

fMRI Report

Flanker's Task

Prepared By: Mariam Ahmed
Submitted to: Dr/Meena Makary



Systems and Biomedical Engineering Department
Spring 2024
SBE30xx
20/04/2024

Table of Contents

1. Data Inspection.....	4
1.1 About the Dataset.....	4
1.2 Data Acquisition Information.....	4
1.3 Anatomical Images Description.....	4
1.4 Functional Images.....	4
1.5 Findings of Each Subject.....	5
2. Data Preprocessing.....	6
2.1 Skull stripping.....	6
2.1 Preprocessing.....	6
Observation in the FEAT report.....	7
3. Exercises Findings.....	8
1. BET on Subject 8 with 0.1 vs 0.9 threshold.....	8
2. Preprocess Run 2 for subject 8.....	8
3. 3 mm vs 12 mm smoothing kernel.....	9
4. 3 DOF vs 12 DOF.....	9
5. BBR vs 12 DOF.....	10
1. The human Brain.....	11
2. Regions of the Brain.....	11
2.1 Cerebrum.....	11
Main Functions.....	11
2.1.1 Cerebral Cortex.....	12
Main Functions.....	12
Region Location in MNI space.....	12
2.2 Brain Stem.....	12
Region location in MNI space.....	12
2.2.1 Midbrain.....	12
Main Functions.....	12
2.2.2 Pons.....	13
2.2.3 Medulla.....	13
Main Functions.....	13
Brain stem anatomy in the MNI space.....	13
2.3 Cerebellum.....	13
Main Functions.....	13
Region Location in MNI space.....	14
2.4 Diencephalon vs Telencephalon.....	14
Location in the MNI space.....	14
3. Deeper Level Structure.....	15
3.1 Pituitary Gland.....	15
Main Functions.....	15
Region Location in MNI space.....	15
3.2 Amygdala.....	15
Main Functions.....	15

Region Location in MNI space.....	15
3.3 Hippocampus.....	16
Main Functions.....	16
Region Location in MNI space.....	16
3.4 Ventricle.....	16
Main Functions.....	16
Region Location in MNI space.....	16
3.5 Thalamus.....	17
Main Functions.....	17
Region Location in MNI Space.....	17
3.6 Basal Ganglia.....	17
Main Functions.....	17
Region Location in MNI Space.....	17
3.7 Corpus Callosum.....	17
Main Functions.....	17
Region Location in MNI Space.....	18
3.8 Mammillary bodies.....	18
Main Functions.....	18
Region Location in MNI Space.....	18
3.9 Olfactory bulbs.....	18
Main Functions.....	18
Region Location in MNI Space.....	19
3.10 Optic chiasm.....	19
Main Functions.....	19
Region Location in MNI Space.....	19
4. Lobes of the Brain.....	19
4.1 Frontal Lobe.....	19
4.2 Parietal Lobe.....	20
4.3 Occipital Lobe.....	20
4.4 Temporal Lobe.....	21
4.5 Insular Lobe.....	21
1. Timing Files.....	22
2. First Level Analysis.....	22
Summary of the GLM FEAT reports.....	25
Results.....	29

Task 1

Quality Control

1. Data Inspection

1.1 About the Dataset

Flanker's dataset is collected from 26 healthy adults, it's a task based experiment which is based on the slow event-related Eriksen Flanker task. (*Flanker task (event-related),*)

In Flanker's task, the subjects are shown targets that are centered and flanked by other non-target stimuli. And the participants are asked to press left or right arrow keys depending on the target's direction. The stimulus is either congruent or incongruent, congruent means that the direction of the non-target and the target is the same, and the incongruent means that the target and non-target are in opposing directions. (www.sciencedirect.com, n.d.)

1.2 Data Acquisition Information

"*Functional imaging data were acquired using a research dedicated Siemens Allegra 3.0 T scanner, with a standard Siemens head coil, located at the NYU Center for Brain Imaging.*

We obtained 146 contiguous echo planar imaging (EPI) whole-brain functional volumes (TR=2000 ms; TE=30 ms; flip angle=80, 40 slices, matrix=64x64; FOV=192 mm; acquisition voxel size=3x3x4mm) during each of the two flanker task blocks.

A high-resolution T1-weighted anatomical image was also acquired using a magnetization prepared gradient echo sequence (MPRAGE, TR=2500 ms; TE= 3.93 ms; TI=900 ms; flip angle=8; 176 slices, FOV=256 mm). "(Flanker task (event-related),)

1.3 Anatomical Images Description

When looking at the data, there's a folder for each subject, each containing 1 anatomical image and 2 functional (BOLD) images, upon observing the files of each subject individually using FSLEyes, almost all of the anatomical images have the same quality which is high quality, there are merely slight differences between the quality of the images, some are slightly of better contrast than others, yet overall they're all clean and no obvious artifacts that would cause hindrance was spotted, for example, the only image with aliasing notices was outside of the brain region and would be removed when performing skull striping anyway.

1.4 Functional Images

The functional data are found in 2 runs, when inspecting the 4D functional data, multiple motion artifacts were found, with varying severity (from mild to moderate to severe), yet some were clean and had very little artifacts that it's not noticeable.

1.5 Findings of Each Subject

The following table summarizes the observations of each subject.

subject No.	Motion Artifacts Observed in BOLD Run 1	Motion Artifacts Observed in BOLD Run 2	T1
1	Motion Artifact Detected, Level = Moderate	Motion Artifact Detected, Level = Mild	High Quality
2	Motion Artifact Detected, Level = Mild	no motion artifacts detected	High Quality
3	contains a lot of motion artifacts in multiple volumes, artifacts level = mild to moderate	contains a lot of motion artifacts in multiple volumes, artifacts level = moderate to severe	High Quality
4	Motion Artifact Detected, Level = Mild	contains a lot of motion artifacts in multiple volumes, artifacts level = mild to moderate	High Quality
5	contains some motion artifacts in one or few volumes, artifacts level = mild	Motion artifacts noticed in volume 36	High Quality
6	no motion artifacts detected	motion artifacts noticed in volume 8	High Quality
7	no motion artifacts detected	no motion artifacts detected	High Quality
8	contains a lot of motion artifacts in multiple volumes, artifacts level = moderate	contains a lot of motion artifacts in multiple volumes, artifacts level = moderate	High Quality
9	no motion artifacts detected	motion artifacts noticed in volume 8	High Quality
10	contains a lot of motion artifacts in multiple volumes, artifacts level = moderate	contains a lot of motion artifacts in multiple volumes, artifacts level = moderate	High Quality
11	contains a lot of motion artifacts in multiple volumes, artifacts level = moderate	contains a lot of motion artifacts in multiple volumes, artifacts level = moderate	High Quality
12	no motion artifacts detected	no motion artifacts detected	High Quality
13	no motion artifacts detected, but there's flashing at the eye region	no motion artifacts detected, but there's flashing at the eye region	High Quality
14	contains some motion artifacts in multiple volumes, artifacts level = mild to moderate	severe motion artifact in volume 112	Very High Quality
15	almost no motion artifacts detected	no motion artifacts detected	High Quality
16	contains a lot of motion artifacts in multiple volumes, artifacts level = moderate	contains a lot of motion artifacts in multiple volumes, artifacts level = moderate	Very High Quality
17	contains a lot of motion artifacts in multiple volumes, artifacts level = moderate	contains a lot of motion artifacts in multiple volumes, artifacts level = moderate	High Quality
18	contains a lot of motion artifacts in multiple volumes, artifacts level = moderate to severe	contains a lot of motion artifacts in multiple volumes, artifacts level = moderate to severe	High Quality
19	contains a lot of motion artifacts in multiple volumes, artifacts level = moderate to severe	severe motion artifact in volume 76	High Quality
20	contains some motion artifacts in multiple volumes, artifacts level = mild to moderate	contains a lot of motion artifacts in multiple volumes, artifacts level = moderate to severe	High Quality
21	contains a lot of motion artifacts in multiple volumes, artifacts level = moderate to severe	contains a lot of motion artifacts in multiple volumes, artifacts level = moderate to severe	aliasing artifact in sagittal view, however, it's outside of the skull so it

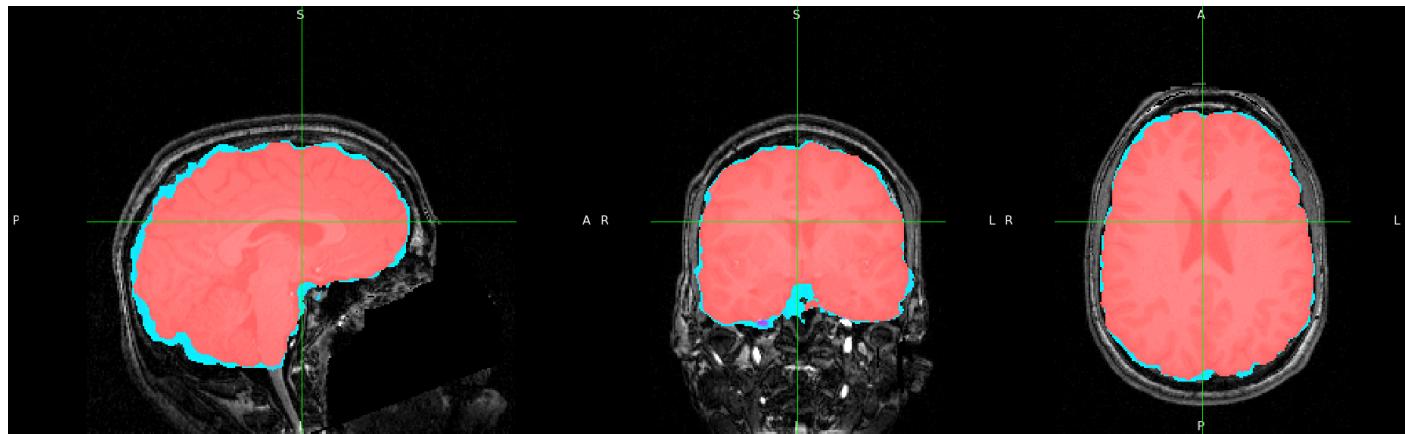
			wouldn't affect my data
22	contains some motion artifacts in multiple volumes, artifacts level = mild to moderate	contains some motion artifacts in multiple volumes, artifacts level = mild to moderate	High Quality
23	contains some motion artifacts in multiple volumes, artifacts level = mild	contains some motion artifacts in multiple volumes, artifacts level = mild	Very High Quality
24	contains some motion artifacts in multiple volumes, artifacts level = mild	contains some motion artifacts in multiple volumes, artifacts level = mild to moderate	Very High Quality
25	contains some motion artifacts in multiple volumes, artifacts level = mild to moderate	contains a lot of motion artifacts in multiple volumes, artifacts level = moderate to severe	High Quality
26	almost no motion artifacts detected	almost no motion artifacts detected	Very High Quality

2. Data Preprocessing

2.1 Skull stripping

When choosing 5 random subjects(2, 8, 12, 13, 19) and using the BET extraction tool in FSL, I've tried both 0.5 and 0.2 thresholds and saw the coverage of each relative to each other and whether they cover the entire brain or not. Using threshold of 0.5 was too high for all of the five subjects, as it seemed to leave parts of the brain near the skull and parts of the cerebellum as well, but 0.2 had pretty good coverage for all 5 of the subjects, based on this, the threshold that will be used automatically for the rest of the subjects will be by default 0.2.

The following screenshot shows subject 2 as an example of the difference between 0.5 threshold which is in pink and 0.2 threshold which is in blue.



2.1 Preprocessing

Preprocessing was done on the same 5 random subjects, motion correction using MCFLIRT, no slice timing correction because the acquisition time is only 2 seconds which isn't long enough for slice timing, and registration was done with 12 DOF and normal search, the used image was the skull stripped image with 0.2 threshold of the each subject and the standard 2mm MNI image.

Looking at the FEAT reports, I observed the quality of registration per subject for each run, and reported the quality in the following table, where the quality is either well-aligned, satisfactory, and poor.

As for the motion correction, according to Andy's brain book, further advanced correction techniques should be applied if there's spikes in motion plots that are greater than half of the voxel resolution, and drift that are greater than the size of the entire voxel. This means that if the relative motion is more than 1.5mm from volume to volume or if the absolute motion is more than 3mm then this subject should be flagged for further correction.(Chapter 7: Checking your Preprocessed Data — Andy's Brain Book 1.0 documentation, no date)

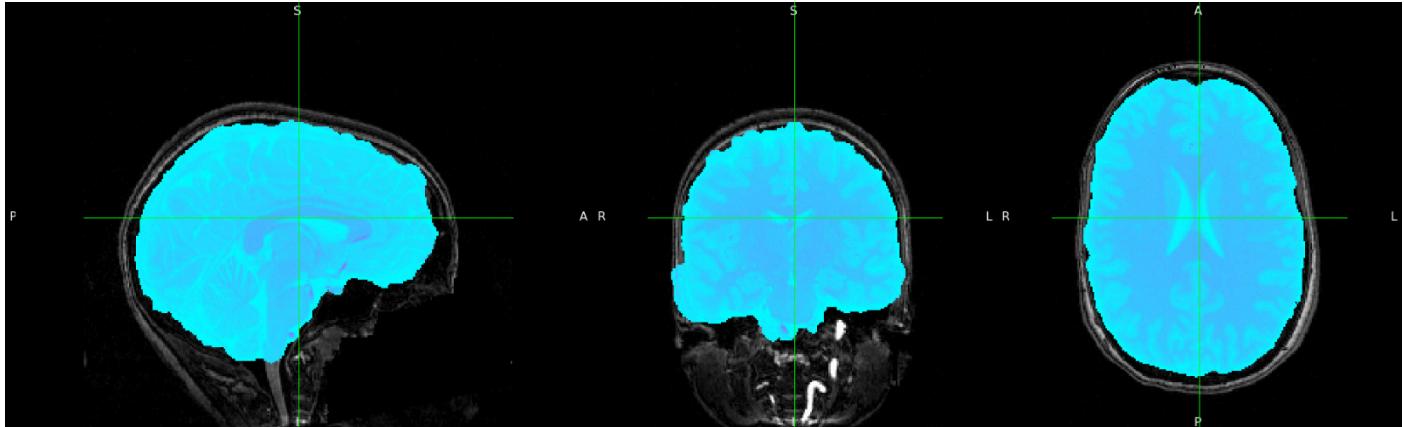
Observation in the FEAT report

subject no.	Registration results for run 1	Registration results for run 2	Reference Volume in Run 1	Reference Volume in Run 2	observations for Run 1 of motion correction	observations for Run 2 of motion correction
2	well aligned	satisfactory	around the 70th volume	around the 70th volume	There is motion spikes in the graph but they are much smaller than the thresholds so that subject's motion correction is acceptable, there was also a huge amount of translation in x axis	The relative motion is very little, almost neglected, and there's a spike at the beginning of the graph in the absolute motion that goes up 0.5 but still it's less than the threshold. there was a huge amount of translation in x axis, as well as y axis
8	satisfactory	satisfactory	around the 70th volume	around the 70th volume	There are spikes in the translational graphs in x, y at the last couple of volumes and spikes in z direction in rotational in the nearly the same volumes, these spikes are also present in mean displacement graph at the same couple of volumes, that could mean there was a significant motion artifact near the end of the scan, however, still nothing more than the threshold	There are spikes in the absolute and relative displacement, around the 30s and 90s volumes, nothing higher than the thresholds, huge rotations in x and y are observed and spikes in translations in z direction are found
12 (RUN 1 IS NOISY)	satisfactory	well aligned	around the 70th volume	around the 70th volume	The subject's graphs are very irregular and very spiky in the 3 graphs, both the absolute and relative motion are the highest observed and it's very noisy, even tho it doesn't exceed the threshold, this subject should be flagged for how noisy it is in order to be put in consideration .	Run 2 is not as noisy as run 1 but there are some observed spikes, across most volumes, the max relative and absolute motion are very small, and less than the threshold.
13	well aligned	well aligned	around the 70th volume	around the 70th volume	The subject is mainly stable except for the first couple of volumes, still nothing higher than the thresholds observed.	There's a huge spike in the 3 graphs around the 50th volume, that could mean a significant motion artifact around that volume, nothing higher than the threshold observed
19(Motion artifact in Run 1 needs further processing)	well aligned	well aligned	around the 70th volume	around the 70th volume	Around the 50th volume there's a huge spike, in the three graphs, and the relative motion is higher than 1.5mm and the absolute motion is higher than 2.5mm	There's a huge spike of motion near the 80th volume, and that spike is also present around the z axis in translation, and x axis in rotation.

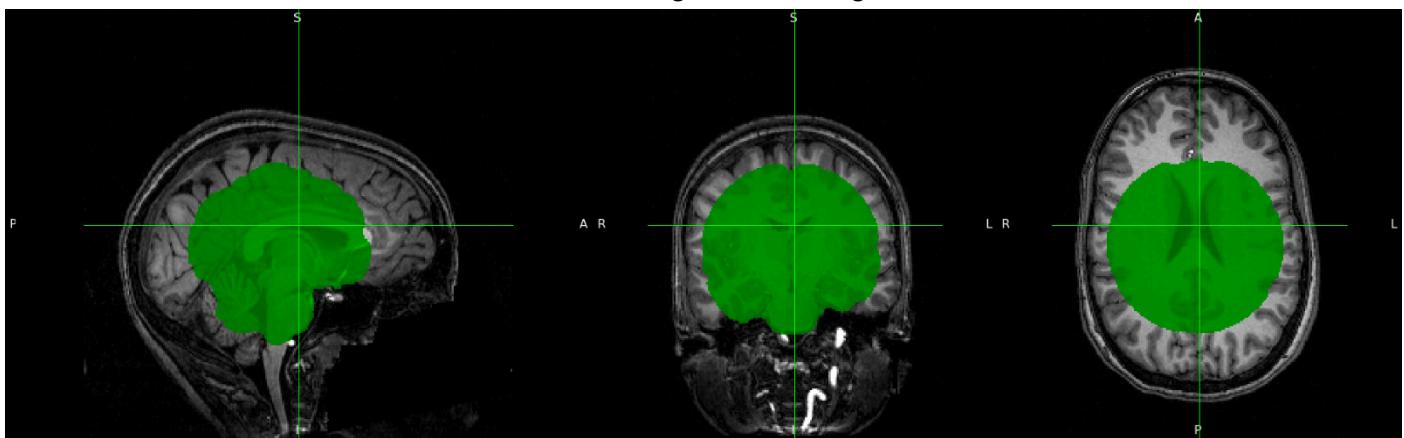
3. Exercises Findings

1. BET on Subject 8 with 0.1 vs 0.9 threshold

The following is the 0.1 threshold



The following is the 0.9 image



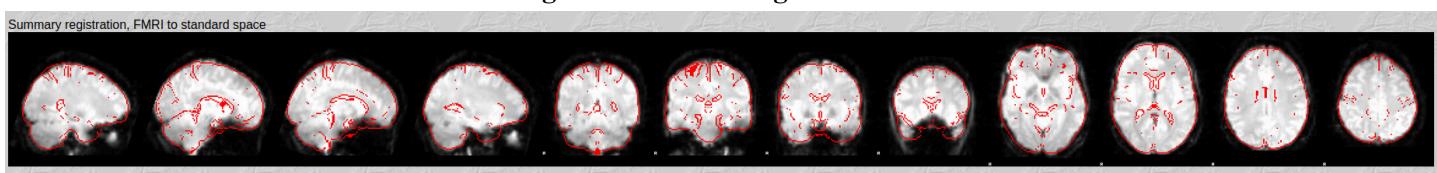
Comparing both of them together, the 0.9 threshold is too high that is only takes a small fragment of the brain image, however the 0.1 threshold has a really good brain coverage which is plausible because most of the subjects works with 0.2 threshold

If I was to choose one of them I would choose the 0.1 threshold over 0.9 because having extra parts from the skull is better than leaving out parts of the brain.

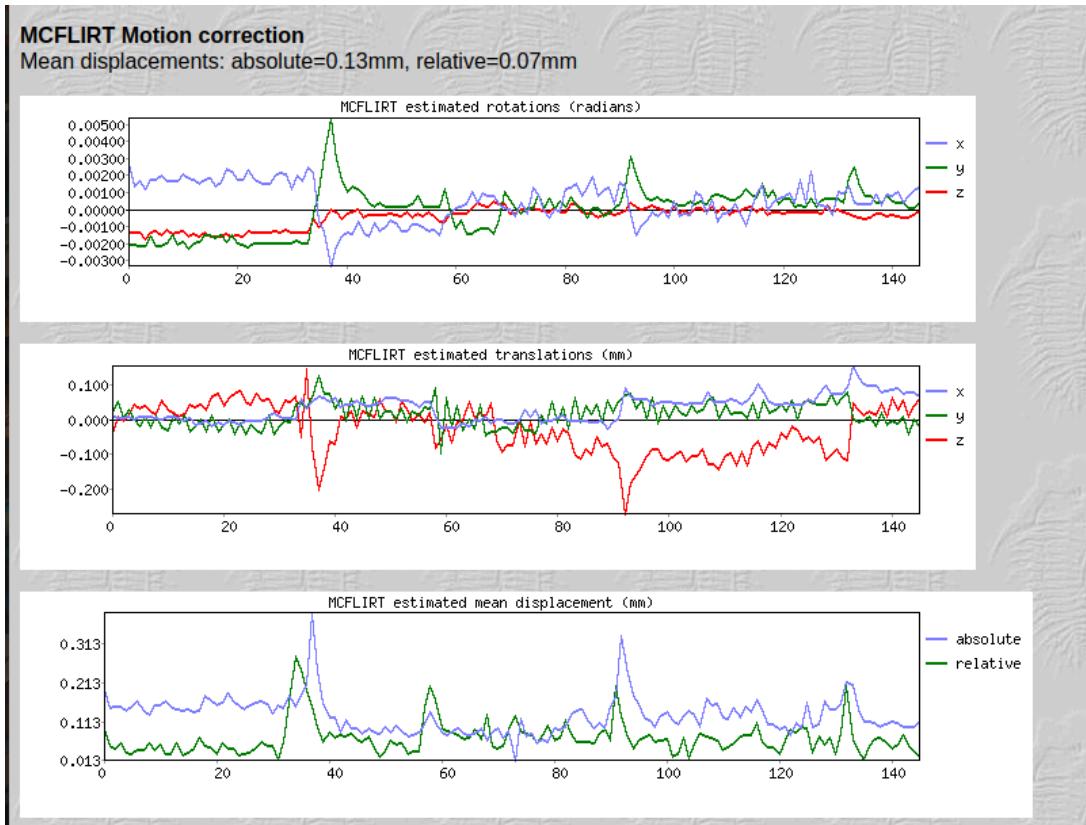
2. Preprocess Run 2 for subject 8

Subject 8 was already one of the randomly selected subjects so the exercise was already done in section before and the findings are in the table.

The following is the result of registration for run 2



The following is the result of motion correction



3. 3 mm vs 12 mm smoothing kernel

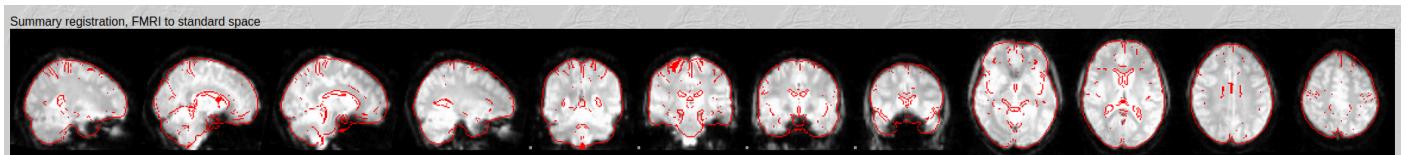
Upon observing, the 3 mm smoothing kernel doesn't seem to be visually different, but generally the more you smooth the better the noise removal but when dealing with small regions of interest that will cause a problem.

4. 3 DOF vs 12 DOF

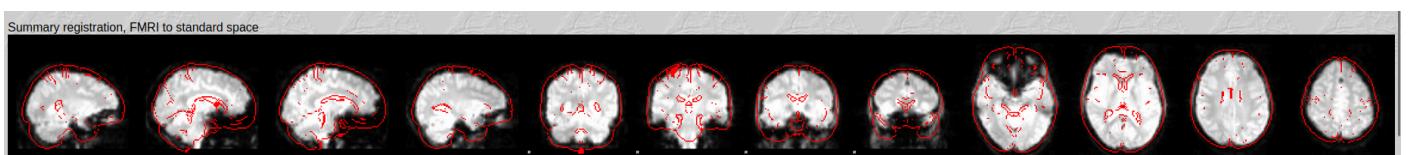
The 3 DOF seems to have much worse registration than 12 DOF, as 3 DOF includes transnationals only, thus leading to worse registration.

The following are pictures from the feat report from 12 DOF vs 3 DOF

12 DOF



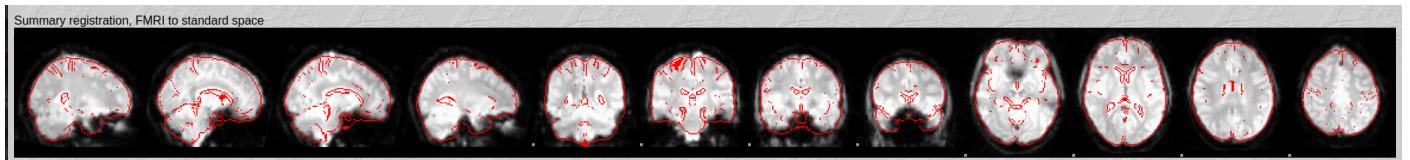
3 DOF



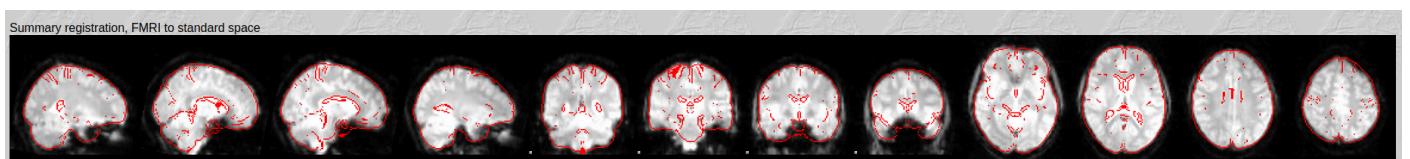
5. BBR vs 12 DOF

When observing the output of the BBR and comparing it to the 12 DOF, one noticeable thing is that it's more time consuming, and when looking at the FEAT output there are slight differences in the registration, not very significant, but there's a difference, the following are screenshots of the FEAT reports of both of them.

BBR



12 DOF



Task 2

Neuroanatomy

1. The human Brain

The brain is remarkably the most complex organ of the body that controls all body functions, from basic physiological needs like breathing up to thoughts, personality and ideology, thus it can't be dealt with like it's a separate entity of oneself, however, it's often dealt with as an abstract entity or a black box, nevertheless, we keep trying to understand this "black box" and how it functions.

Physically, the brain weighs on average 3 pounds or 1.3 kgs, and it's composed of 60% fat and the rest is water, protein, carbohydrates and salts. The brain is not a muscle but rather composed of mainly nerves and blood vessels, when looking at it we will see 3 main regions:

White Matter: which is the axons of neurons, and it's responsible for transmission of information and signals to other parts of the nervous system.

Gray Matter: which is the cell body of neurons, which is responsible for processing and interpreting information

Cerebrospinal Fluid: which is an ultrafiltrate of plasma that's contained within the brain, that is responsible for vital functions like nutrition providing, removal of waste and brain protection from trauma

"Instinct is something which transcends knowledge. We have, undoubtedly, certain finer fibers that enable us to perceive truths when logical deduction, or any other willful effort of the brain, is futile."

— Nikola Tesla, My Inventions

2. Regions of the Brain

The brain can be divided into the forebrain, the midbrain and the hindbrain, besides the spinal cord. The hindbrain is composed of the brain stem and upper part of the spinal cord, it regulates the most basic body functions and needs like breathing and heart rate, as for the midbrain, it's mainly responsible for voluntary movements and some reflex actions, as for the forebrain, it handles the most complex tasks among the three divisions, it's composed of the cerebrum and the structures of the inner brain.

However, a more higher level anatomical division of the brain could be the cerebrum, brainstem and cerebellum, which will be used throughout this report to identify the different regions of the brain.

The following regions of the brain are located in the MNI space, either with the help of the FSL Atlas, which will appear highlighted like a heatmap, or done manually, where the region with the view that shows the region the most is highlighted and pointed at with an arrow.

2.1 Cerebrum

It's made up of the cerebral cortex which is the gray matter, and at the center there's white matter.

Main Functions

Since the cerebrum is a broad area of the brain that has plenty of subregions below it, describing its functionality would be stating the functionality of its subregions like:

1. Initiation and Coordination of movement
2. Temperature regulation
3. Speech judgment

4. Thinking and reasoning

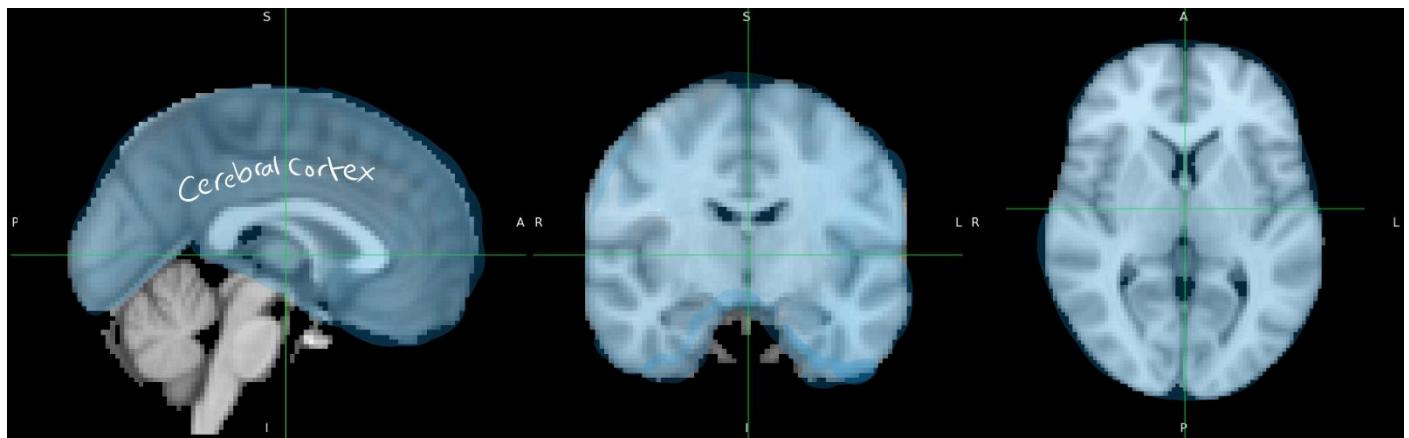
2.1.1 Cerebral Cortex

It's the outer gray matter covering the cerebrum, and it occupies the largest surface area in the brain. It's named that way because it resembles the bark of a tree, they're made up of hills (gyri) and valleys(sulci), a deep sulcus is called a fissure.

Main Functions

There's no direct functions of the cortex that are known, just like the cerebrum, thus it's mainly known as the “silent cortex” or “association cortex”, because they interpret and they make sense of the stimuli from different sensory pathways.

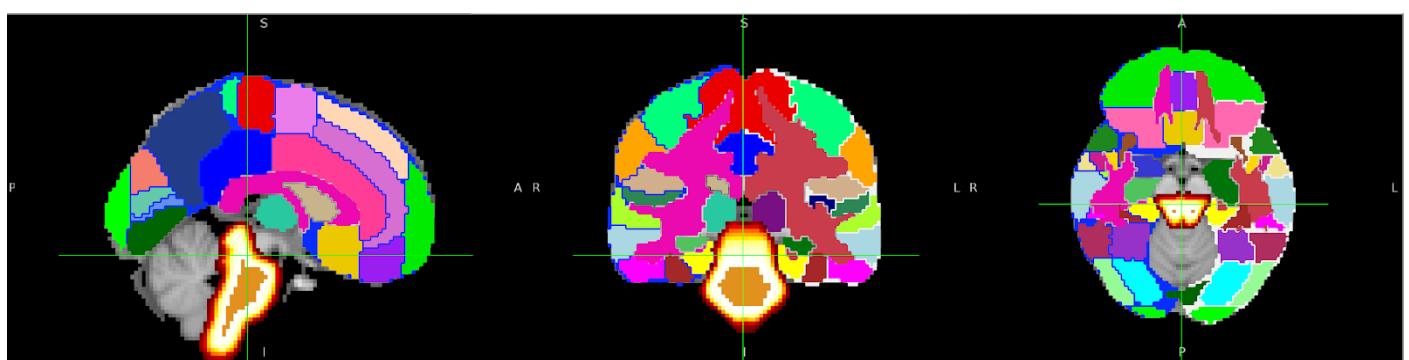
Region Location in MNI space



2.2 Brain Stem

It connects the cerebrum with the spinal cord, it includes the midbrain, the pons, and the medulla.

Region location in MNI space



2.2.1 Midbrain

Main Functions

1. Hearing
2. Movement
3. Calculating responses and environmental changes

2.2.2 Pons

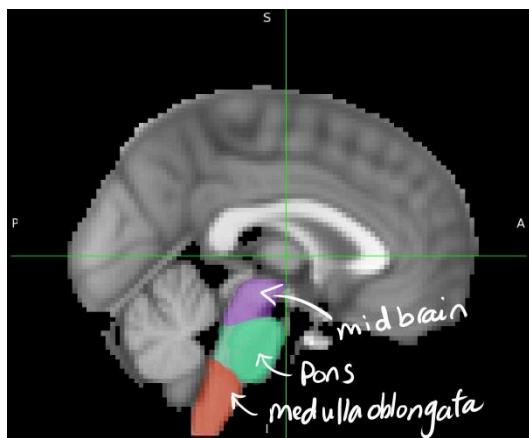
1. Its name means “the bridge” as it connects the midbrain and the medulla
2. Also responsible for activities like
 - a. tear production
 - b. Chewing
 - c. Blinking
 - d. focusing vision
 - e. Balance
 - f. Hearing
 - g. Facial expression

2.2.3 Medulla

Main Functions

1. Regulating body activities (eg, heart rhythm, breathing, blood flow, and oxygen and carbon dioxide levels.)
2. produces reflexive activities such as sneezing, vomiting, coughing and swallowing.

Brain stem anatomy in the MNI space



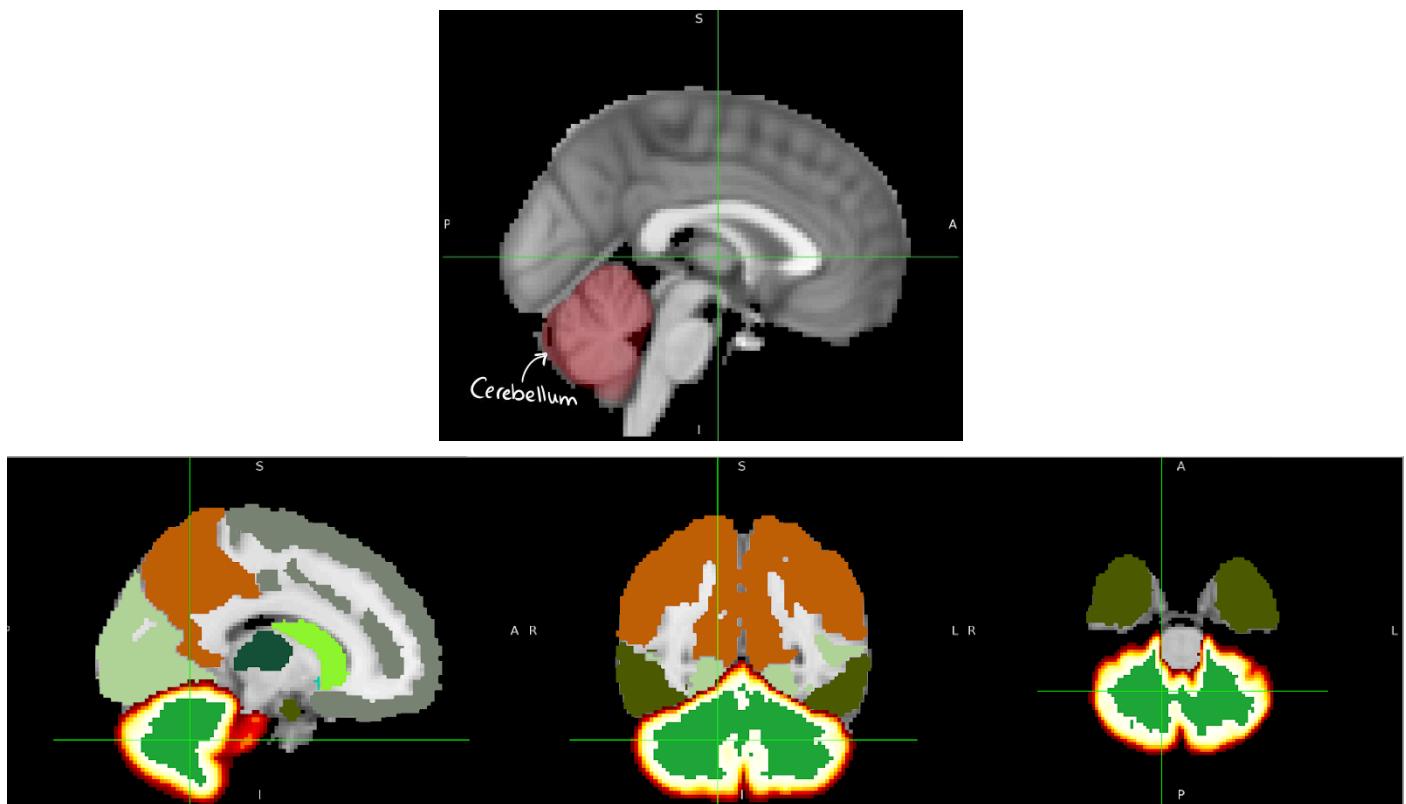
2.3 Cerebellum

It's a fist sized portion at the back of the head

Main Functions

responsible for coordinating voluntary muscle movements and to maintain posture, balance and equilibrium.

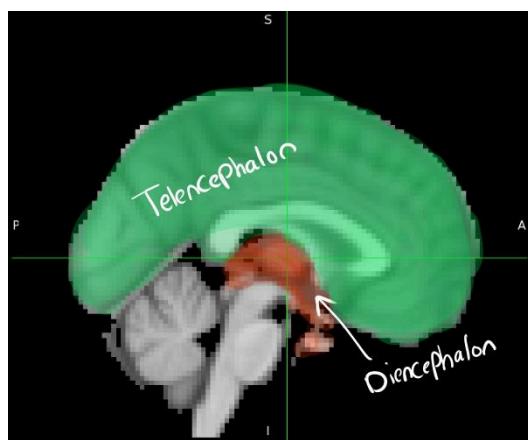
Region Location in MNI space



2.4 Diencephalon vs Telencephalon

It's also worth mentioning that 2 important regions of the brain are the diencephalon and telencephalon, where the telencephalon encompasses the cerebral lobes and the basal ganglia, where the diencephalon includes the epithalamus, thalamus, hypothalamus, subthalamus, which are all regions around the thalamus

Location in the MNI space



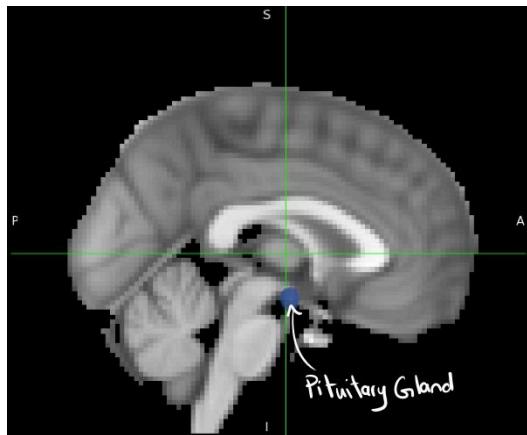
3. Deeper Level Structure

3.1 Pituitary Gland

Main Functions

1. governs the function of other glands in the body
2. Regulates the flow of hormones from the thyroid, adrenals, ovaries and testicles
3. Receives chemical signals from the hypothalamus through its stalk and blood supply.

Region Location in MNI space



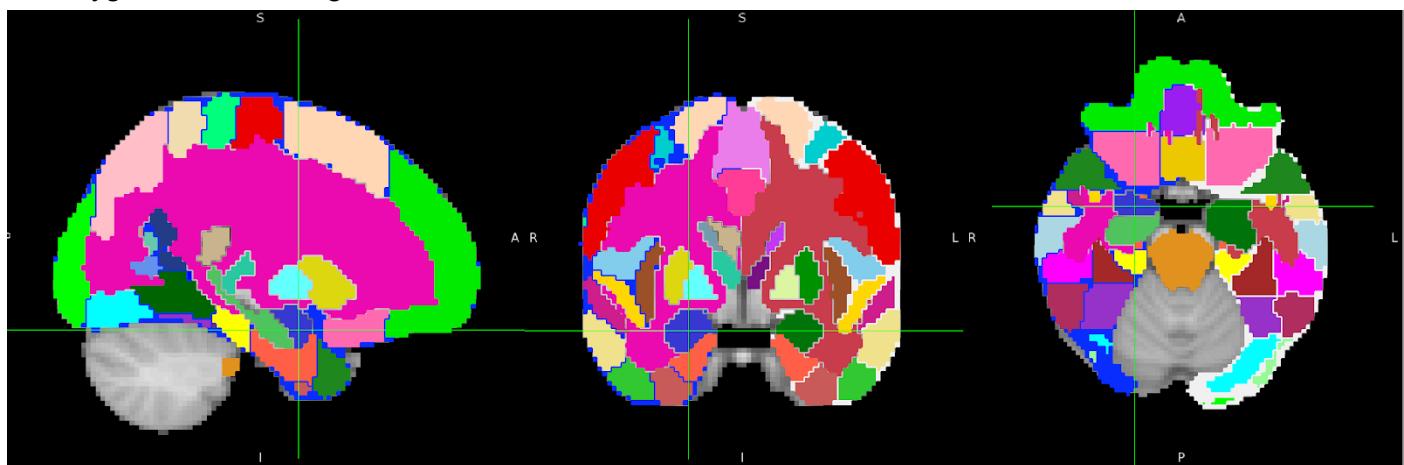
3.2 Amygdala

Main Functions

1. Regulates emotion and memory
2. Linked to the brain's reward system
3. Linked to stress, and the “fight or flight” response when someone perceives a threat.

Region Location in MNI space

The amygdala is the blue region where the cursor is located.

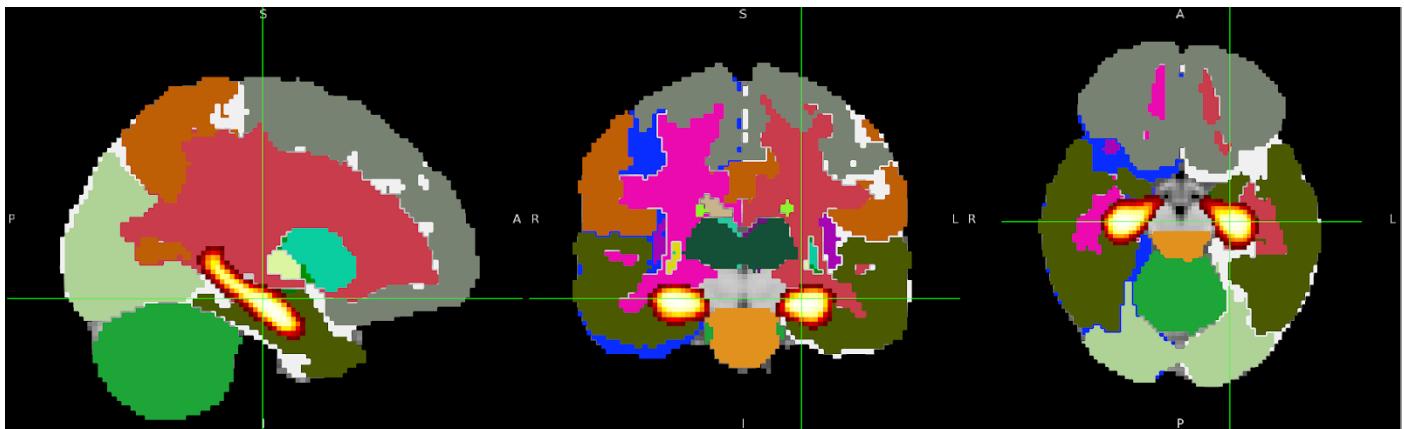


3.3 Hippocampus

Main Functions

1. It supports memory, learning, navigation and perception of space.
2. It receives information from the cerebral cortex
3. May play a role in Alzheimer's disease.

Region Location in MNI space



3.4 Ventricle

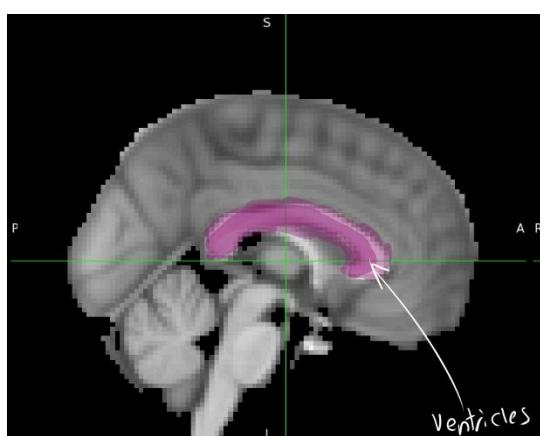
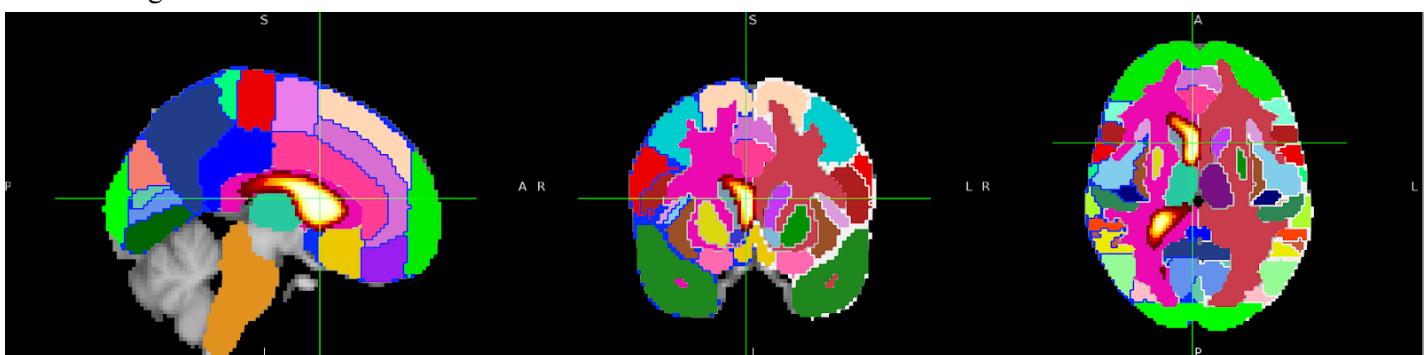
Main Functions

Contains the CSF that:

1. Surrounds and cushions the spinal cord and brain
2. Washes out waste and impurities
3. Delivers nutrients.

Region Location in MNI space

This is the right lateral ventricle

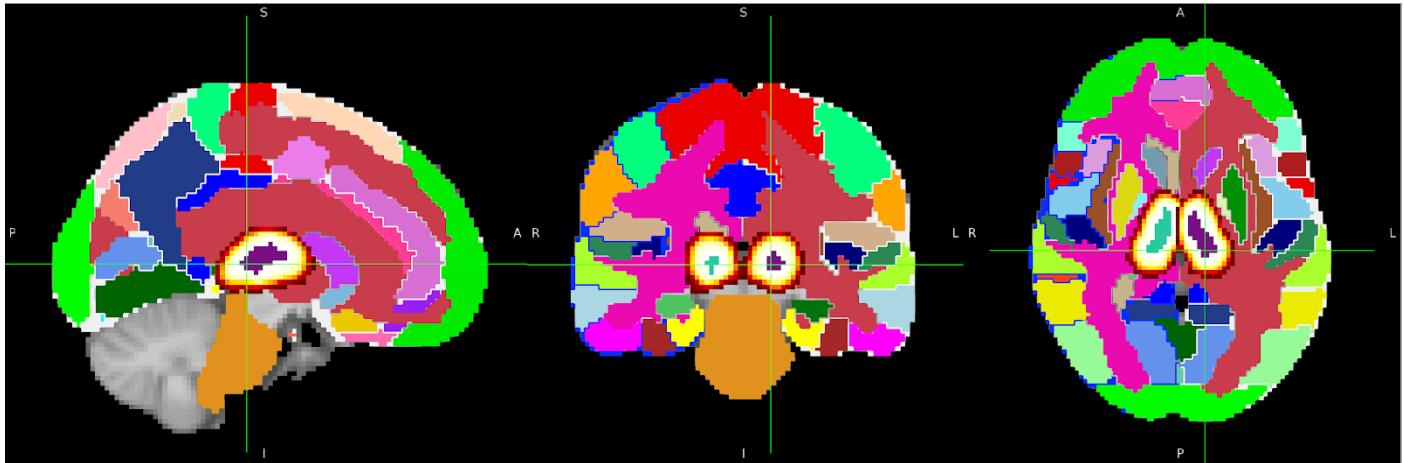


3.5 Thalamus

Main Functions

1. Processing of all sensory information except smell before sending it to the cerebral cortex
2. Processing of all motor information as well before sending it to the cerebral cortex
3. Plays a role in Sleep, wakefulness, consciousness, learning and memory.

Region Location in MNI Space

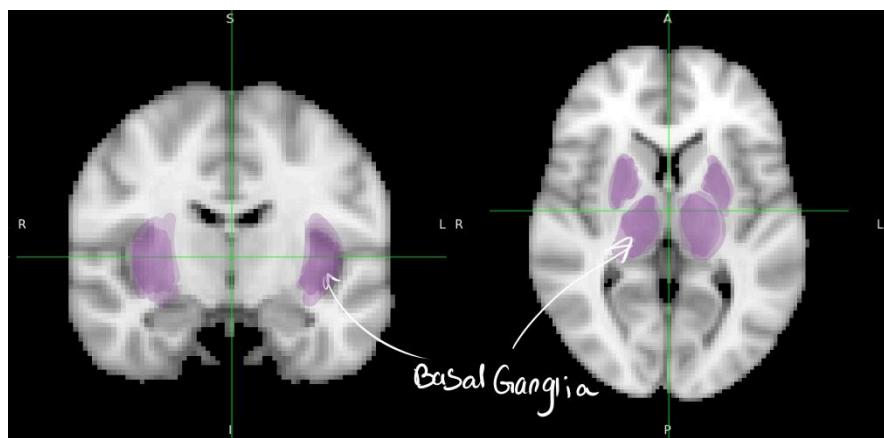


3.6 Basal Ganglia

Main Functions

1. Responsible primarily for motor control
2. Responsible for Motor learning
3. Plays a role in executive functions and behaviors, and emotions.

Region Location in MNI Space

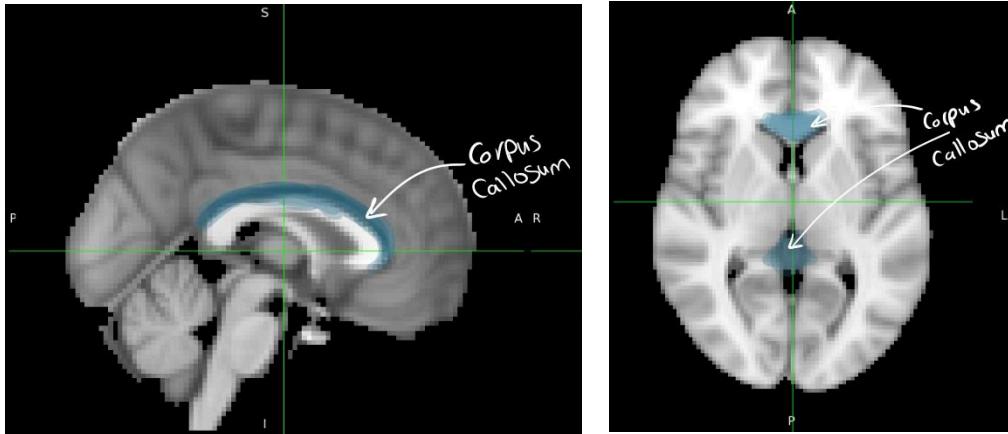


3.7 Corpus Callosum

Main Functions

Transmits information between the left and the right hemisphere.

Region Location in MNI Space

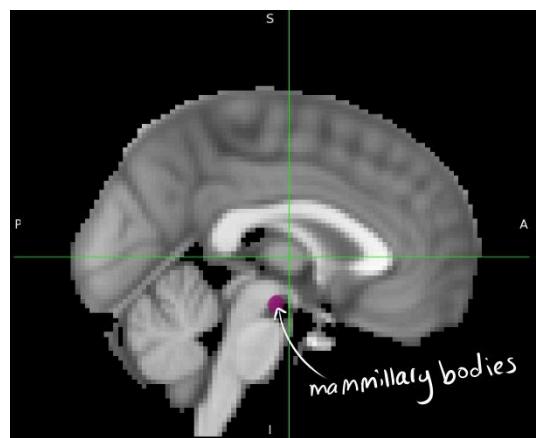


3.8 Mammillary bodies

Main Functions

It's mainly associated with recollective memory.

Region Location in MNI Space

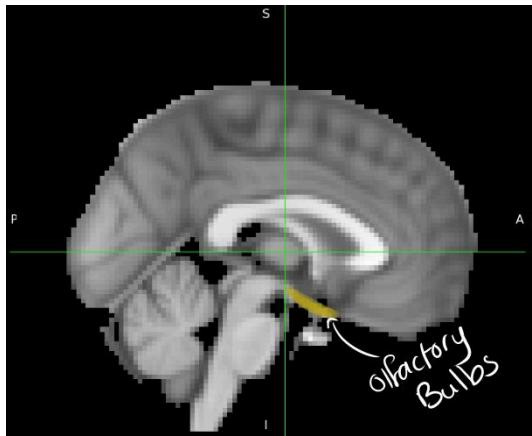


3.9 Olfactory bulbs

Main Functions

plays the central role in the processing of olfactory information

Region Location in MNI Space

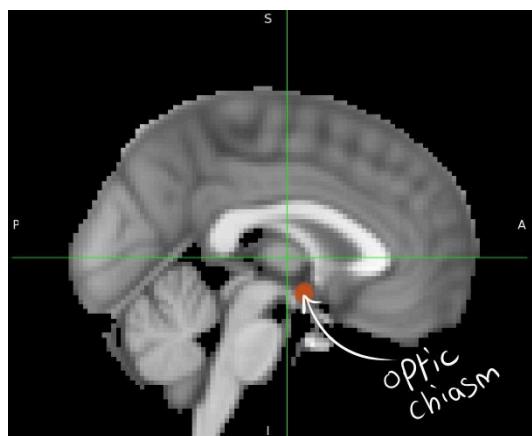


3.10 Optic chiasm

Main Functions

allows for the crossing of fibers from the nasal retina to the optic tract on the other side which enables vision from one side of both the eyes to be appreciated by the occipital cortex of the opposite side.

Region Location in MNI Space



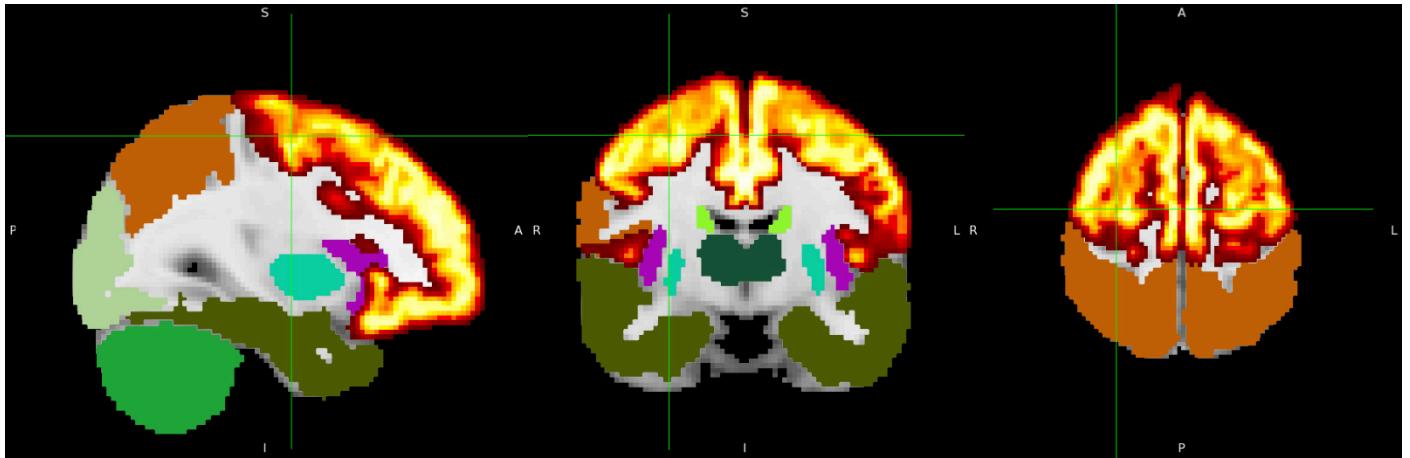
4. Lobes of the Brain

The brain can be divided to left and right hemispheres, where the left hemisphere controls the right side of the body and the right hemisphere controls the left side of the body, and they're connected by corpus callosum

4.1 Frontal Lobe

It's near the rostral of the brain, it's mainly involved in:

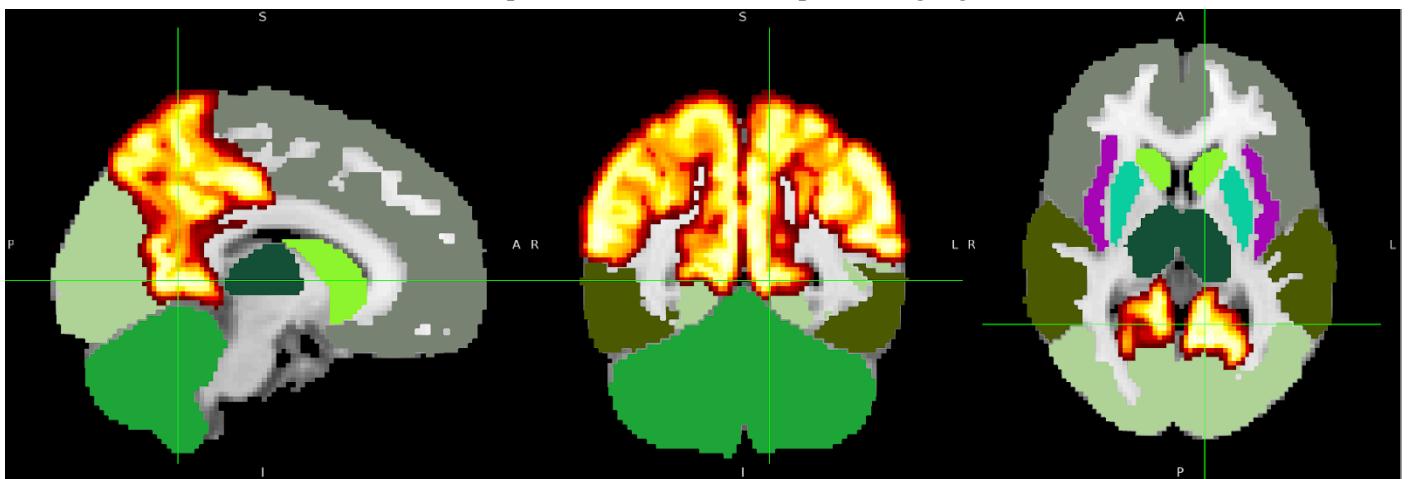
1. Personality characteristics
2. Decision-making
3. Movement
4. Attention
5. Also contains Broca's area, which is associated with speech ability.



4.2 Parietal Lobe

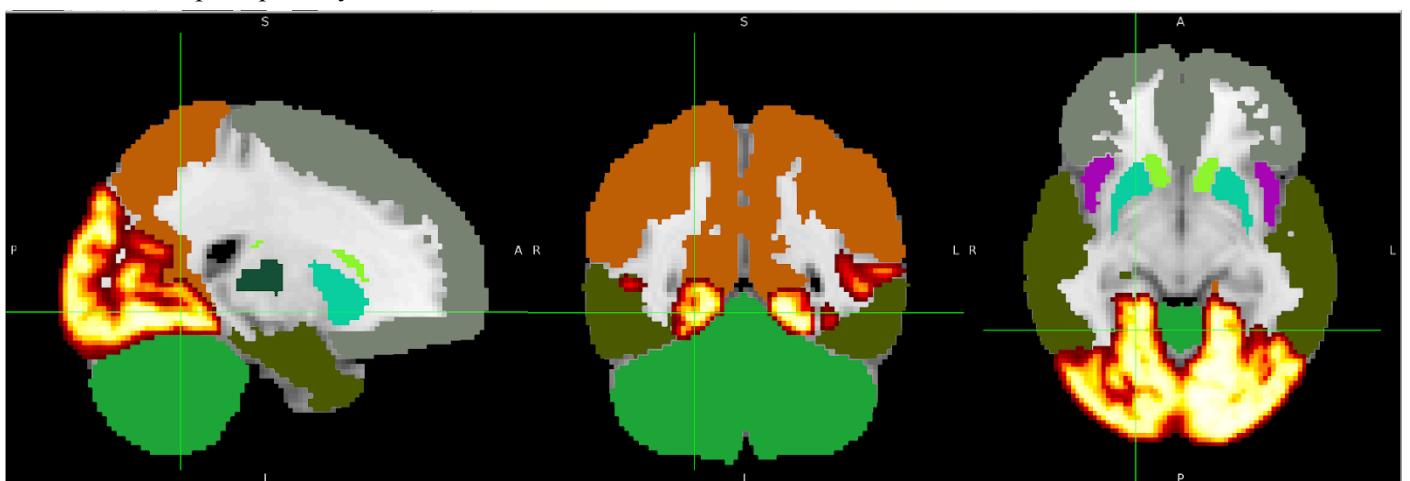
It's the middle part of the brain, mainly known for sensation and perception and integration of sensory input

1. it helps a person identify objects and understand spatial relationships
2. Involved in interpreting pain and touch in the body
3. Houses Wernicke's area, which helps the brain understand spoken language.



4.3 Occipital Lobe

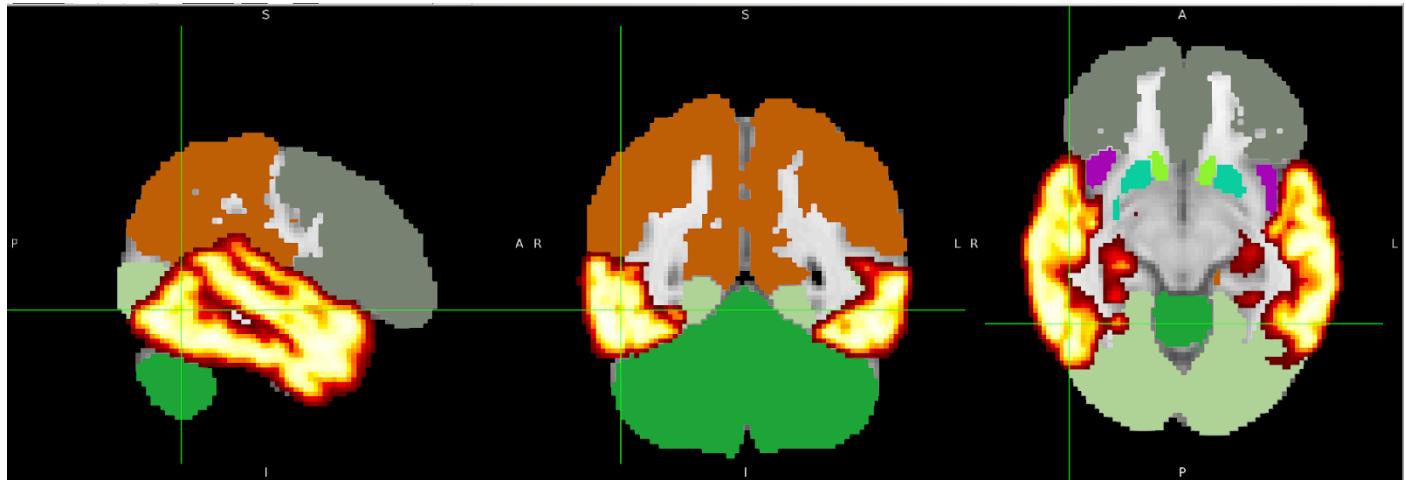
Center of visual perception system



4.4 Temporal Lobe

Mainly for processing hearing languages and sensing things like temperatures
They're involved in:

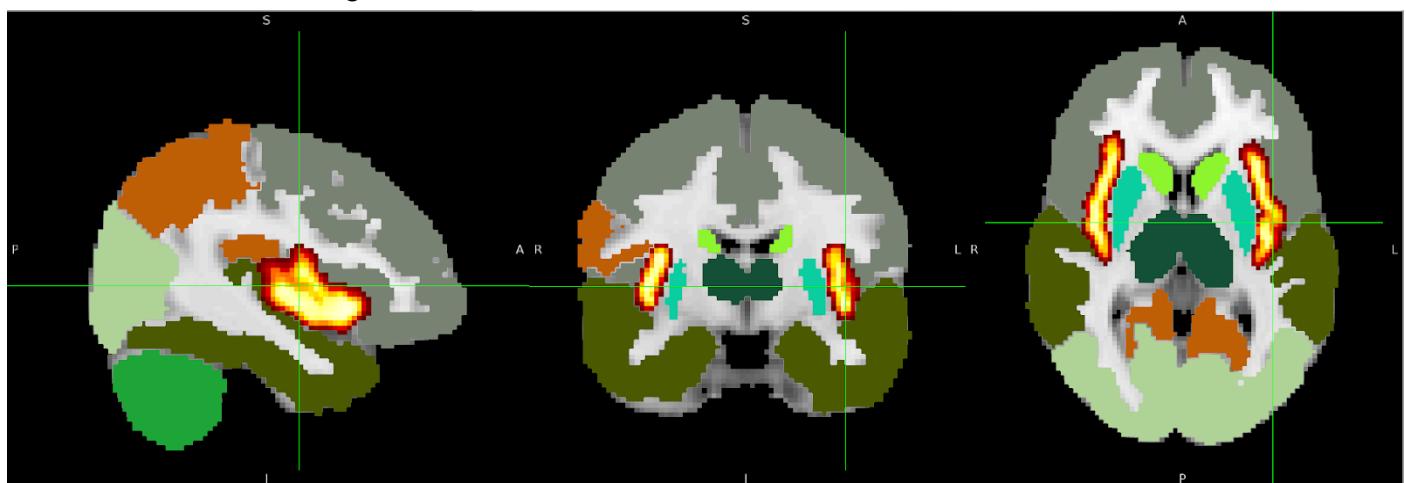
1. short-term memory, speech
2. musical rhythm
3. some degree of smell recognition.



4.5 Insular Lobe

The insula is important for:

1. gustatory and sensorimotor processing
2. risk-reward behavior
3. Autonomics
4. pain pathways
5. Auditory
6. Vestibular functioning.



Task 3

Modeling

After preprocessing of the Brain data, the next step that needs to be taken in the modeling, where the GLM is used to find the activation matrix which corresponds to the response to the task which in our case is either congruent or incongruent.

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_{12} X_{12} + \varepsilon$$

- Where Y is the time series
- Betas are the parameter estimates, which is the convolution of the time series and the paradigm
- And the Xs are the design matrices or regressors

In the case of flanker's task we have only 2 regressors, congruent or incongruent so that leaves the equation as

$$Y = \beta_1 X_1 + \beta_2 X_2 + \varepsilon$$

1. Timing Files

After downloading the script from Andy's book and running it, files for each subject were created that contained the timing files of the congruent and incongruent separately for each run (*Chapter 5: Creating Timing Files — Andy's Brain Book 1.0 documentation*, no date)

Output Example

The screenshot shows a text editor window with the following details:

- File menu: Open
- File menu: New
- Title bar: congruent_run1.txt
- Path: ~/Documents/fMRI/Data/sub-02/Func
- Content:

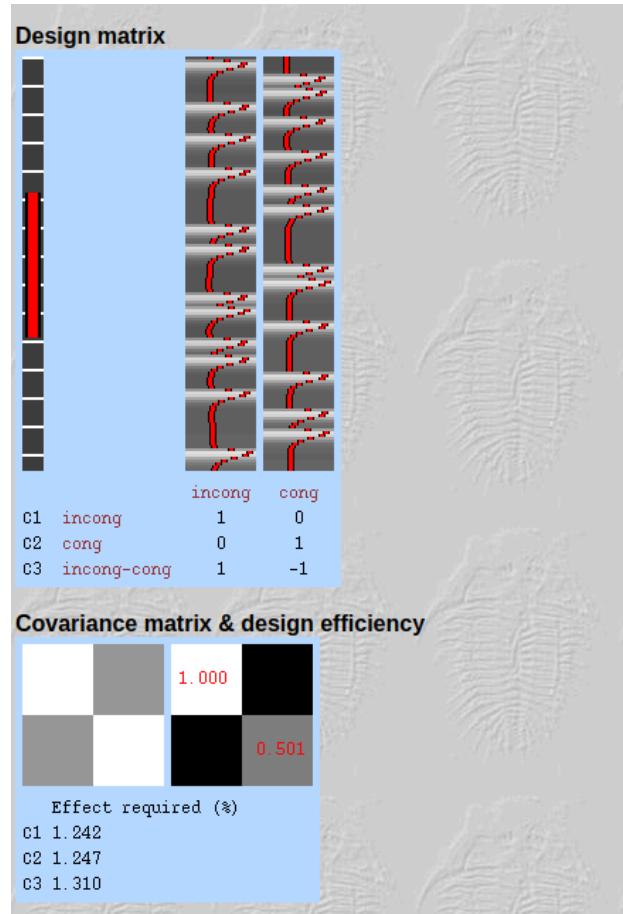
```
1 0.0 2.0 1
2 20.0 2.0 1
3 52.0 2.0 1
4 64.0 2.0 1
5 126.0 2.0 1
6 150.0 2.0 1
7 164.0 2.0 1
8 174.0 2.0 1
9 222.0 2.0 1
10 234.0 2.0 1
11 246.0 2.0 1
12 260.0 2.0 1
```

2. First Level Analysis

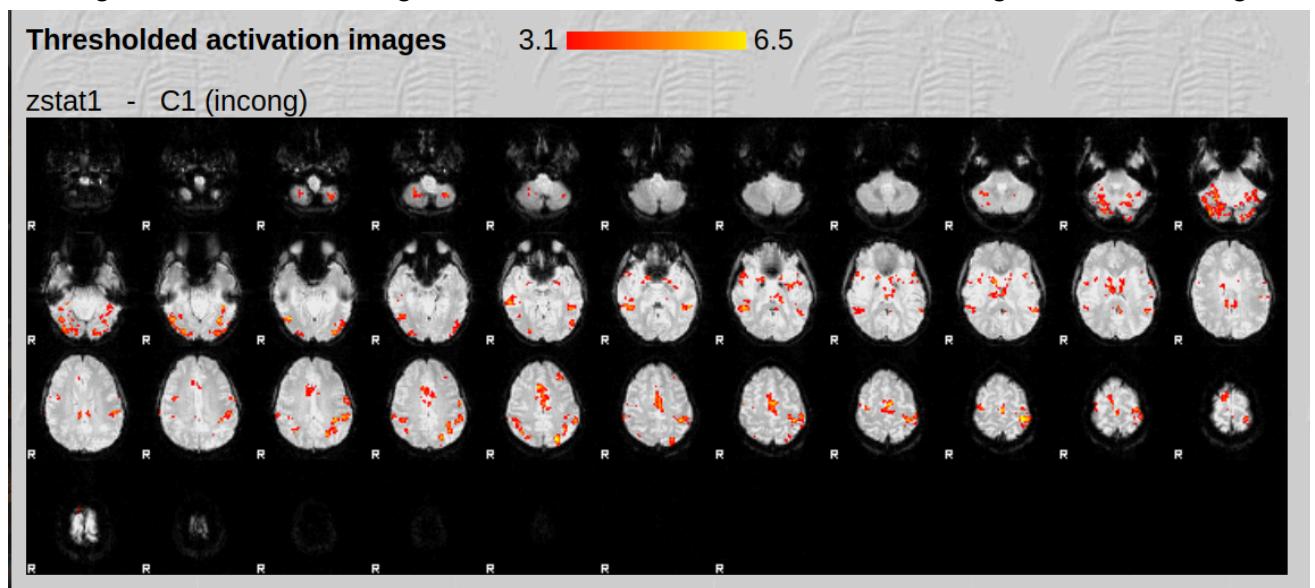
For the same 5 random subjects from task 1, I performed the first level analysis using FEAT GUI, having two Explanatory variables, one for the incongruent and one for the congruent, and 3 COPEs (constants of parameter estimates), one for the congruent, one for the incongruent and one for the difference between them

Observing the output

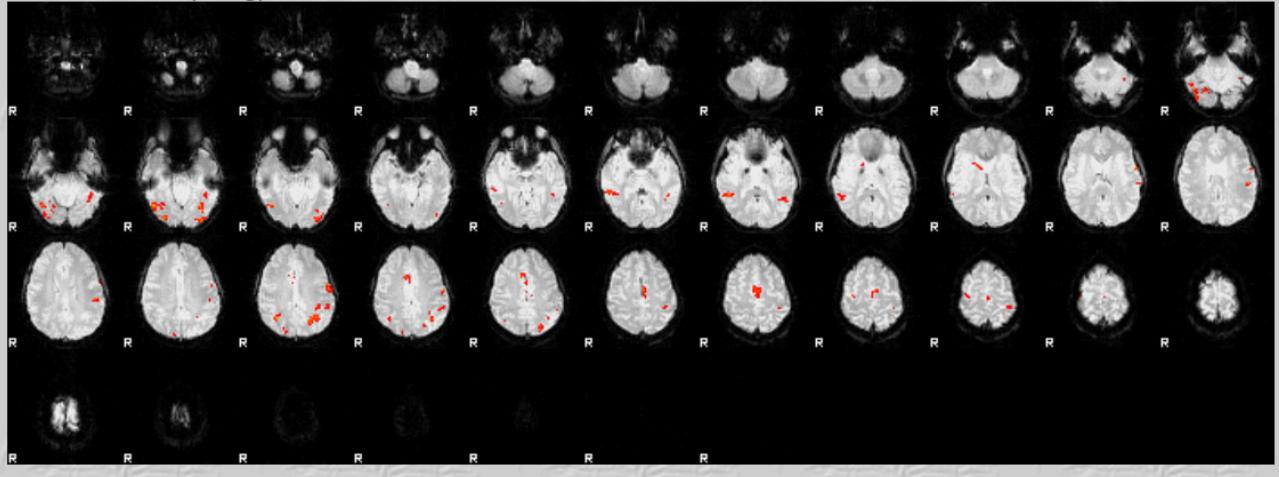
The following is an example of the output model in the FEAT report, using subject 12 run 2, this shows the design matrix and the design efficiency



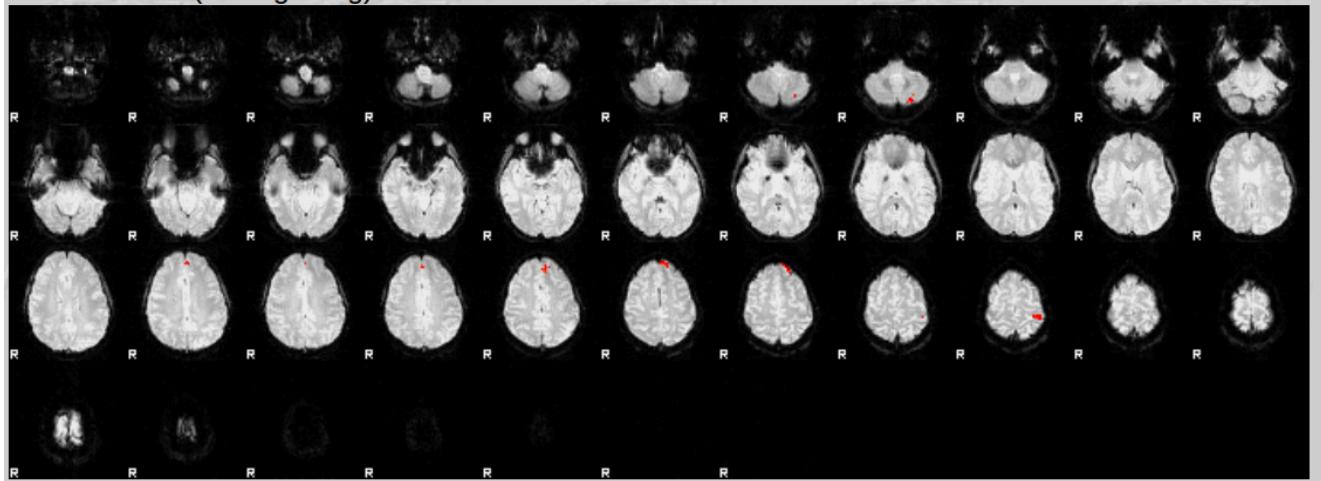
The following shows the post-status part of the report where the activation matrix is visualized for the COPE, once for the congruent, once for the incongruent and once for the difference between the congruent and the incongruent.



zstat2 - C2 (cong)

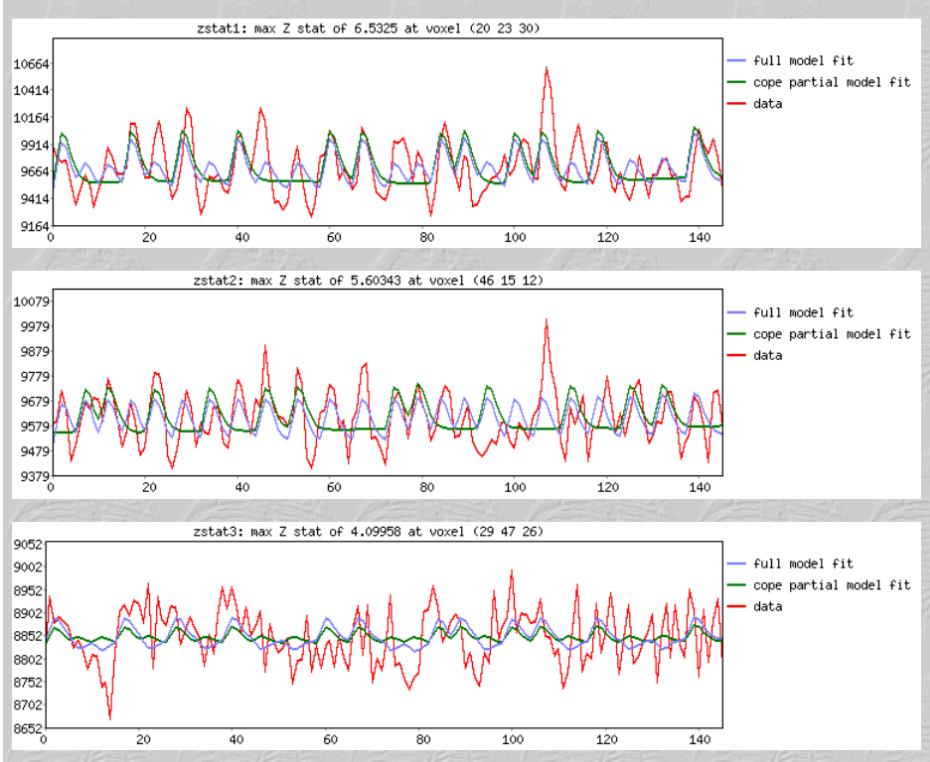


zstat3 - C3 (incong-cong)

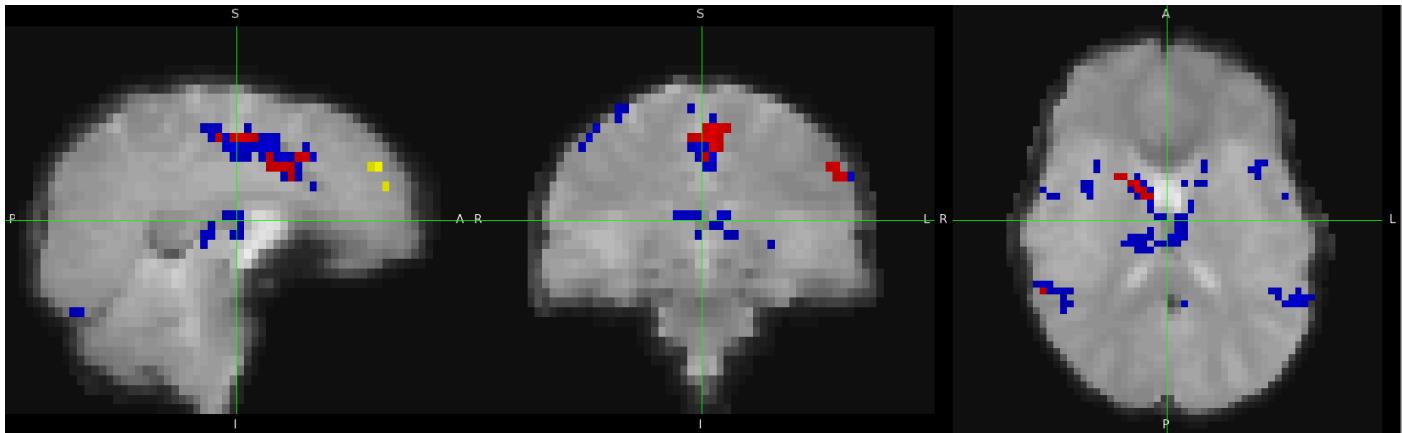


And the following are the time series plots

Time series plots



The following is the output for the same subject and the same run using FSL eyes, where the blue voxels are the COPE of the incongruent, the red is the congruent and the yellow is the difference



This was done for all 5 subjects (2, 8, 12, 13, 19) for each run, 10 FEAT reports were obtained, the following is a table containing data of the threshold activation numbers from the FEAT reports of the 5 subjects

Summary of the GLM FEAT reports

Subject No.	Threshold Activation of Run 1	Threshold Activation of Run 2	Notes for Run 1	Notes for Run 2
2	3.1–7.2	3.1–5.4	Incongruent activity is relatively higher than the congruent	Run 2 has relatively less activity than Run 1
8	3.1–6.1	3.1–6.9	Incongruent and Congruent both have similar activity	Run 2 has overall more activity than run 1 and incongruent has more activity than congruent
12	3.1–8.7	3.1–6.5	Run 1 has high activity in several places in the brain	Run 2 has relatively less activity than Run 1
13	3.1–4.4	3.1–6.0	There's barely any activity apparent at all, only a few voxels in the congruent	There's little activity but it's more than Run 1, you can see a couple of voxels in both the congruent and the incongruent
19	3.1–6.9	3.1–6.9	The congruent and incongruent both have similar activation matrices, nearly the exact voxels	There's little activity in Run 2, and both congruent and incongruent are similar to each other

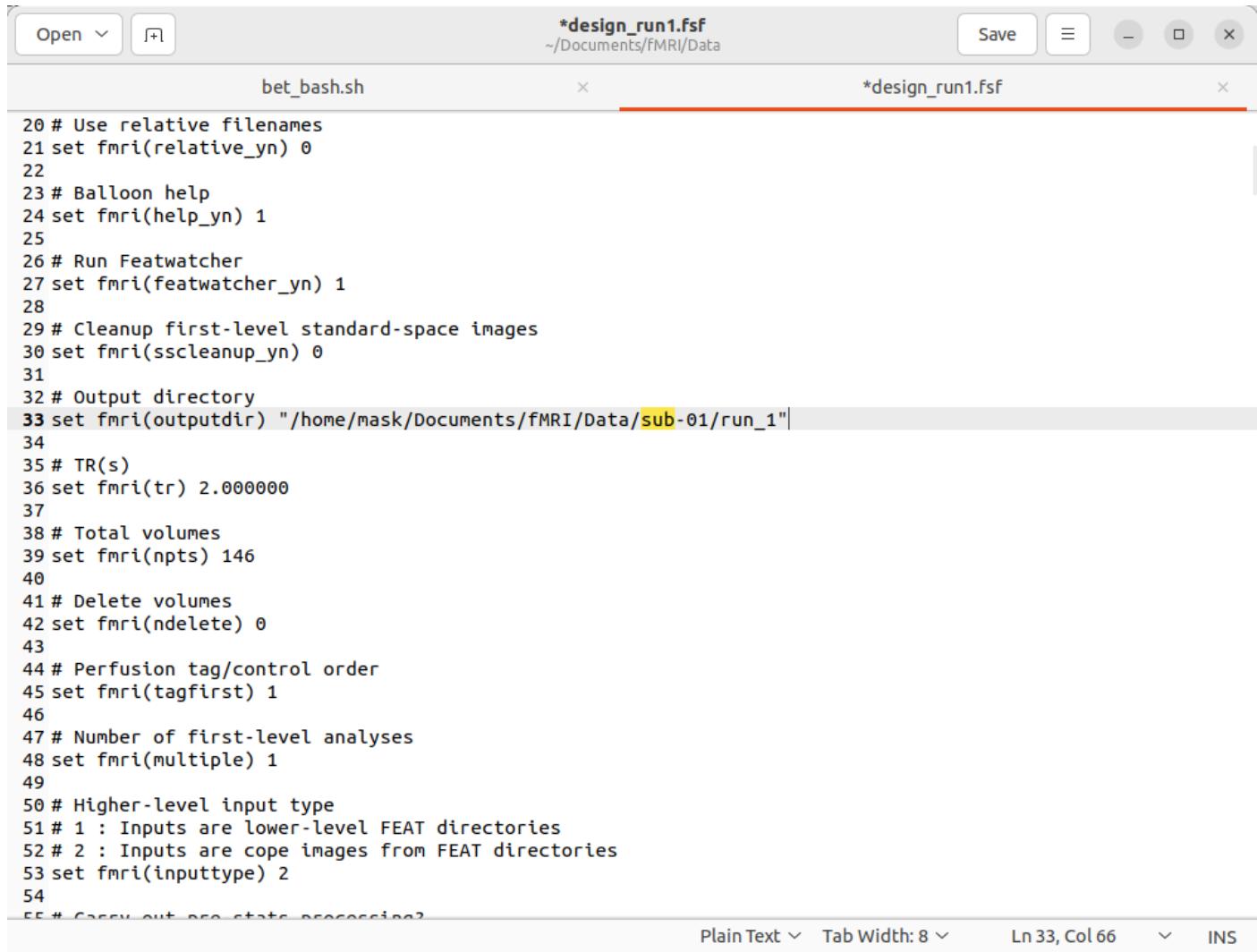
Task 4

Scripting

So far, we've preprocessed and set up models, as well as run first level analysis for 5 subjects manually, which is time consuming and extremely prone to errors, that's why we will need a script for all of the previously mentioned steps so that it would be done on both runs of the 26 subjects automatically.

That was done by looking at the saved settings of the design matrix, named `design.fsf` and observed that almost all of the settings are common, except for the paths and the subject numbering, that's why the script uses 'seq' to generate the numbering of the subjects and 'sed' in order to replace texts in a copy of the design matrix after copying it using another command in the script

Here for example sub-01 needs to be replaced with the numbers of each individualistic subject



```
Open  *design_run1.fsf ~/Documents/fMRI/Data Save  -  ×
bet_bash.sh  ×  *design_run1.fsf  ×

20 # Use relative filenames
21 set fmri(relative_yn) 0
22
23 # Balloon help
24 set fmri(help_yn) 1
25
26 # Run Featwatcher
27 set fmri(featwatcher_yn) 1
28
29 # Cleanup first-level standard-space images
30 set fmri(sscleanup_yn) 0
31
32 # Output directory
33 set fmri(outputdir) "/home/mask/Documents/fMRI/Data/sub-01/run_1"| 34
34
35 # TR(s)
36 set fmri(tr) 2.000000
37
38 # Total volumes
39 set fmri(npts) 146
40
41 # Delete volumes
42 set fmri(ndelete) 0
43
44 # Perfusion tag/control order
45 set fmri(tagfirst) 1
46
47 # Number of first-level analyses
48 set fmri(multiple) 1
49
50 # Higher-level input type
51 # 1 : Inputs are lower-level FEAT directories
52 # 2 : Inputs are cope images from FEAT directories
53 set fmri(inputtype) 2
54
55 # Carry out pre-stats processing?
Plain Text ▾ Tab Width: 8 ▾ Ln 33, Col 66 ▾ INS
```

And the following is the copy of the design.fsf file in another random subject as a way to check if the text was replaced

```
Open  Save  design.fsf  ~Documents/fMRI/Data/sub-21  design_run1.fsf  x
design.fsf  x  design_run1.fsf  x
24 set fmri(help_yn) 1
25
26 # Run Featwatcher
27 set fmri(featwatcher_yn) 1
28
29 # Cleanup first-level standard-space images
30 set fmri(sscleanup_yn) 0
31
32 # Output directory
33 set fmri(outputdir) "/home/mask/Documents/fMRI/Data/sub-21/run_1"  sub  ↵ 1 of 10  ⌂ ⌃
34
35 # TR(s)
36 set fmri(tr) 2.000000
37
38 # Total volumes
39 set fmri(npts) 146
40
41 # Delete volumes
42 set fmri(ndelete) 0
43
44 # Perfusion tag/control order
45 set fmri(tagfirst) 1
46
47 # Number of first-level analyses
48 set fmri(multiple) 1
49
50 # Higher-level input type
51 # 1 : Inputs are lower-level FEAT directories
52 # 2 : Inputs are cope images from FEAT directories
53 set fmri(inputtype) 2
54
55 # Carry out pre-stats processing?
56 set fmri(filtering_yn) 1
57
58 # Brain/background threshold, %
59 set fmri(brain_thresh) 10
```

Plain Text ▾ Tab Width: 8 ▾ Ln 33, Col 53 ▾ INS

I've run a BET script first with 0.2 threshold in order to make sure that the brain is extracted for all subjects and the naming is coherent, all of them named subxx_T1w_brain_f02.nii.gz so that the bash script would run successfully

BET Script

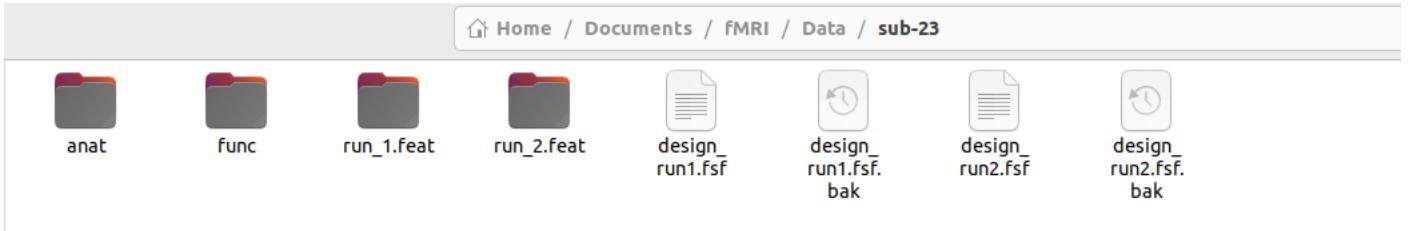
```
sub-02 sub-03 sub-04 sub-05 sub-06 sub-07 sub-08 sub-09 sub-10 sub-11 sub-12
Open ▾ bet_bash.sh ~/Documents/fMRI/Data Save ⌂ ×
1 export FSLEDIR=/usr/local/fsl
2 source $FSLEDIR/etc/fslconf/fsl.sh
3
4 for id in `seq -w 1 26`:
5 do
6     subj="sub-$id"
7     echo "====> Starting processing of $subj"
8     echo
9     cd $subj
10
11     # If the brain mask doesn't exist, create it
12     if [ ! -f anat/${subj}_T1w_brain_f02.nii.gz ]
13     then
14         bet2 anat/${subj}_T1w.nii.gz anat/${subj}_T1w_brain_f02.nii.gz -f 0.2
15         # echo "Skull-stripped brain not found, using bet with a fractional intensity threshold of 0.2"
16     fi
17     cd ..
18 done
```

Afterwards, I've run the script that performs the first level analysis for all subjects, the first two lines are handling a problem with FSL exporting.

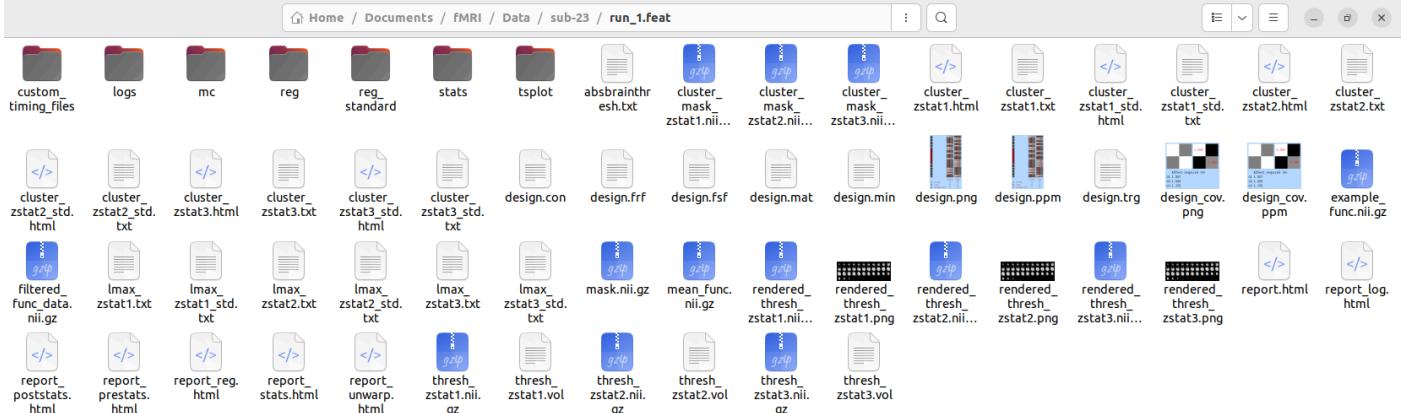
```
Open ▾ *model_bash.sh ~/Documents/fMRI/Data Save ⌂ ×
1 export FSLEDIR=/usr/local/fsl
2 source $FSLEDIR/etc/fslconf/fsl.sh
3
4 for id in `seq -w 1 26` ; do
5     subj="sub-$id"
6     echo "====> Starting processing of $subj"
7     echo
8     cd $subj
9
10    cp ..../design_run1.fsf .
11    cp ..../design_run2.fsf .
12
13
14    sed -i.bak "s|sub-01|${subj}|g" design_run1.fsf
15    sed -i.bak "s|sub-01|${subj}|g" design_run2.fsf
16
17    echo "====> Starting feat for run 1"
18    feat design_run1.fsf
19    echo "====> Starting feat for run 2"
20    feat design_run2.fsf
21    echo
22
23    cd ..
24 done
```

Results

The script did take a while to generate all of the feat reports but it successfully created the feat files for all of the 26 subjects the following is an example of the output files for subject 23.



And the following is the files generated in the FEAT for run 1 as example

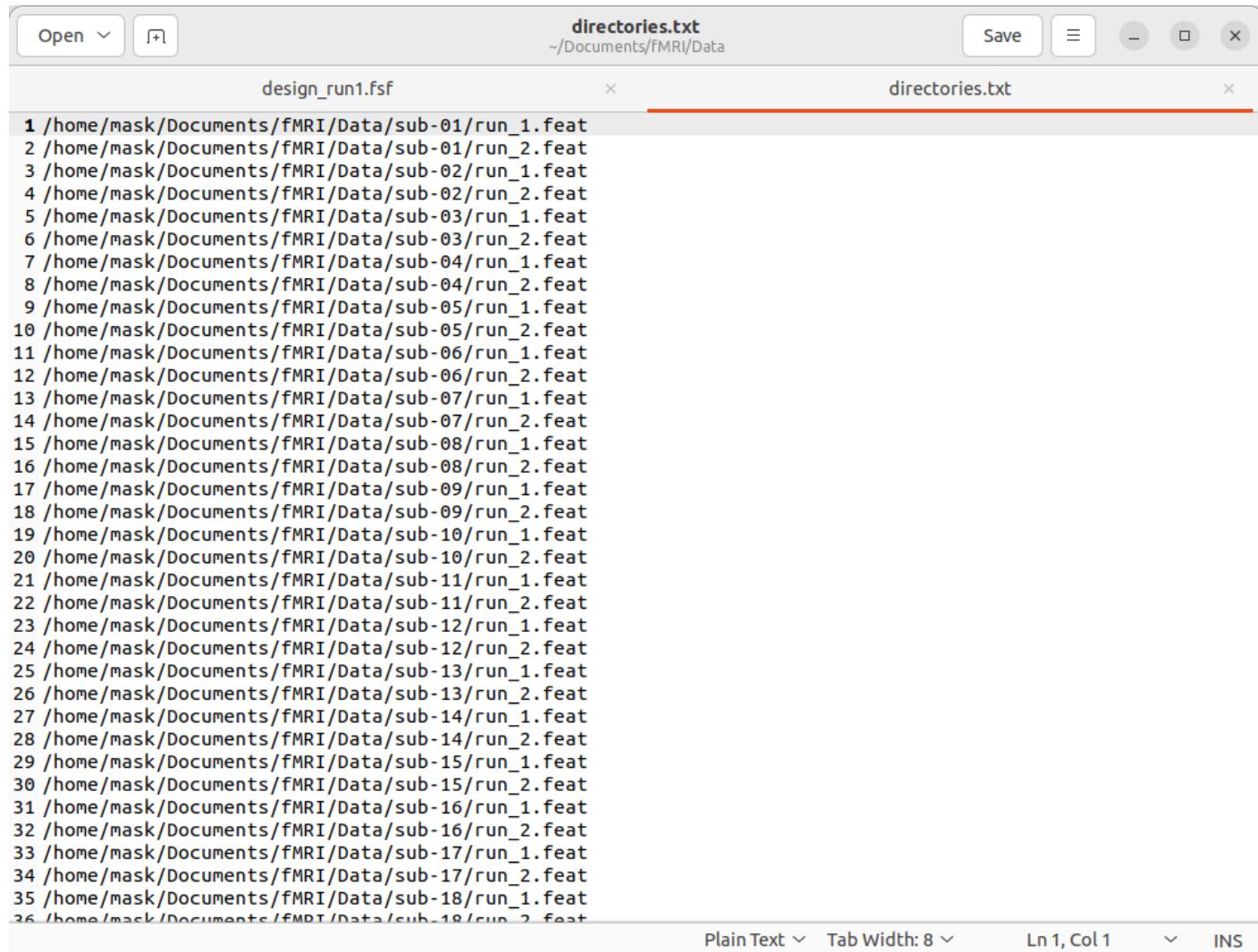


Task 5

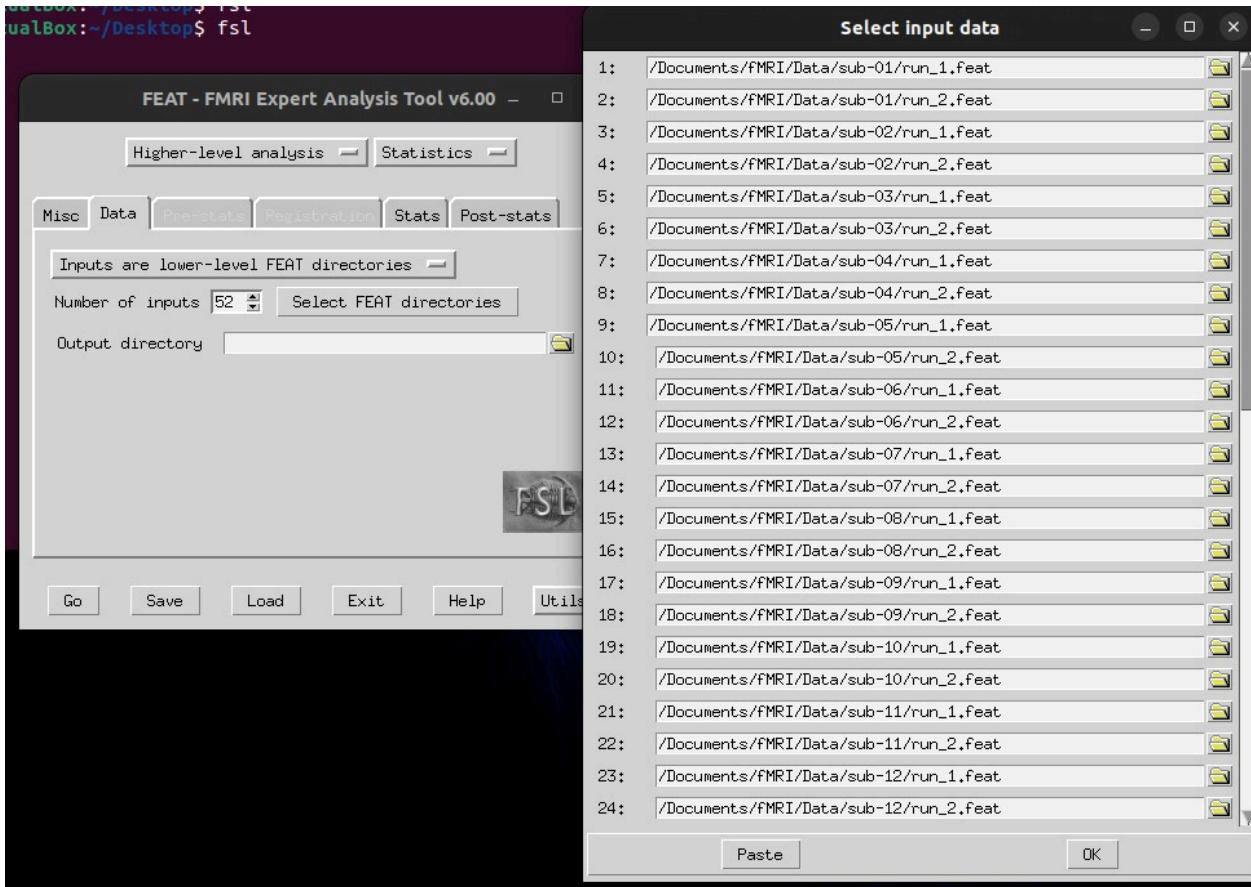
Second Level Analysis

After the preprocessing was successfully done for all 26 subjects, we can go to the second level analysis, we will be averaging the parameter estimate and the contrast estimate of the two runs of each subject

We have 52 FEAT directories to be used in the second level analysis, because we have 26 subjects and 2 runs, so to obtain the directories the command “`ls -d $PWD/sub-??/run*`” is going to be used, the following is the output of the command

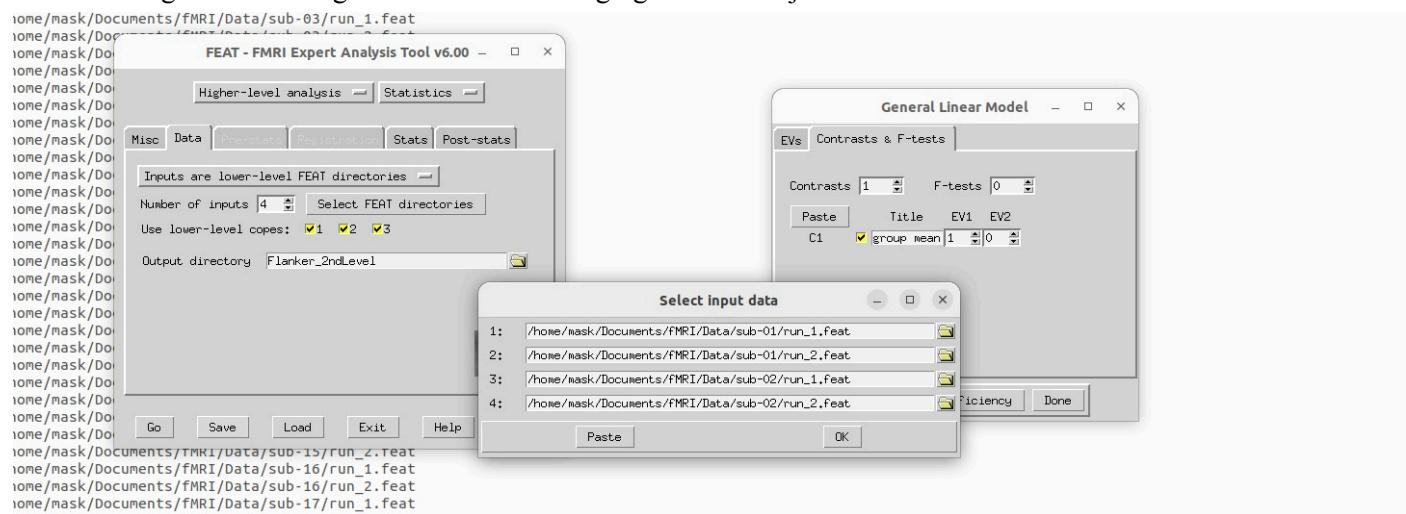


```
1 /home/mask/Documents/fMRI/Data/sub-01/run_1.feat
2 /home/mask/Documents/fMRI/Data/sub-01/run_2.feat
3 /home/mask/Documents/fMRI/Data/sub-02/run_1.feat
4 /home/mask/Documents/fMRI/Data/sub-02/run_2.feat
5 /home/mask/Documents/fMRI/Data/sub-03/run_1.feat
6 /home/mask/Documents/fMRI/Data/sub-03/run_2.feat
7 /home/mask/Documents/fMRI/Data/sub-04/run_1.feat
8 /home/mask/Documents/fMRI/Data/sub-04/run_2.feat
9 /home/mask/Documents/fMRI/Data/sub-05/run_1.feat
10 /home/mask/Documents/fMRI/Data/sub-05/run_2.feat
11 /home/mask/Documents/fMRI/Data/sub-06/run_1.feat
12 /home/mask/Documents/fMRI/Data/sub-06/run_2.feat
13 /home/mask/Documents/fMRI/Data/sub-07/run_1.feat
14 /home/mask/Documents/fMRI/Data/sub-07/run_2.feat
15 /home/mask/Documents/fMRI/Data/sub-08/run_1.feat
16 /home/mask/Documents/fMRI/Data/sub-08/run_2.feat
17 /home/mask/Documents/fMRI/Data/sub-09/run_1.feat
18 /home/mask/Documents/fMRI/Data/sub-09/run_2.feat
19 /home/mask/Documents/fMRI/Data/sub-10/run_1.feat
20 /home/mask/Documents/fMRI/Data/sub-10/run_2.feat
21 /home/mask/Documents/fMRI/Data/sub-11/run_1.feat
22 /home/mask/Documents/fMRI/Data/sub-11/run_2.feat
23 /home/mask/Documents/fMRI/Data/sub-12/run_1.feat
24 /home/mask/Documents/fMRI/Data/sub-12/run_2.feat
25 /home/mask/Documents/fMRI/Data/sub-13/run_1.feat
26 /home/mask/Documents/fMRI/Data/sub-13/run_2.feat
27 /home/mask/Documents/fMRI/Data/sub-14/run_1.feat
28 /home/mask/Documents/fMRI/Data/sub-14/run_2.feat
29 /home/mask/Documents/fMRI/Data/sub-15/run_1.feat
30 /home/mask/Documents/fMRI/Data/sub-15/run_2.feat
31 /home/mask/Documents/fMRI/Data/sub-16/run_1.feat
32 /home/mask/Documents/fMRI/Data/sub-16/run_2.feat
33 /home/mask/Documents/fMRI/Data/sub-17/run_1.feat
34 /home/mask/Documents/fMRI/Data/sub-17/run_2.feat
35 /home/mask/Documents/fMRI/Data/sub-18/run_1.feat
36 /home/mask/Documents/fMRI/Data/sub-18/run_2.feat
```

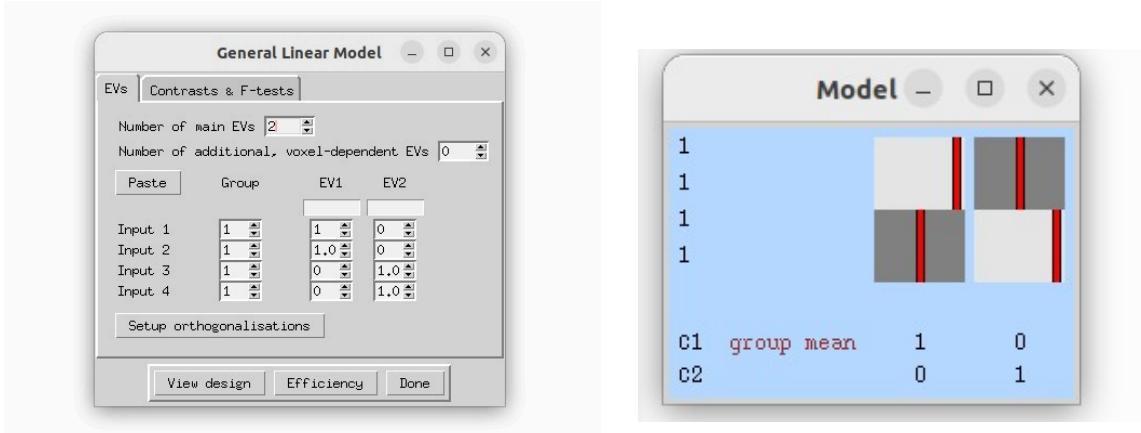


However, we will be displaying the output of averaging two subjects only, because the GUI isn't working at all with the 26 subjects.

The following are the settings of the GUI of averaging the two subjects

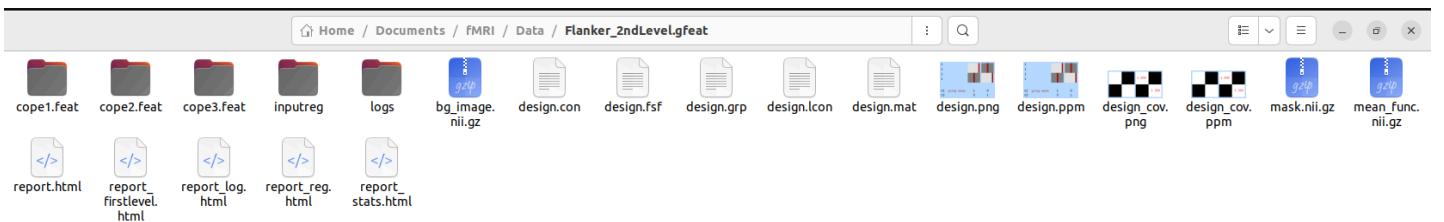


The following is the GLM EVs matrix



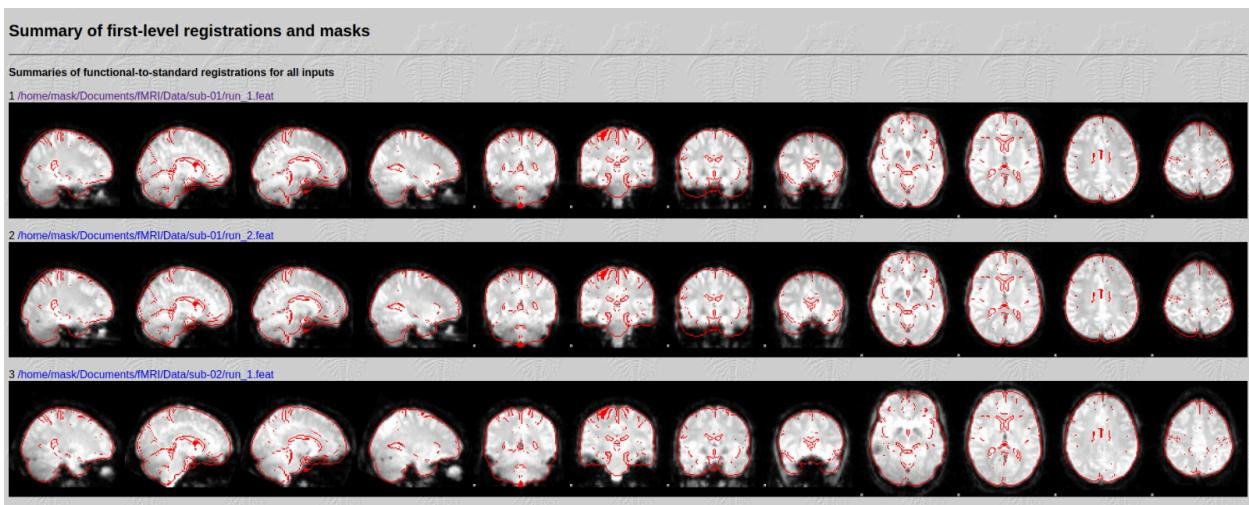
The following is the output model

These are the output files of the 2nd level analysis

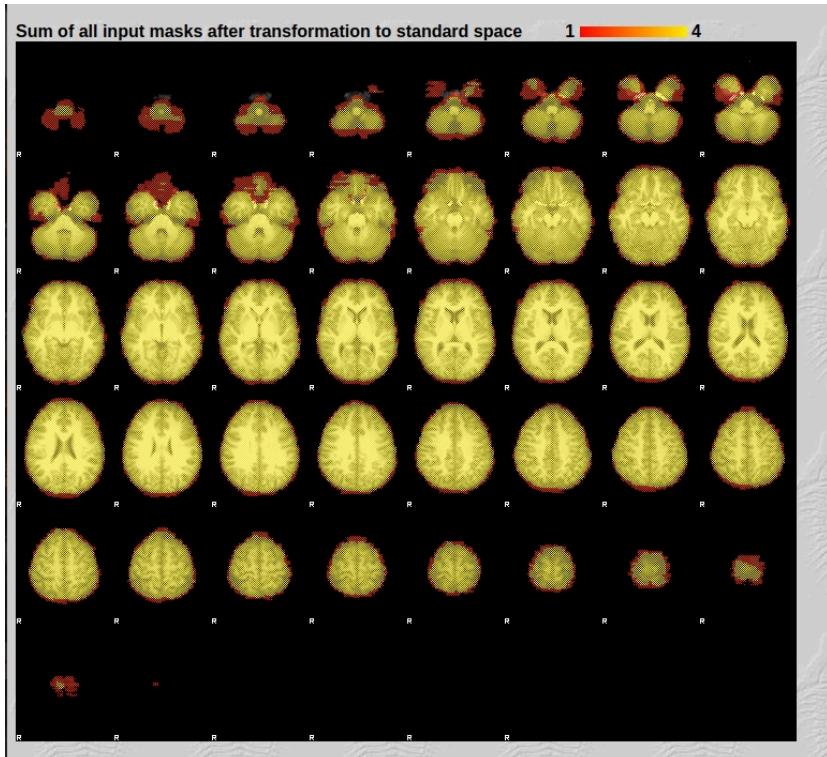


The following is the FEAT report output:

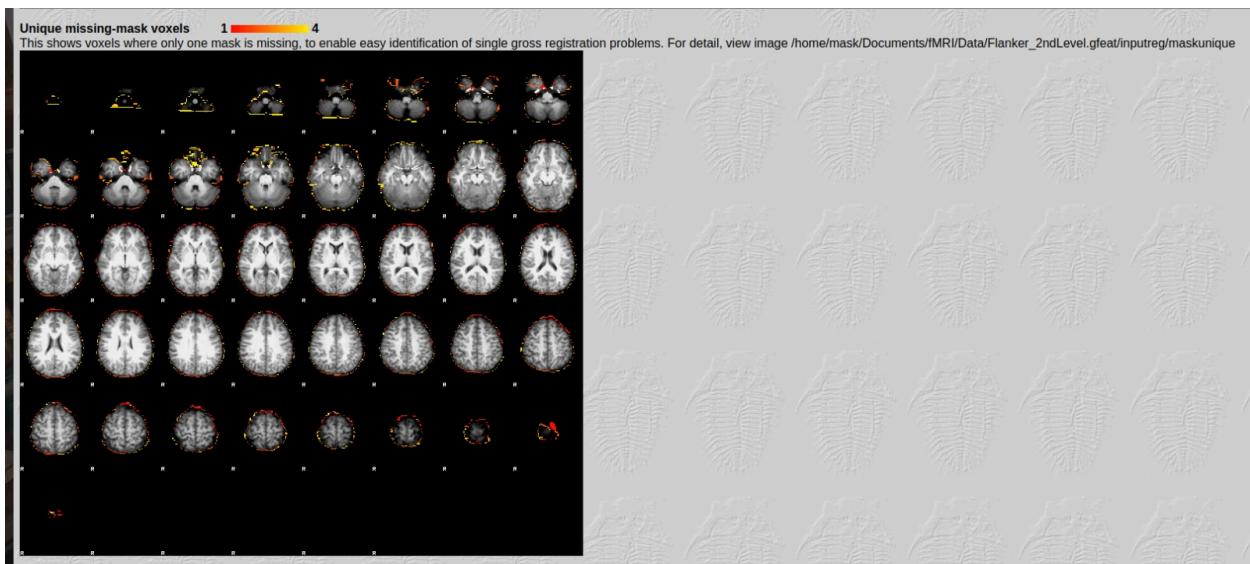
First, there's the registration of each subject and each run which is from the old analysis



Second, we get the sum of the masks, which are my ROI, in the standard space



Third, we get the unique missing mask voxels, ,which is most probably an indicator of problems in registration



References

1. www.sciencedirect.com. (n.d.). Eriksen Flanker Task - an overview | ScienceDirect Topics. [online] Available at: <https://www.sciencedirect.com/topics/neuroscience/eriksen-flanker-task>.
2. *Flanker task (event-related)* (no date). <https://openfmri.org/dataset/ds000102/>.
3. Chapter 7: Checking your Preprocessed Data — Andy's Brain Book 1.0 documentation (no date).
https://andysbrainbook.readthedocs.io/en/stable/fMRI_Short_Course/Preprocessing/Checking_Preprocessing.html.
4. *Neuroanatomy Online: Lab 1 - Overview of the nervous system - the prosencephalon (Forebrain)* (no date).
https://nba.uth.tmc.edu/neuroanatomy/L1/Lab01p05_index.html#:~:text=The%20telencephalon%2C%20in%20turn%2C%20consists,will%20elaborate%20on%20these%20subdivisions.
5. *Chapter 5: Creating Timing Files — Andy's Brain Book 1.0 documentation* (no date).
https://andysbrainbook.readthedocs.io/en/stable/fMRI_Short_Course/Statistics/05_Creating_Timing_Files.htm.
6. *Brain anatomy and how the brain works* (2021).
<https://www.hopkinsmedicine.org/health/conditions-and-diseases/anatomy-of-the-brain>.
7. Lanciego, J.L., Luquin, N. and Obeso, J.A. (2012b) 'Functional neuroanatomy of the basal ganglia,' *Cold Spring Harbor Perspectives in Medicine*, 2(12), p. a009621.
<https://doi.org/10.1101/cshperspect.a009621>.