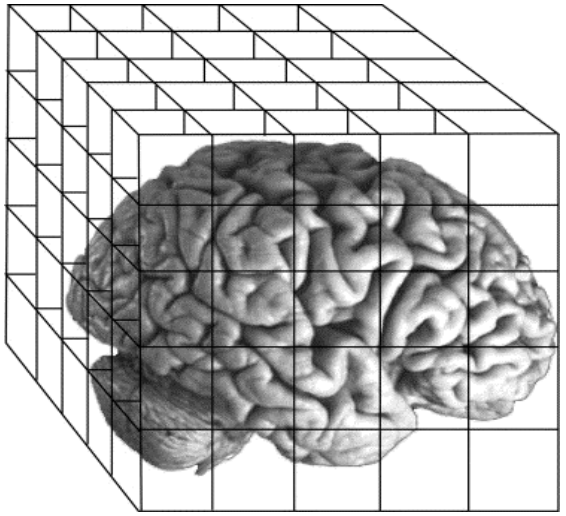


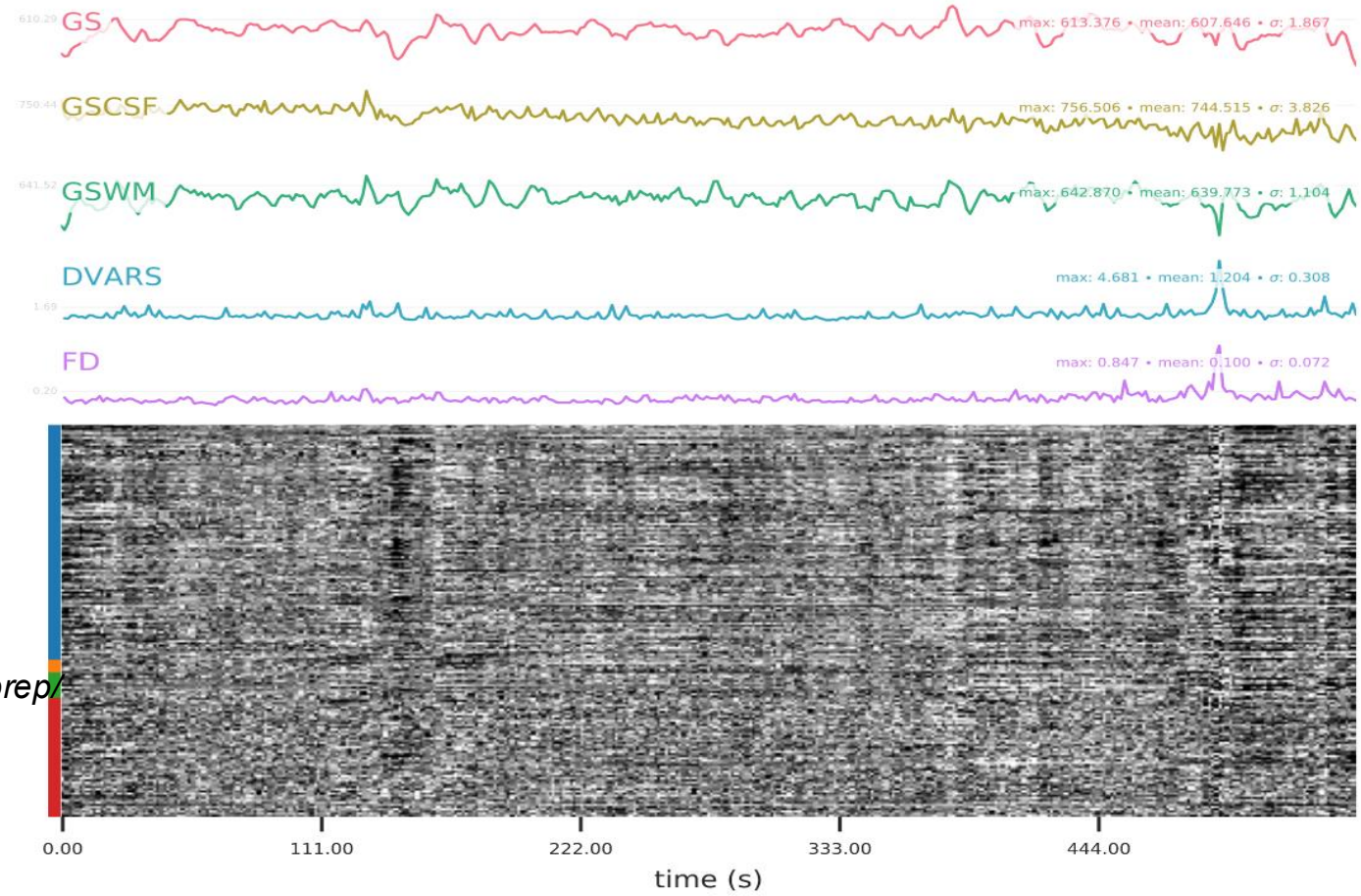
What should nuisance regressor look like?

One **value** per each **datapoint** in our data.

GLM

Nuisance regressors.

Some measures that we get *for free...*

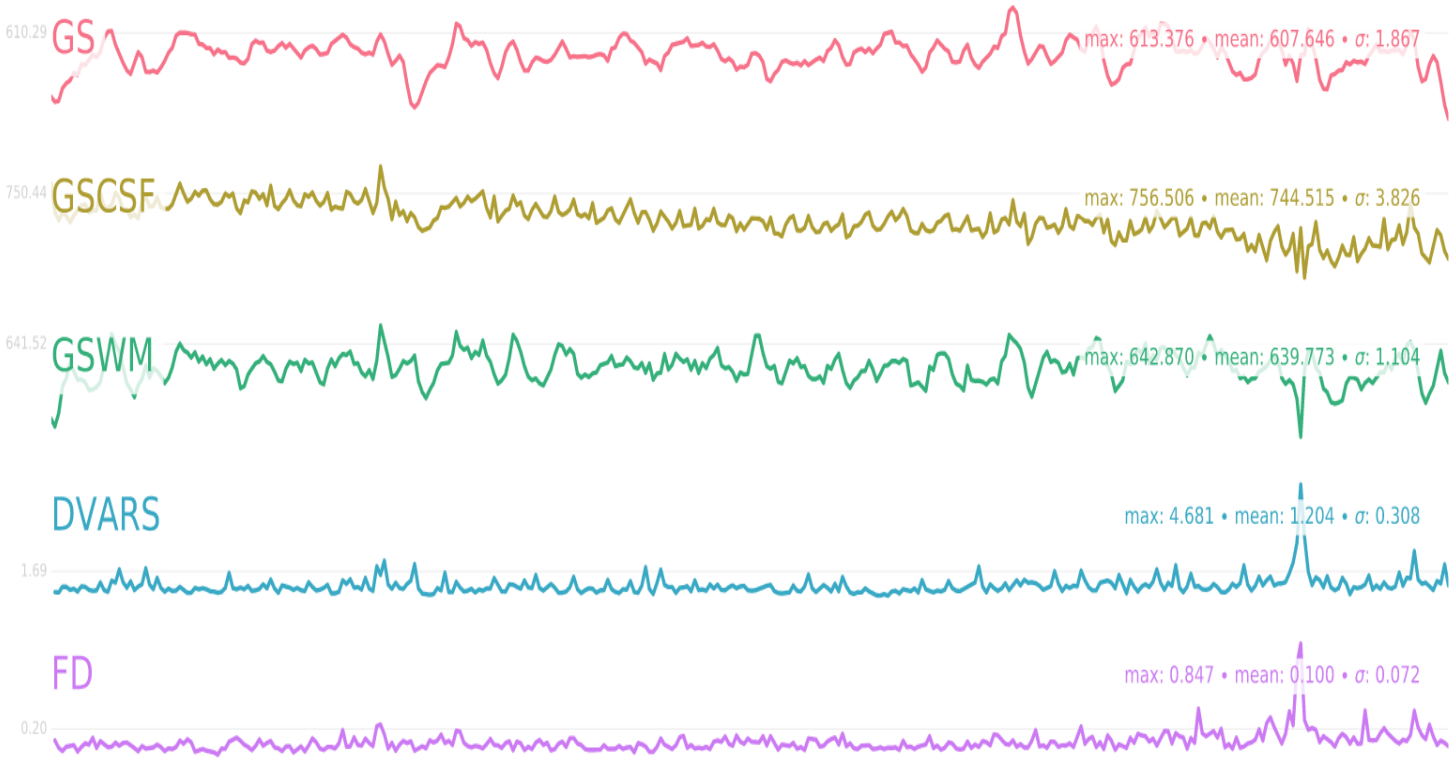


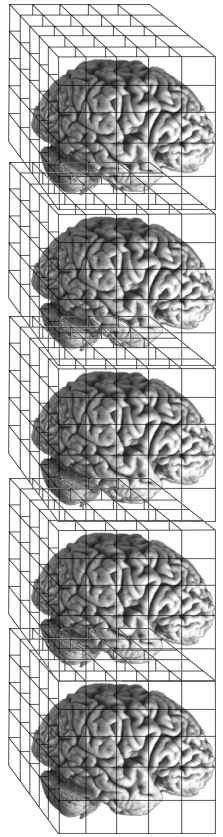
from data_fmri-analysis_intro/process-specific/preproc_data/fmriprep/sub-009.html

GLM

Nuisance regressors.

If we can identify the time course of each factor that we believe can influence our signal change, we can add them in our model.



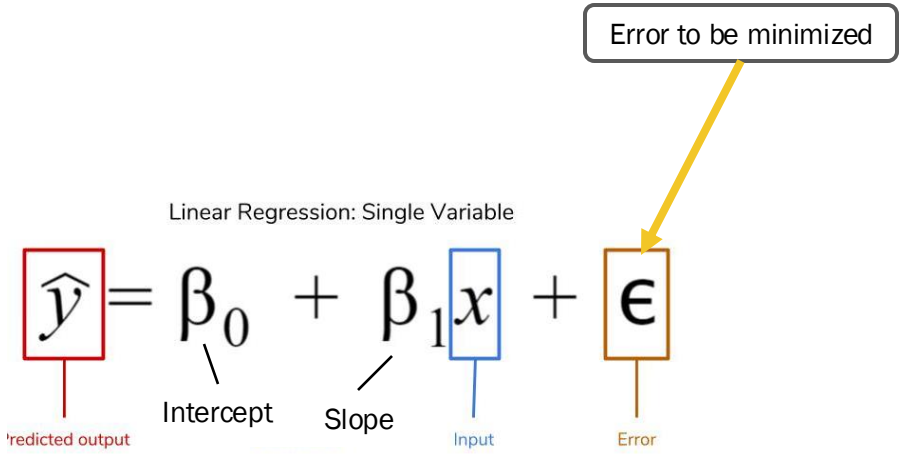


GLM

Nuisance regressors.

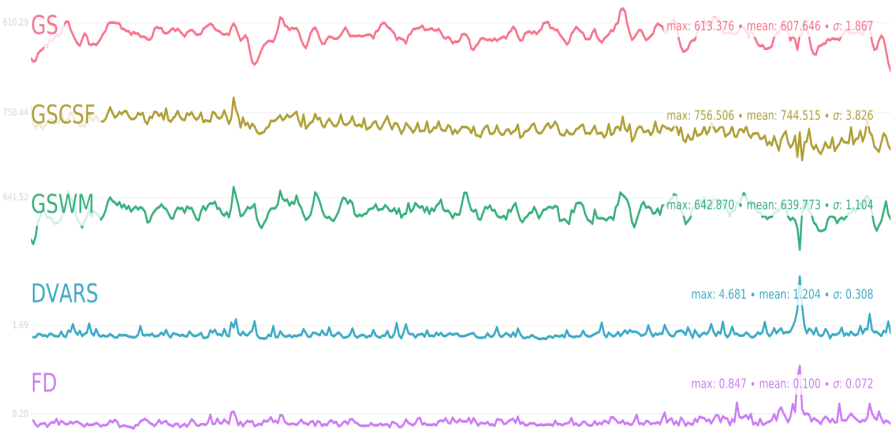
Betas estimated from nuisance regressors are usually not of interest for our analysis, but they can account for an important portion of the variance in our signal.

It is important to know *how many* nuisance regressors we will include in our model because that will change the number of betas we get out of the regression!

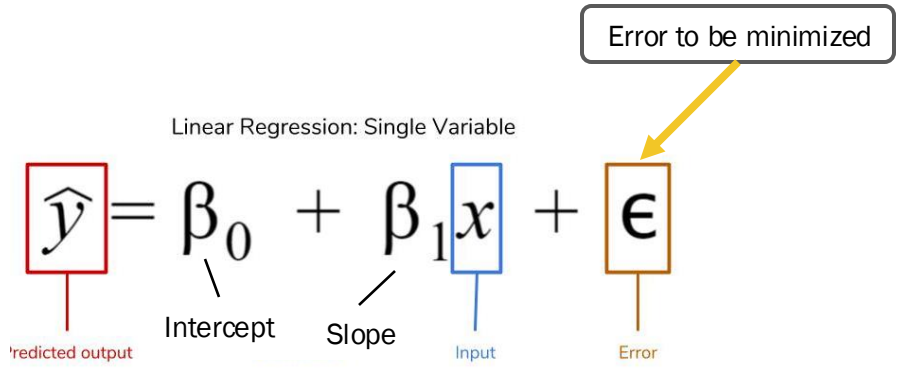


GLM

Nuisance regressors.

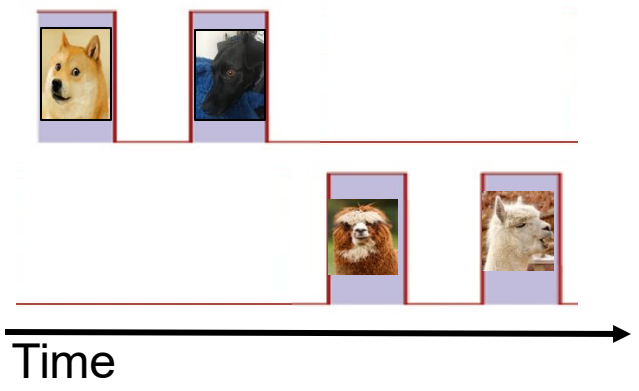


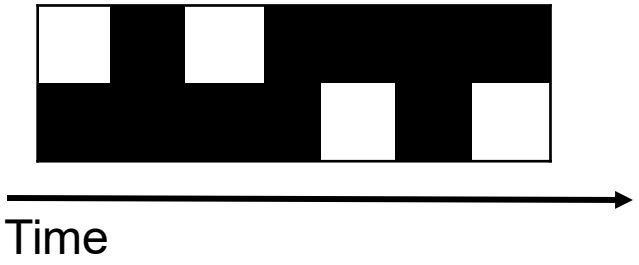
QUESTION: Should we convolve our nuisance regressors with an HRF?



GLM

One last tip.

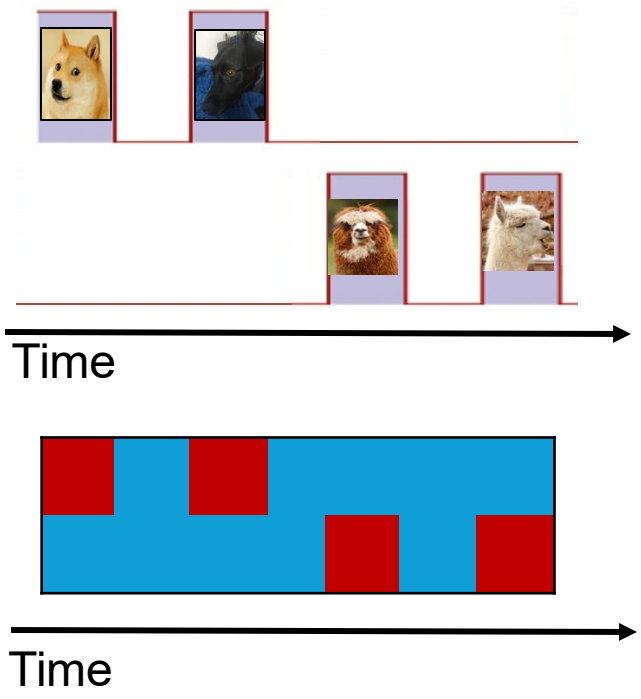




QUESTION:
Can you relate these two figures?

GLM

One last tip.

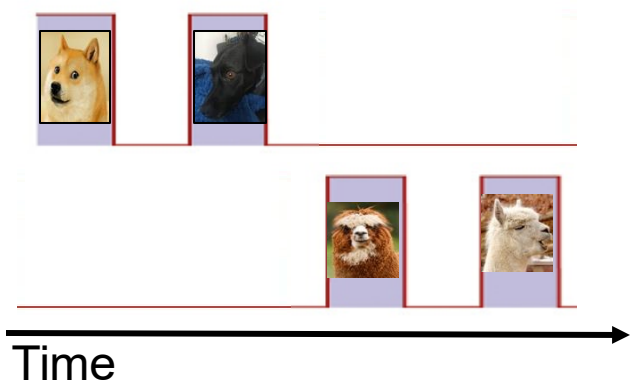


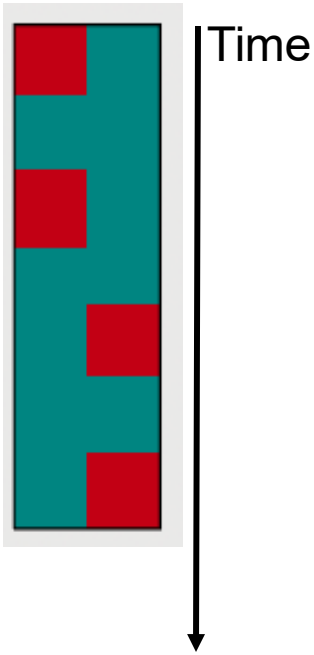
QUESTION:
Can you still do it?

GLM

One last tip.

QUESTION:
What about now?





GLM

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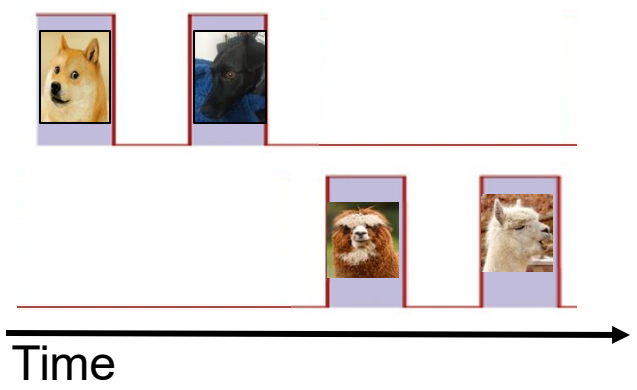

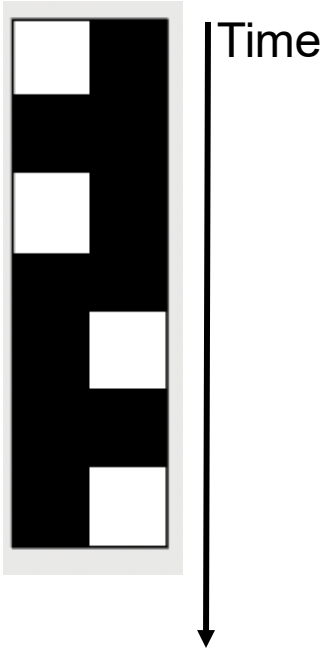

GLM

One last tip.

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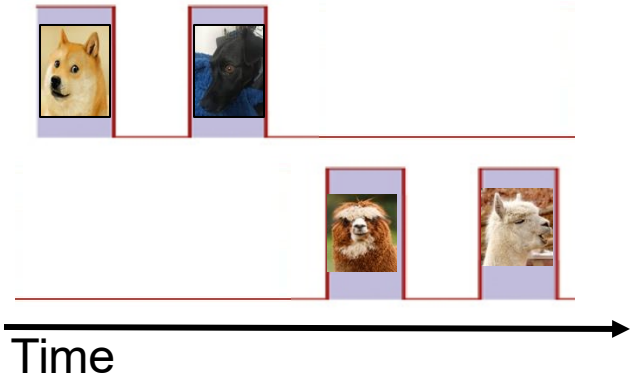

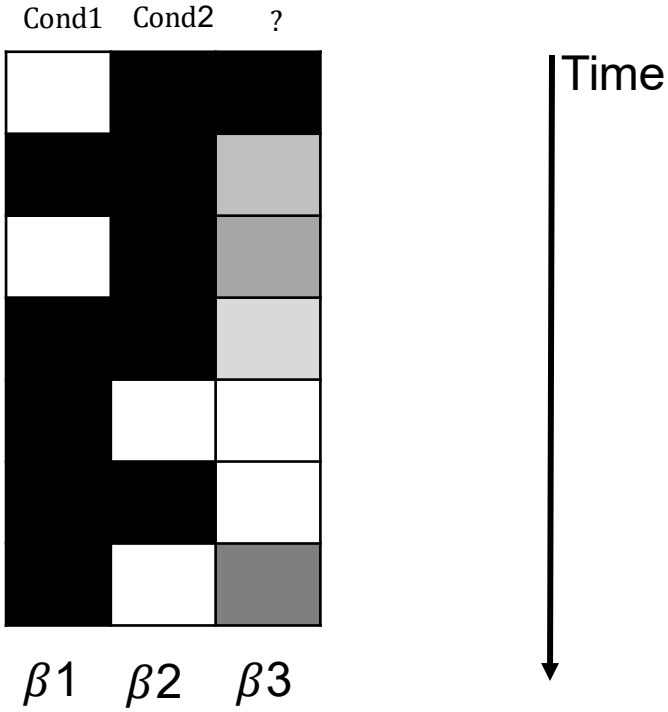

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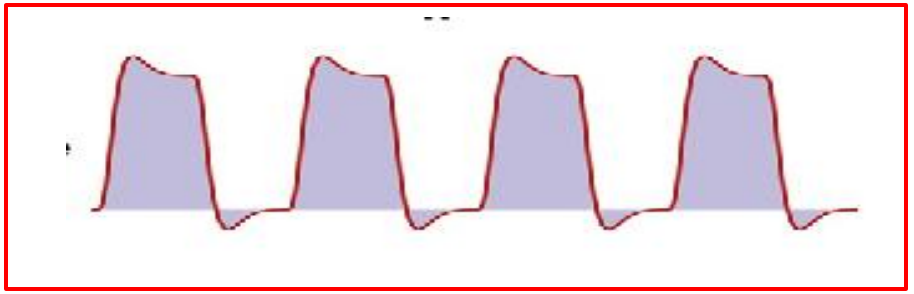

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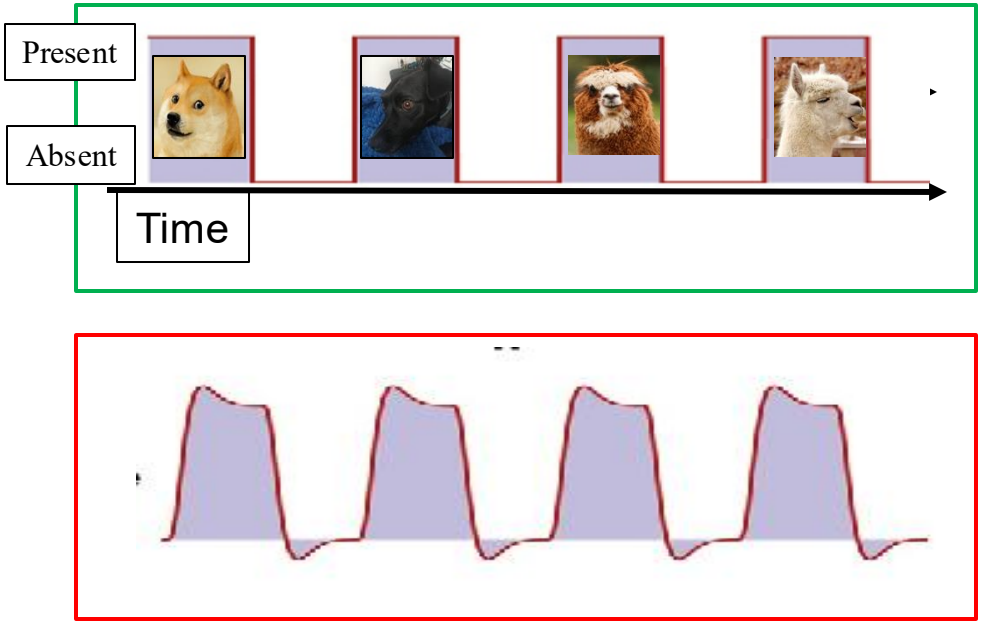
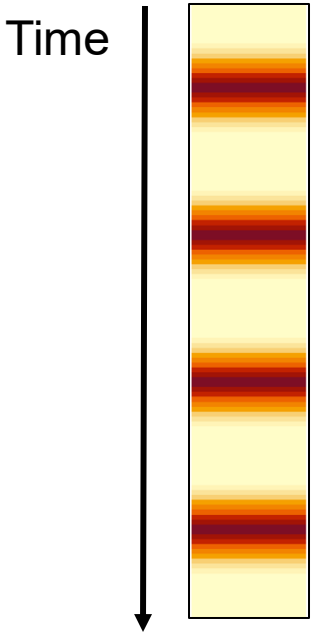
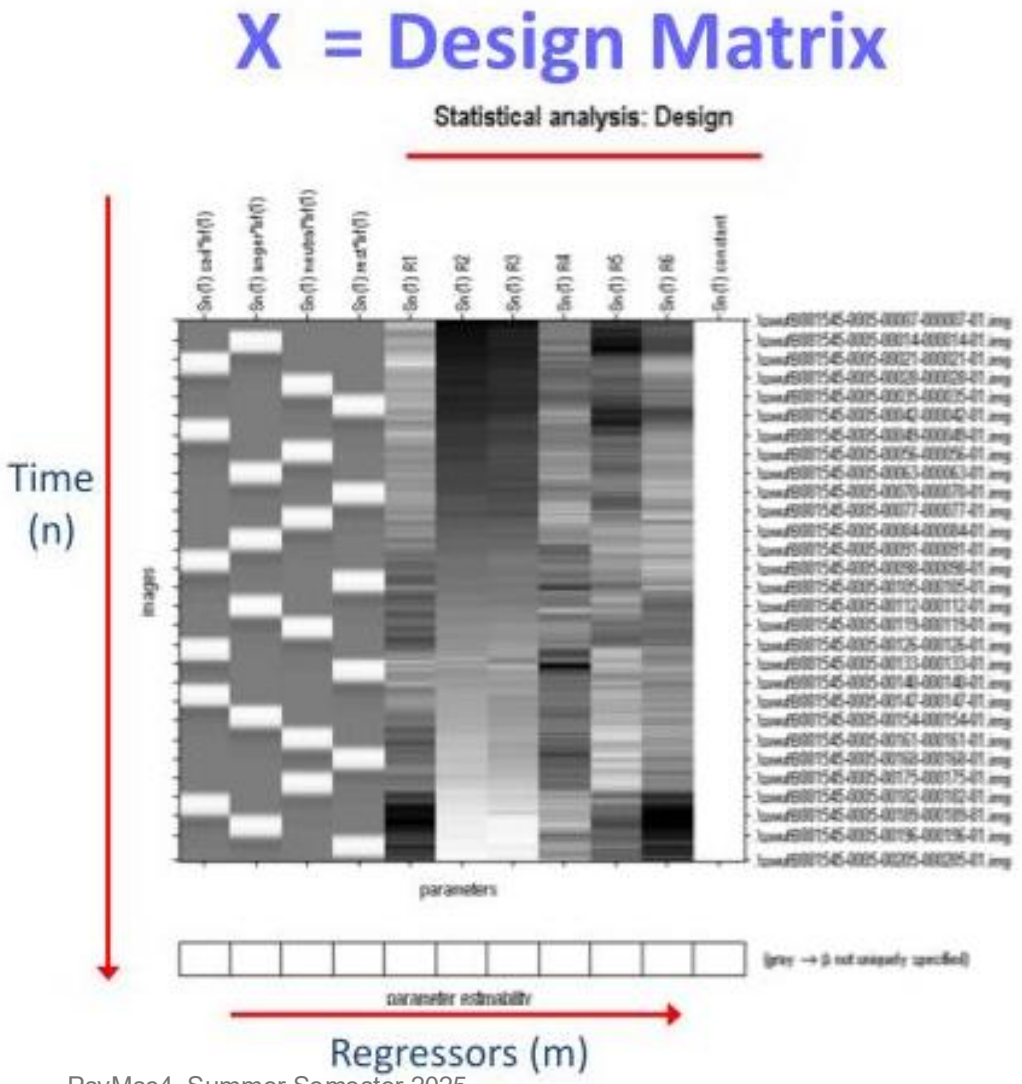




GLM

One last tip.

QUESTION:
Can you understand
This design matrix?



GLM

General recap.

- fMRI sequences measure BOLD signal.
- Regression is the usual approach to analyze BOLD signal change.
- We use the condition (or stimulus) time course to model BOLD time course in each voxel.
- Regression will give us beta estimates for each voxel.
- The number (and meaning) of each beta estimates depends on the task model that we use.
- Nuisance regressors can help “cleaning” our signal.
- Estimations on head motions are the most common nuisance regressors used.