Variability evaluation of experts in human brain diffusion tractography

General instructions

- The virtual manual dissections can only be performed with the software **TrackVis** (http://trackvis.org/) or **MI-Brain** (https://www.imeka.ca/mi-brain). Choose the software you are the most used to, please refrain from switching software unless necessary.
    - Usage of scripts to perform any steps of the segmentation automatically or semi-automatically is forbidden.
    - The tractograms were compressed to facilitate data sharing between organizers and participants.
    - Only drawn ROIs are allowed, these ROIs must be saved as nifti files. Do not use the disk, sphere or atlas option in trackvis or the cube, ellipse in MI-Brain.

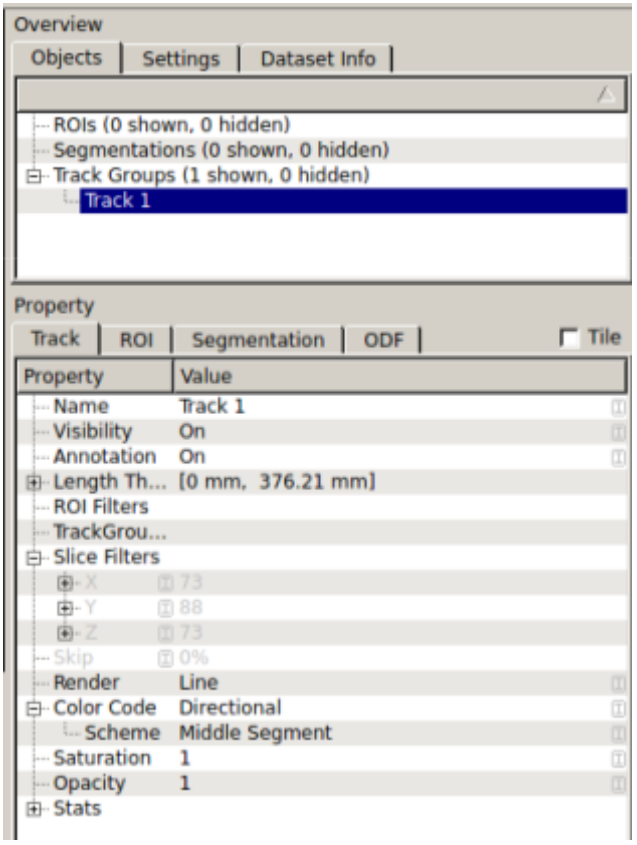
- The dissection plan presented below is technically the same for both hemispheres, however only the left pyramidal tract and left arcuate fasciculus are required for this study.
    - The bundles of interest need to be segmented separately and saved as *"PYT_L.trk*", "*AF_L.trk*" and "*CC.trk*"in the same folder as their associated subject.
    - To be optimal and facilitate analysis, the ROIs should be drawn in the same order as they are presented in the dissection plan. Please refrain from skipping ROIs during the protocol.

- The goal of this project is to study intra/inter participants' variability. While staying within the limits of common sense, the amount of work for each dissection should be aimed at respecting the definition and maximize reproducibility. *(We suggest approximately 20 minutes per tractogram to dissect the 3 bundles)*
    - Perform the dissection in alphanumerical order and note the requested information in the spreadsheet (metadata).
    - Once a dissection is completed, please consider it final and do not edit previous subjects (except in major cases, please inform us if this happens).
    - We suggest "practice" on the first subject to familiarize with the dissection plan, the instructions and the software. When the participant is comfortable with the task, the second subject can be started.

- Others
    - Note that the size of ROI is mentioned in mm, the resolution of HCP datasets is 1.25mm isotropic. (*10mm/1.25mm = 8 voxels*)
    - Any suggestions related to size of ROIs was based on the approximate size of landmark in a few datasets, the final decision should be based on the observed landmark in a dataset.
    - After each ROI is drawn, save it using the provided filename. Once all ROIs are saved, proceed with the final bundle segmentation.

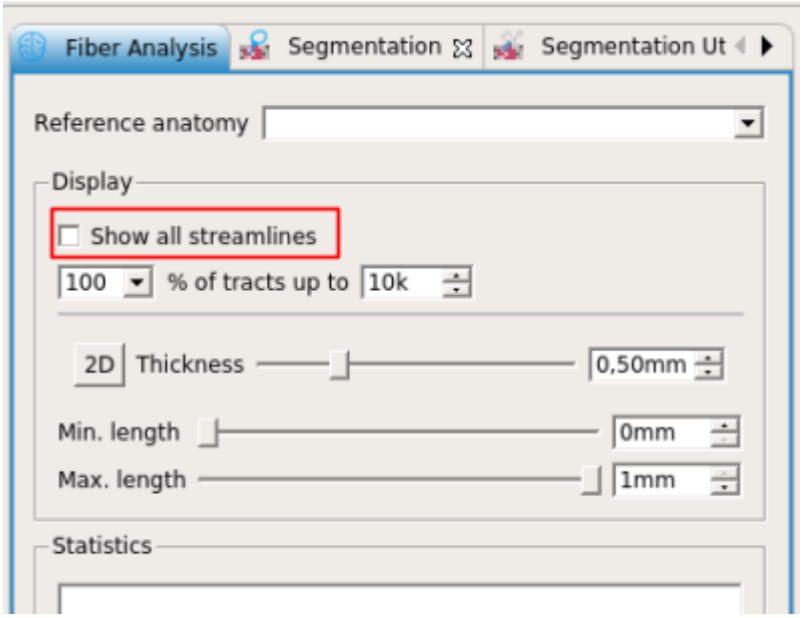
- DON’T FORGET TO REMOVE **SKIP** OR **SLICE FILTERING** IN TRACKVIS

Trackvis skip and slice filtering options :
By default Trackvis is not showing all streamlines, which can affect your decision during the segmentation. Make sure to remove those options before doing any dissection.
In the menu on the right, look for the Slice Filters and Skip option. By double clicking on the *Y* and the *Skip* you will see a checkbox appear. Uncheck it



DON’T FORGET TO CHECK **SHOW ALL STREAMLINES** IN MI-BRAIN

Show all streamlines option:
By default MI-Brain is not showing all streamlines, which can affect your decision during the segmentation. In the Fiber Analysis plugin view, simply check the option *Show all streamlines*

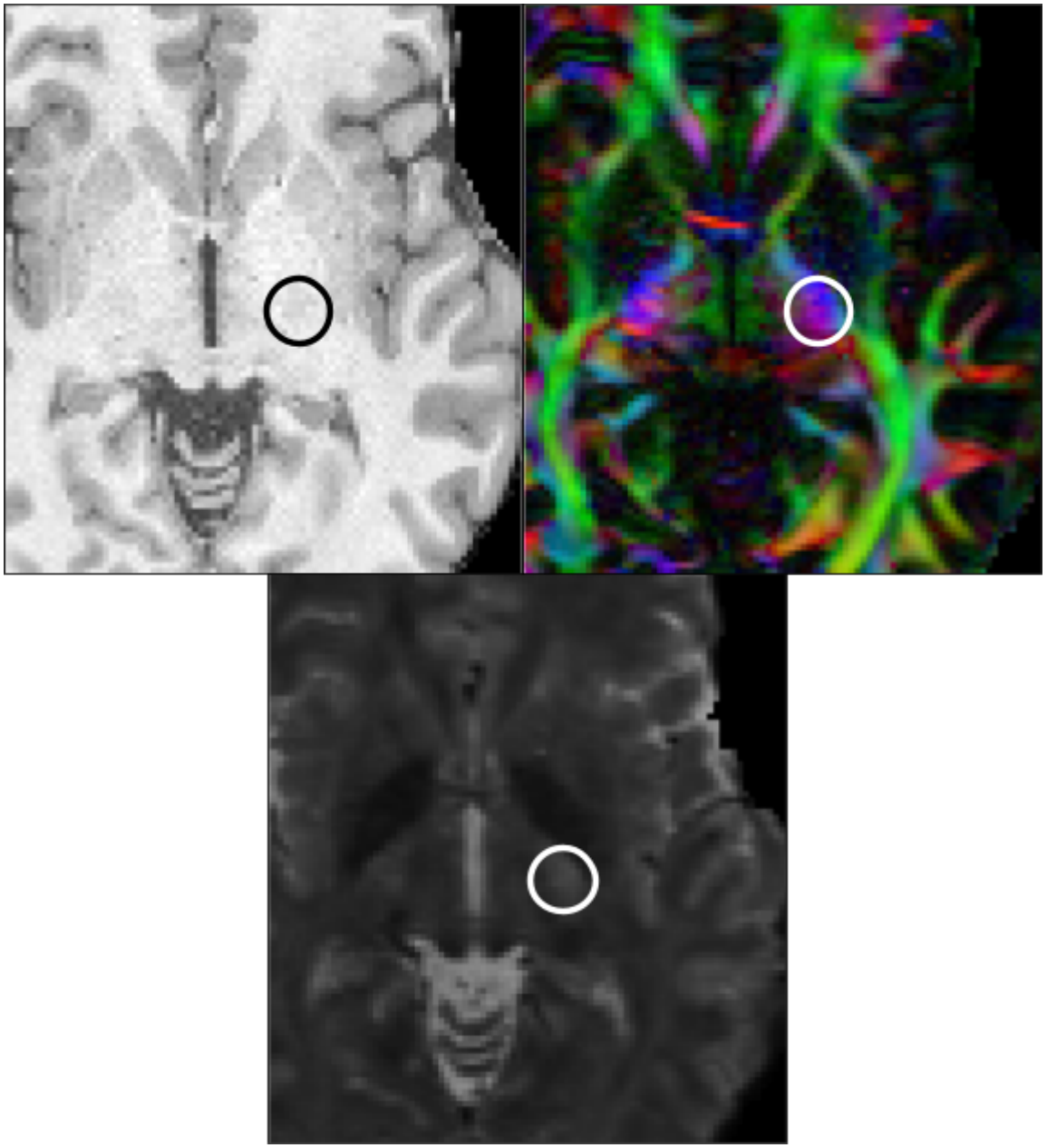


Instructions for the virtual dissection of the Pyramidal Tract

Internal Capsule ROI (IC-ROI)

The IC-ROI is a disk with a diameter of 8-12mm delineated on a single axial slice. The position of this ROI in axial is the approximate barycenter of the thalamus as it nearly corresponds to the middle of the adjacent internal capsule. The IC-ROI is centered on the B0 hypersignal localized between the posterior part of the putamen and the thalamus, within the internal capsule The same region is seen in blue on the RGB map, the IC-ROI needs to overlap on the hypersignal of the B0 and the blue signal of the RGB.

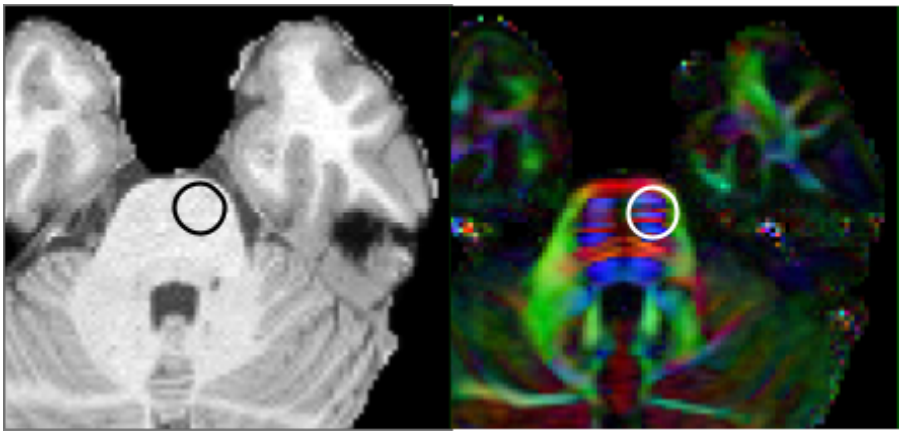
Save this ROI as IC_L.nii



Midbrain ROI (MB-ROI)

MB-ROI is a disk with a diameter of 12-16mm delineated on a single axial slice. It is used to discriminate the PyT (motor pathway) localized in the anterior part of the midbrain from the lemniscus tract (sensory pathway) localized in the posterior part of the midbrain. To position this ROI on axial slice, the RGB color map is used to highlight both tracts in blue color. The axial section in which the two tracts are the most distant from each other is then selected, and the ROI need to be centered on the blue signal located in the anterior part of the midbrain.

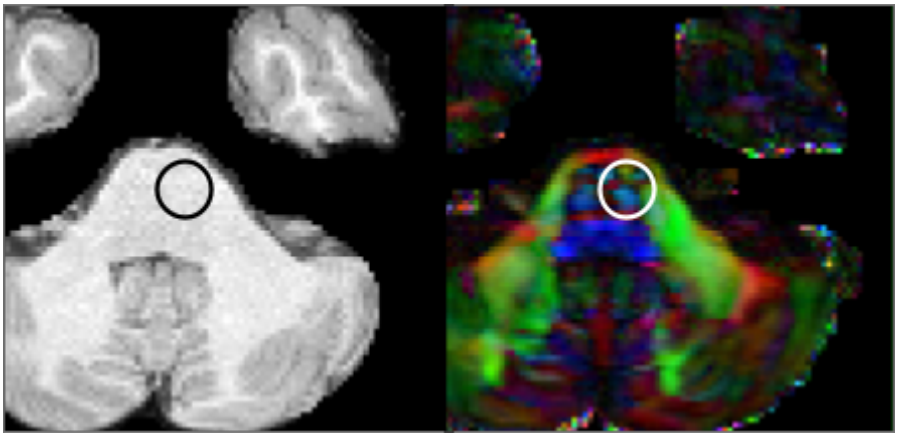
Save this ROI as MB_L.nii



Pyramids of the Medulla Oblongata (MO-ROI)

MO-ROI is a disk with a diameter of 10-14mm delineated on a single axial slice, which is used to select fibers entering in the medulla while not passing through the cerebellum. Note that at this level, the fibers are forming a pyramidal section. To position the MO-ROI in axial, the T1 and RGB color map are used at the level of the medulla oblongata. The criterion of selection is that the white matter of the medulla oblongata (rather in blue) has to be separated from the white matter of the cerebellum (rather in green) and had to form a pyramidal section in the T1 map when varying the grey-scale. The ROI then needs to be centered on the blue signal located in the anterior part of the Medulla Oblongata.

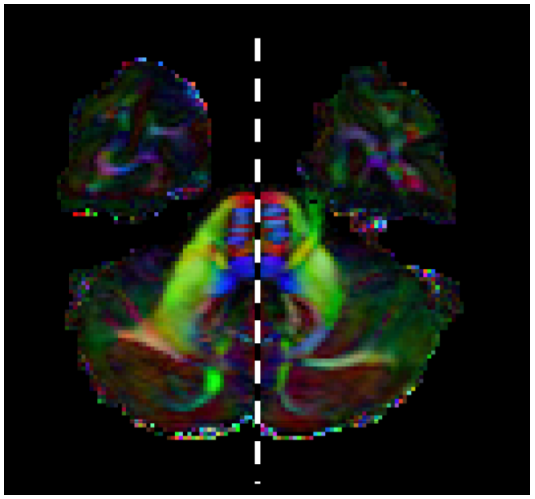
Save this ROI as MO_L.nii



Mid-sagittal plane cleaning

To prevent any contamination from implausible commissural streamlines, an extra mid-sagittal plane must be added. Create a planar sagittal ROI on the whole volume at the interhemispheric fissure. Be sure to verify the brainstem in order not to cut the pathway where the pyramidal tract is expected to go through, move the plan to the left to avoid this situation.

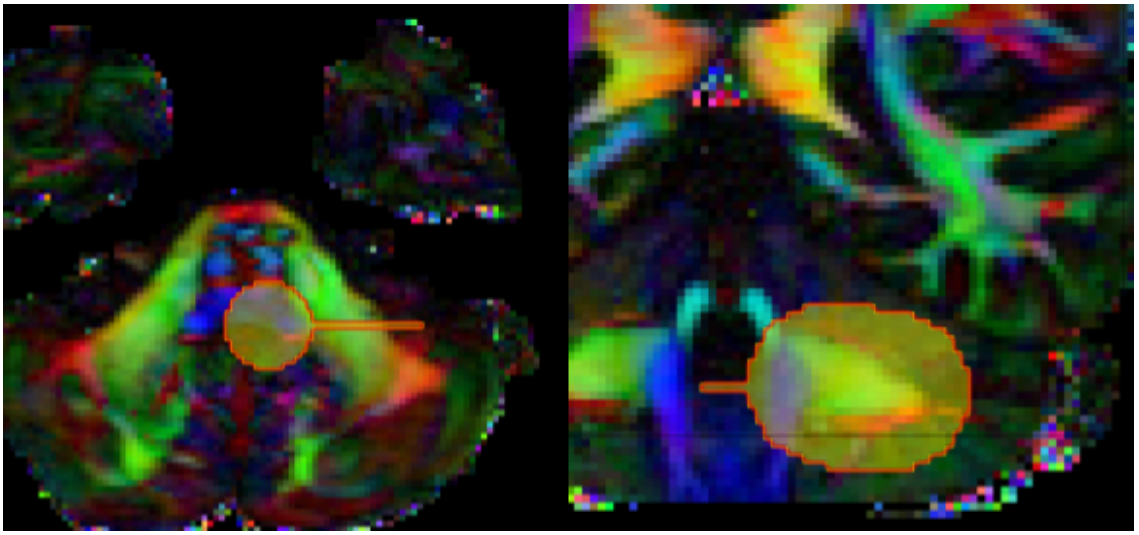
Save this as one ROI named MID_SAGITTAL_PLANE.nii



Cerebellum cleaning

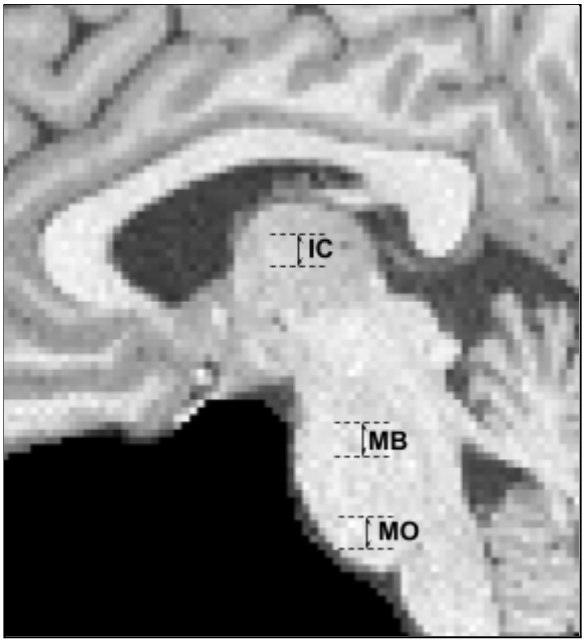
Spurious streamlines entering the cerebellum can be cleaned using two planar ROIs. One the same axial slice as the MO-ROI, place a much larger ROI (around 15-20mm) to prevent streamlines from using the wrong pathway (going behind the pyramid instead of going through it). The second ROI is a coronal plane placed behind the medulla oblongata ROI of size around 15-20mm. This ROI should cut off the entrance of the cerebellar pedoncule without affecting the streamlines reaching down to the spinal cord. The result of this operation should be two intersecting disks with an offset of their center in the x-axis.

Save this as one ROI named MO_L_NOT.nii



How to easily locate these ROIs

For those with difficulties to locate the approximate position of the 3 previous ROIs, these small intervals should help to locate the landmarks described above. These are approximate positions to facilitate the initial search if you are not familiar with the anatomical structures used in the description. (see example)



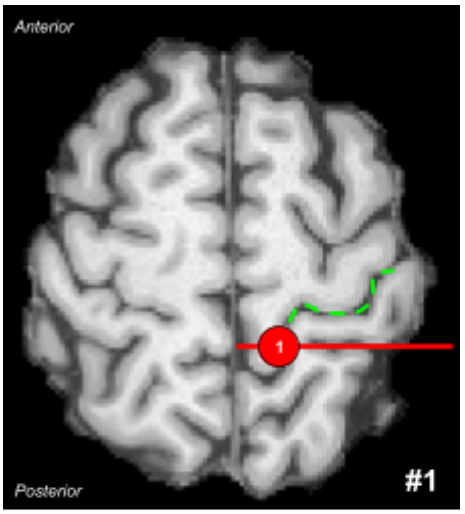
Precentral and postcentral ROIs

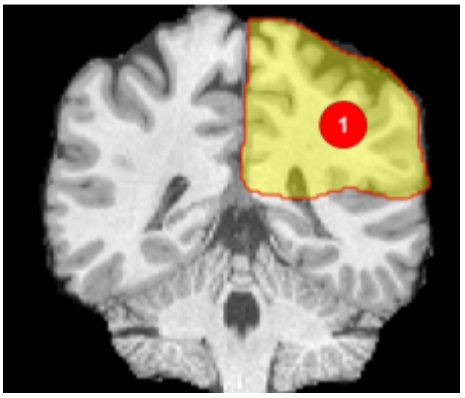
The bundle of interest should be restricted to termination within the precentral or postcentral gyri. Exclusion ROIs (covering two coronal slices) must be placed anterior to the precentral gyrus and posterior to the postcentral gyrus to avoid the superior part of the PyT from projecting too much anteriorly or posteriorly (see example).

1. Use the T1 in the axial plane to locate the Rolando sulcus (green line in figure #1), known as the deepest (most medial termination) sulcus seen on the axial slice and that includes the omega shape of the motor hand area, namely the genu of Rolando. The gyrus immediately posterior the Rolando sulcus is the <u>postcentral gyrus</u> while the immediately anterior one is the <u>precentral gyrus</u>.

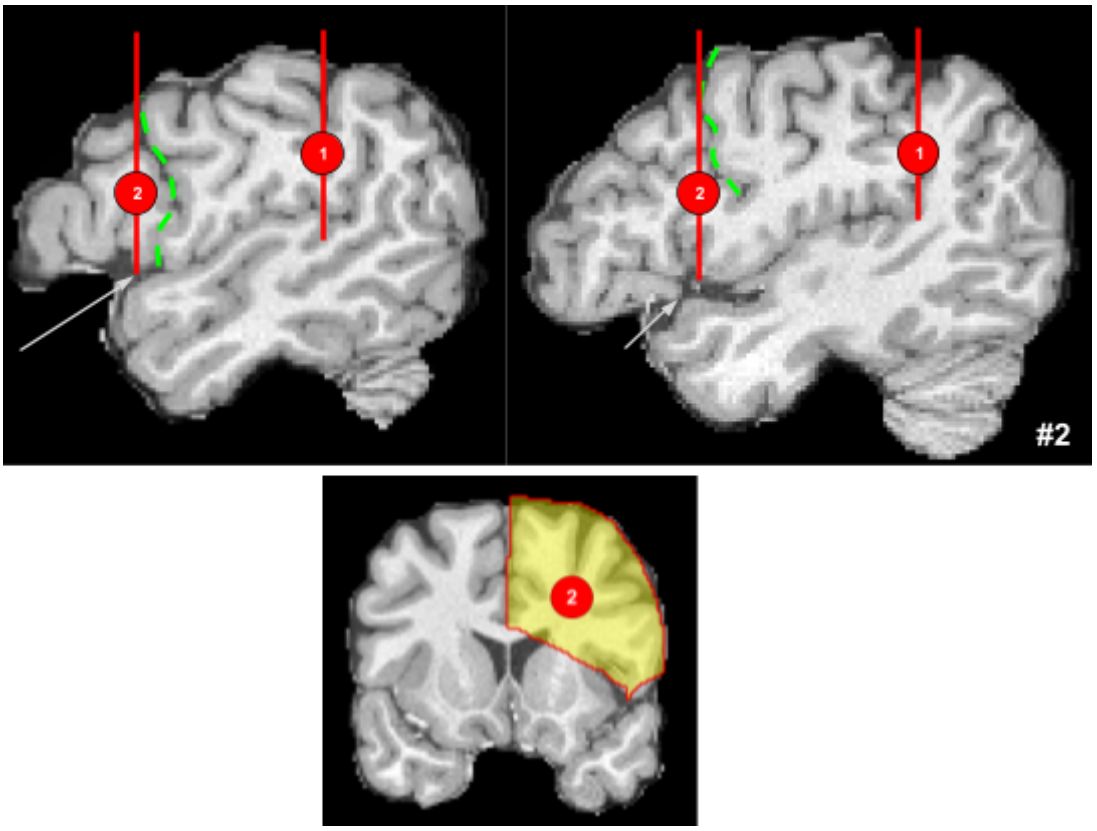
   The first coronal planar exclusion ROI is then placed at the most posterior portion of the postcentral gyrus, at the level of the postcentral sulcus (red line 1).

   Save the postcentral gyrus ROI (1) as POST_C_L.nii





2. The second coronal planar exclusion ROI is placed at the most anterior portion of the precentral gyrus, at the level of the precentral sulcus (red line 2). Use the T1 in the sagittal incidence to find the approximate region where the sylvian fissure starts. From the surface of the T1, scroll medially until you see the fissure, the lateral sulcus divides both the frontal lobe and temporal lobe.
   Above that point, you should see the precentral gyrus generally following the Z axis. You may have to look at more than one sagittal slice to find the gyrus.



It is important not to cut the brainstem in the plane for the postcentral gyrus (1) and not to include nuclei in the plane for the precentral gyrus (2). The inclusion of the temporal lobe in postcentral gyrus ROI (1) is important as it will be used later for the arcuate fasciculus segmentation. The exclusion of the nuclei and temporal stem in the precentral gyrus ROI is important as it will be used later for the arcuate fasciculus segmentation.

Save the precentral gyrus ROI (2) as PRE_C_L.nii.

These ROIs must be segmented on the right side too (POST_C_R.nii and PRE_C_R.nii), they will be required later for the corpus callosum segmentation.

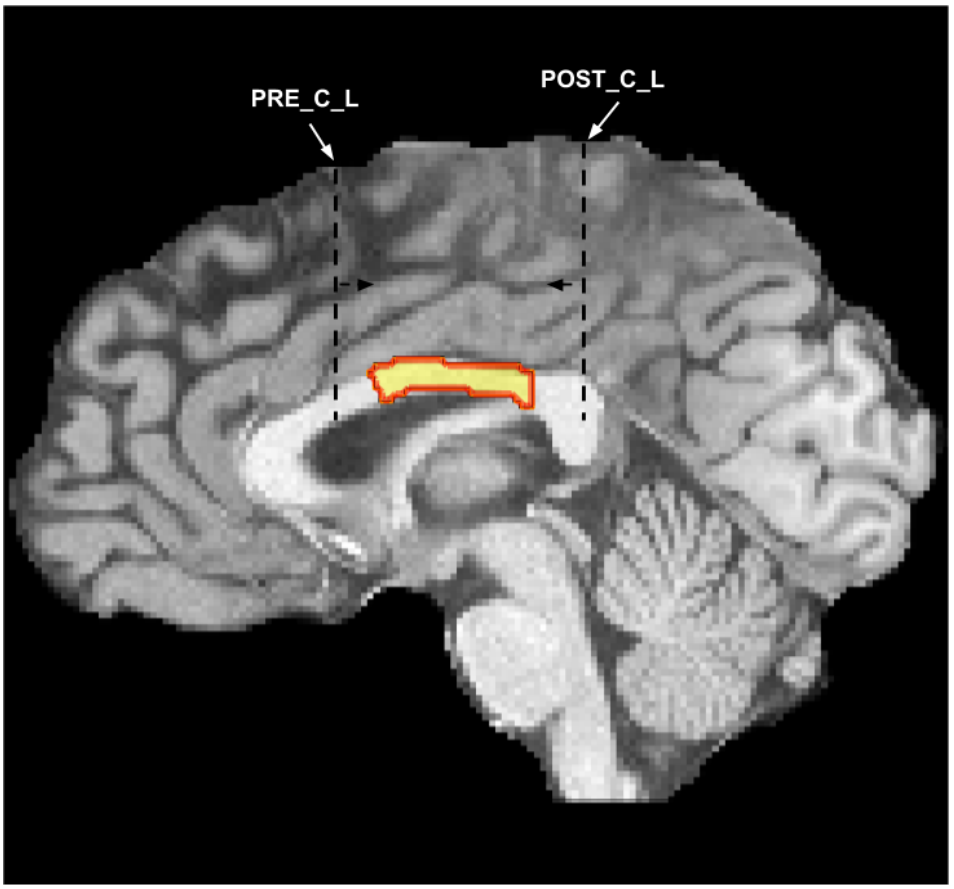
Instructions for the virtual dissection of the Corpus Callosum

Central Corpus Callosum ROI (CCC-ROI)
In order to restrict the corpus callosum segmentation to the precentral and postcentral gyrus, a ROI must be added in the mid-sagittal plane. This ROI approximates the mid-anterior, central and mid-posterior region of the CC. However, this is in fact done solely to exclude the genu, the anterior portion of the CC and the splenium.

On the T1w image, from the center between the precentral gyrus and the postcentral gyrus (defined above), draw a 20-30mm long square region. This region should not have any curvature and should stop before the precentral gyrus and the postcentral gyrus planes.

The precentral gyrus and postcentral gyrus in both hemispheres (described above) are necessary to restrict the corpus callosum terminations.

Save this ROI as CENTRAL_CC.nii

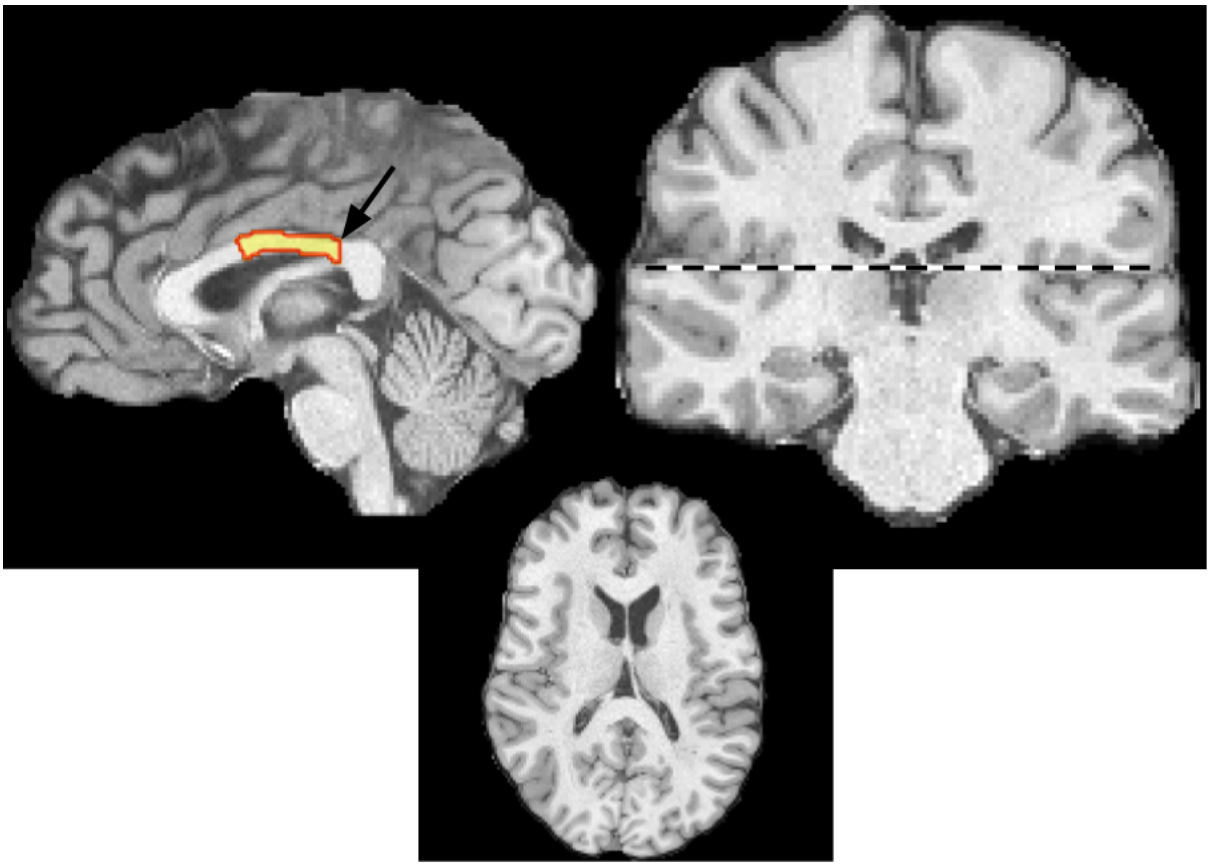


Lower limit of the Corpus Callosum (LOW-ROI)

To prevent streamlines from reaching into the nuclei, a planar axial exclusion ROI must be added. Using the most posterior position of the CCC-ROI as a coronal landmark (described above). Create a planar sagittal ROI on the whole volume just below the ventricle (or the sylvian fissure, whichever is lower).

This plane is used to approximate the position of the nuclei below the central corpus callosum as well as preventing the most posterior streamlines to curve into the temporal lobe following the tapetum.

Save this ROI as LOWER_AXIAL_LIM.nii

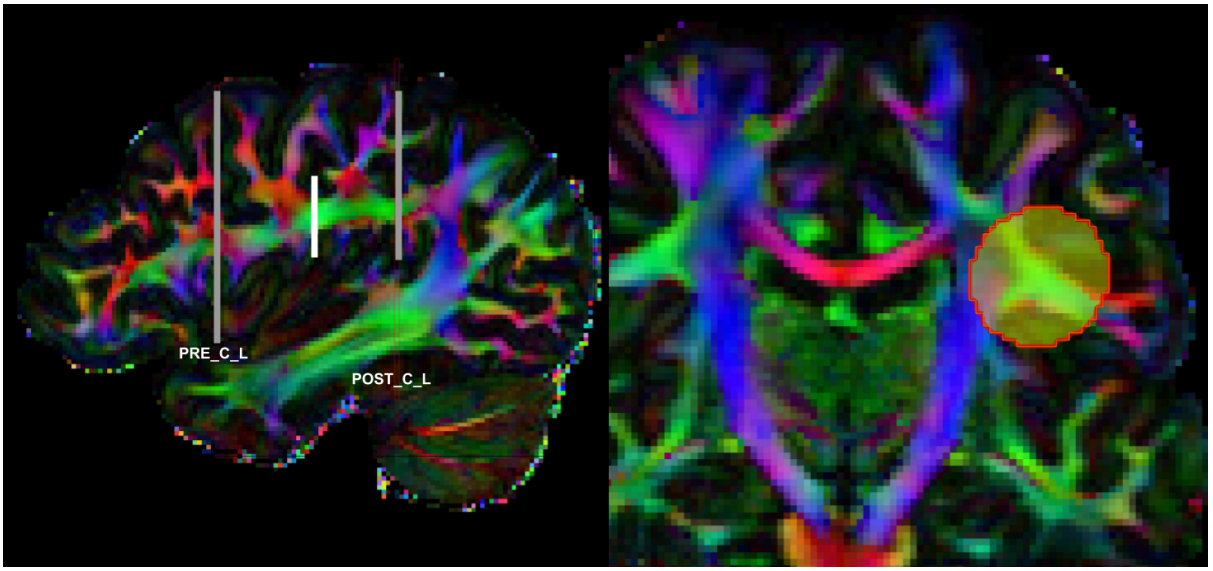


Instructions for the virtual dissection of the Arcuate Fasciculus

Centrum semiovale ROI (CS-ROI)

The CS-ROI is a disk/square with a diameter of 15-20mm delineated on a single coronal slice. The approximate center between the precentral gyrus and the postcentral gyrus (defined above) is used as a coronal landmark. The CS-ROI is centered on the green signal from the RGB map. This region approximates the core/stem of the dorsal pathways in the centrum semiovale. The green signal to locate is triangular in shape and should not extend into the core/stem of the superior longitudinal fasciculus I/II.

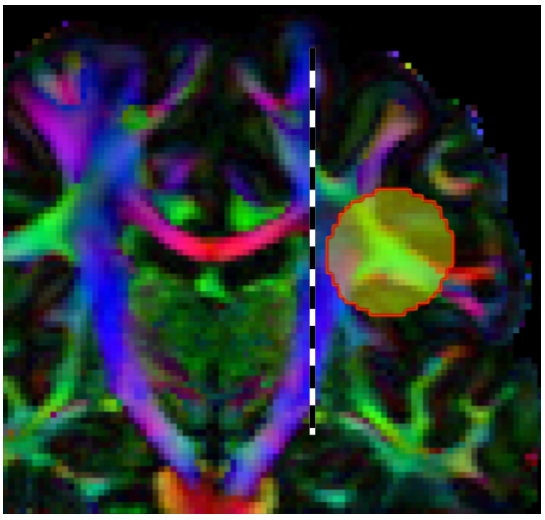
Save this ROI as CENTRAL_CS_L.nii



Medial limit of the Arcuate Fasciculus

The medial limit of the arcuate fasciculus can be approximated using a planar sagittal exclusion ROI estimated from the same slice as the CS-ROI. At the most medial position of the green signal on the RGB map, create a planar sagittal ROI on the whole volume.

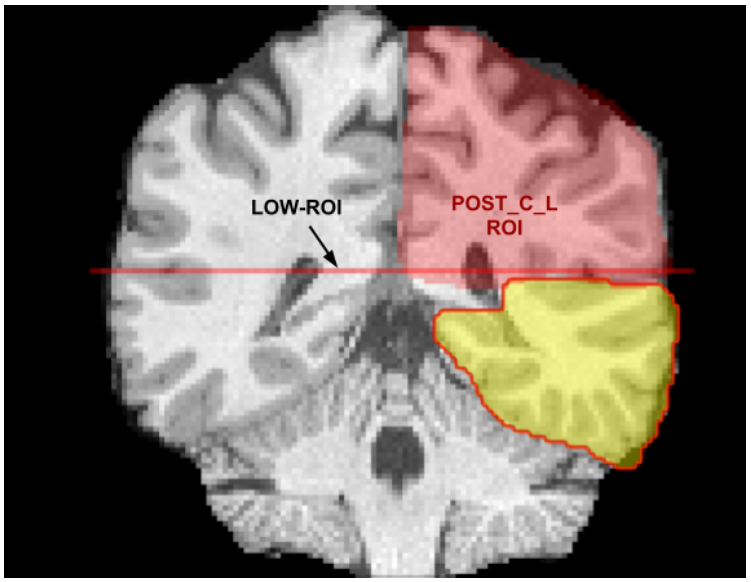
Save this ROI as MEDIAL_SAGITTAL_LIM.nii



Temporal lobe entrance ROI (TEMP-ROI)

The TEMP-ROI should approximate the entrance to the temporal lobe. On the same coronal slice as the postcentral gyrus ROI (described above, PyT), below the lower axial limit ROI (describe above, CC), draw a large square/circle ROI of approximately 25-35mm to encompass the temporal lobe.

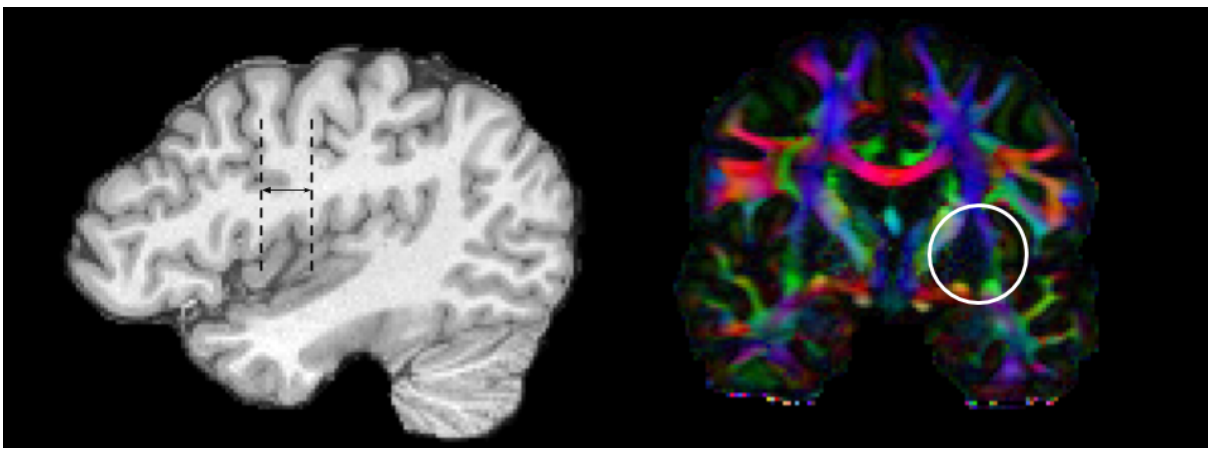
Save this ROI as TEMPORAL_ENTRY.nii



Temporal stem entrance ROI (STEM-ROI)

To prevent streamlines from reaching into the temporal stem, a disk/square coronal exclusion ROI must be added. Using the sylvian fissure, just behind the precentral gyrus (described above) as a coronal landmark, draw a disk/square of approximately 20-25mm encompassing the green signal in the RGB in its lower portion. The ROI should not cut into the main stem/core of the AF passing through the centrum semiovale. This ROI will be used to remove streamlines entering the temporal lobe via the temporal stem (part of the uncinate fasciculus).

Save this ROI as TEMPORAL_STEM.nii



Overview of the files and segmentation

After the segmentation, 15 files should have been saved. Only 2 files are related to the right hemisphere. The results of each segmentation must be saved separately, meaning that three tractography files (**TRK**) must be saved.

An example of the files, ROIs and bundles, is provided as a demonstration of the approximate expectation from this protocole. It should not be interpreted as perfect, only to help visualize the shape and position of what is asked. They represent the expected results of the dissection plan. This should help the non-experts among the participants.

Pyramidal Tract left (PYT_L.trk)

IC_L.nii	inclusion	small
MB_L.nii	inclusion	small
MO_L.nii	inclusion	small
MO_L_NOT.nii	exclusion	large
PRE_C_L.nii	exclusion	large
POST_C_L.nii	exclusion	large
MID_SAGITTAL_PLANE.nii	exclusion	plane

Arcuate Fasciculus left (AF_L.trk)

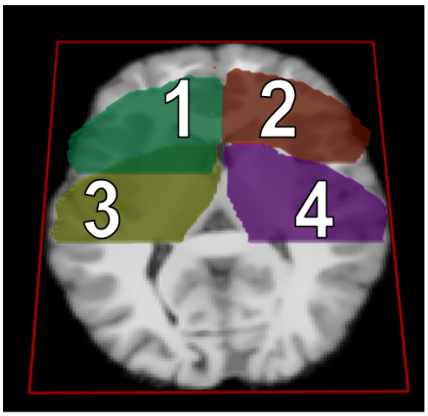
CENTRAL_CS.nii	inclusion	small
PRE_C_L.nii	inclusion	large
POST_C_L.nii	inclusion	large
TEMPORAL_ENTRY.nii	inclusion	large
TEMPORAL_STEM.nii	exclusion	large
MEDIAL_SAGITTAL_LIM.nii	exclusion	plane

Central Corpus Callosum (CC.trk)

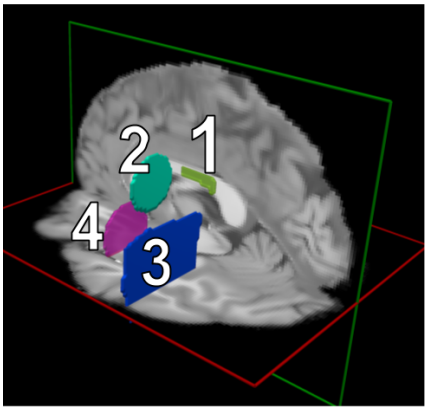
CENTRAL_CC.nii	inclusion	small
PRE_C_L.nii	exclusion	large
POST_C_L.nii	exclusion	large
PRE_C_R.nii	exclusion	large
POST_C_R.nii	exclusion	large
LOWER_AXIAL_LIM.nii	exclusion	plane

Approximate location of the ROIs

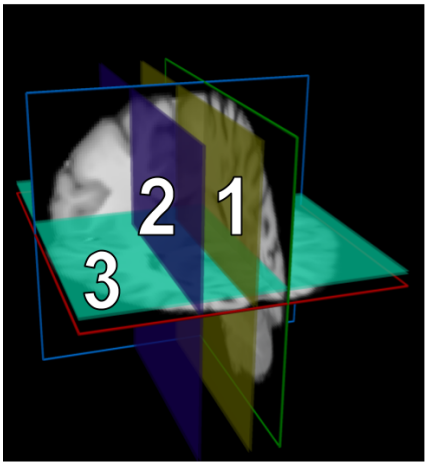
The ROIs are shown here in 3D and associated with their expected filename. Please follow the main description, this should be used only as an *aide-memoire*. (See example files)



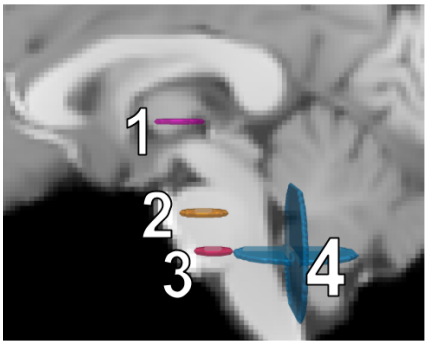
1. PRE_C_L
2. PRE_C_R
3. POST_C_L
4. POST_C_R



1. CENTRAL_CC
2. CENTRAL_CS
3. TEMPORAL_ENTRY
4. TEMPORAL_STEM



1. MID_SAGITTAL_PLANE
2. MEDIAL_SAGITTAL_LIM
3. LOW_AXIAL_LIM

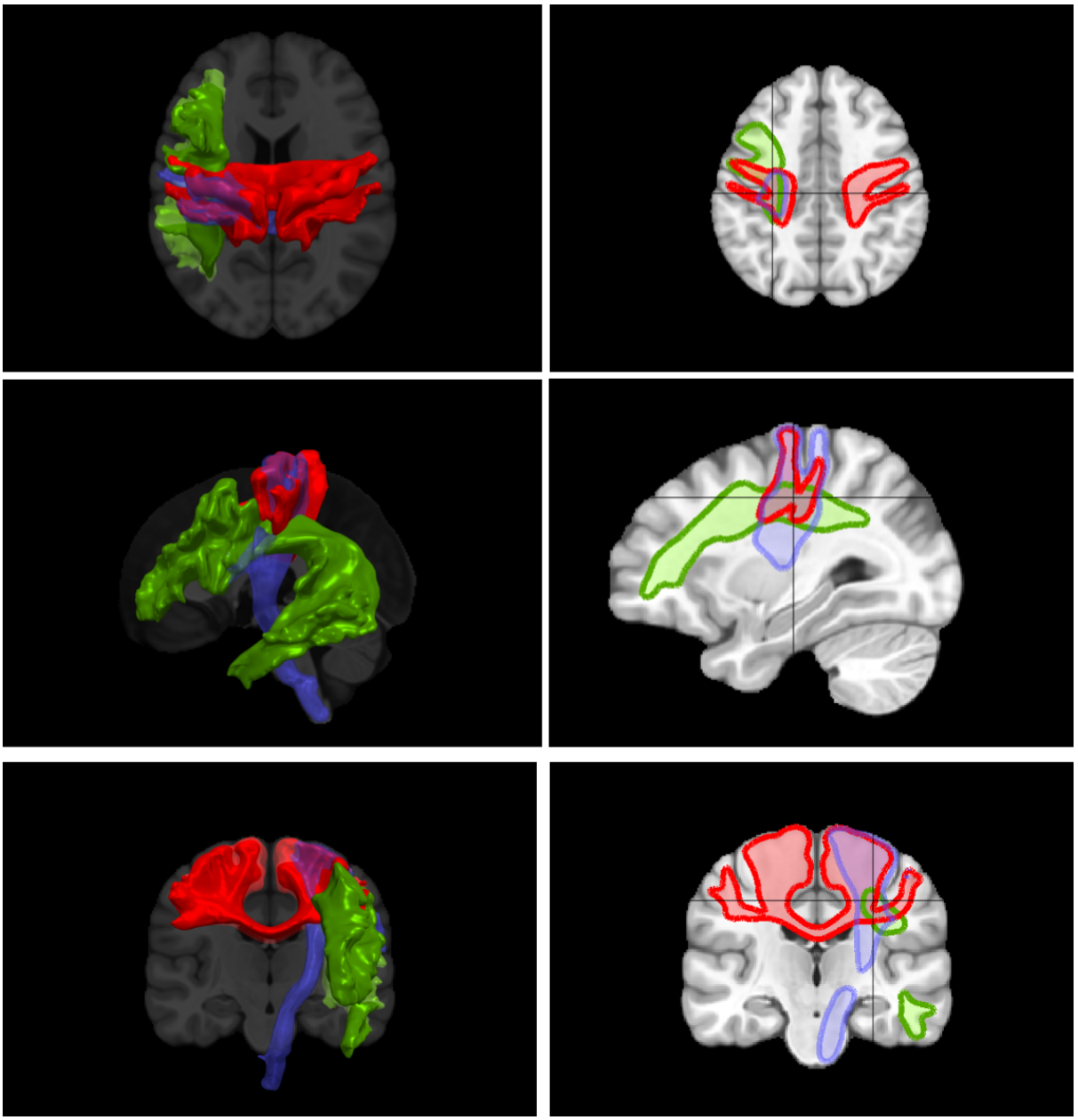


1. IC_L
2. MB_L
3. MO_L
4. MO_L_NOT

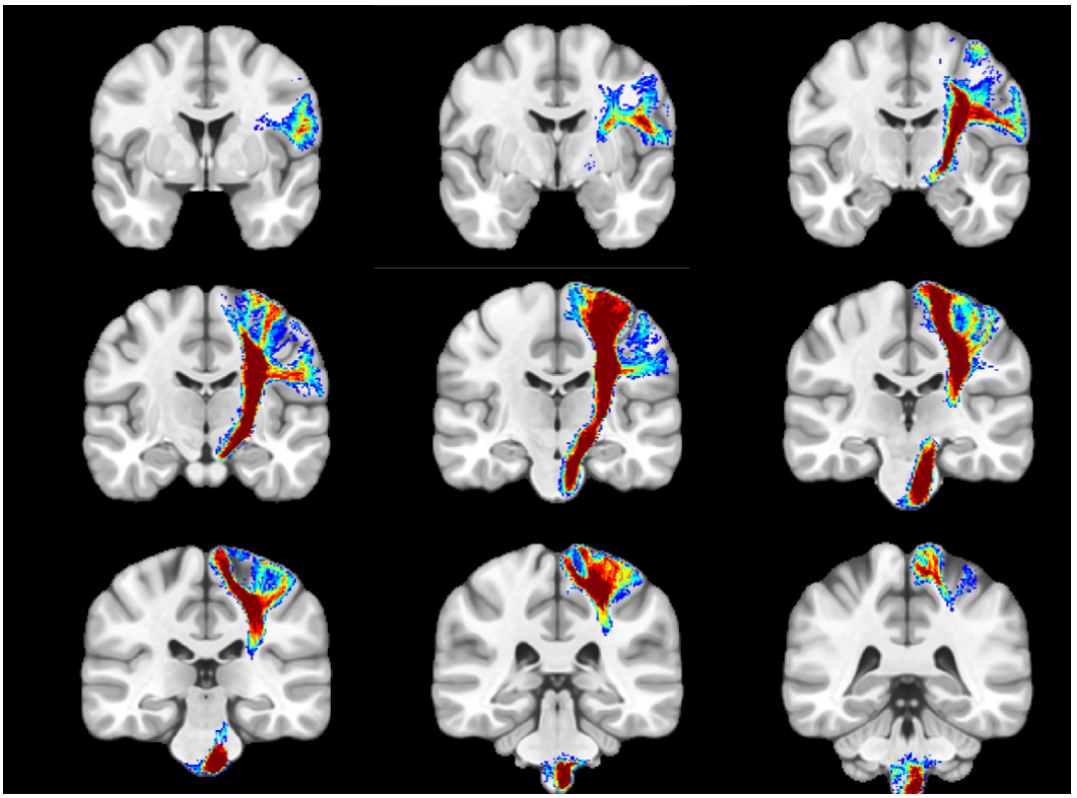
Average position/shape of bundles

Based on a small sample (10) of HCP datasets registered to MNI space, this is the expected position and shape of the bundle presented in this document. This should be used only as a way to easily orient yourself in the provided dataset. Furthermore, any results with a drastic difference from these shapes should be investigated as a potential error resulting from using the wrong segmentation rules or misnaming ROIs.

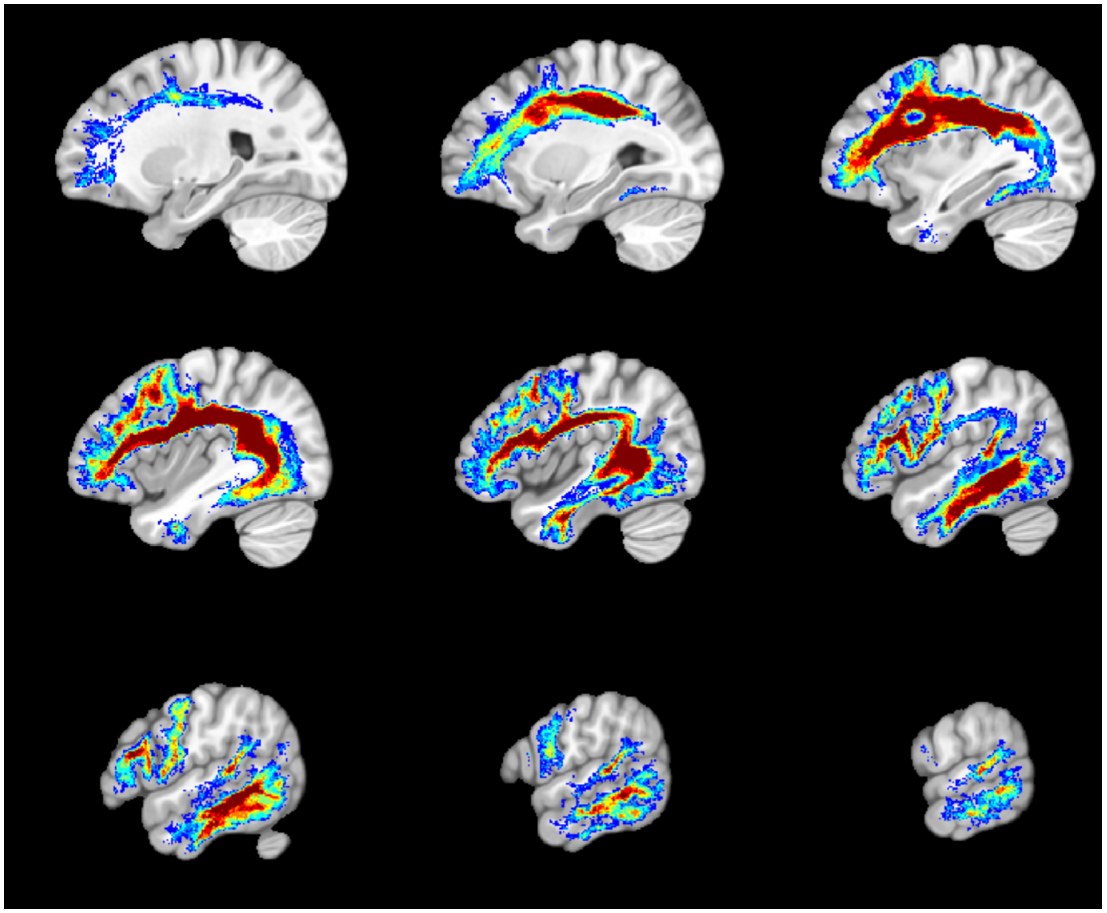
Isosurface at the probability value of 0.5.



Coronal mosaic of the probability value over a population of 10 for the pyramidal tract left.



Sagittal mosaic of the probability value over a population of 10 for the arcuate fasciculus.



Coronal mosaic of the probability value over a population of 10 for the corpus callosum.