Artificial Intelligence in Medicine

INFN - CSN5
2019-2021

AIM3.T3 Predictive models for transcranial-MR-guided Focused Ultrasound Surgery

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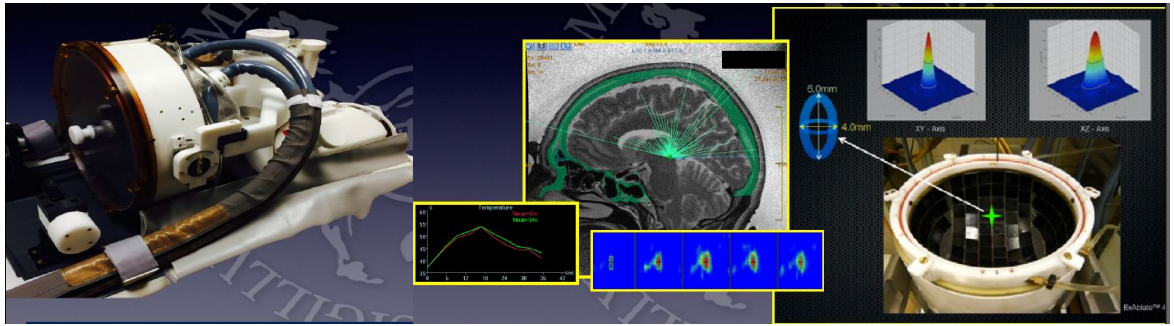
Focused Ultrasound (FUS) equipment

Focused Ultrasound (FUS) equipment (ExAblate 4000, InSightec Ltd. - Haifa, Israel) consists of an hemispheric 1024-element phased-array transducer operating at 650 kHz



First installation in Italian site

World first installation on a 1.5T scanner

PON -MIUR 2007–3013: PONa3_00011

Ricerca Finalizzata Call 2016 young researcher: GR-2016-02364526

Ministero dell'Istruzione dell'Università e della Ricerca

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What is Essential Tremor (ET)?

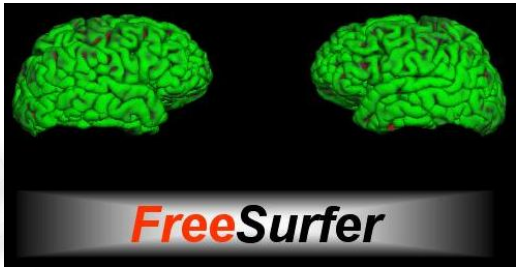
- Most common adult-onset movement disorder
- 5% general population
- Genetics: variable penetrance, no gene found (polygenic)
- Central generator: thought to represent cerebellar-thalamo-cortical outflow pathology
- Kinetic and postural, mainly arms; 4-12Hz
- Progressive
  - Arms -> head (“yes-yes” vs. “no-no”)
  - Voice / vocal cord, chin, tongue
- Unilateral -> bilateral

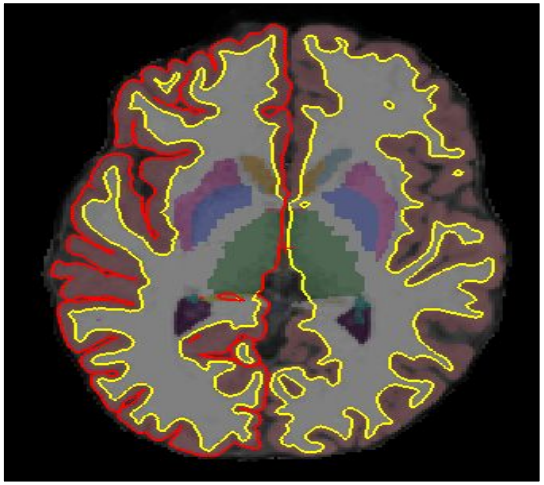
Flowchart of our target identification

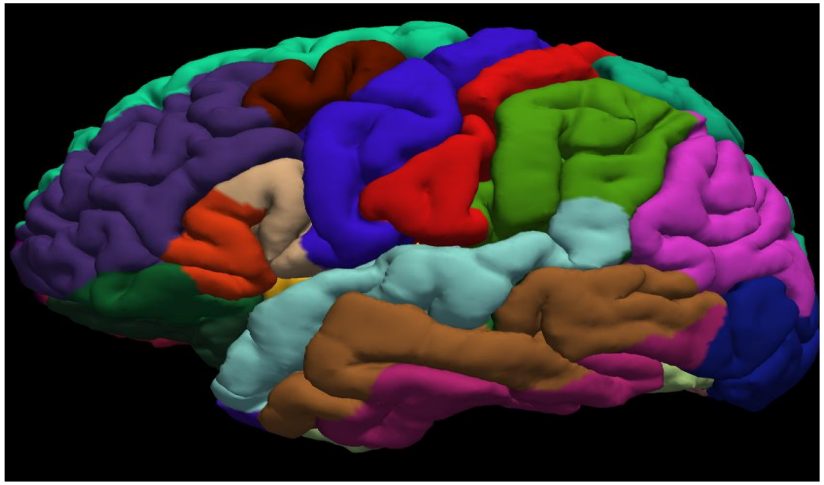
- **SEGMENTATION OF THE CEREBRAL CORTEX**
- **PROBABILISTIC TRACTOGRAPHY**
- **THALAMIC PARCELLATION**

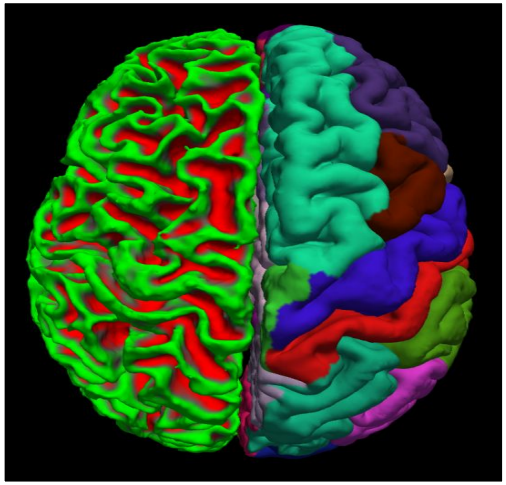
SEGMENTATION OF THE CEREBRAL CORTEX

The T_1w FSPGR 3D datasets (1x1x1mm^3) were used. The FreeSurfer 6.0 workflow was used to segment both the cortical and deep gray matter.

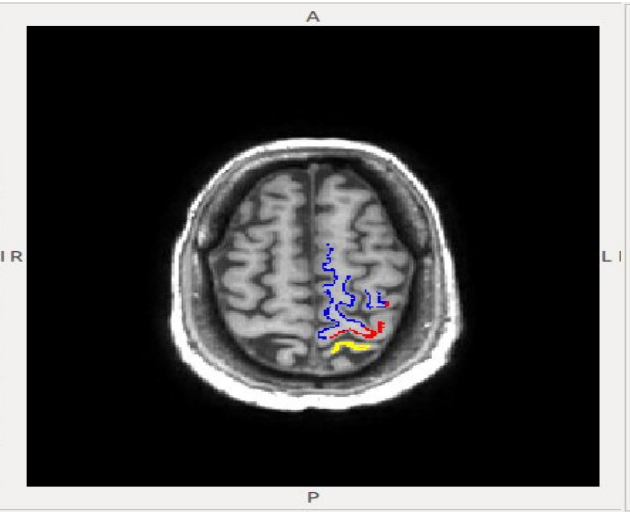


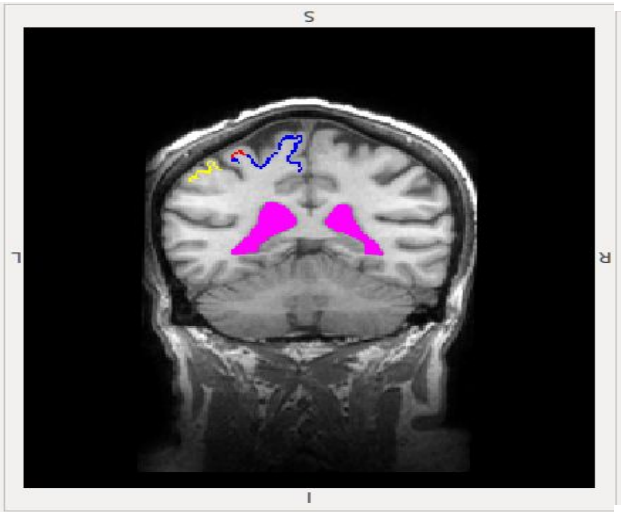


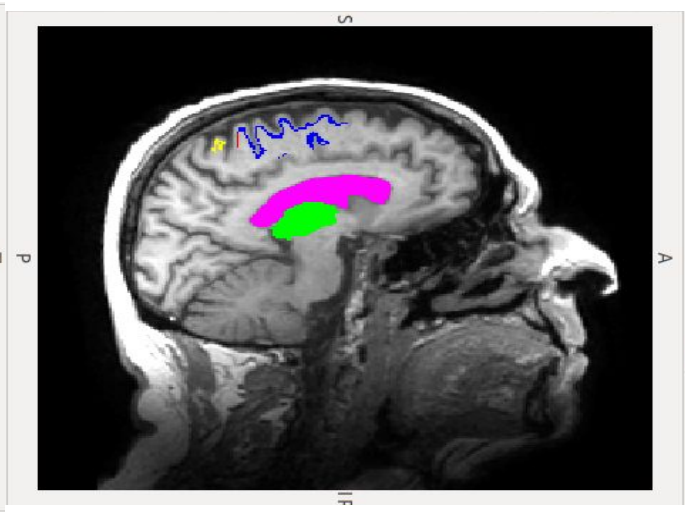




SEGMENTATION OF THE CEREBRAL CORTEX





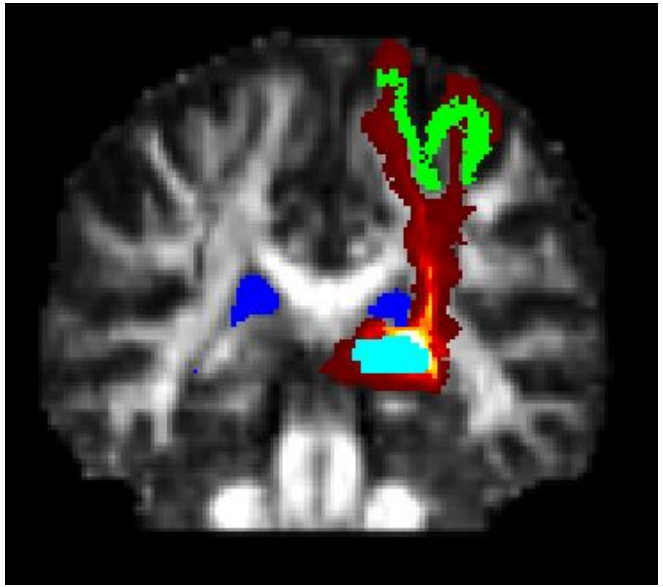


- VENTRICLES
- RIGHT THALAMUS
- BRODMAN AREA 6
- PRECENTRAL GYRUS
- POSTCENTRAL GYRUS

Flowchart of our target identification

- SEGMENTATION OF THE CEREBRAL CORTEX
- PROBABILISTIC TRACTOGRAPHY
- THALAMIC PARCELLATION

Probabilistic tractography



- Need to search through a large solution space of all possible connections between two regions:
  - Computationally expensive
  - Sensitive to initialization

- Fits the entire pathway, using diffusion orientation at all voxels along pathway length
- Constrained to connection of two specific end regions

Seeds
- → pre-central gyrus
- → post-central gyrus
- → Brodman Area 6

Target
- → Thalamus

Regions excluded
- → Ventricles

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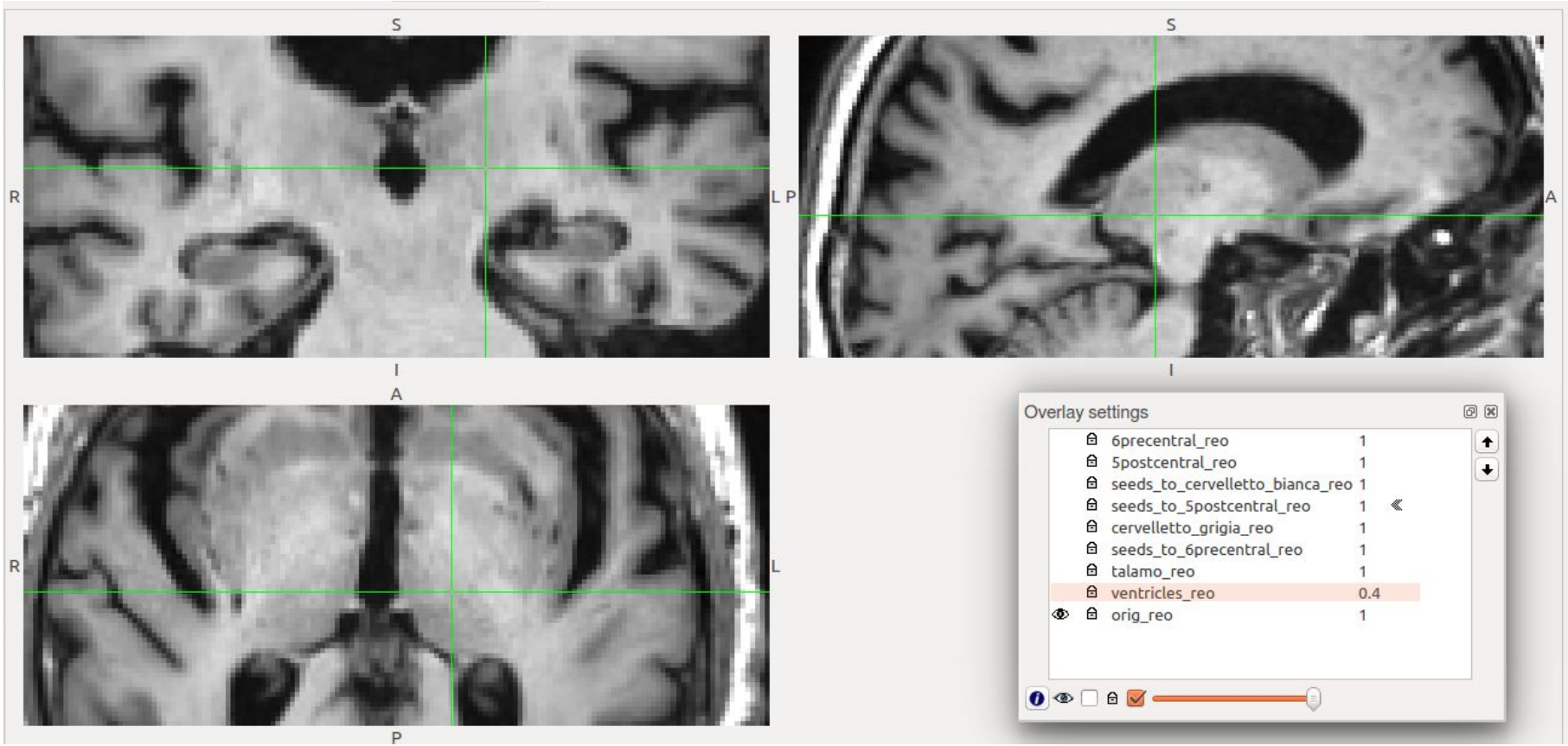
THALAMIC PARCELLATION



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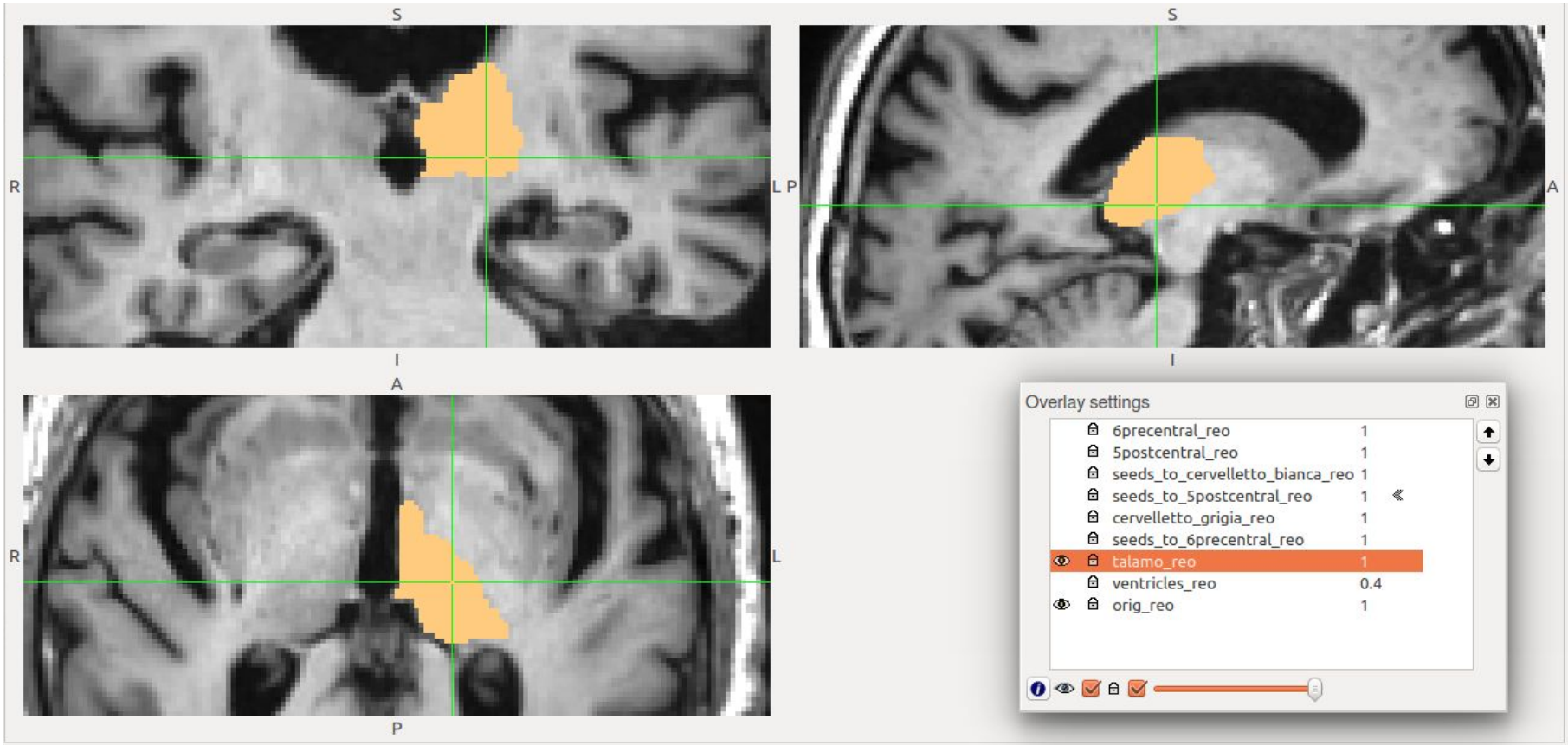

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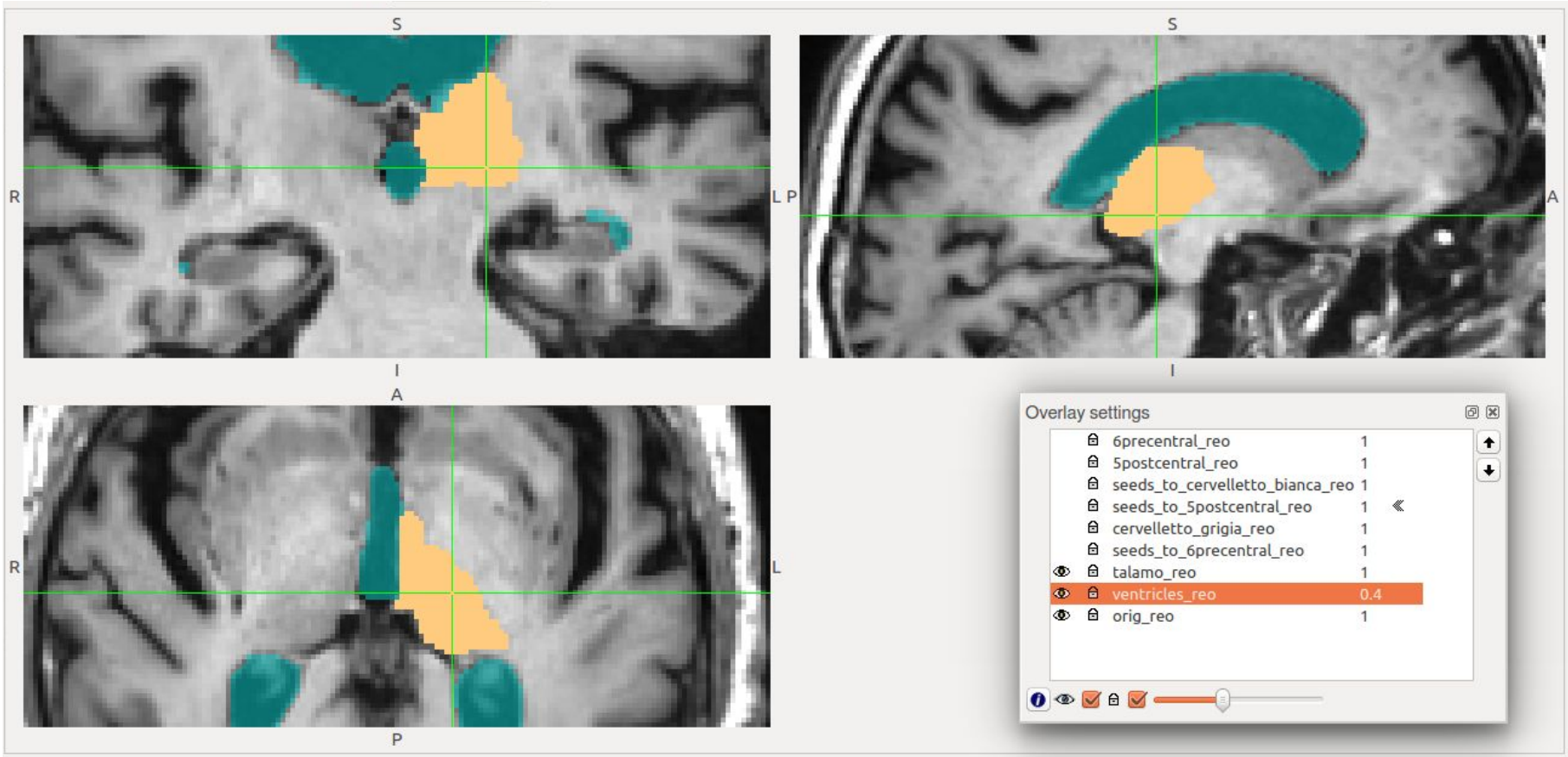

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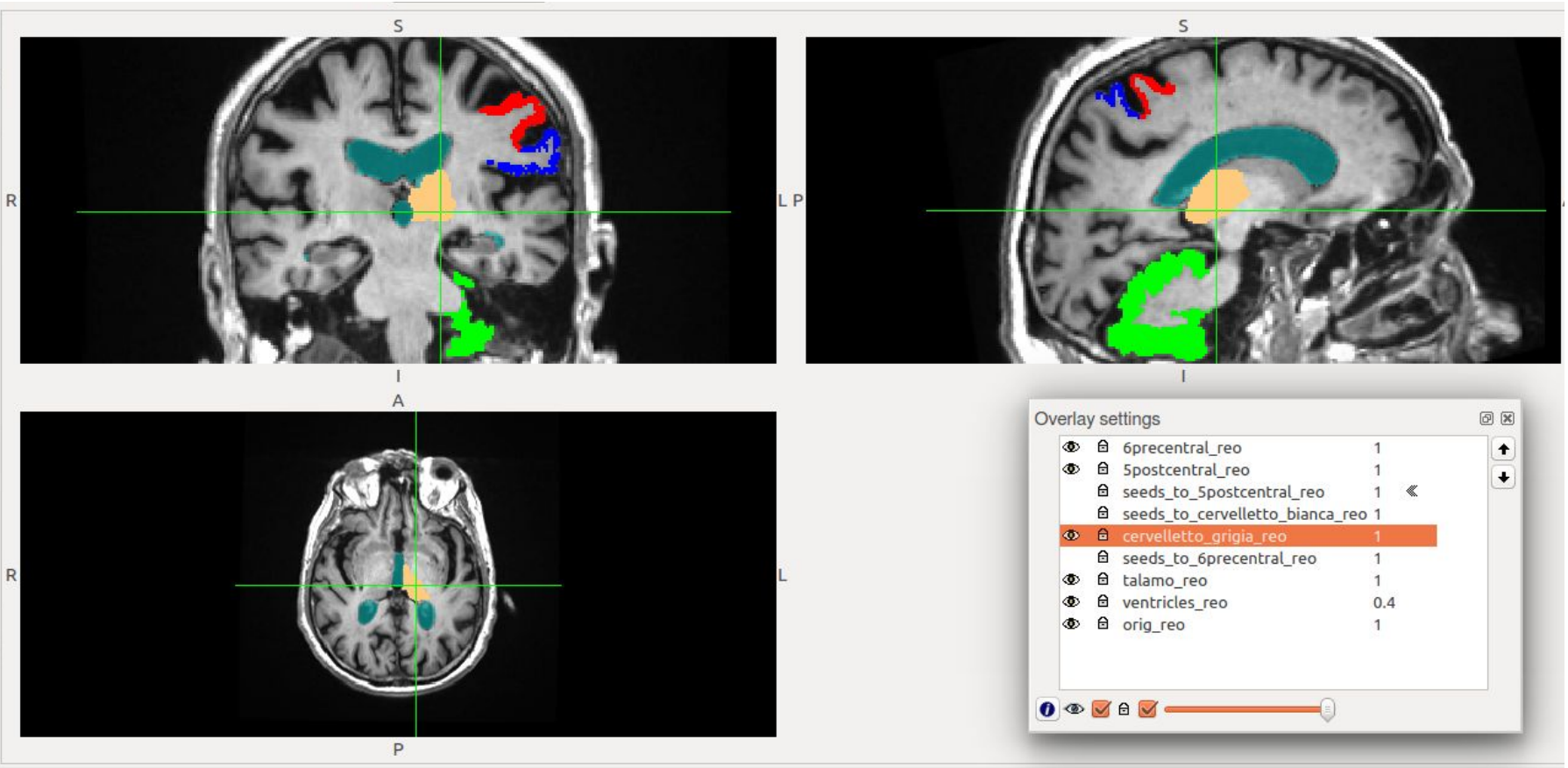

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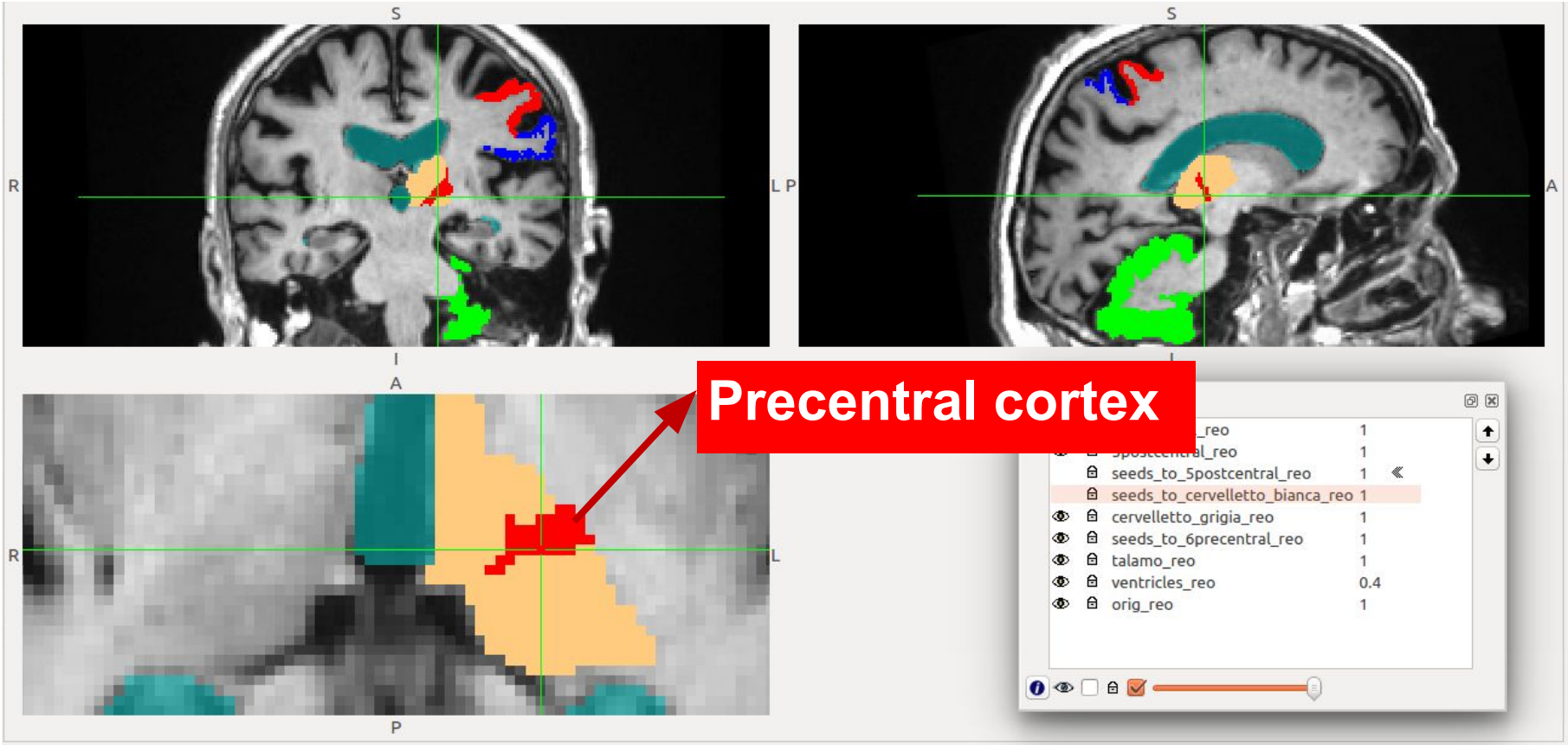

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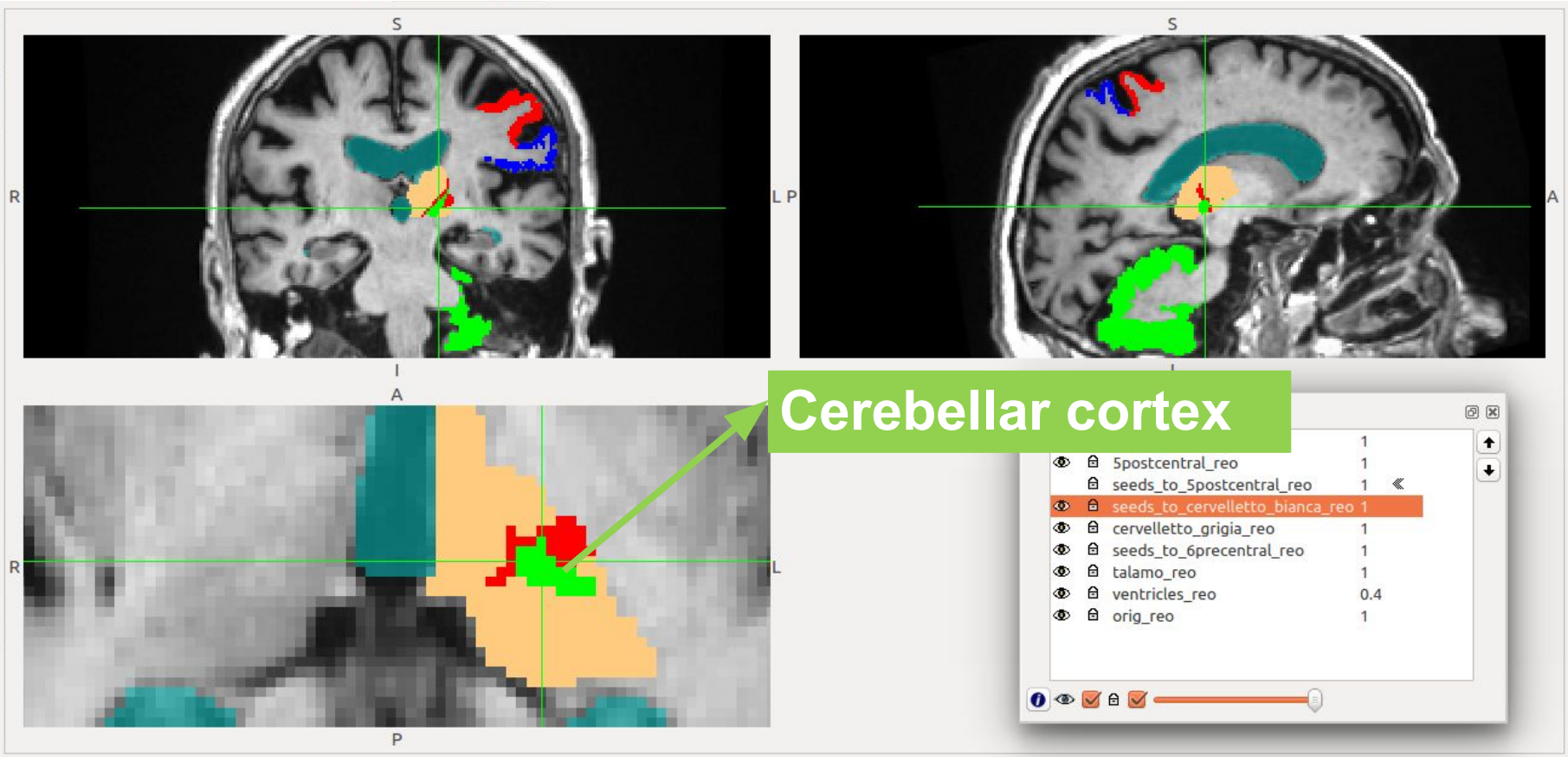

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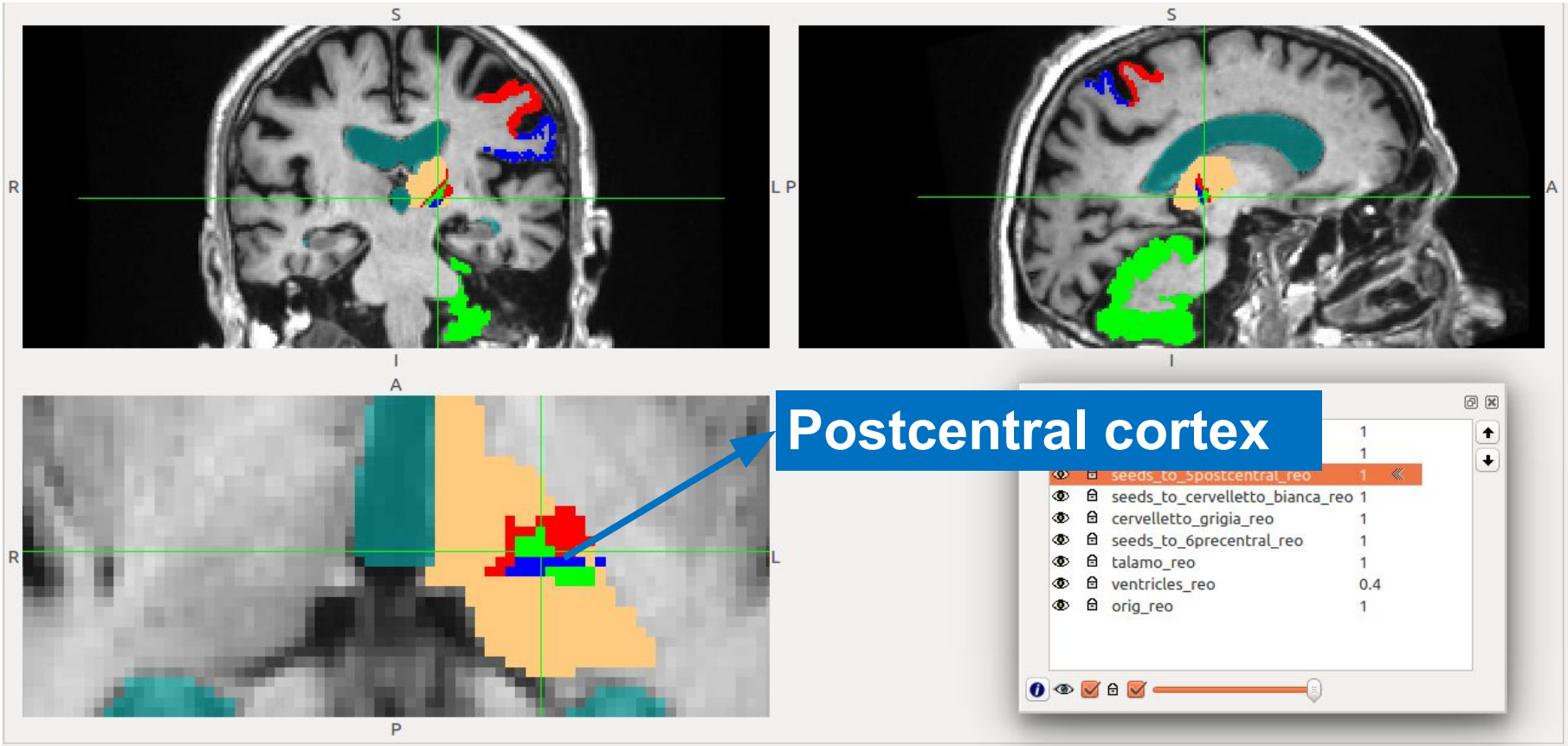
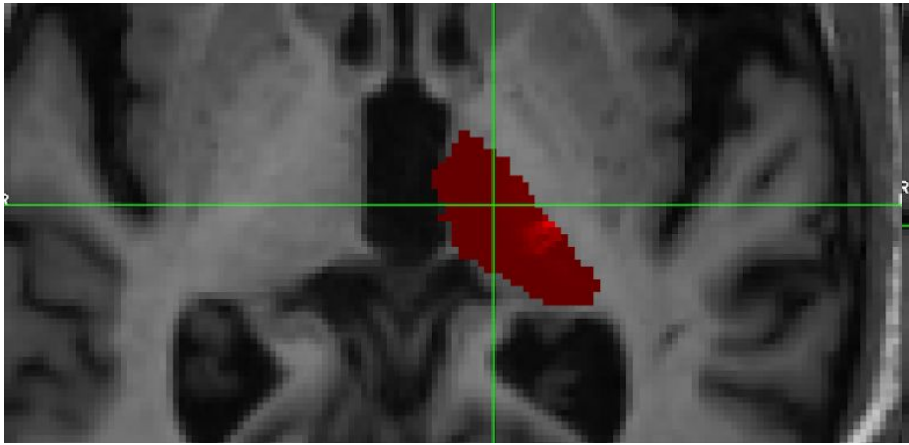
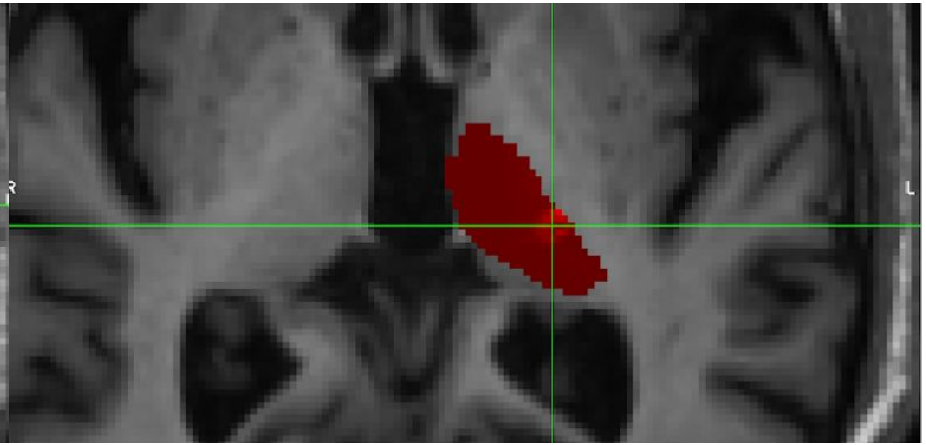


THALAMIC PARCELLATION vs ATLAS TARGETING

ATLAS TARGETING



THALAMIC PARCELLATION



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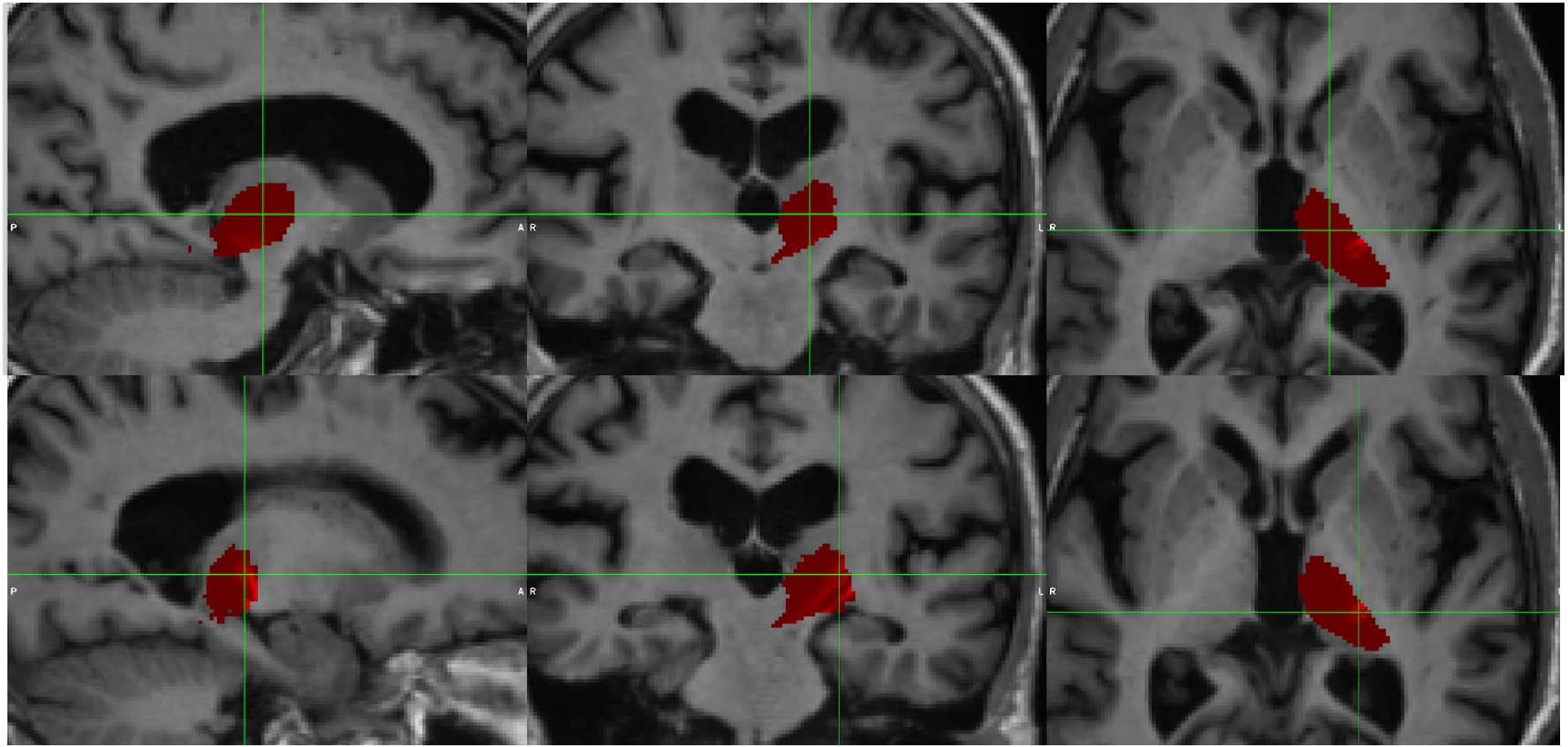


Number of cases

Up to now about 80 patients treated

Patient undergo:

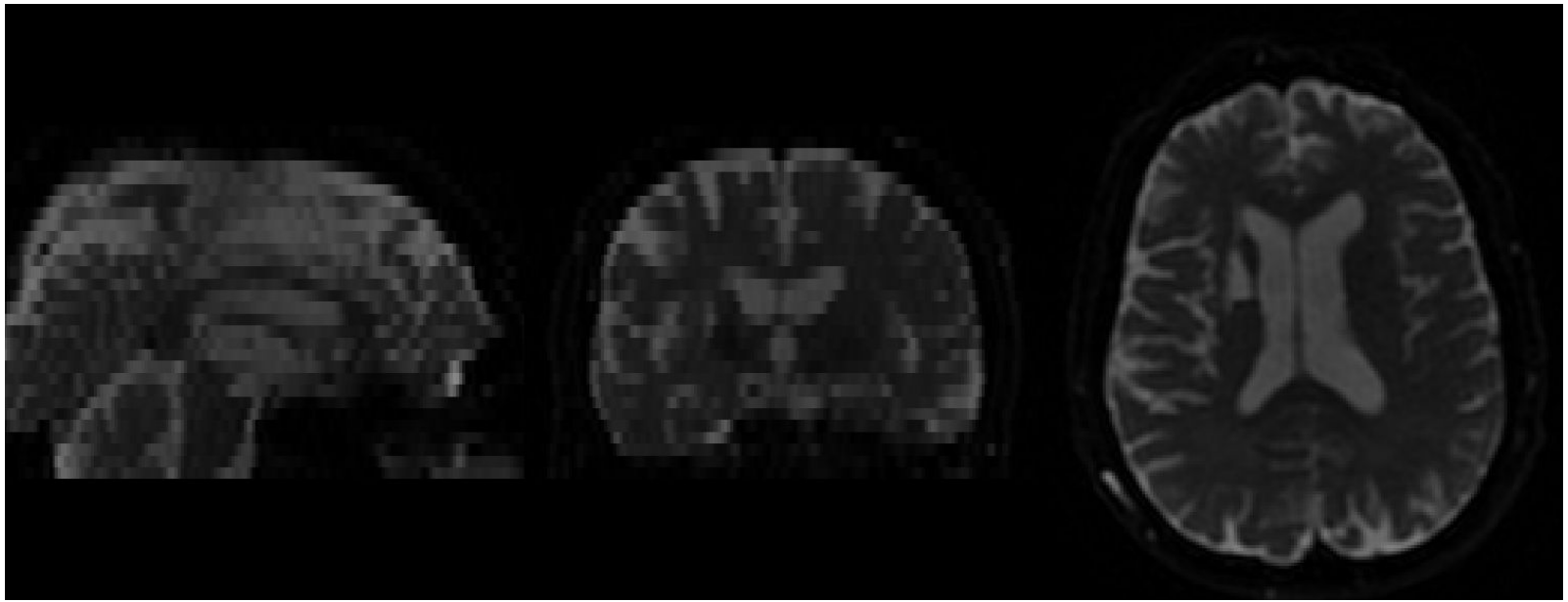
1. MRI screening acquisition
2. MRI Acquisitions during treatment
3. MRI Acquisitions 2 days after treatment
4. Follow-ups at 6, 12 and 24 months (many of these acquisitions were not possible this year because of COVID19)

Acquisitions 1., 3., and 4. include structural images, DWI and rs-fMRI

Different protocols for MR image acquisition

Change of acquisition protocol (in order to improve images quality)

DWI ACQUISITIONS



Old protocol

Anisotropic voxel

Different protocols for MR image acquisition

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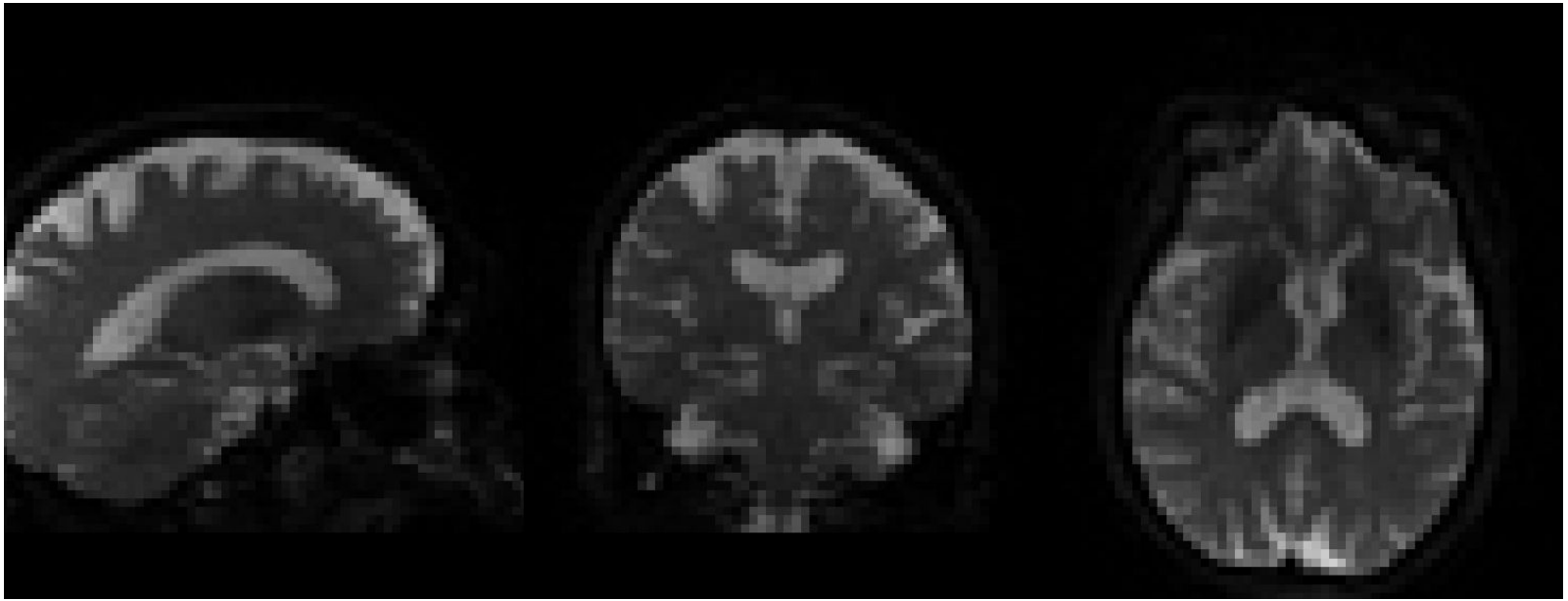
DWI ACQUISITIONS



New protocol

Isotropic voxel

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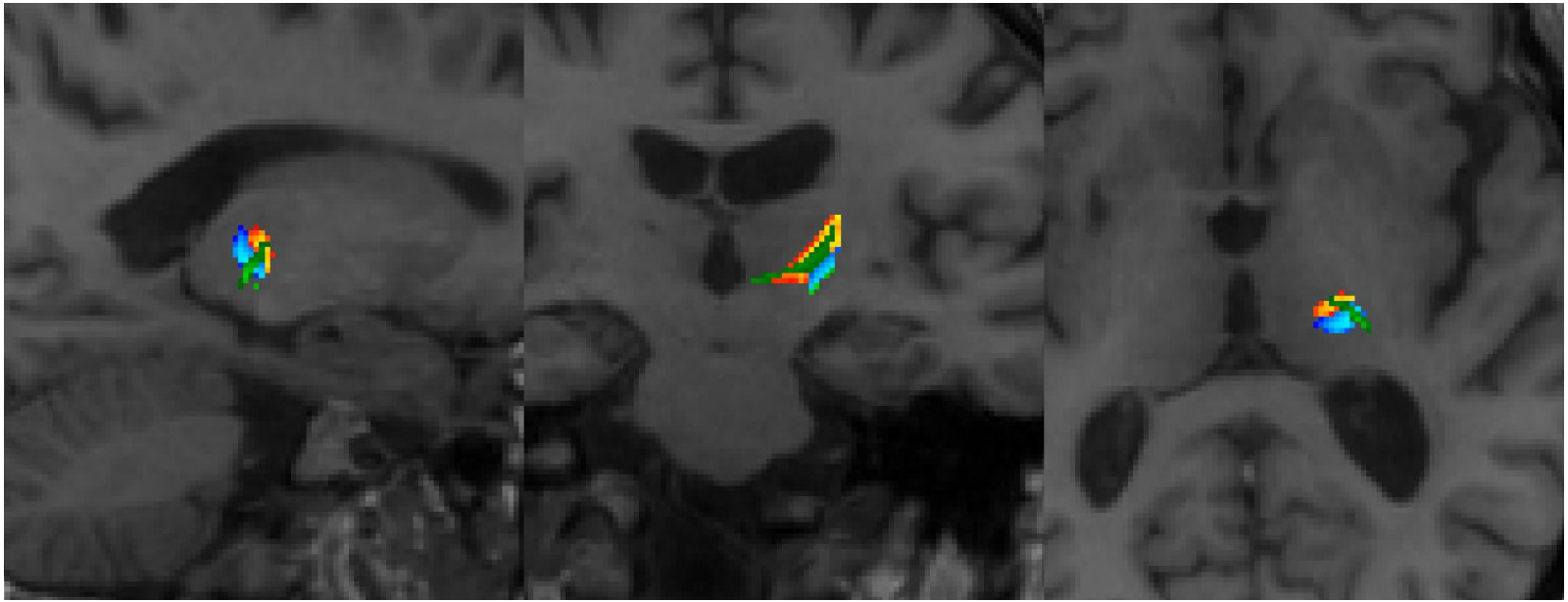
TRACTOGRAPHY MAPS



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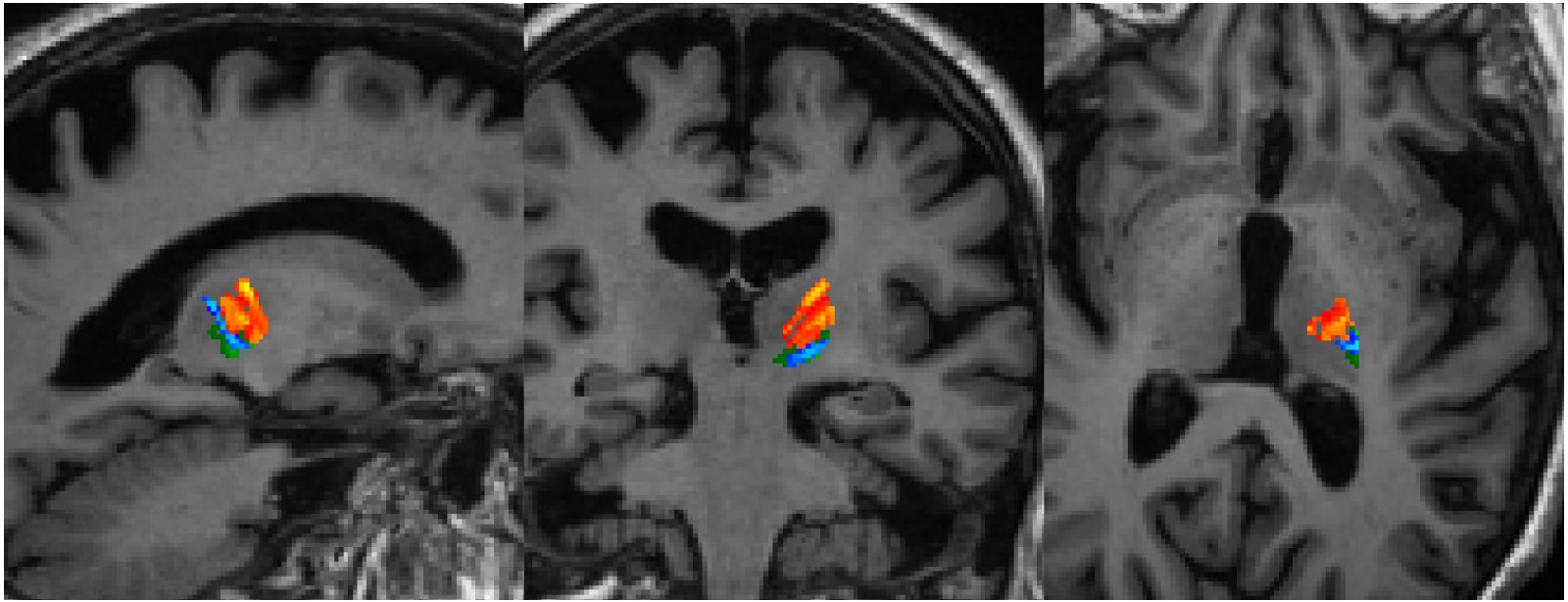
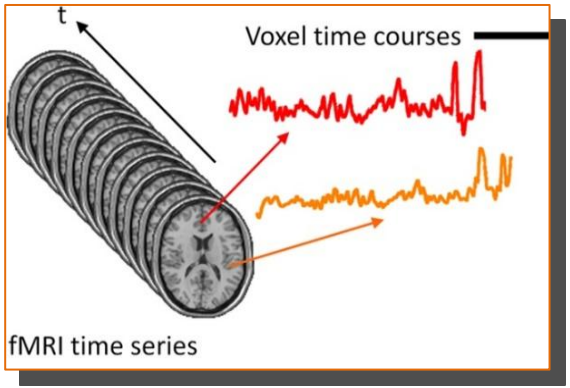


New protocol

rs-fMRI analyses

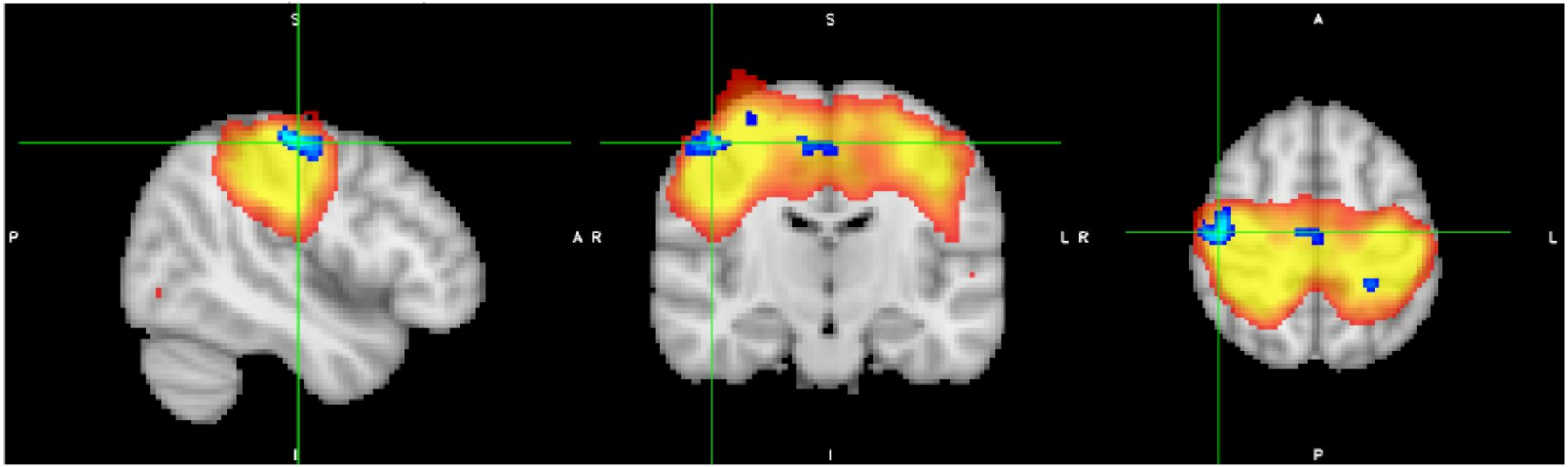


Independent Component Analysis (**ICA**): starting from the registered signal it allows to extract the original spatial and temporal sources (time course), exploiting the hypothesis of statistical independence and non-gaussianity of the sources.

FSL
FMRIB SOFTWARE LIBRARY

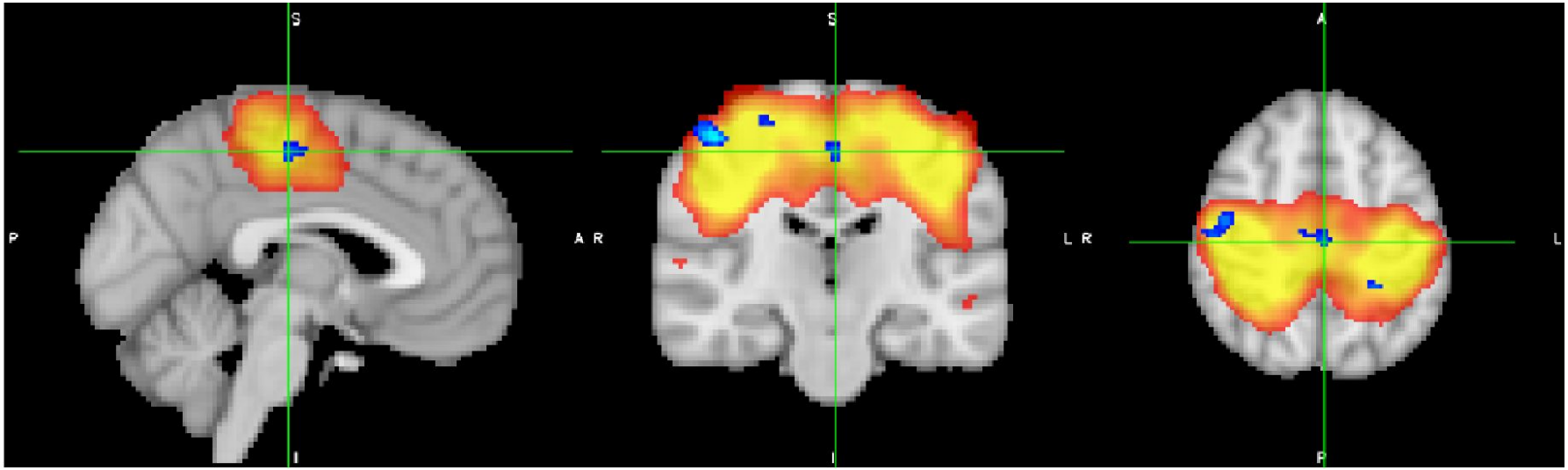
MELODIC
Multivariate Exploratory Linear Optimised Decomposition into Independent Components

rs-fMRI analyses



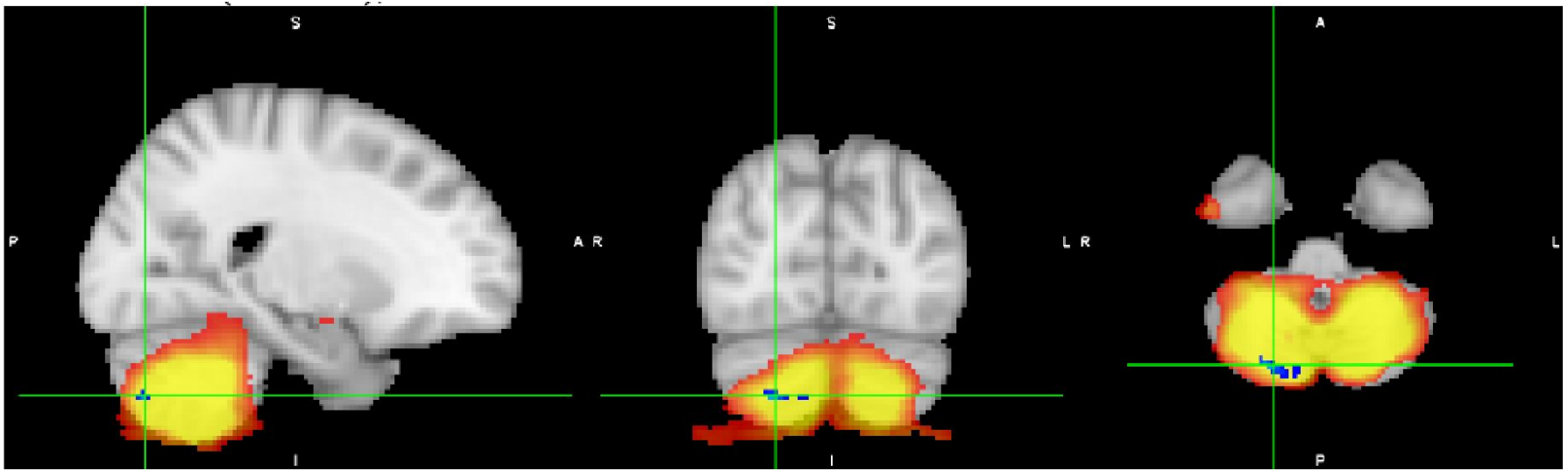
Increased resting state functional connectivity in patients with essential tremor undergoing left thalamotomy using high intensity focused ultrasound guided by MRI in right precentral gyrus (primary motor area, M1)

rs-fMRI analyses



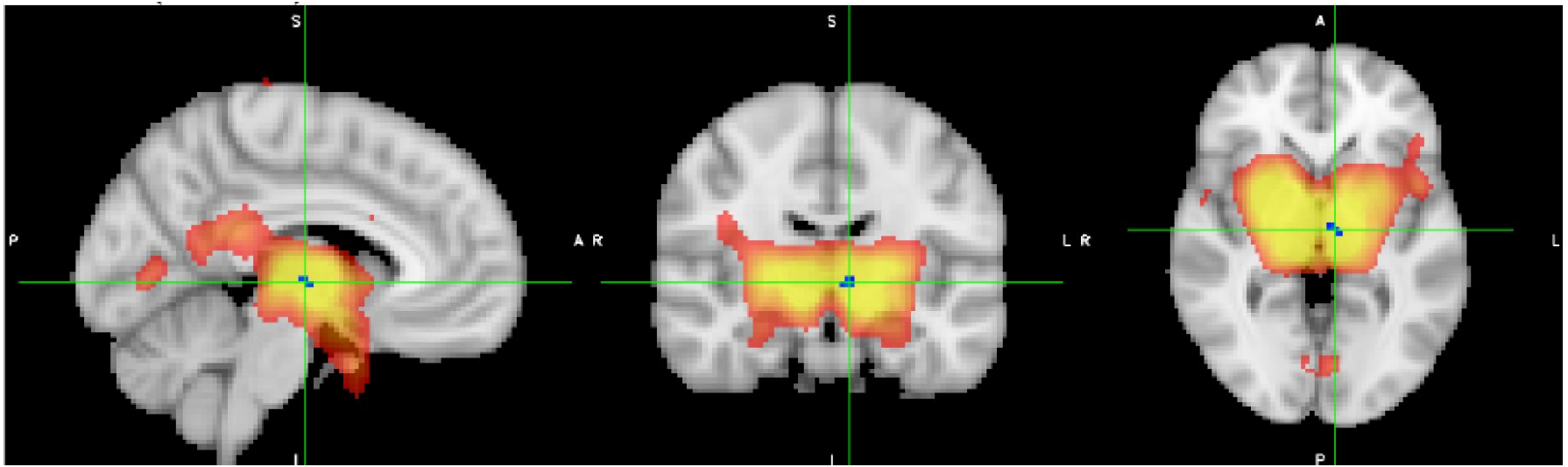
Increased resting state functional connectivity in patients with essential tremor undergoing left thalamotomy using high intensity focused ultrasound guided by MRI in (Supplementary motor areas, SMA)

rs-fMRI analyses



Increased resting state functional connectivity in patients with essential tremor undergoing left thalamotomy using high intensity focused ultrasound guided by MRI in Crus II of the right cerebellar hemisphere

rs-fMRI analyses

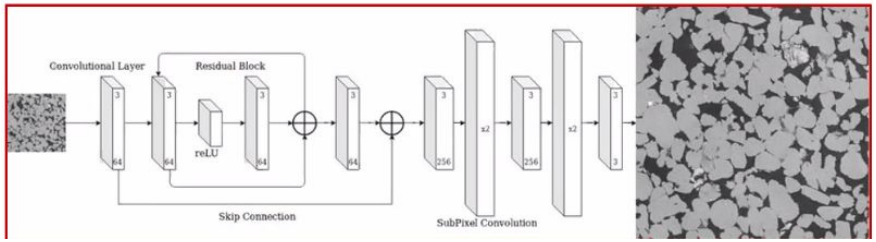


Increased resting state functional connectivity in patients with essential tremor undergoing left thalamotomy using high intensity focused ultrasound guided by MRI in left thalamus

Future work on upsampling via superresolution

Application of superresolution techniques for upsampling DWI an fMRI images to the voxel size of new protocol acquisitions

Collaboration with BO Unit



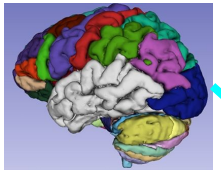
The full database of 80 patients (and more in the next future) could be used for all analyses

DEEP LEARNING FOR THALAMIC PARCELLATION

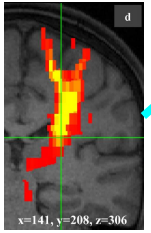
We plan to apply convolutional neural network to T1w and DWI datasets to reconstruct parcellation maps

Collaboration with BO Unit

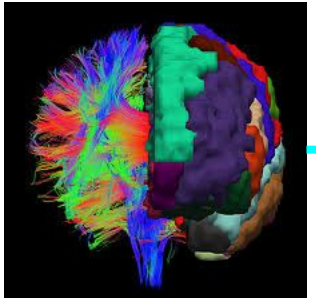
Cortex segmentation



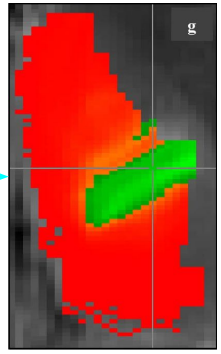
Probabilistic tractography



Combination of these 3D maps



Accurate *a priori* identification of the target inside the thalamus

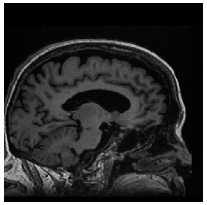


DEEP LEARNING FOR THALAMIC PARCELLATION

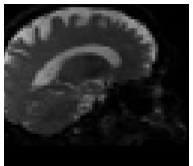
We plan to use convolutional neural network to our T1w and DWI datasets in order to reconstruct parcellation maps

Collaboration with BO Unit

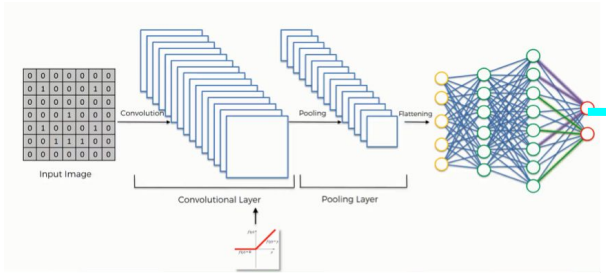
T1w-image



DWI



CNN



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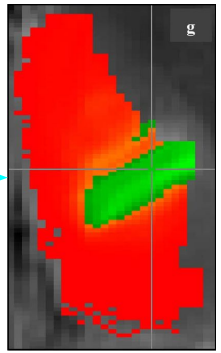

thank you