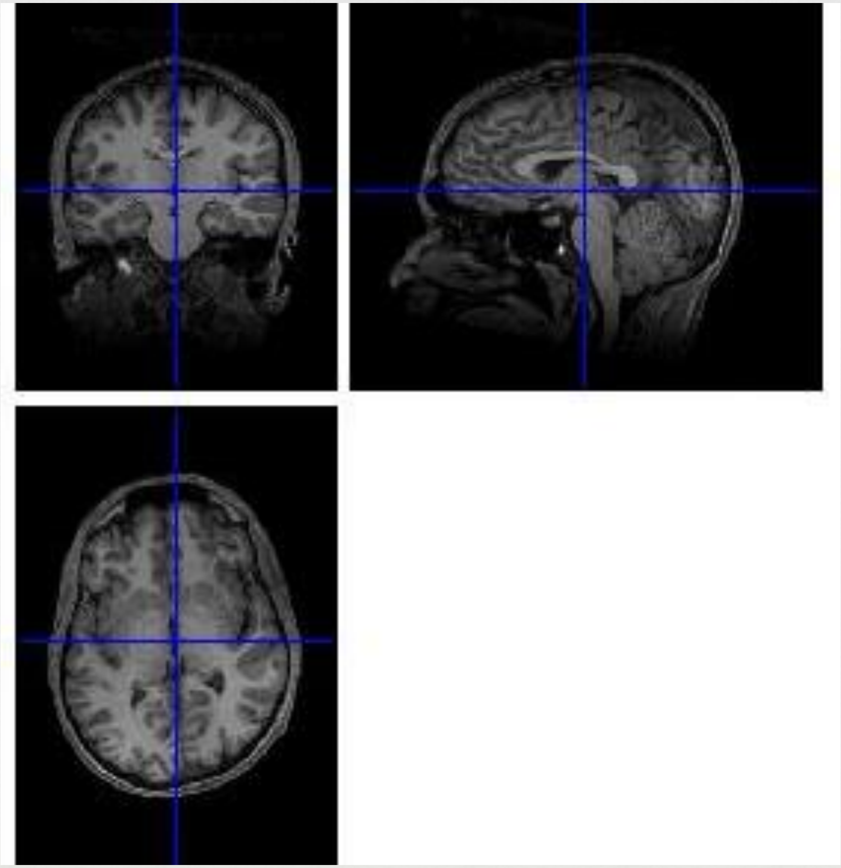
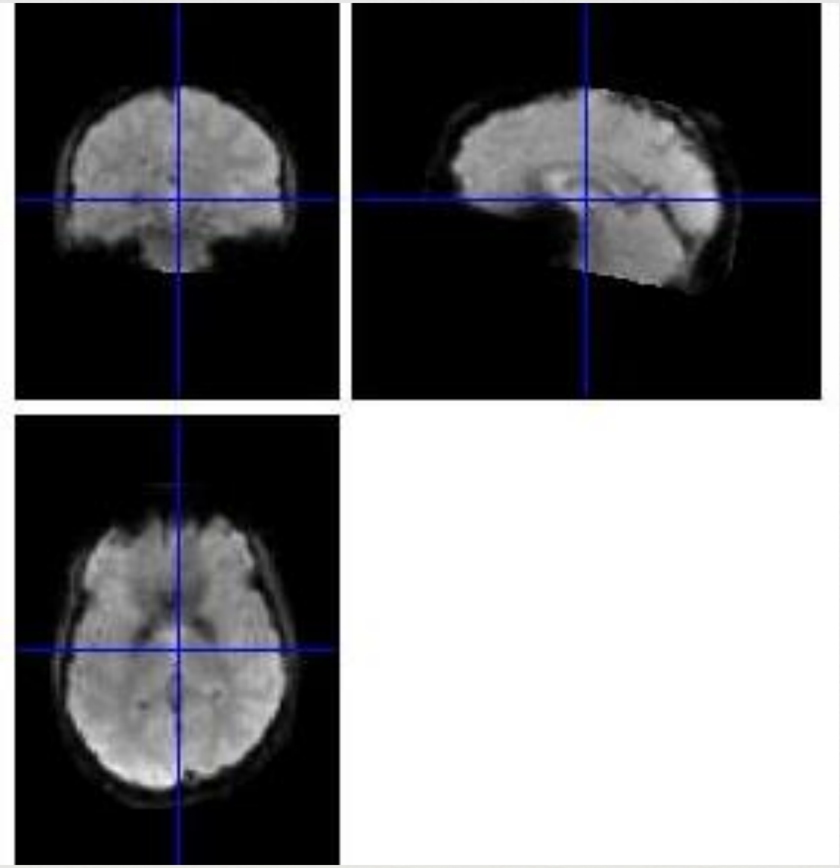
Lecture 11: Example fMRI Data Processing and Analysis using SPM8

November 16, 2016

Step 1: Dicom to NIFTI

Raw Images after DICOM Conversion





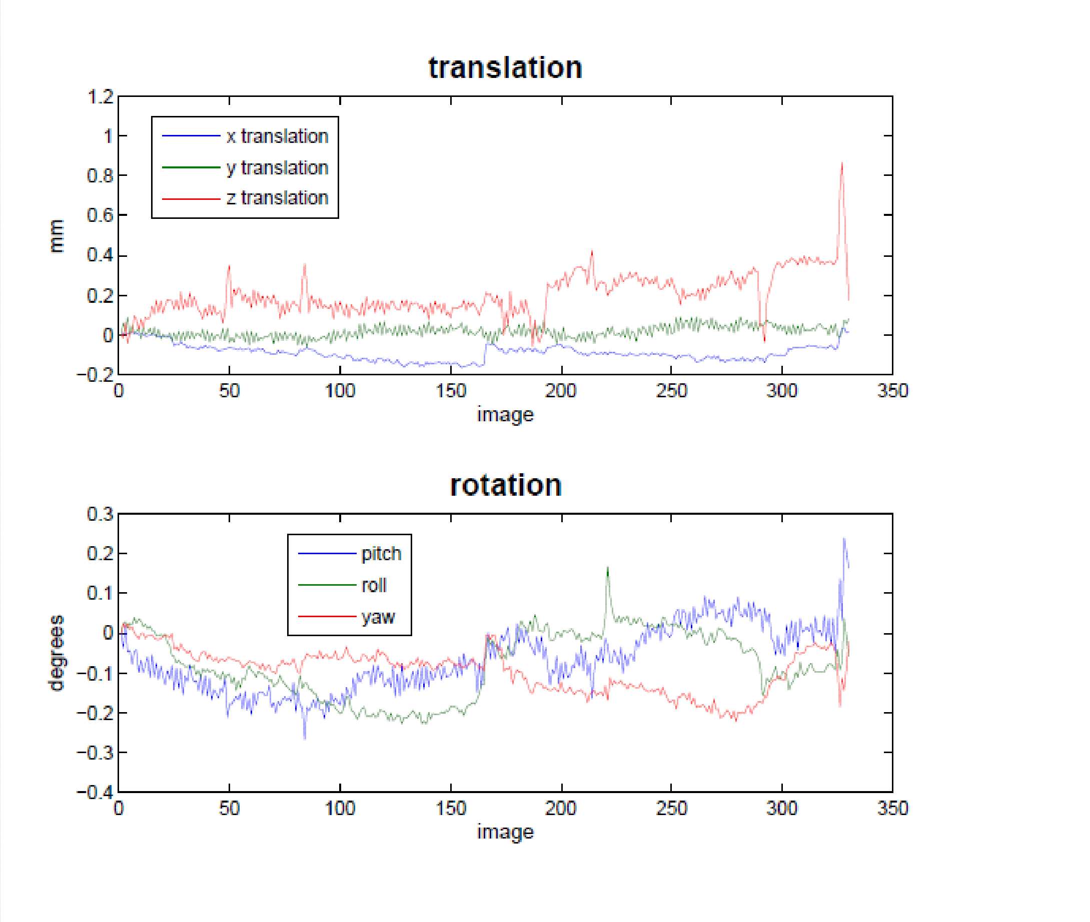
Motion Correction

- Two step procedure:
  - 1. Register all images to the first image in the scan series & compute the mean image
  - 2. Register all images to the mean image computed in step 1

Step 2: Alignment and Motion Correction

- Look at the motion estimates

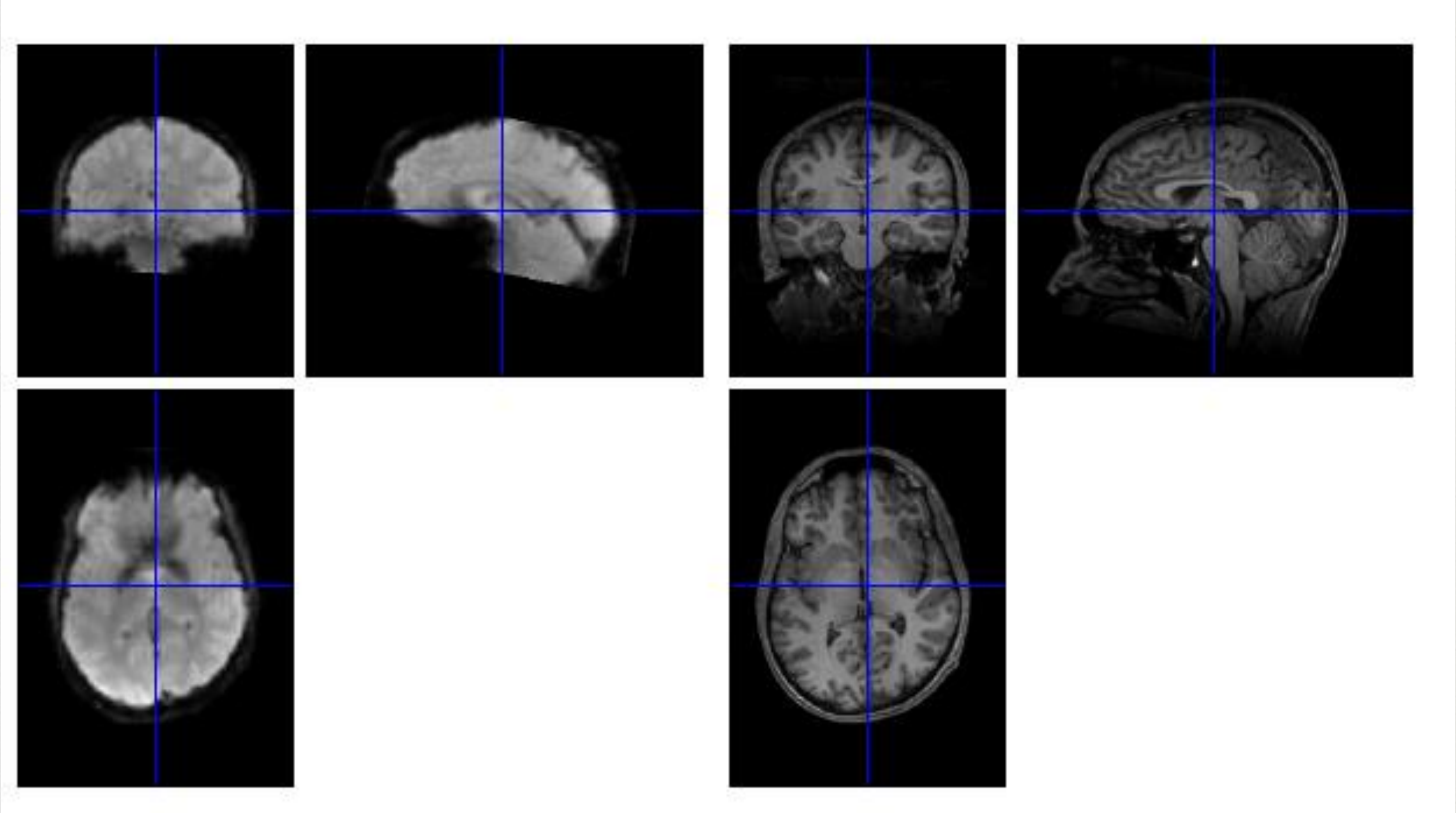
- If they are too high, do not use the data!!



Step 3: Coregistration – anatomical to functional

- Less we move (resample)the functional images, the better

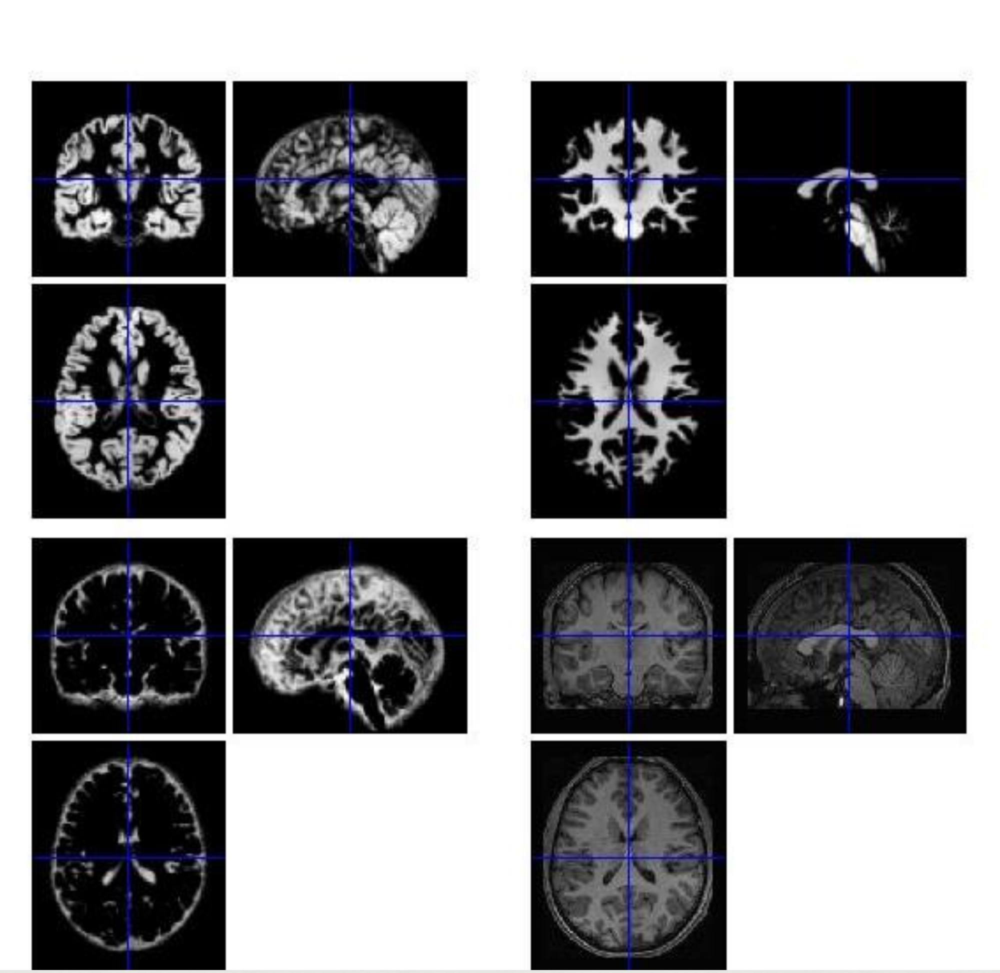
- Minimization of an objective function – Normalized Mutual Information



Step 4: Segmentation / Normalization to MNI Space

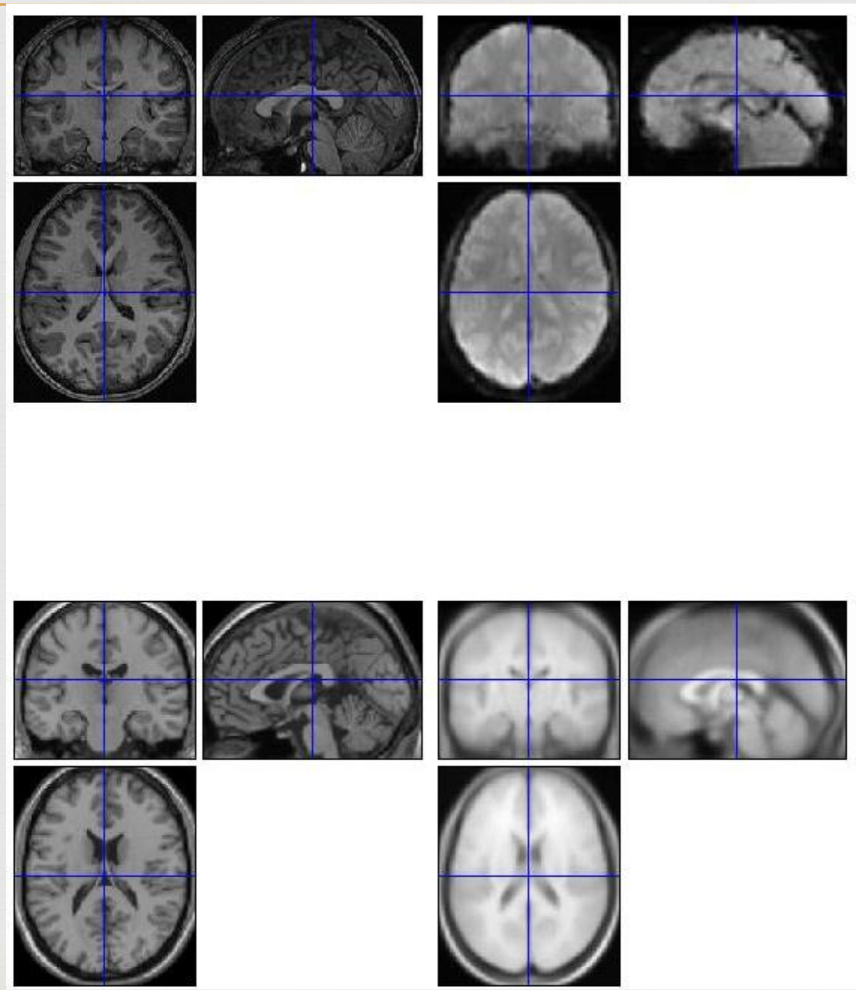
- Breaks down the anatomical image into white matter, gray matter, and CSF

- Aligns it to the MNI brain

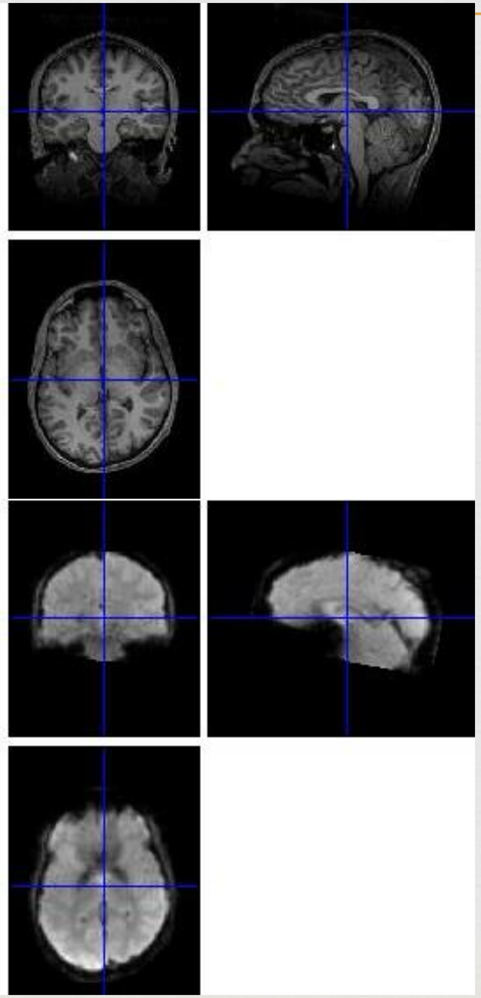


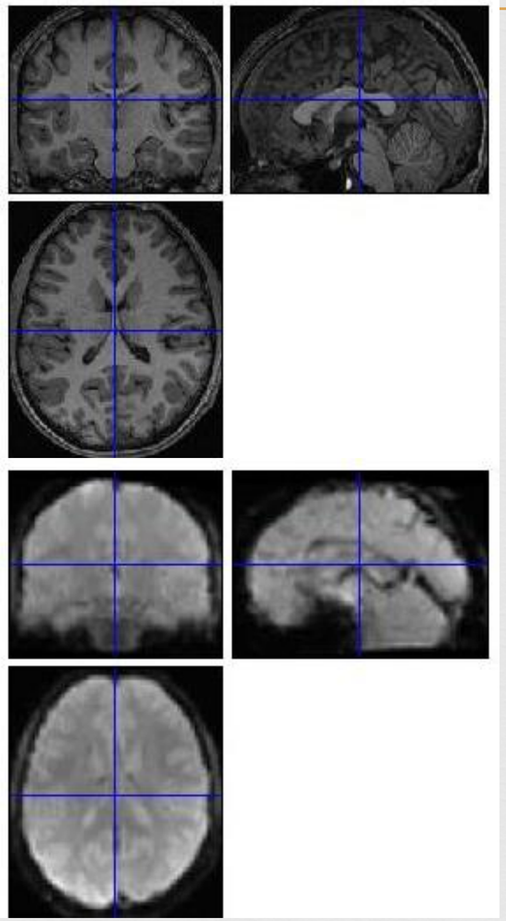
Normalization to MNI:
How well did it do?

- Both the anatomical and functional images are moved into MNI Space
- Top images are our data, bottom are MNI brains

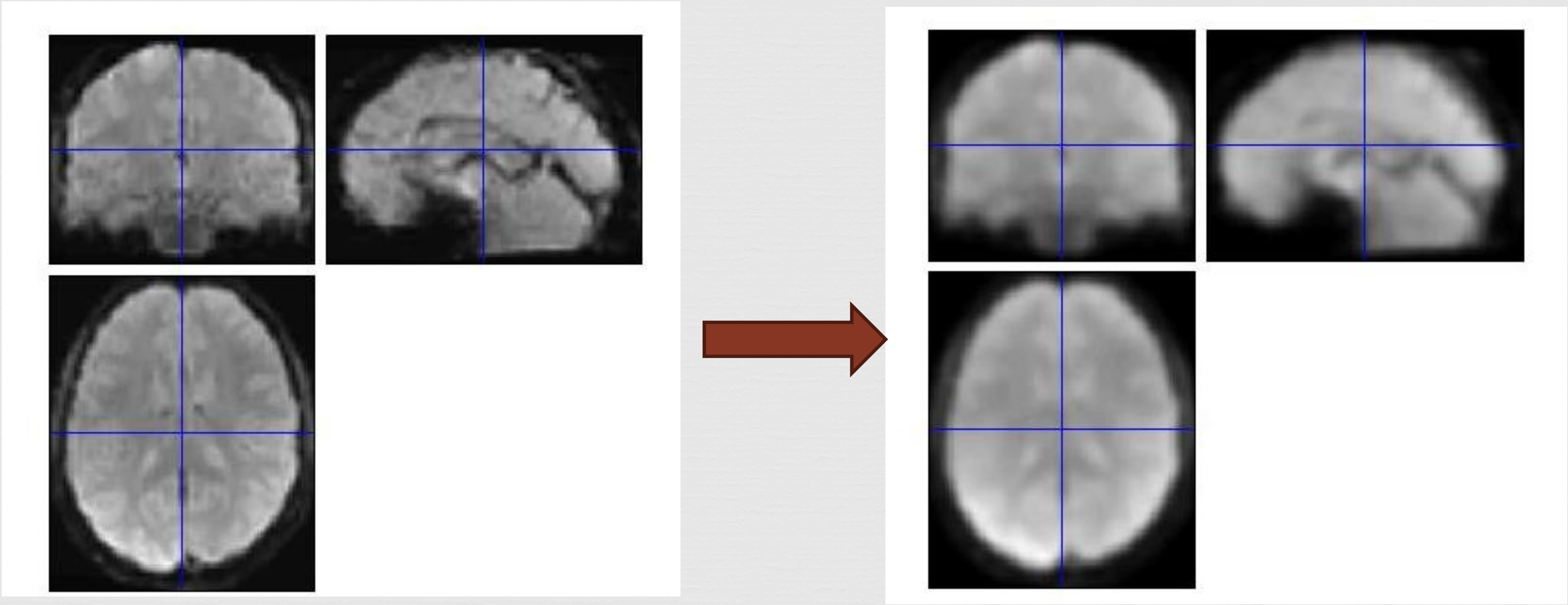


Before to After





Step 5: Smoothing the Data



Modeling the data

- BLOCK DESIGN FACES TASK:
  - Faces are from NimStim database (public database)
  - Four conditions: Angry faces, neutral faces, fearful faces, control figures
  - Need to know the timings and duration of each stimulus
  - Order varies across participants for randomization (no task order effect)

Faces Task – Implicit Emotion Processing

- Implicit = they are not attending to the emotion (designed to activation background emotion processing)

- Instructions:

  - Pay attention and respond as fast as you can
  - If you see a picture of a male, press your middle finger
  - If you see a picture of a female, press your index finger

Task Timing

- 20 second blocks during which 6 images are displayed
- Blocks can be one of the four conditions
- Images are shown for 2 seconds each, with ISI of 3-8 seconds
- Each condition is shown 4 times, resulting in sixteen 20-second blocks

Timing Parameters

- Task collects 165 total images
- TR = 2 seconds
- 165 total images * 2 seconds = 330 seconds total

- 330 seconds * [1min/60seconds] = 5.5 minutes = 5 minutes and 30 seconds total task time

- Collecting 37 slices for each 2 seconds, so collecting 165 * 37 = 6105 slices total

OR: 6105 total slices/330 total seconds = 18.5 slices/second

Example Run Sheet

Step	Name	Nofsl	SlThck	Conc	Res	FOV	Seconds	TR	TI	TE	FA
Step 1	localizer	9	10	9	256x180	300x300	0m15s	8.6	300	4	20

This is a large FOV 3 plane localizer

Step	Name	Nofsl	SlThck	Conc	Res	FOV	Seconds	TR	TI	TE	FA
Step 2	sag_t1_loc	15	4	1	256x232	256x256	0m34s	250	300	2.5	90

Prescribe left-right symmetric to the brain. Along falx in coronal use the eyes or the nasal septum in axial plane

Step	Name	Nofsl	SlThck	Conc	Res	FOV	Seconds	TR	TI	TE	FA
Step 3	cor_t1_loc	15	4	1	128x116	256x256	0m19s	250	300	2.5	90

Make perpendicular on sagital then center in all three planes (without rotating). If needed rotate in the transversal plane

Step	Name	Nofsl	SlThck	Conc	Res	FOV	Seconds	TR	TI	TE	FA
Step 4	axial_ACPC	1	3	1	128x128	256x256	0m21s	250	300	2.46	90

Make perpendicular on both sag and cor. Then incline in sag plane to align to ACPC

Step	Name	Nofsl	SlThck	Conc	Res	FOV	Seconds	TR	TI	TE	FA
Step 5	inplanes_shift_21.7	39	3.1	1	64x 64	205x205	0m10s	2000	0	16	90

Copy center from ACPC then shift with 21.7 (then in steps of 3.1)

Step	Name	Nofsl	SlThck	Conc	Res	FOV	Seconds	TR	TI	TE	FA
Step 6	axial_mprage	192	1	1	256x192	256x192	7m 2s	2200	1000	3.31	9

Copy center from ACPC then shift with 0.5 mm (half slice) PE is R>>L Check under resolution that interpolation is OFF

Step	Name	Nofsl	SlThck	Conc	Res	FOV	Seconds	TR	TI	TE	FA
Step 7	reward	39	3.1	1	64x 64	205x205	8m 6s	2000	0	28	90

Copy center from in-planes check PE to be P>>A

Step	Name	Nofsl	SlThck	Conc	Res	FOV	Seconds	TR	TI	TE	FA
Step 8	faces_oldx2	37	3.1	1	64x 64	200x200	5m36s	2000	0	28	90

Copy center from InPlanes. PE is A>>P

Step	Name	Nofsl	SlThck	Conc	Res	FOV	Seconds	TR	TI	TE	FA
Step 9	dti_68	64	2	1	128x128	256x256	10m 4s	8500	2500	91	90

Copy center from ACPC then shift 7 mm (3 slices and a half)then add/subtract in steps of 2 mm

May not run this sequence!!

Step	Name	Nofsl	SlThck	Conc	Res	FOV	Seconds	TR	TI	TE	FA
Step 10	MSIT	39	3	1	64x 64	205x205	9m26s	2000	0	25	90

First level analysis

- Example onset timings (in seconds):
  - Anger timings [28.5 87 204 301]
  - Fear timings [9 126 223 262.5]
  - Neutral timing [48 144.5 223.5 262.5]
  - Control timings [67.5 106.5 165 282]

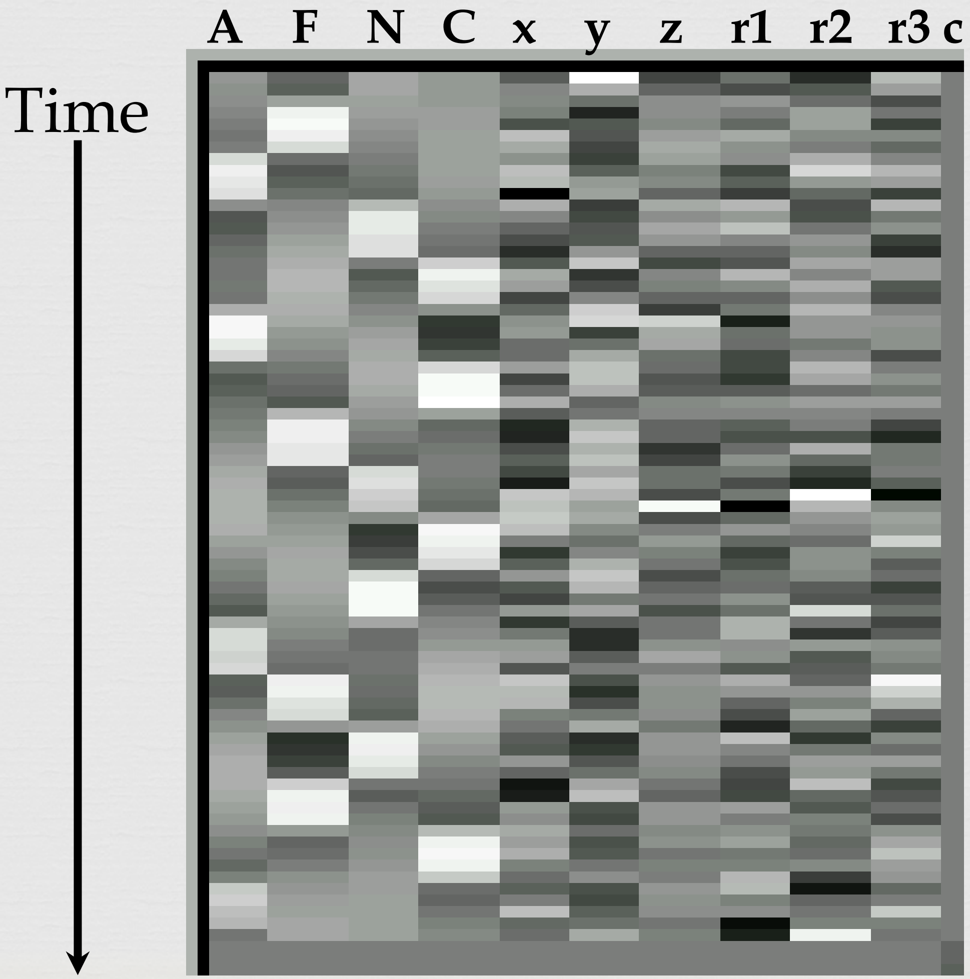
- Block Duration = 19.5 seconds
- Each condition is shown 4 times
- Motion estimates are used for task regressors

Model Estimation

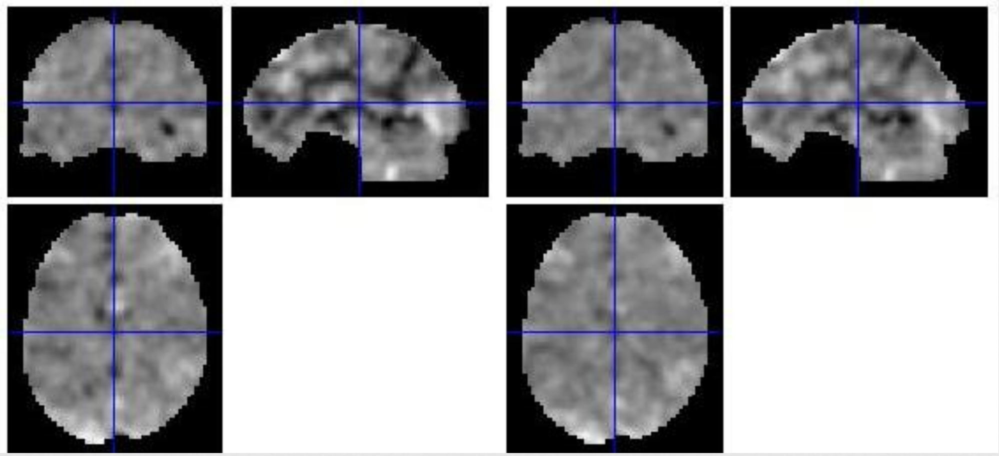
- Canonical hemodynamic response function is used for the basis function
- In SPM, model estimation is done using Restricted Maximum Likelihood Method (estimating Beta coefficients)
- This assumes the error correlation structure is the same at each voxel
- Beta coefficients are computed for condition + each motion parameter + a constant (so for one run, number of Betas = 11)

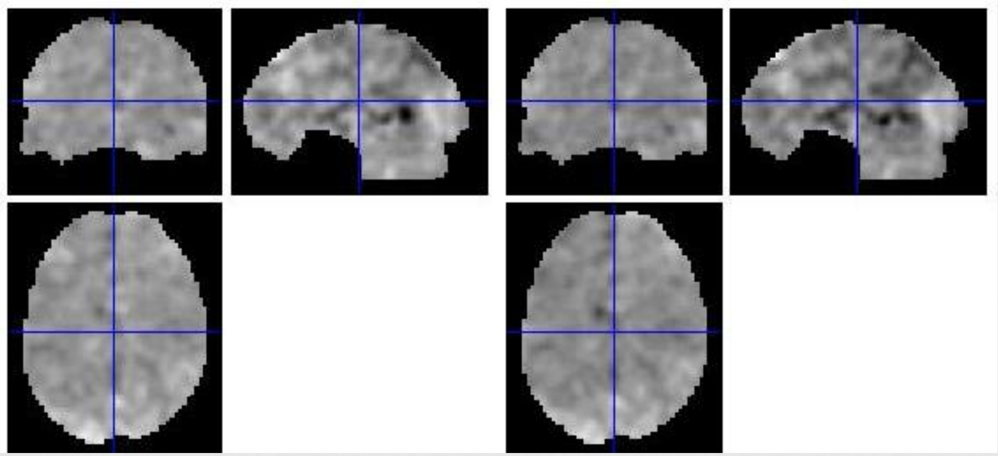
Design Matrix Generated by SPM

- Parameters to model are indicated across the top (11 Betas)
- Time is along the y-axis
- Bright spots indicate the value of the parameters in the model
- Example, Anger is displayed 4 times throughout the task, etc.



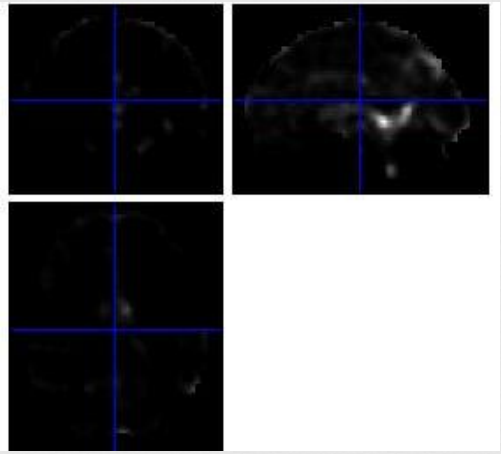
Beta Coefficients for First 4 Conditions



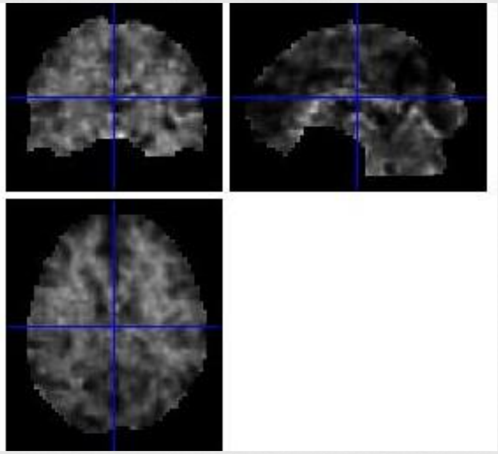


Anger Fear Neutral Control

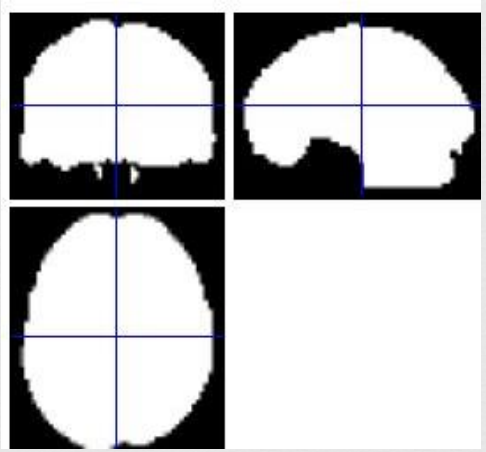
SPM Also Computes These



ResMS = residual variance estimate



RPV= RESEL = resolution element, describes spatial image resolution



Mask = locations where all subjects had data

How do we get activation information from these?

- Activation occurs when there is a difference between two cognitive states

- Need the contrast images
- How do we contrast the images?

- Give weights to each of these conditions
- SPM computes contrasts based on these weights

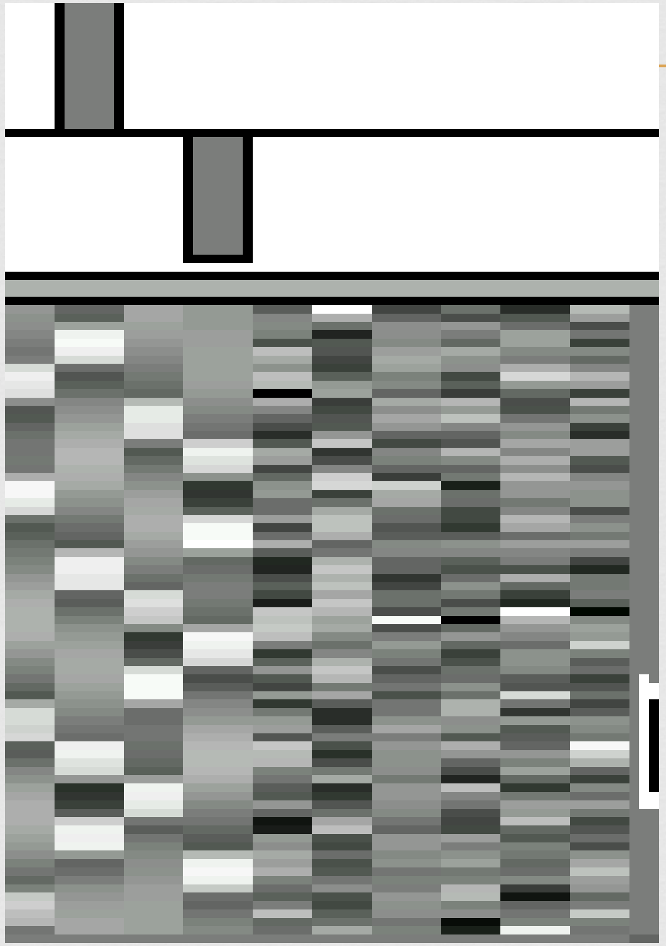
Contrast Weight Examples (SPM8)

[Anger	Fear	Neutral	Control	
[1	0	-1	0	] (Anger > Neutral)
[0	1	0	-1	] (Fear > Control)
[0.5	0.5	-0.5	-0.5	] (Anger and Fear > Neutral and Control)

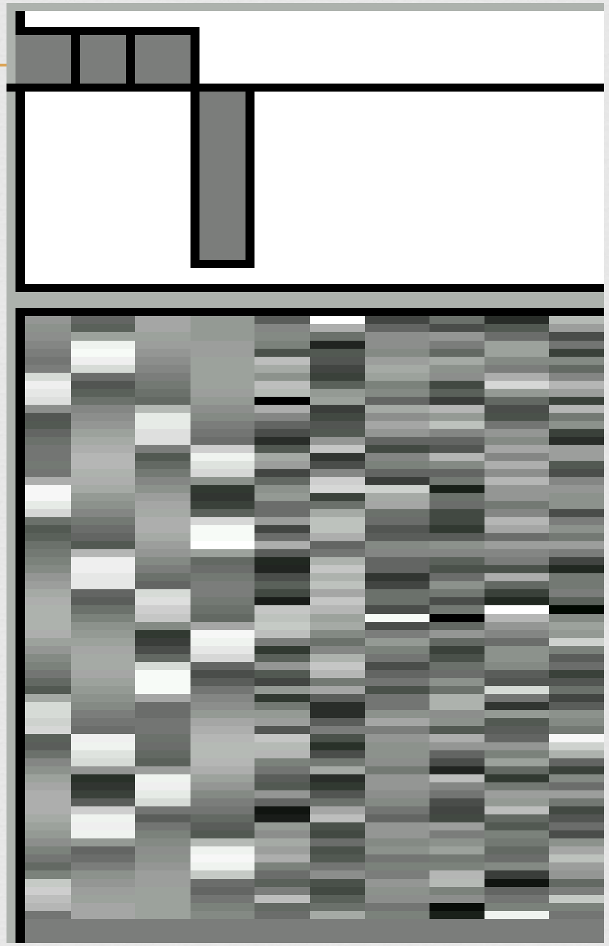
Also:

[1	0	0	0	] (Anger > Baseline)
[0	1	0	0	] (Fear > Baseline)
[0	0	-1	0	] (Baseline > Neutral)
[0.333	0.333	0.333	-1	] (Anger, Fear, Neutral > Control)

Contrasting Betas



Fear > Control



Anger, Fear, Neutral > Control

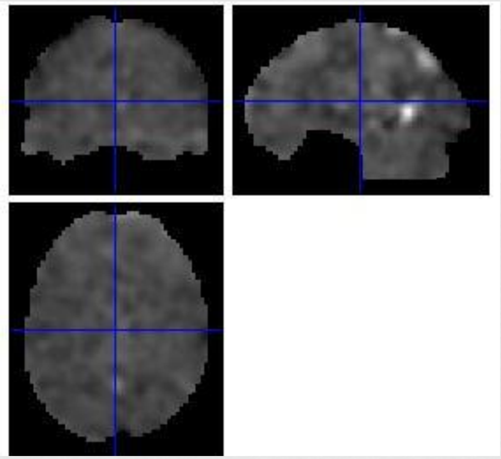
Estimating the CON images

- When you weight the conditions, SPM will create a linear combination of the beta parameters = c′B (c′ is the column vector defining the simple contrast of the parameters)

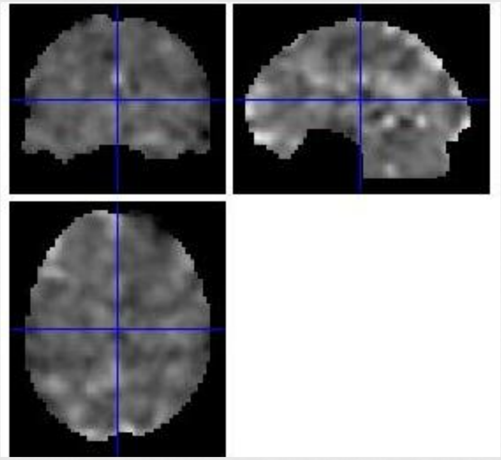
- Next, the hypothesis of: c′B = 0 (null)
  is tested against: c′B > 0

- Once the contrasts are created, the spmT maps are created which indicate the t-values at each voxel

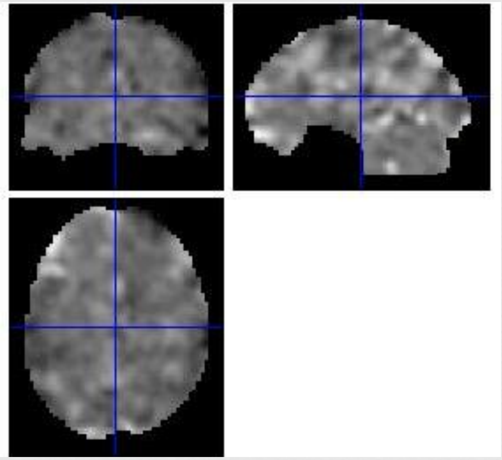
Con Images



Anger > Neutral

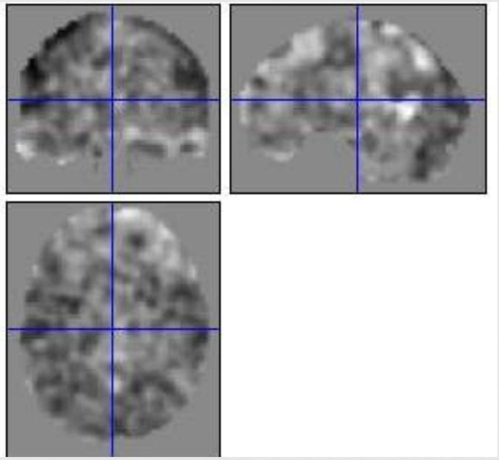


Fear > Control

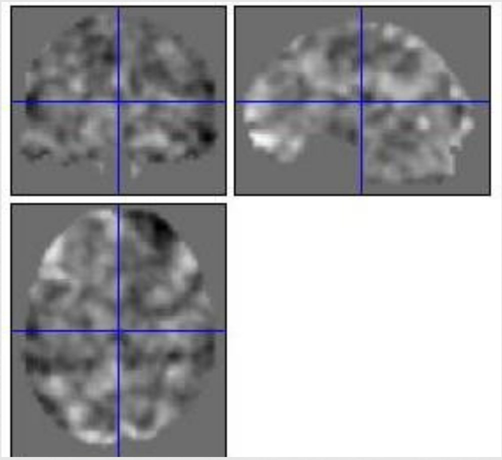


Anger, Fear, Neutral > Control

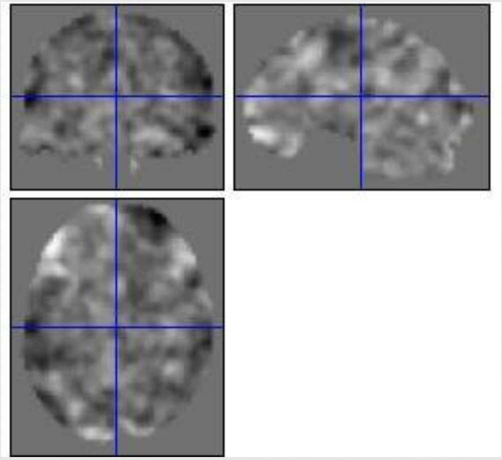
spmT Images



Anger > Neutral



Fear > Control

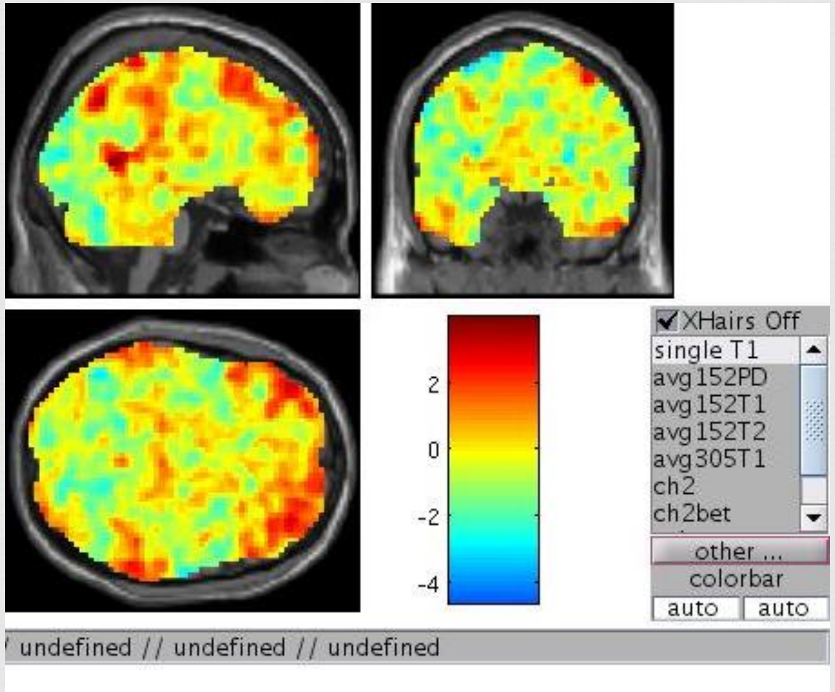


Anger, Fear, Neutral > Control

These images by themselves are not very useful!!!

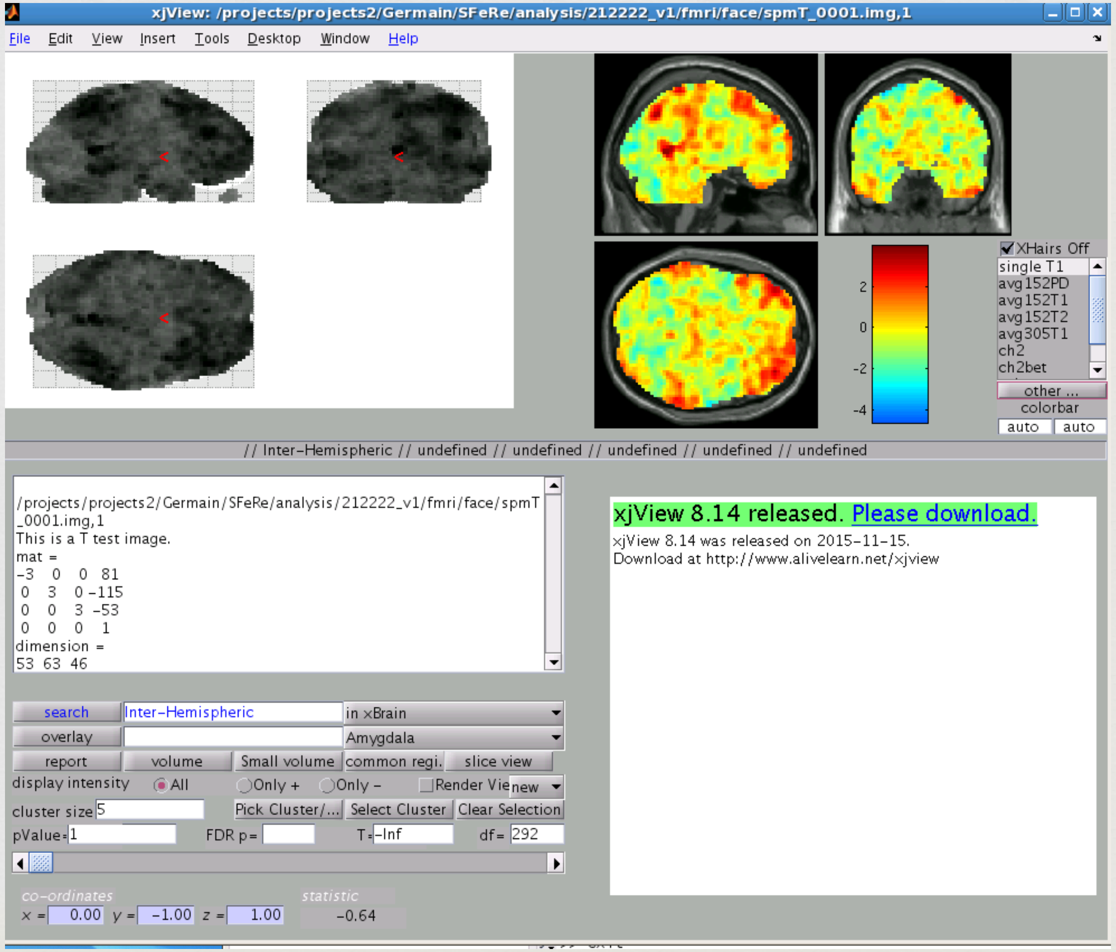
Overlay Onto Anatomical Brains (MNI) & Add Color

- By overlaying onto an anatomical brain, can visualize the approximate brain area of activation
- By adding color the differences in activation significance is much more apparent

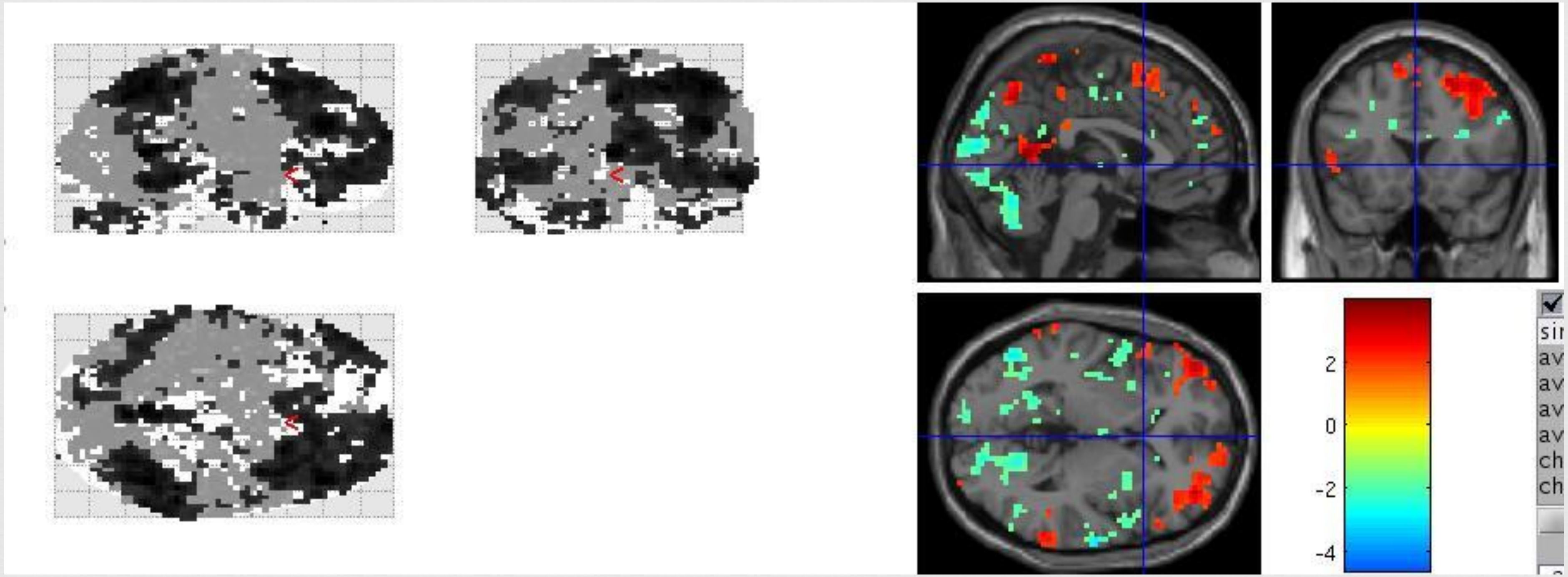


Tools are Available to Help View the Images

- This program, xjView, runs from Matlab and SPM
- Helps you view the images at different thresholds
- Limit p-values and contiguous cluster size

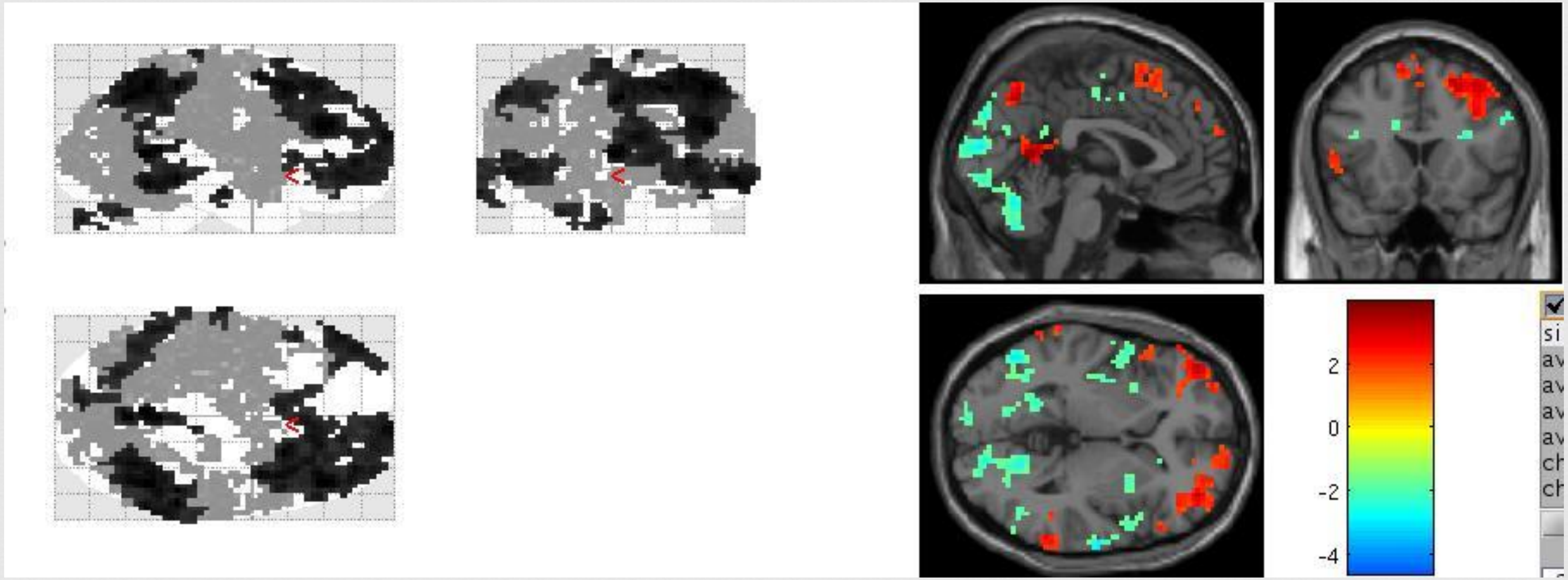


Applying Thresholds



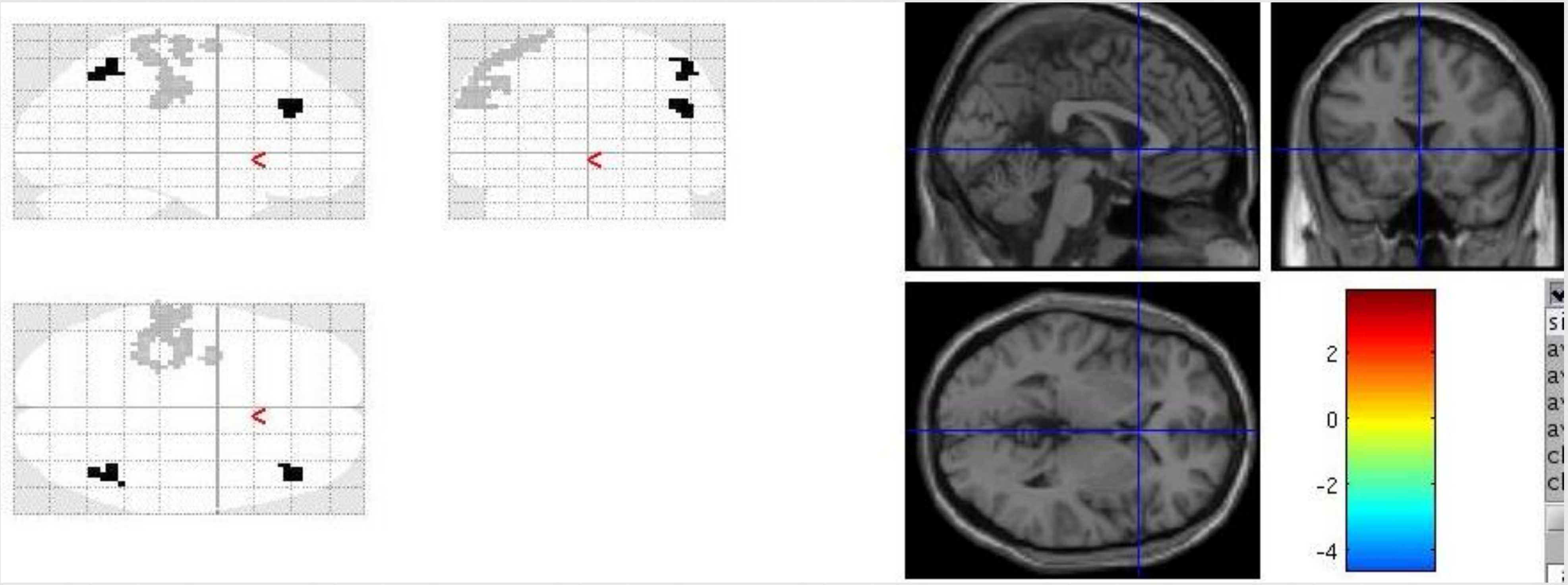
Anger > Control, p-value set to 0.05, k=1, very low threshold

Applying Thresholds



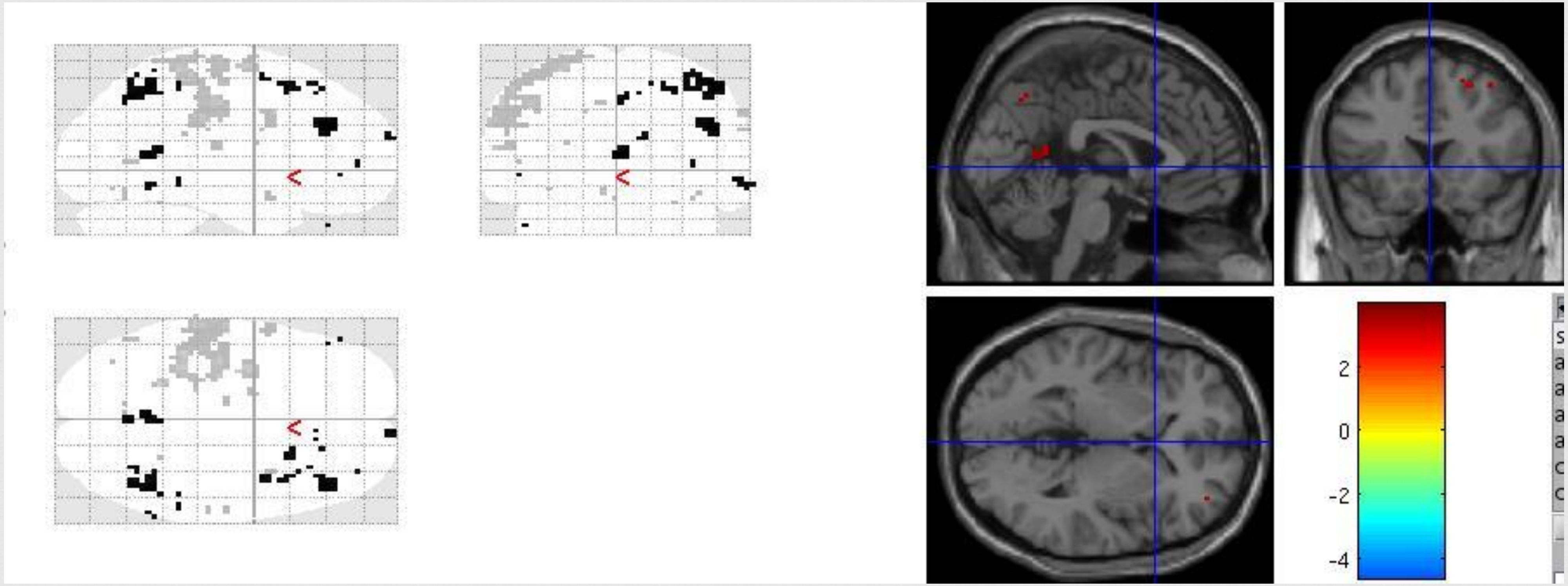
Anger > Control, p-value set to 0.05, k=20, reduces “dots” of activation

Applying Thresholds



Anger > Control, p-value set to 0.001, k=20, reduces everything!

Applying Thresholds



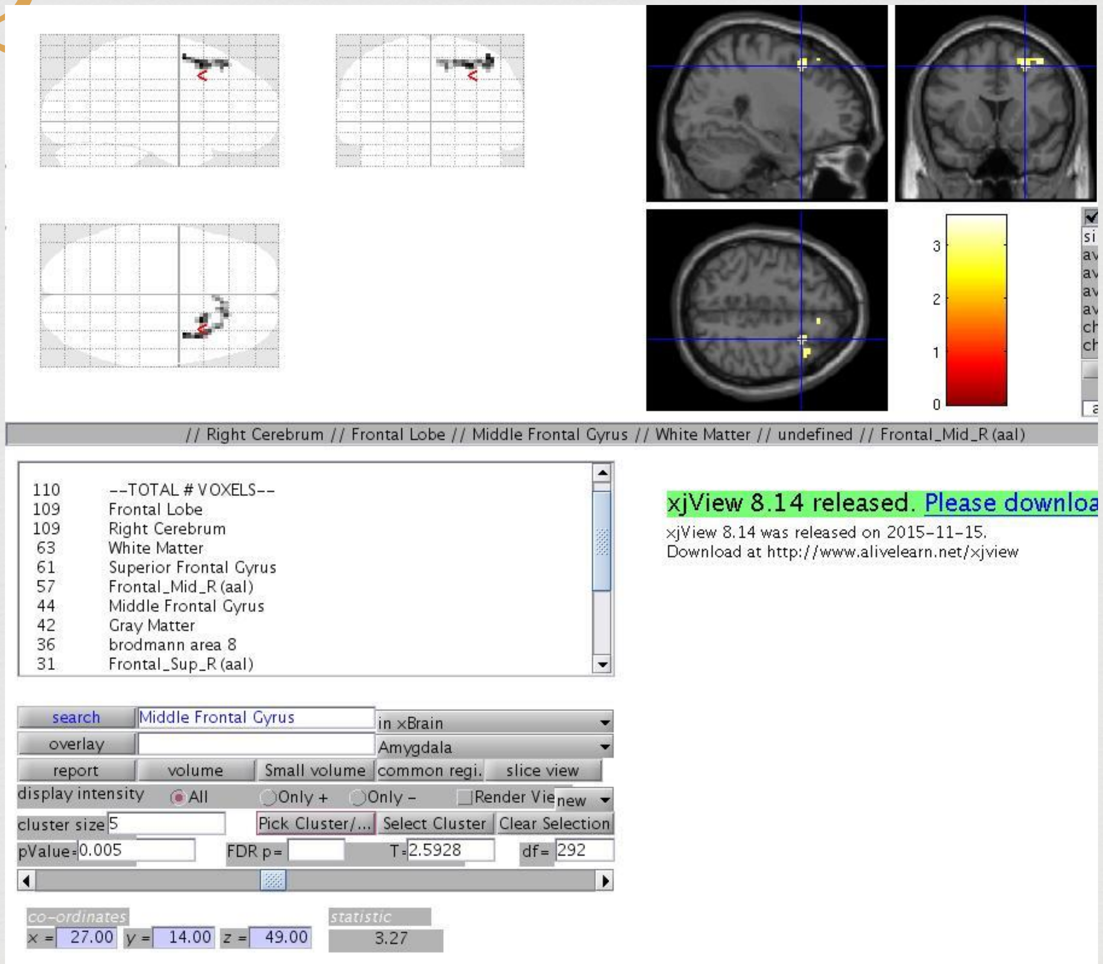
Anger > Control, p-value set to 0.001, k=1, small, very significant clusters and dots of activation

Applying Thresholds

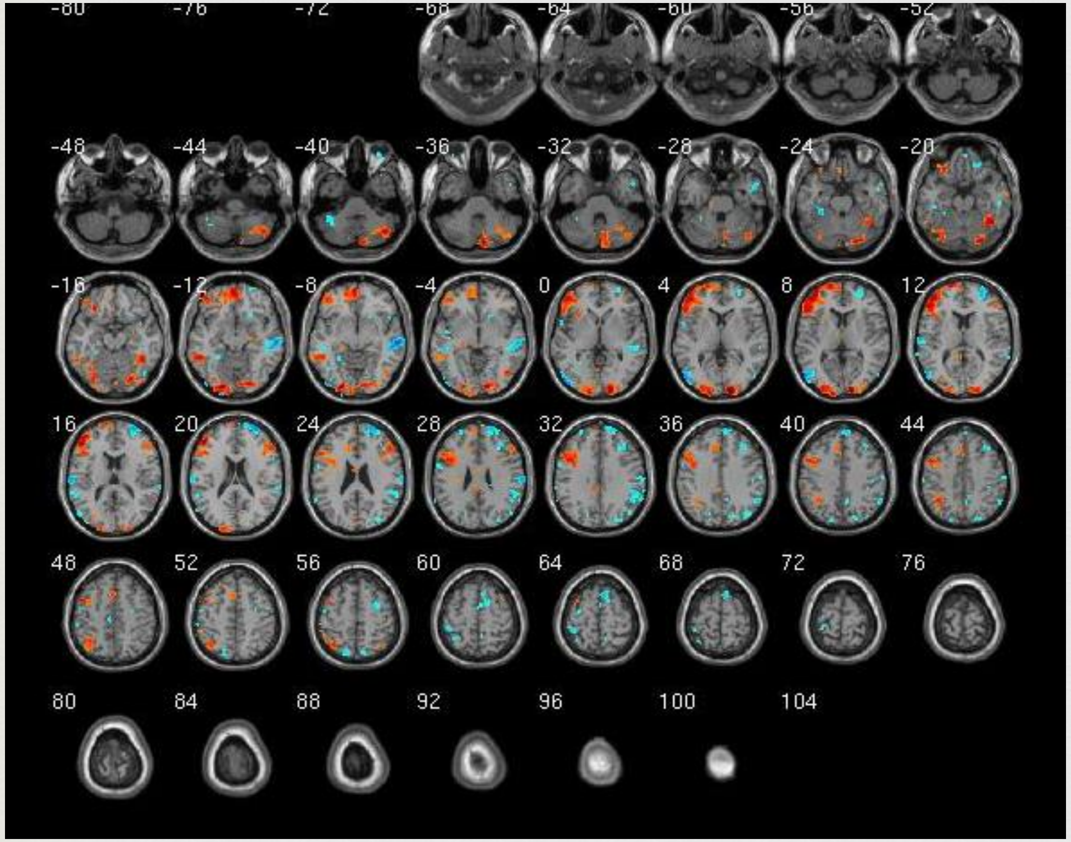
- In general, use p=0.001 or p=0.005
- Use k=5 or higher
- xjView will analyze clusters for you and tell you what anatomical features they contain
- Remember, multiple comparison testing is often best approach!!

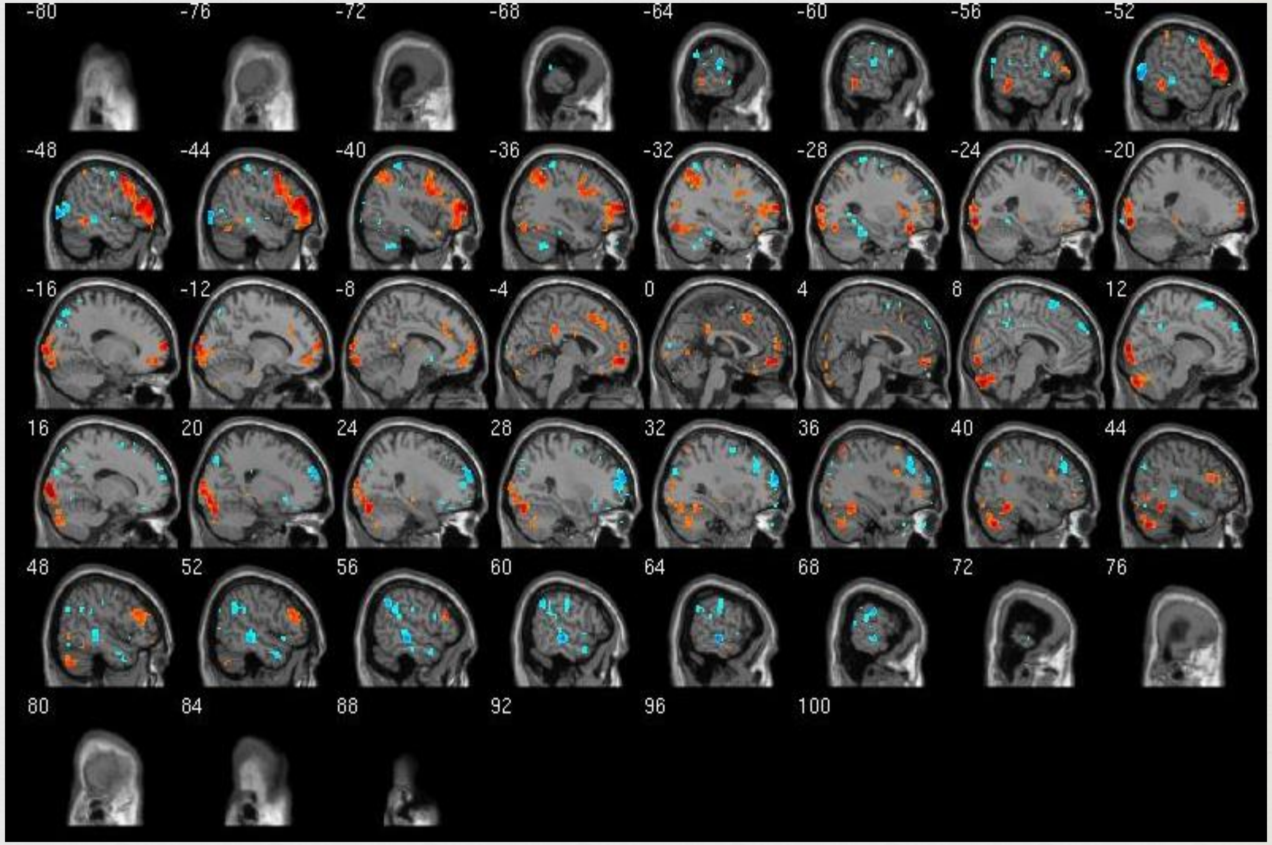
Cluster Analysis

- This particular cluster has 110 voxels
- 109 of these voxels are located in the frontal lob
- 63 are classified as White Matter
- 61 are classified as Superior Frontal Gyrus



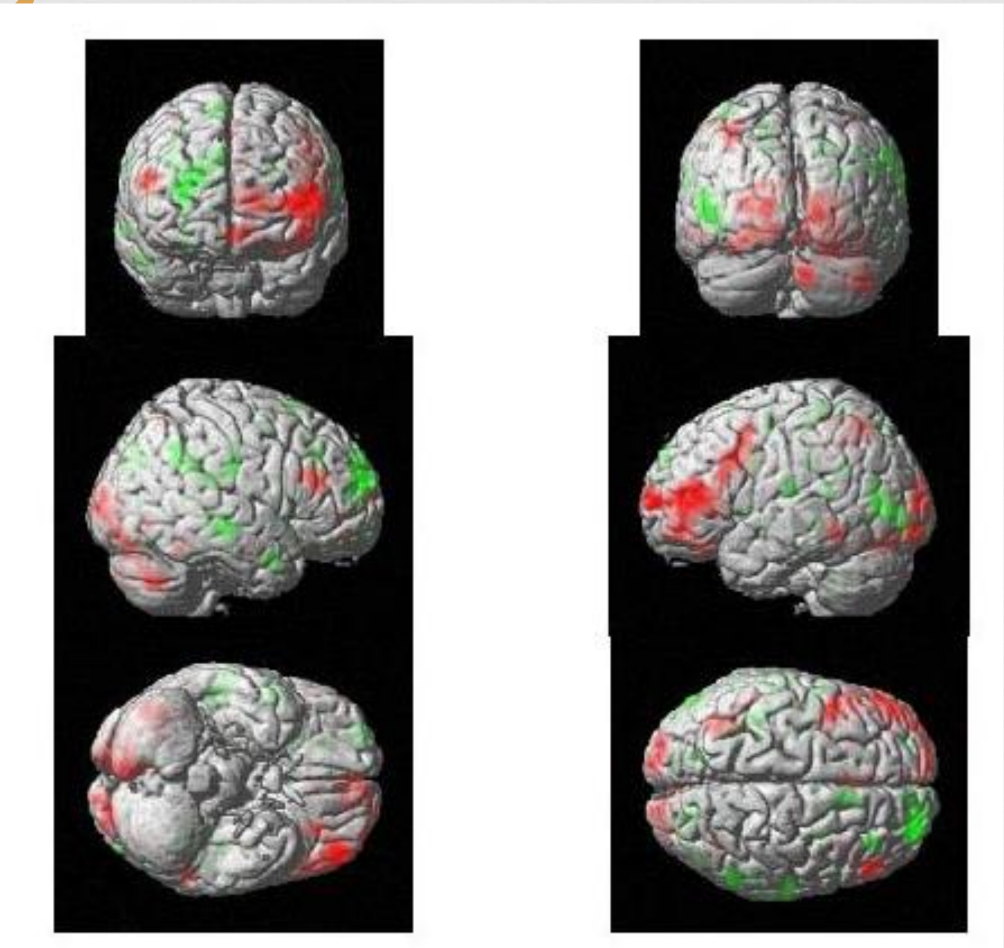
Can Display in Slice View





Can Also Pick "Render View"

Reconstruction of 3D brain with "activation" on the surface

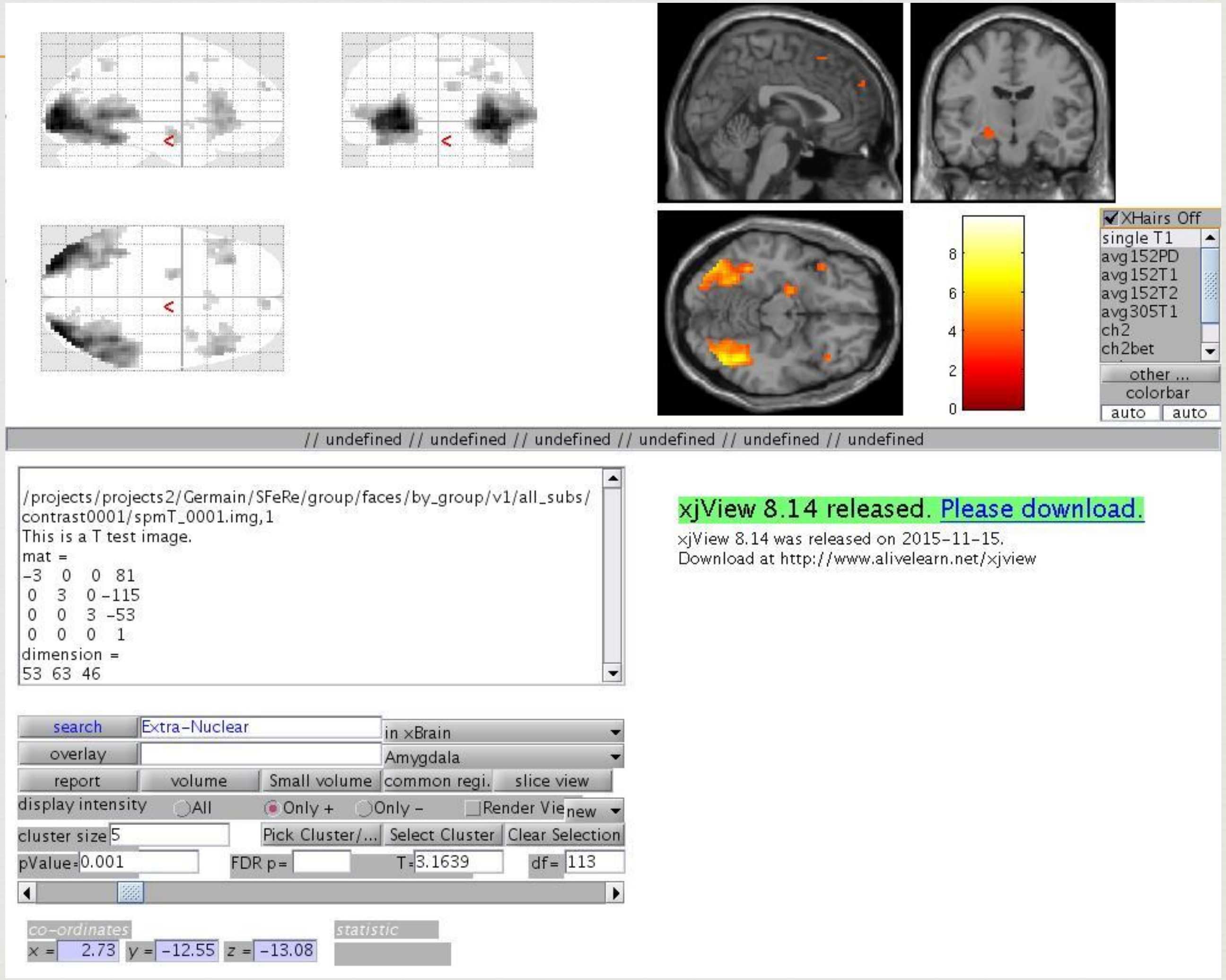


Now, Group Maps

- This is a map of anger>control for 114 normal, healthy subjects
- This image was created using a one-sample t-test
- One-sample t-test are used to find the "average" activation of a group

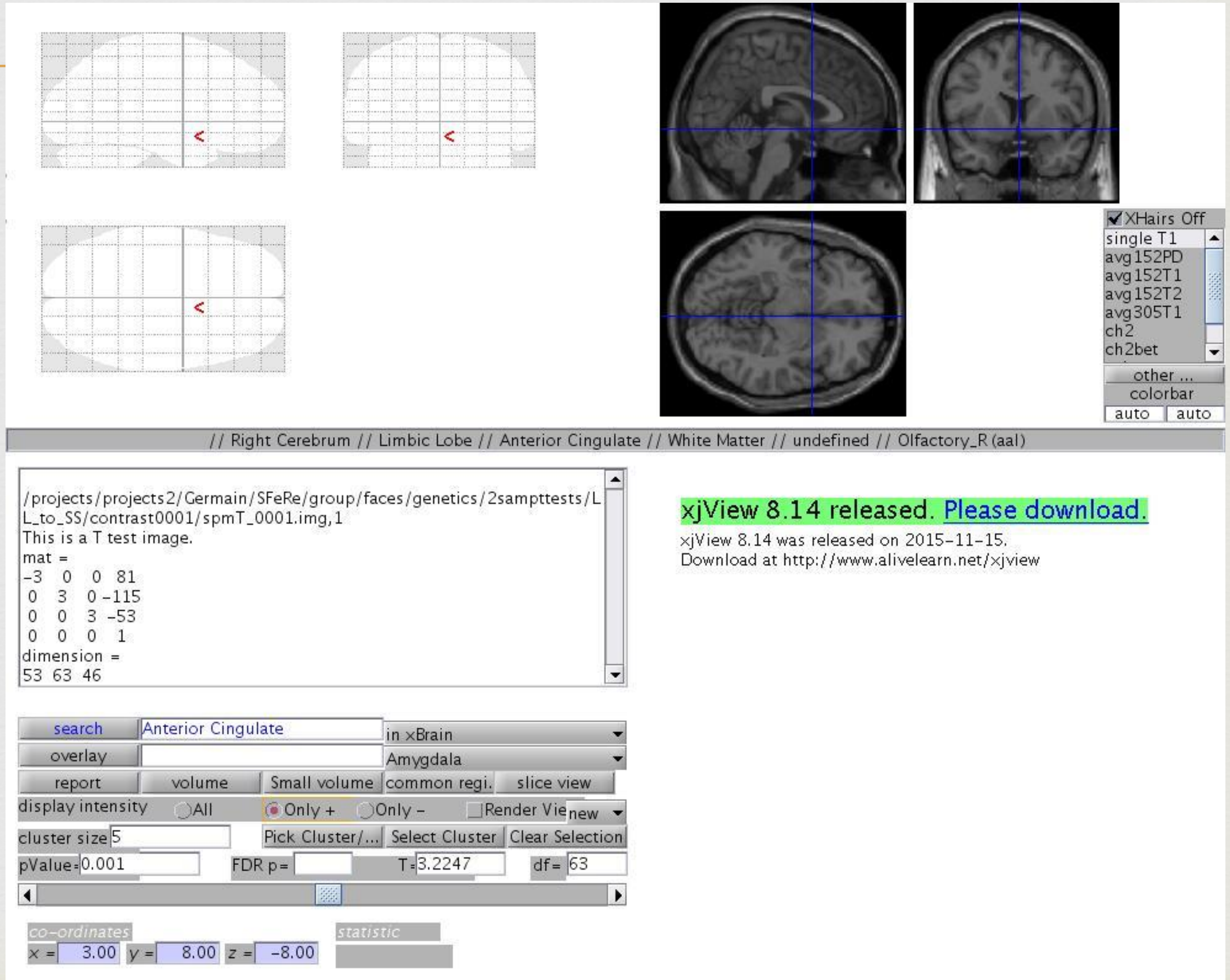
$$t_{calc} = \frac{\bar{Y}}{s / \sqrt{n}}$$

Assuming $\mu = 0$



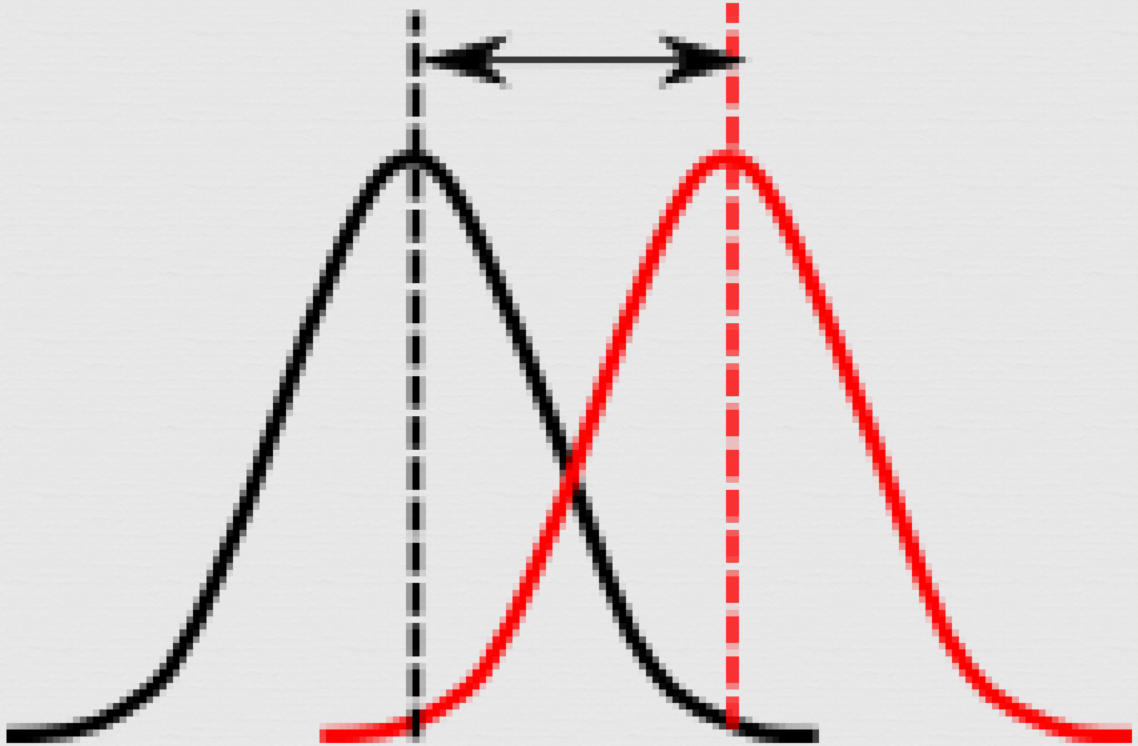
How About Comparing Groups?

- This is a map of anger>control for 32 female genetic carriers of LL vs 33 female genetic carriers of SS (serotonin transporter genes)
- This image was created using a two-sample t-test
- Two-sample t-tests can compare the activation between two groups
- Shows only where LL>SS



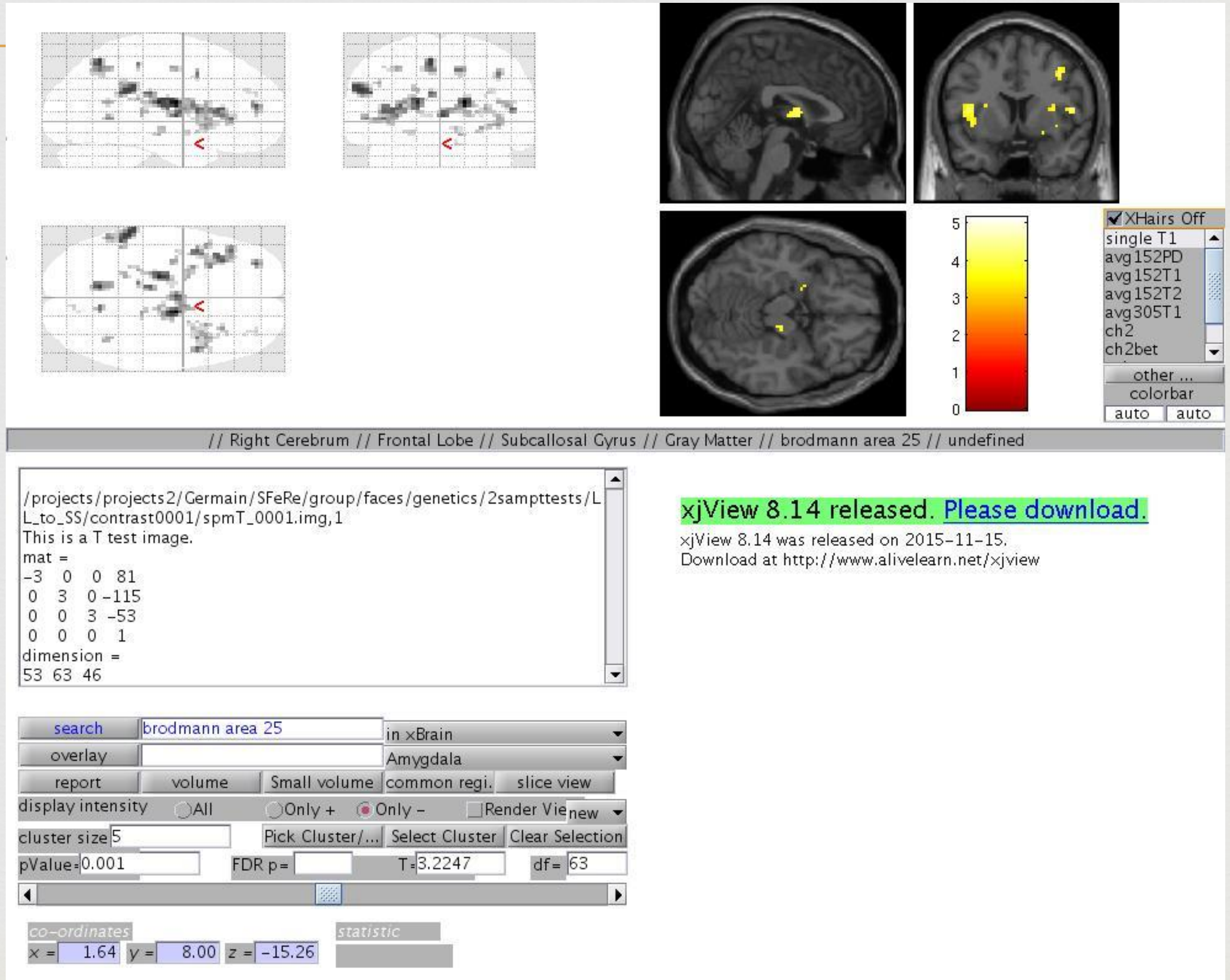
Two Sample T-Test

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_p^2}{n_1} + \frac{s_p^2}{n_2}}}$$



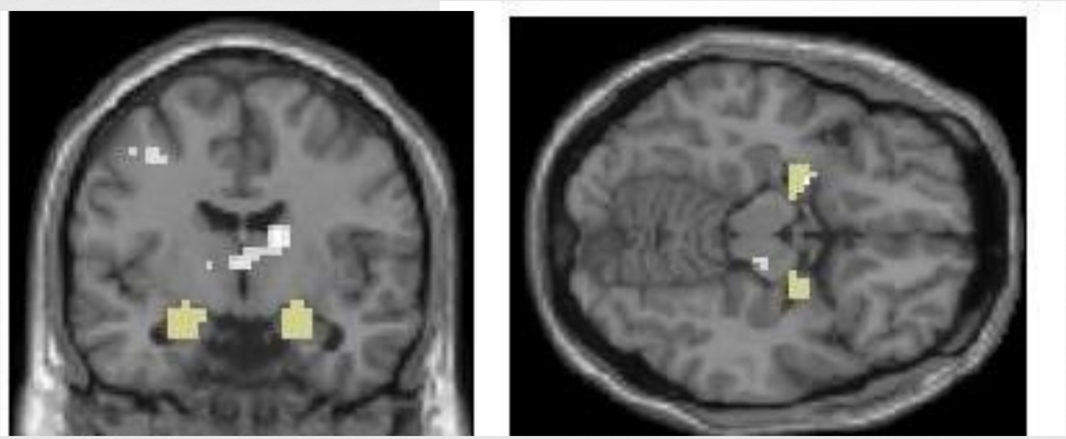
Check the Other Way (SS>LL)

- No activation for LL>SS, but activation for SS>LL
- This image was created using a two-sample t-test
- Shows only where SS>LL



ROI Analysis

- Pick a specific brain region of interest
- Extract the Beta values from this region for each subject
- Statistically compare means for the Beta values for this specific region



Yellow areas show where the amygdala is (left and right)