Introduction into fMRI analysis. PsyMsc4 (Goethe 2021).

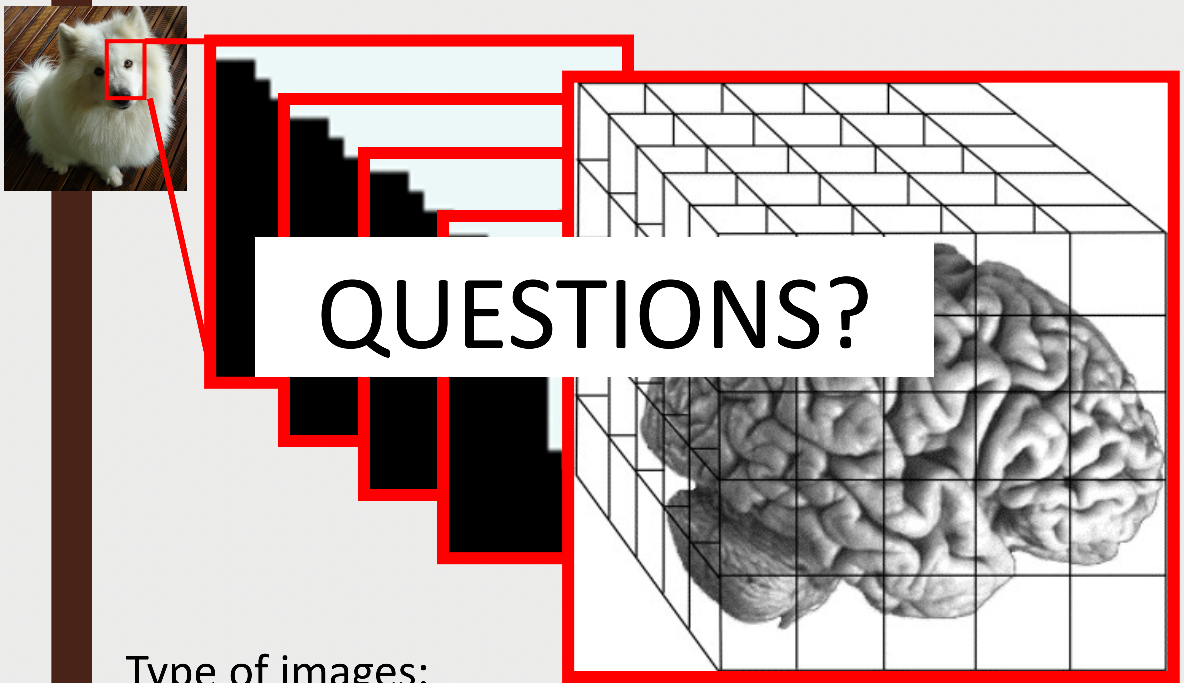
Session-2

Javier Ortiz-Tudela and Francesco Pupillo

LISCO

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

Recap of last week



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.

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.

Preprocessing:

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

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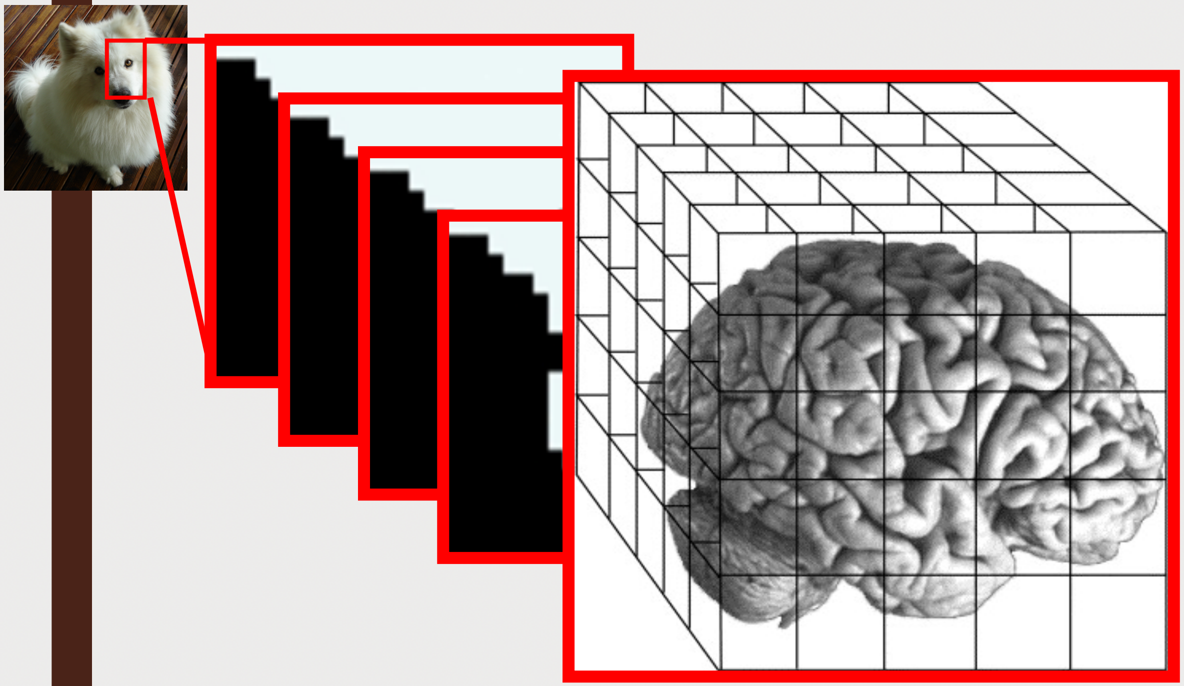
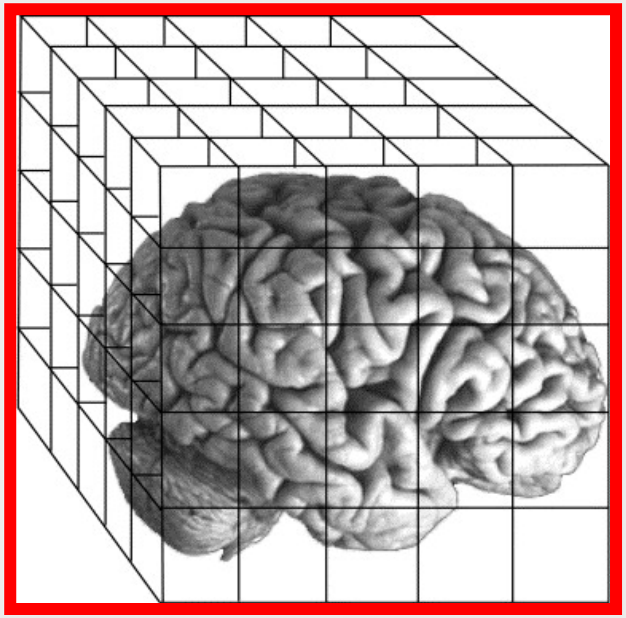
Recap of last week



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.

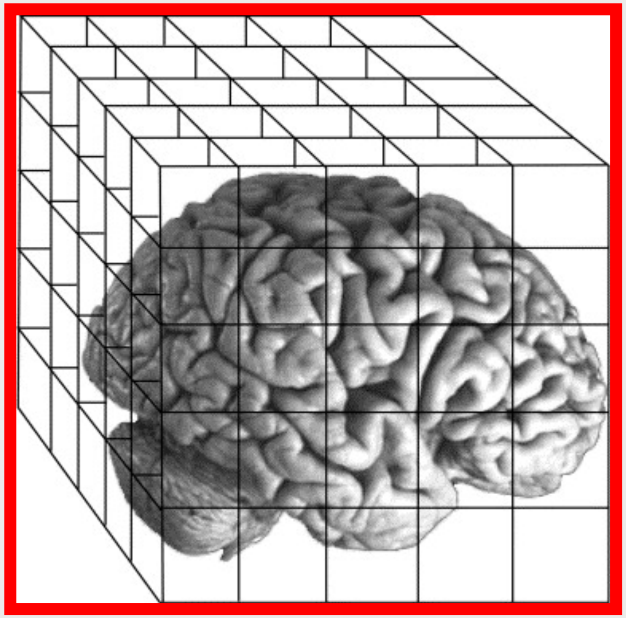
Functional MRI. BOLD signal.



Functional images are used to study brain activity.

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

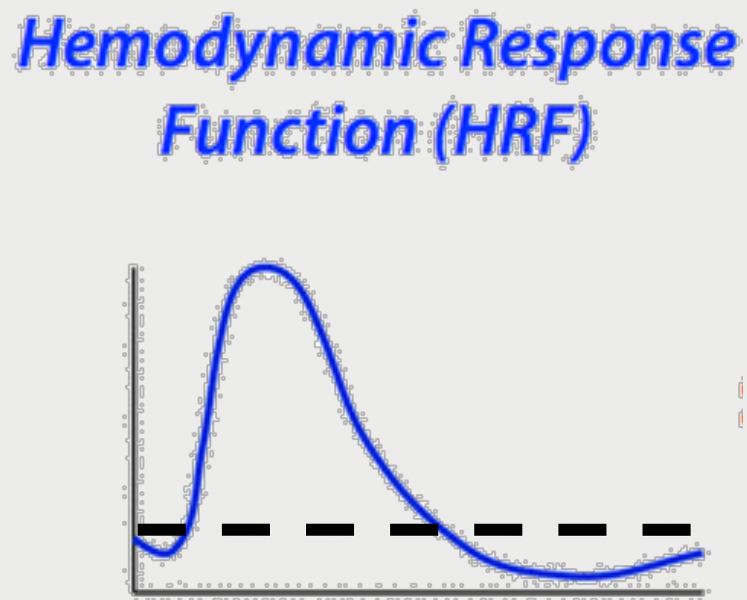
Functional MRI. BOLD signal.



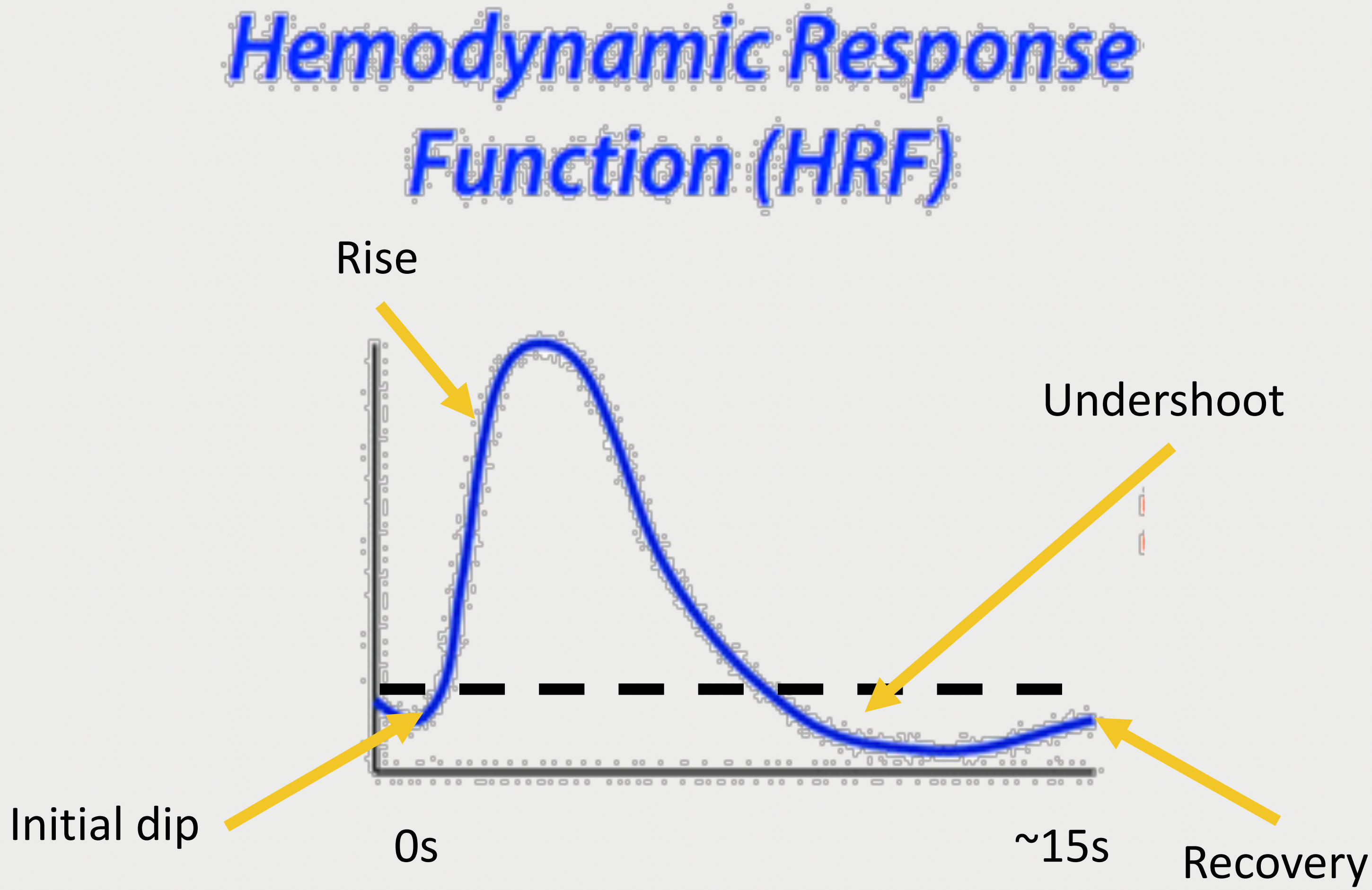
Functional images are used to study brain activity.

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?

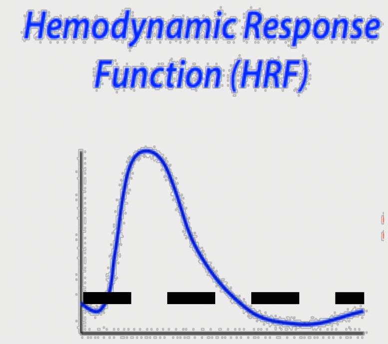


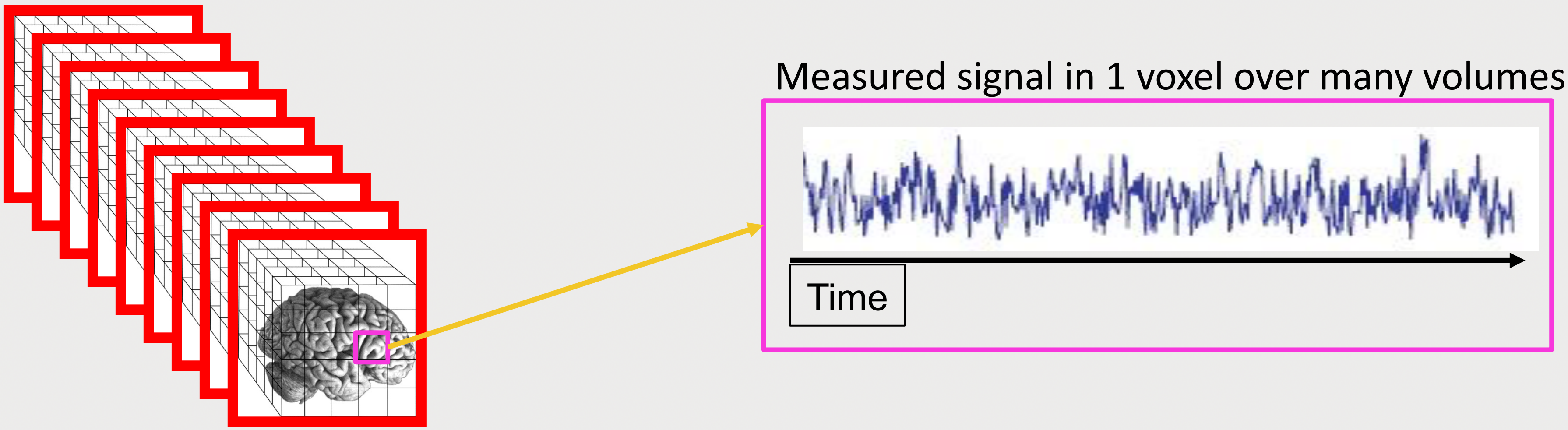
Functional MRI. BOLD signal.



Functional MRI. BOLD signal.

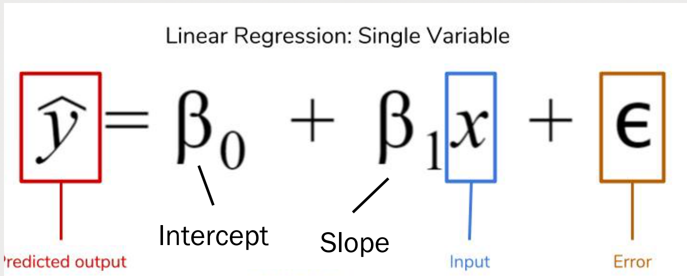
This is the 'ideal' response to stimulation but, of course, the measured signal is noisier.

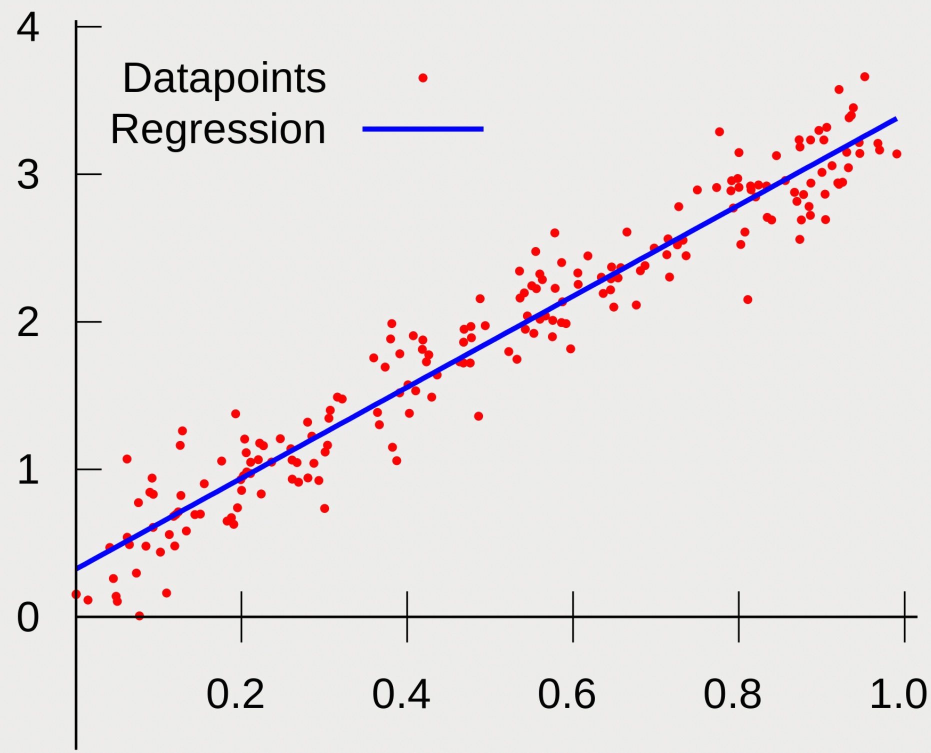




GLM. Generalized Linear Models

If you remember your stats class…





from Wikipedia

GLM. Generalized Linear Models

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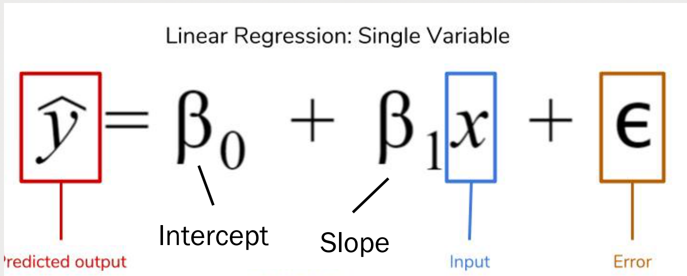
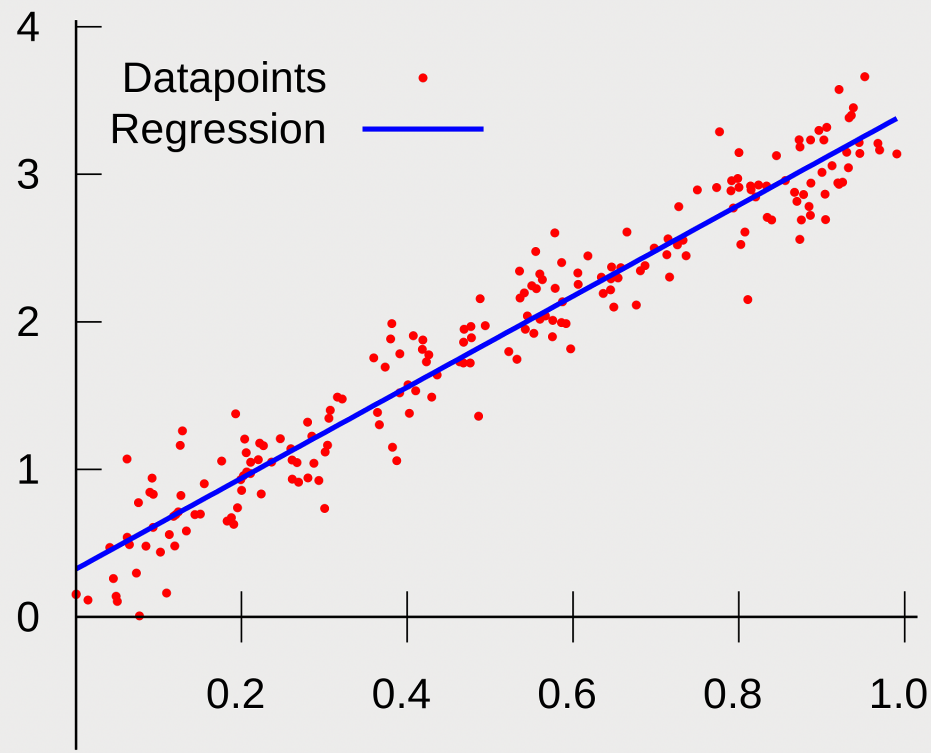


QUESTION: What does the beta value represent?

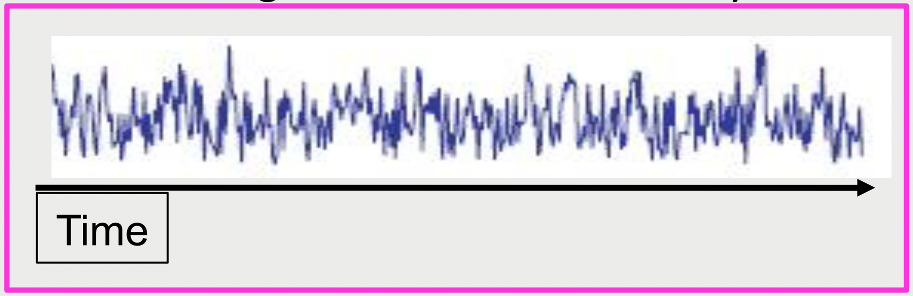


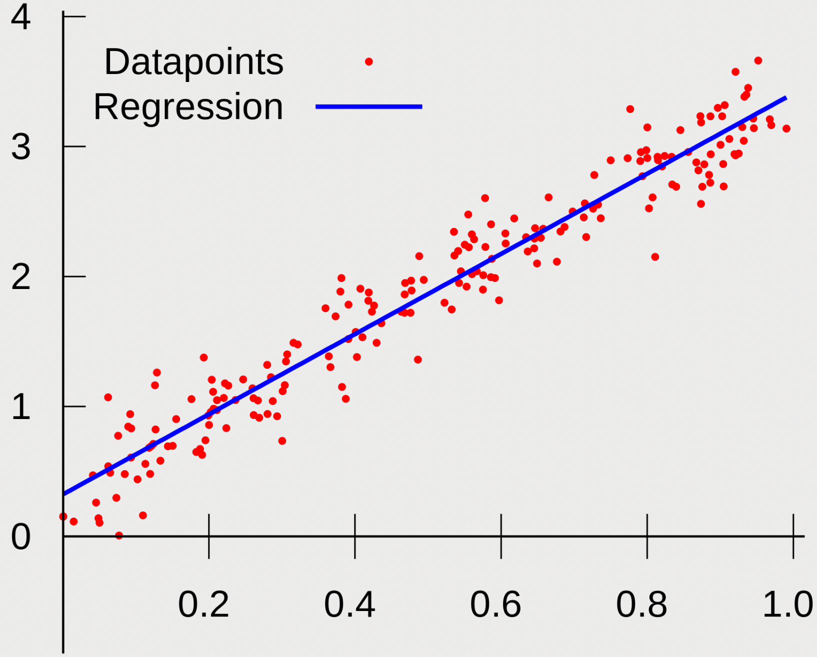
from Wikipedia

GLM. Generalized Linear Models

Regression is the usual approach for analysis of fMRI signals.

Measured signal in 1 voxel over many volumes

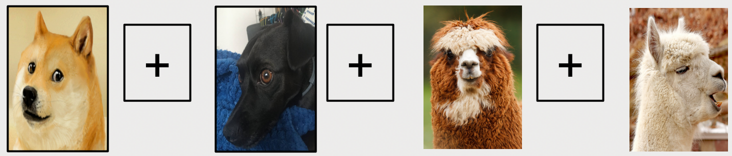




GLM

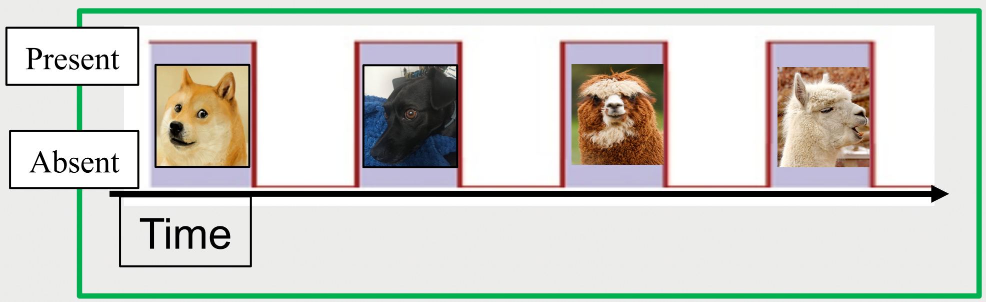
A practical example. Can we find voxels that respond to ANIMAL FACES?

Task
(visual stim.)



Voxel
activity

Task
model



GLM

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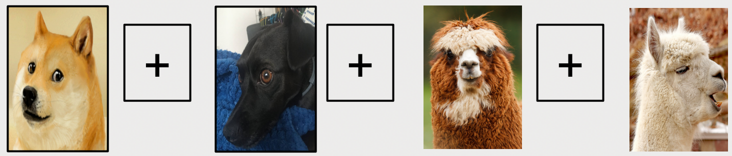
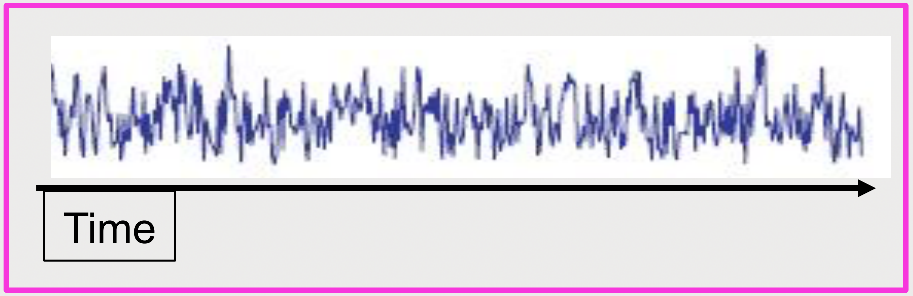
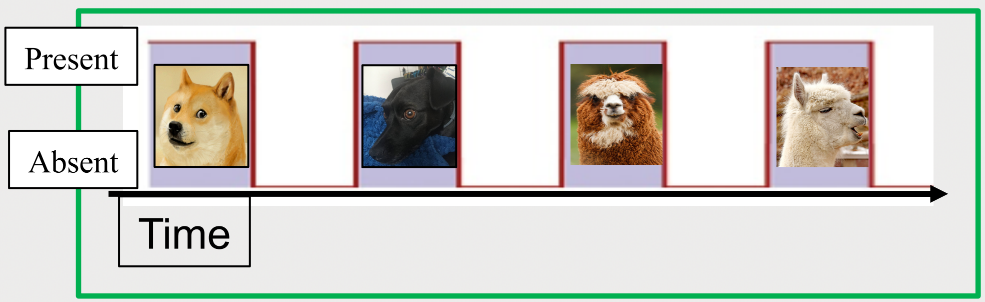


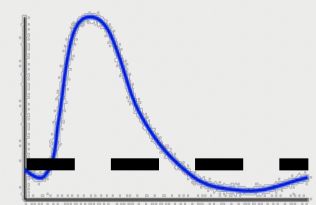
Voxel
activity



Task
model



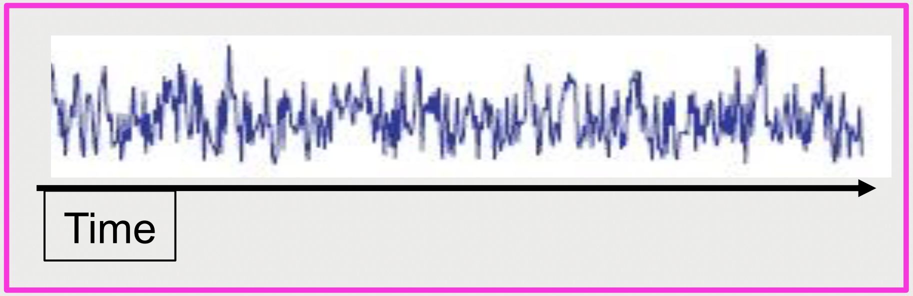
Hemodynamic Response
Function (HRF)



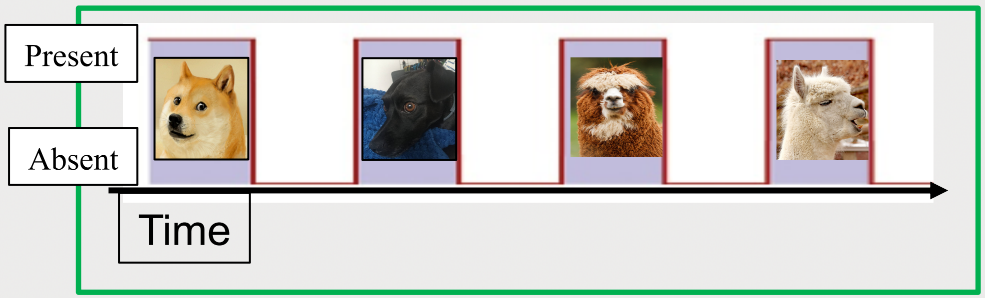
GLM

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

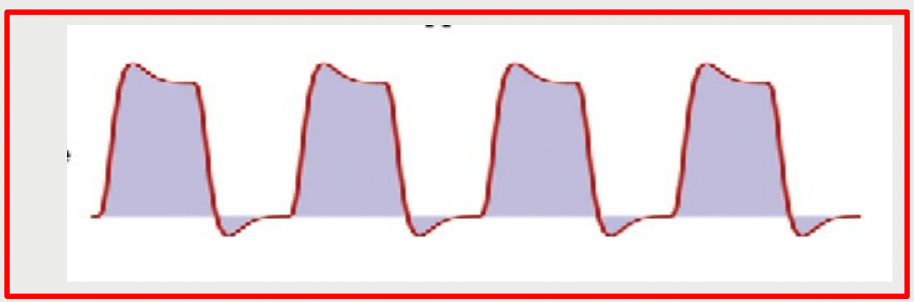
Voxel activity



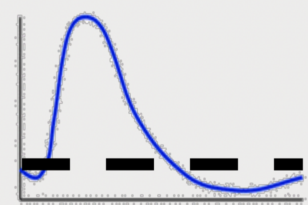
Task model



Response model



Hemodynamic Response Function (HRF)



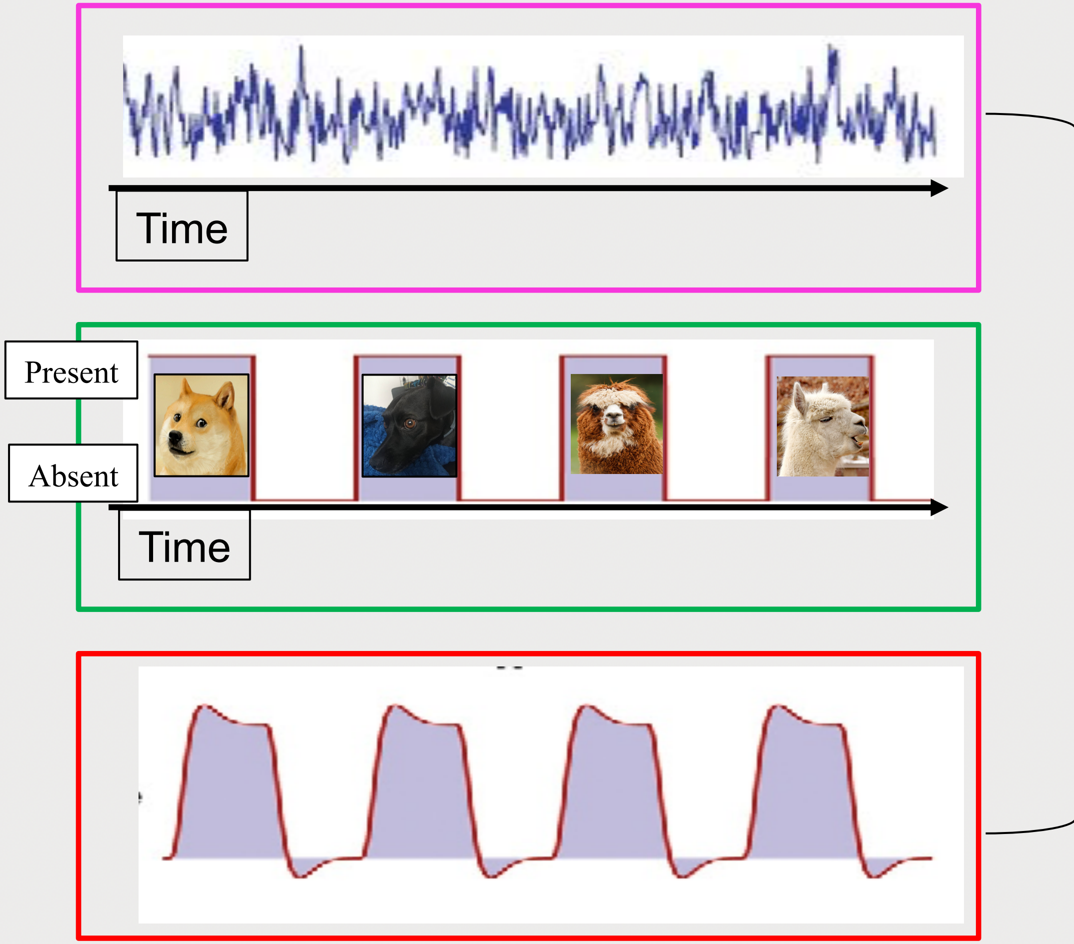
GLM

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

Voxel activity

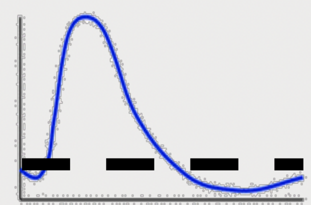
Task model

Response model



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

Hemodynamic Response Function (HRF)



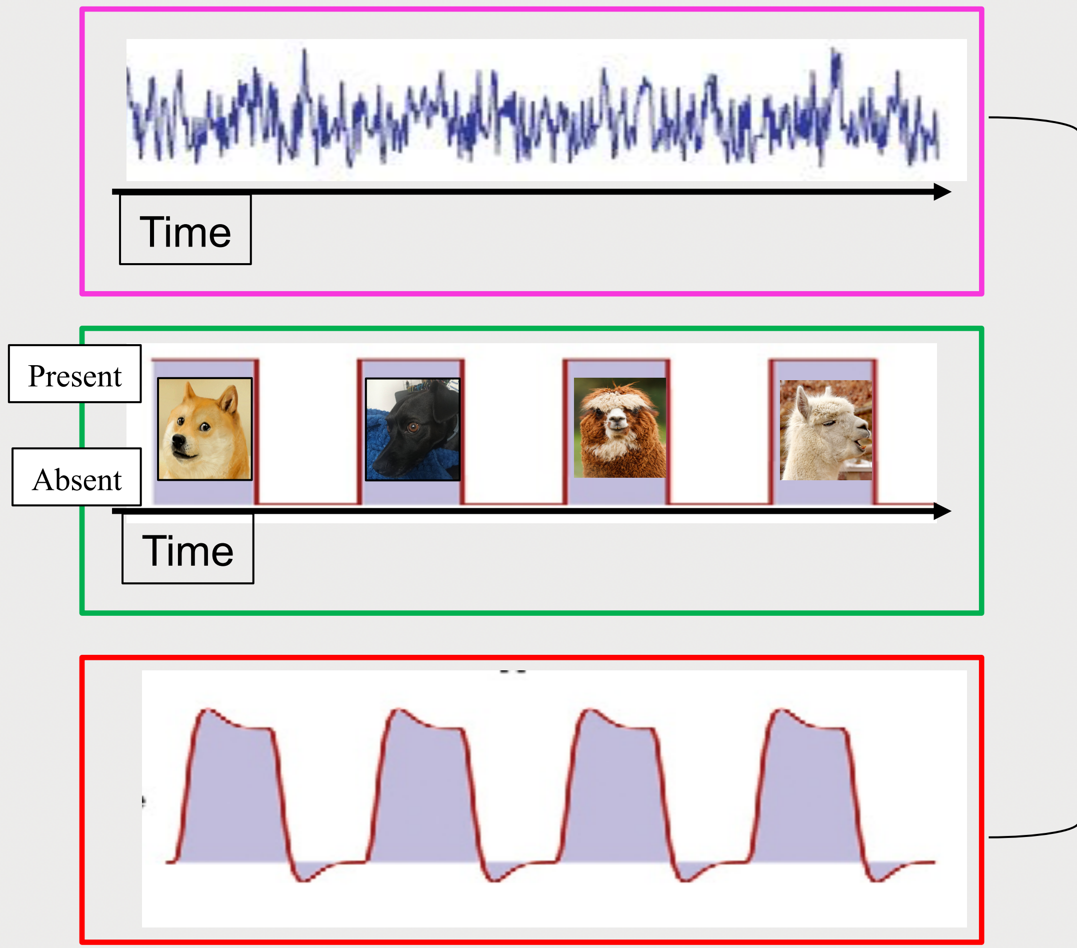
GLM

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

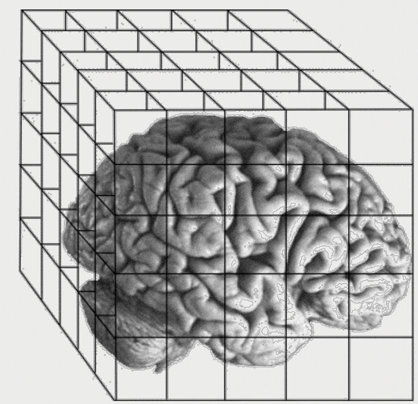
Voxel activity

Task model

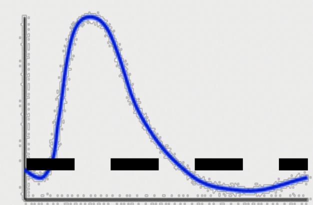
Response model



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



Hemodynamic Response Function (HRF)



GLM

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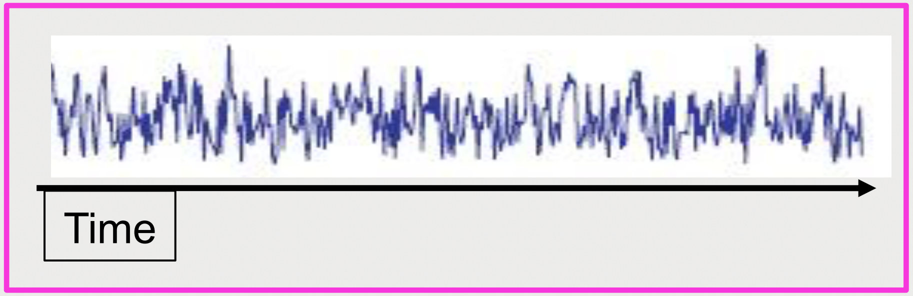
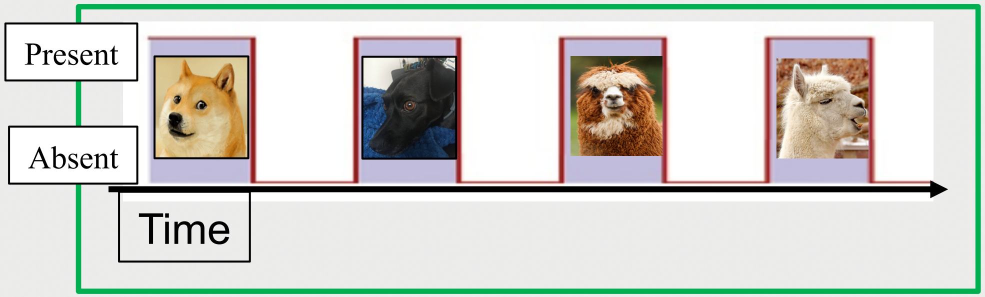
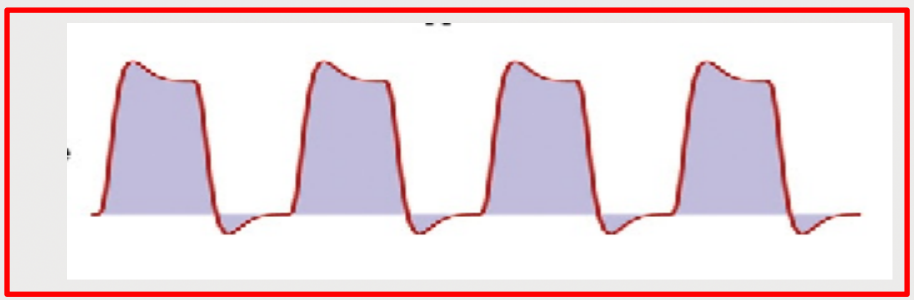
Voxel activity



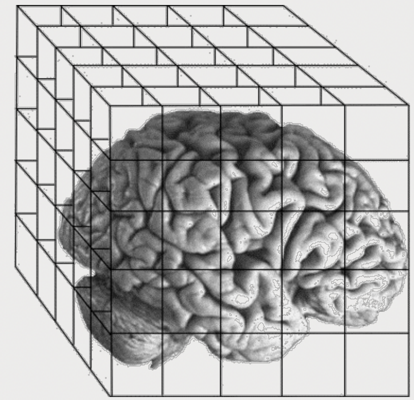
Task model



Response model



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



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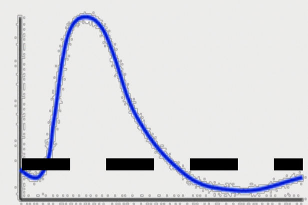
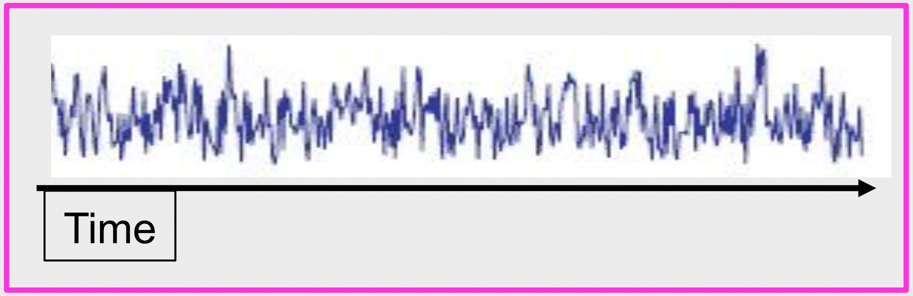


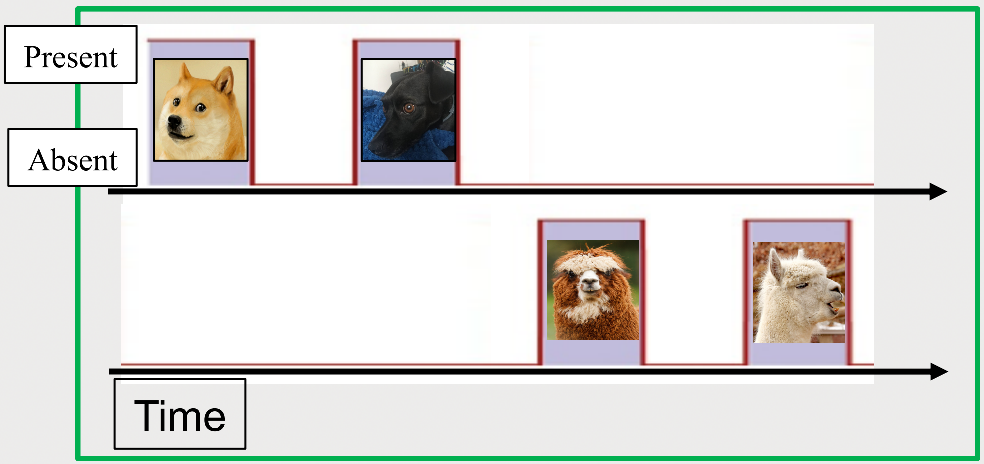
GLM

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

Voxel activity



Task model



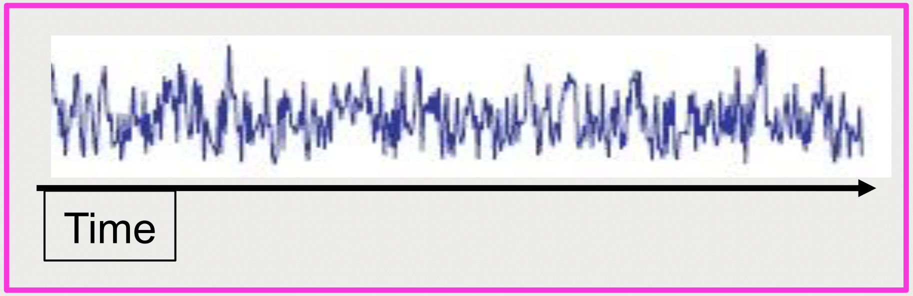
Regressor 1

Regressor 2

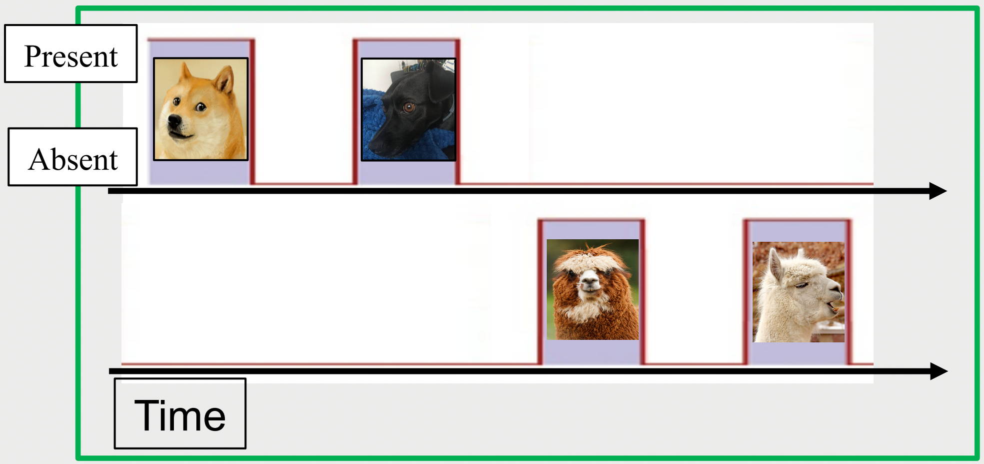
GLM

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

Voxel activity



Task model



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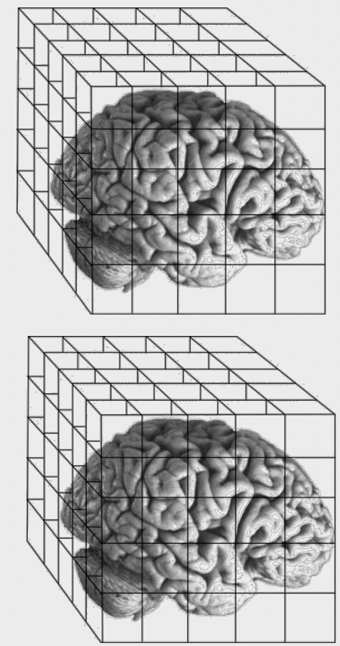
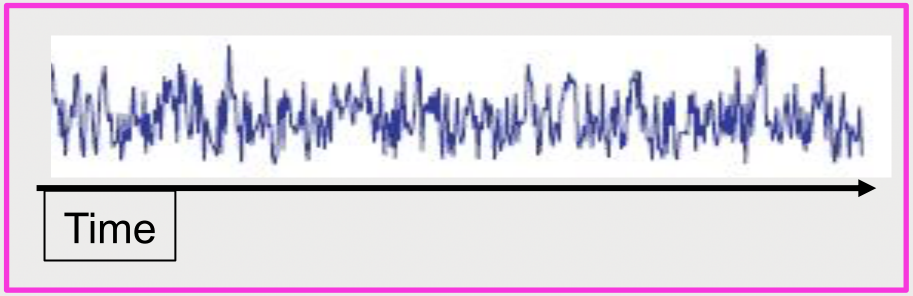


GLM

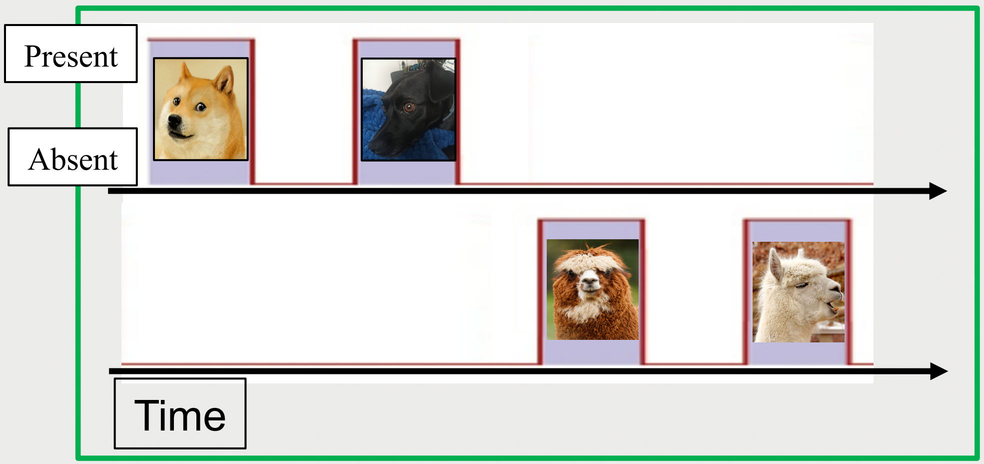
A practical example. Can we find voxels that distinguish to DOGS FACES from ALPACAS FACES?

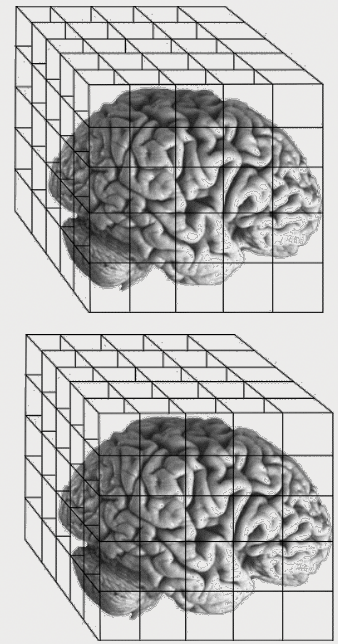
QUESTION: What would the value in each voxel of the beta map represent?

Voxel activity



Task model



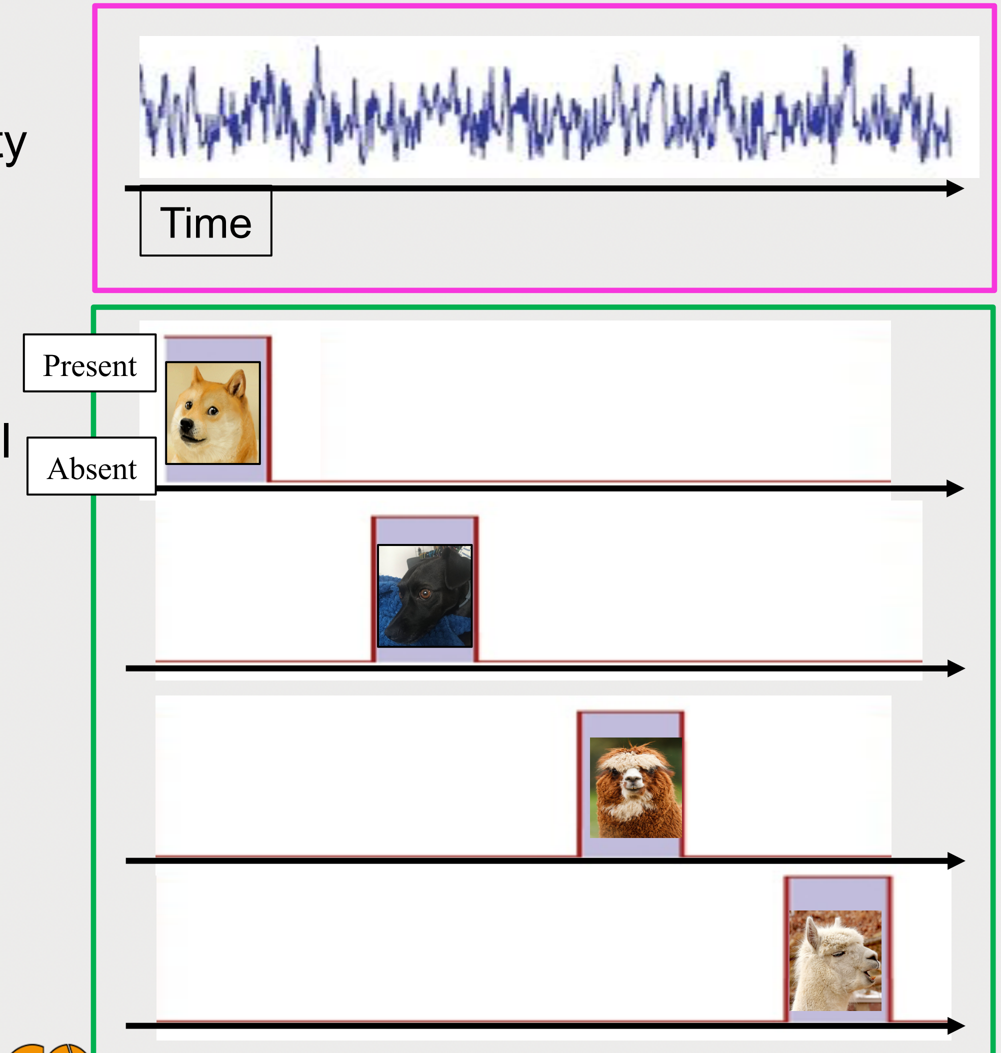


GLM

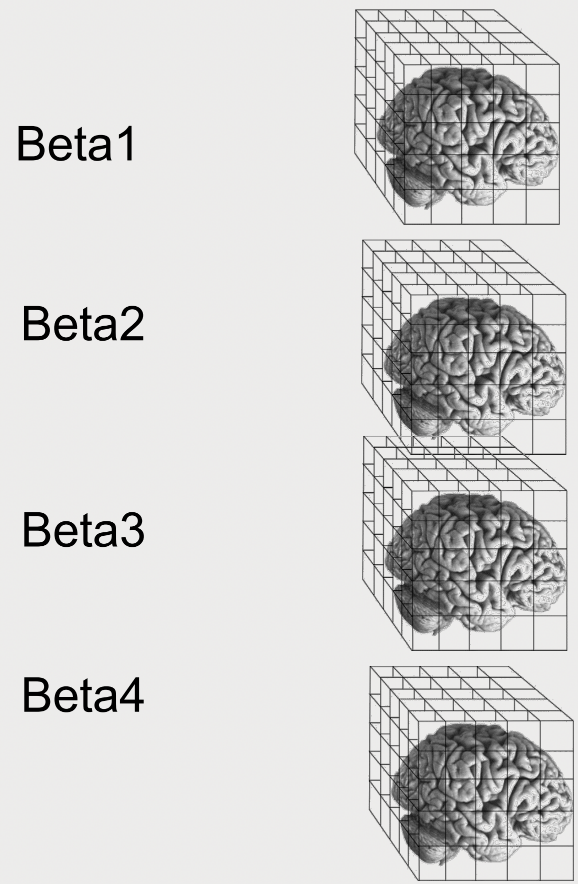
Another practical example. Can we find voxels that distinguish each CHARACTER?

Voxel activity

Task model



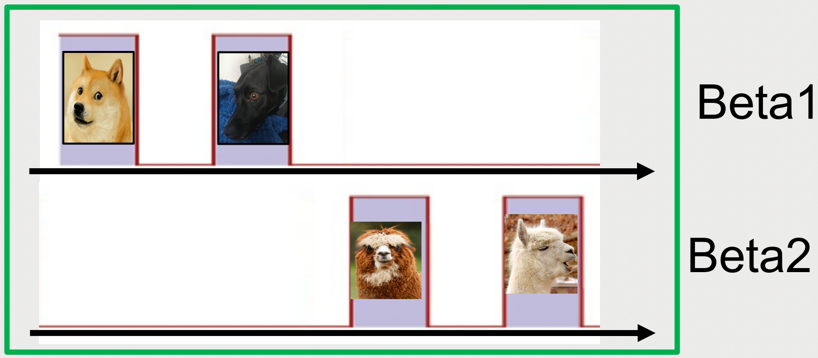
We can have a regressor and, therefore, a beta for **every** trial.



GLM

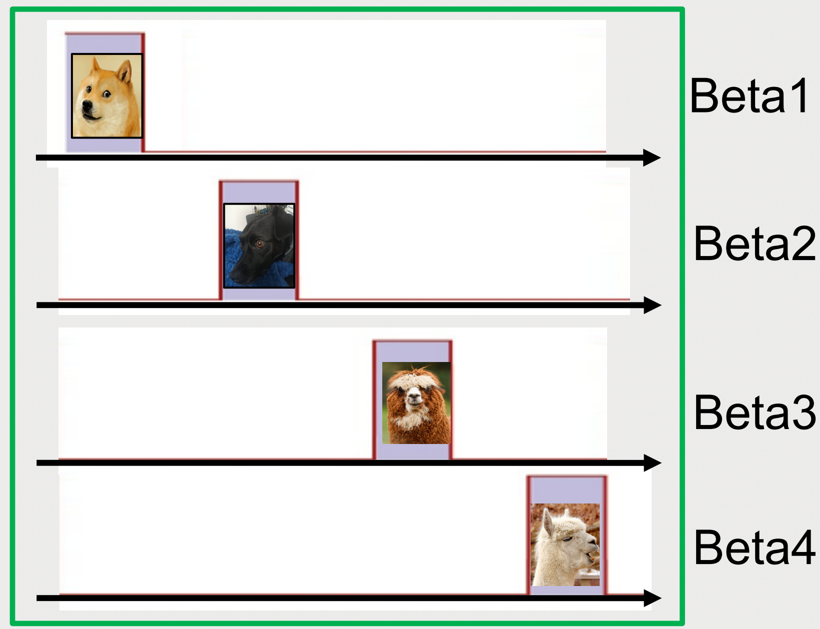
Different GLM (task) models. LSU is widely used for **univariate** analysis while LSA (or more complex models) are often used for **multivariate** analysis.

Least-Squares Unitary (LSU)



"One beta per condition is estimated"

Least-Squares All (LSA)



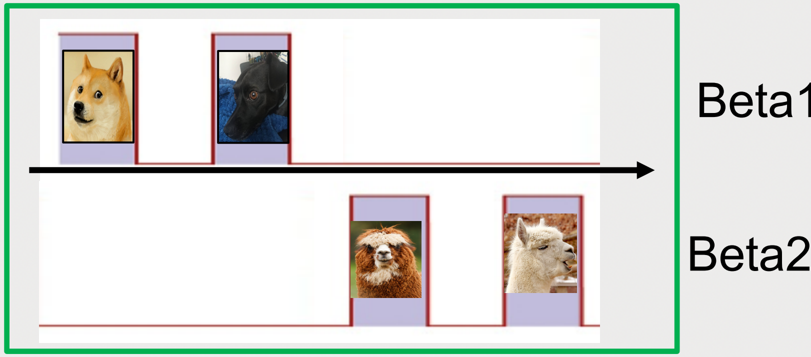
"One beta per trials is estimated"

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.



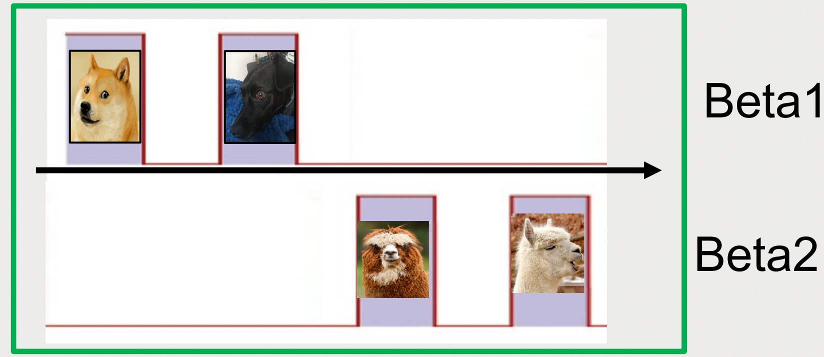
GLM

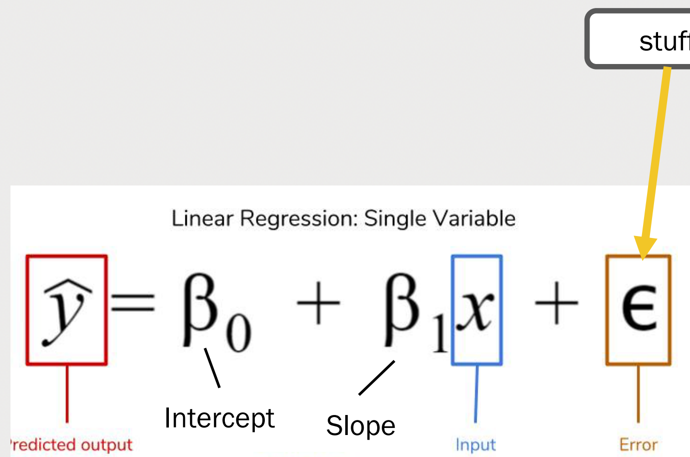
Back to theory.

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*.





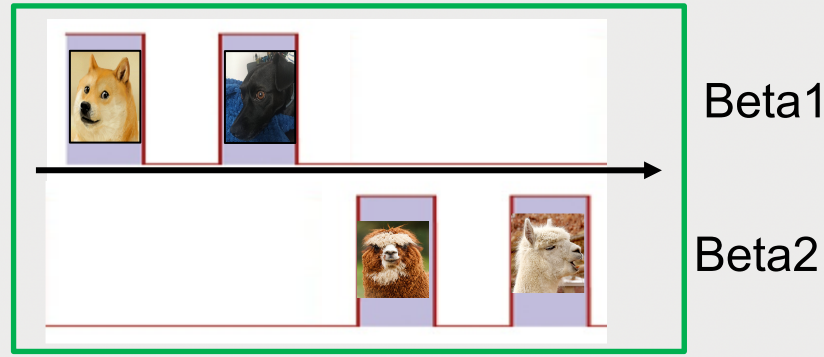
GLM

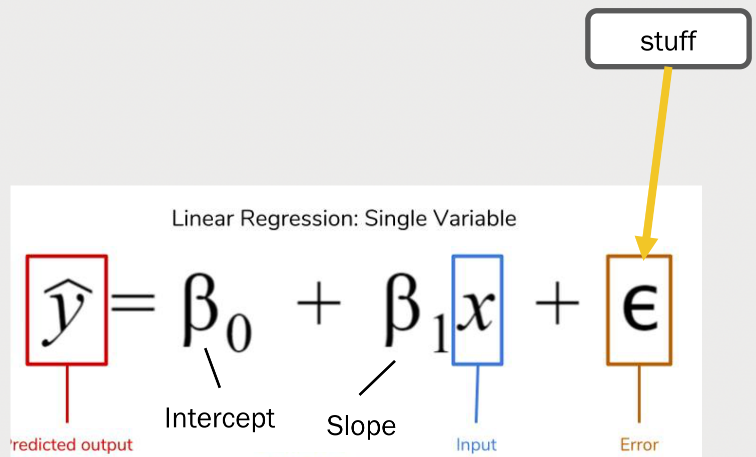
Back to theory.

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.

Enter: Nuisance/confound regressors.



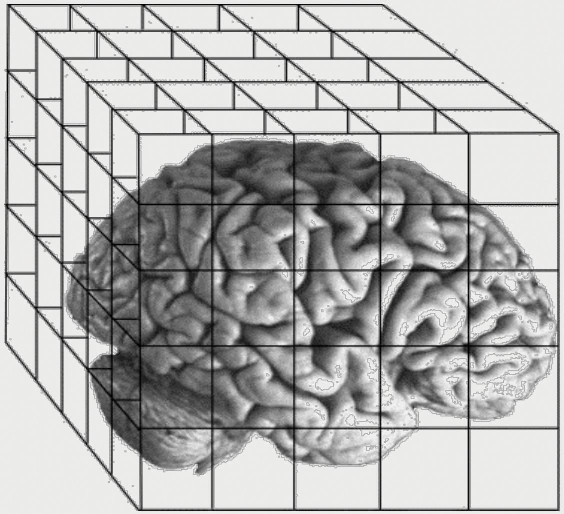


GLM

Nuisance regressors.

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

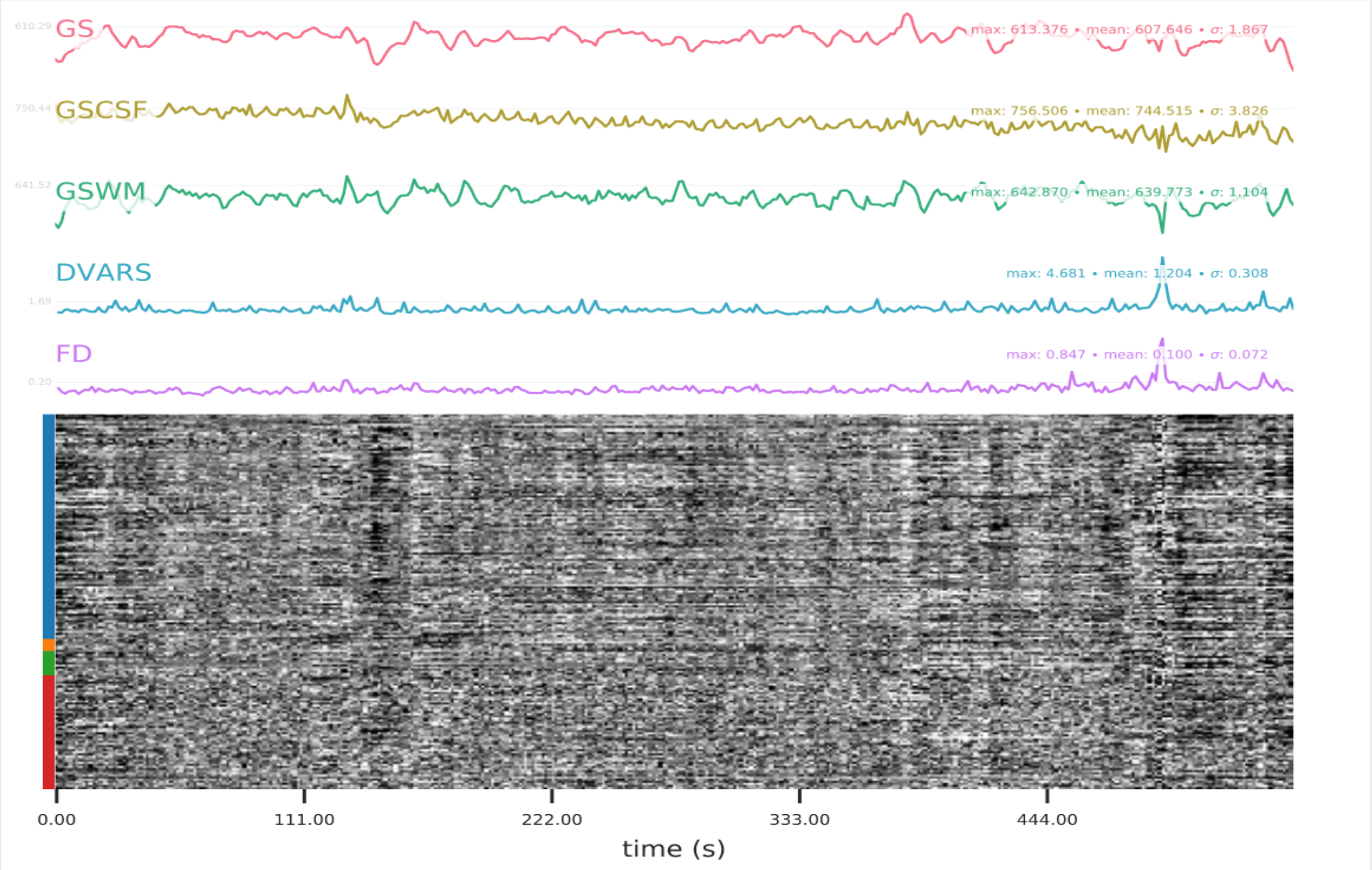
- Head motion.
- Breathing.
- Heart rate.
- Scanner drift.
- …



GLM

Nuisance regressors.

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

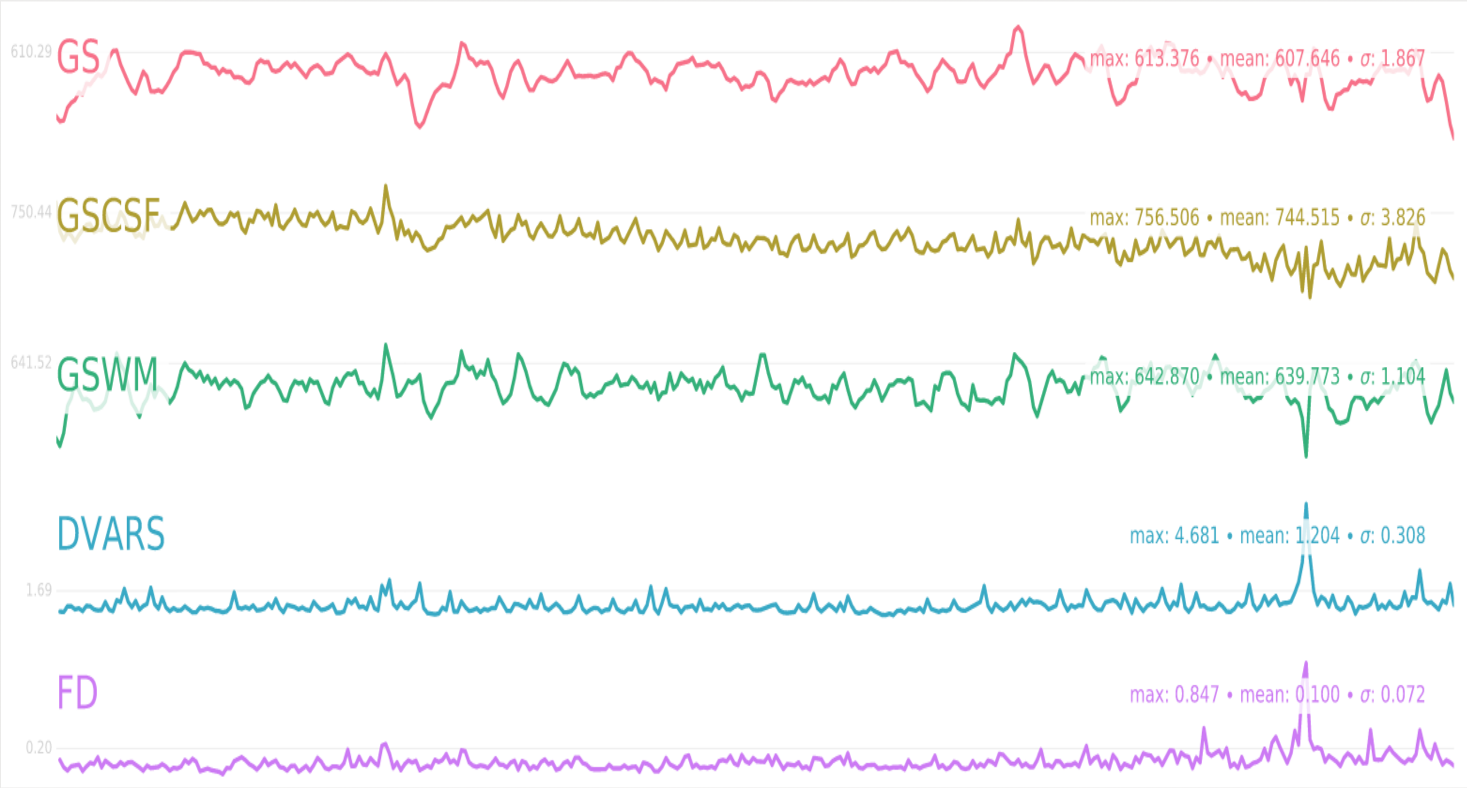


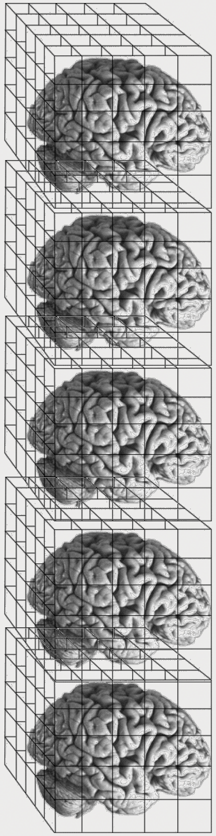
from data_fmri-analysis_intro/process-specific/preproc_data/fmriprep/sub-009.html

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.



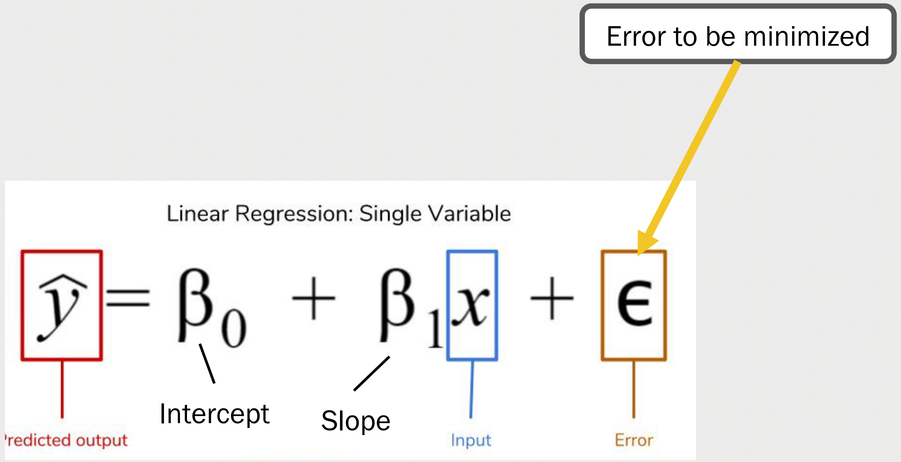


GLM

Nuisance regressors.

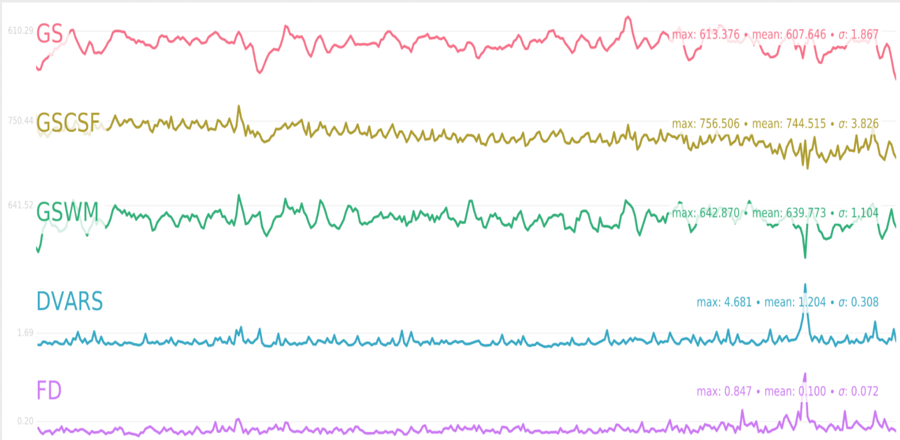
Betas estimated from nuisance regressors are usually not of interest for our analysis but they can account for an important portion of the variance in our signal.

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!



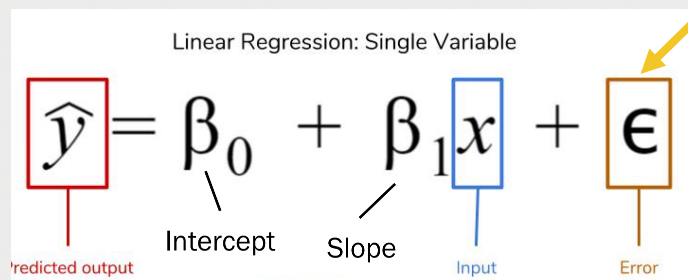
GLM

Nuisance regressors.



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

Error to be minimized



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.