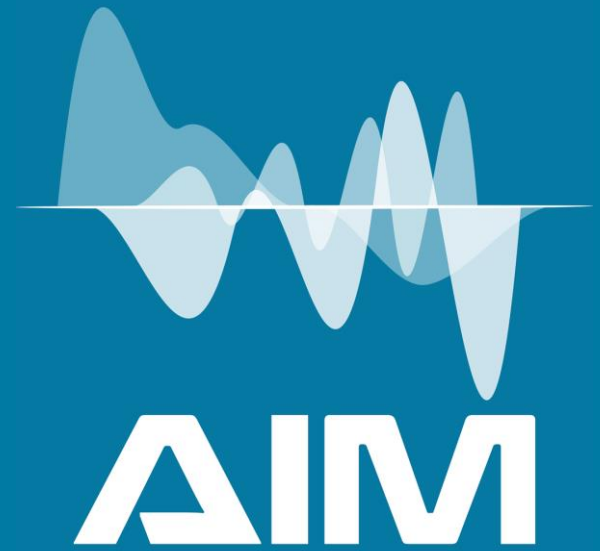# **A**rtificial **I**ntelligence in **M**edicine

Thalamic parcellation through probabilistic tractography for tcMRgFUS treatments.
Preliminary results of fMRI analyses on tcMRgFUS patients

Speakers: Giorgio Collura – Riccardo Borgese

Università degli Studi di Palermo

INFN Istituto Nazionale di Fisica Nucleare

BANDO DELLA RICERCA FINALIZZATA 2016

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Carlo Catalano
Marco D'Amelio

tcMRgFUS at 1.5T

Surgical therapy using magnetic resonance-guided focused ultrasound

(**M**agnetic **R**esonance **g**uided **F**ocused **U**ltrasounds **S**urgery **MRgFUS**)

is a modern and non-invasive ablative technique.

Recent technological developments enabled MRI-guided therapeutic

application of HI-FU to the brain

(**t**rans**c**ranial MRgFUS - tcMRgFUS)
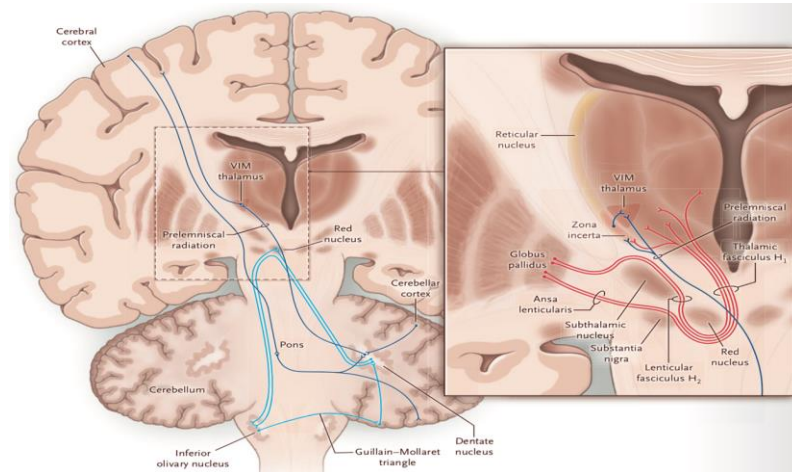
tcMRgFUS

ET interfers with main daily activities like:

- Eating

- Drinking

- Writing

- Typing

- Personal Hygiene

Essential Tremor

tcMRgFUS

The **v**entral **i**nter**m**ediate **n**ucleus (**VIM**) of the thalamus is an established **surgical target** to treat movement disorders such as **essential tremor**

tcMRgFUS

The **v**entral **i**nter**m**ediate **n**ucleus (**VIM**) of the thalamus is an established **surgical target** to treat movement disorders such as **essential tremor**

It is **not** readily **visible** on **conventional MR imaging**
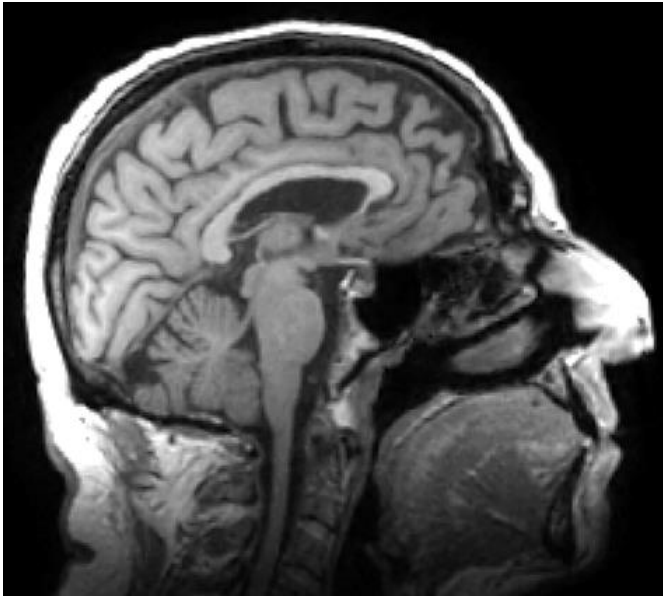
tcMRgFUS
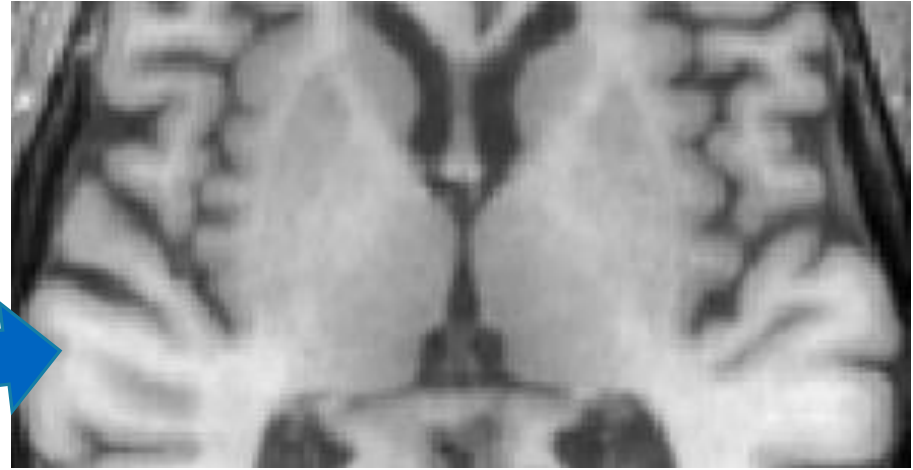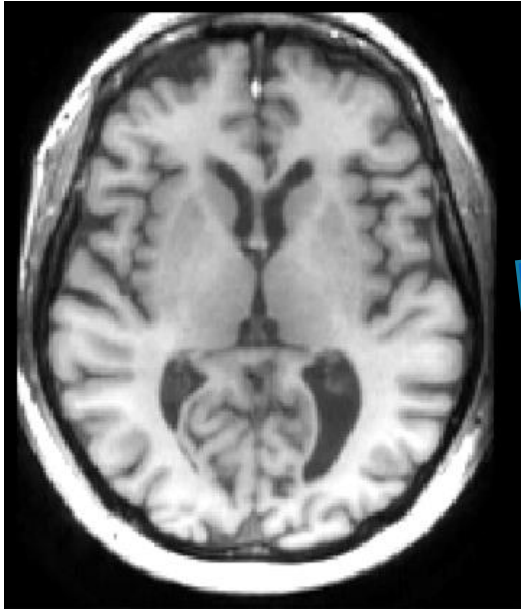
tcMRgFUS
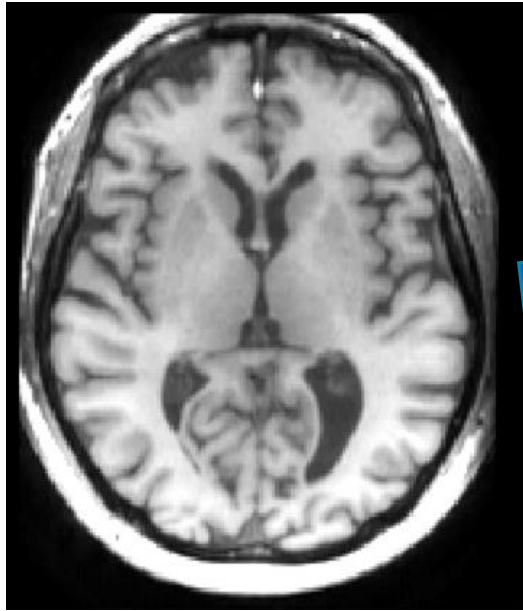
Thalamus

FLOW CHART OF ANALYSIS PERFORMED

➢ **SEGMENTATION OF THE CEREBRAL CORTEX**

➢ **PROBABILISTIC TRACTOGRAPHY**

➢ **THALAMIC PARCELLATION**

➢ **COMPARISON *A POSTERIORI* BETWEEN LESION AND PARCELLATION**

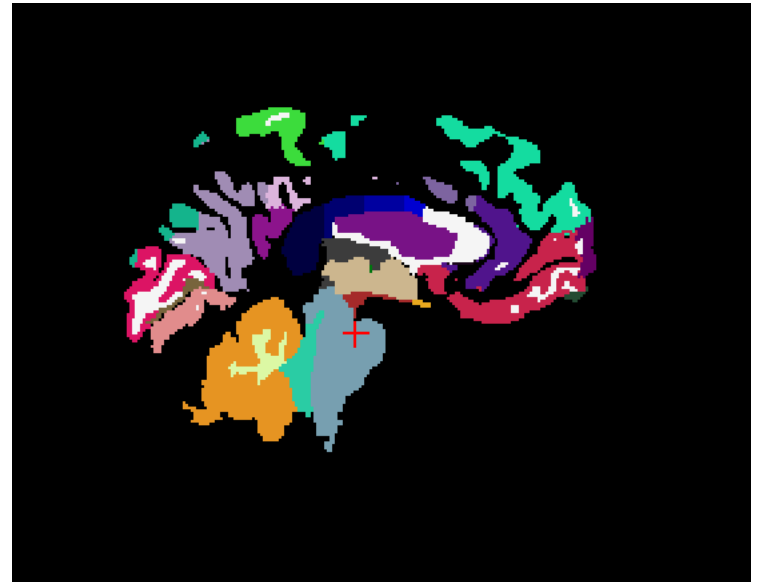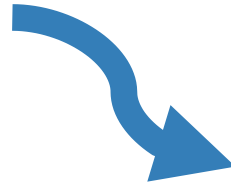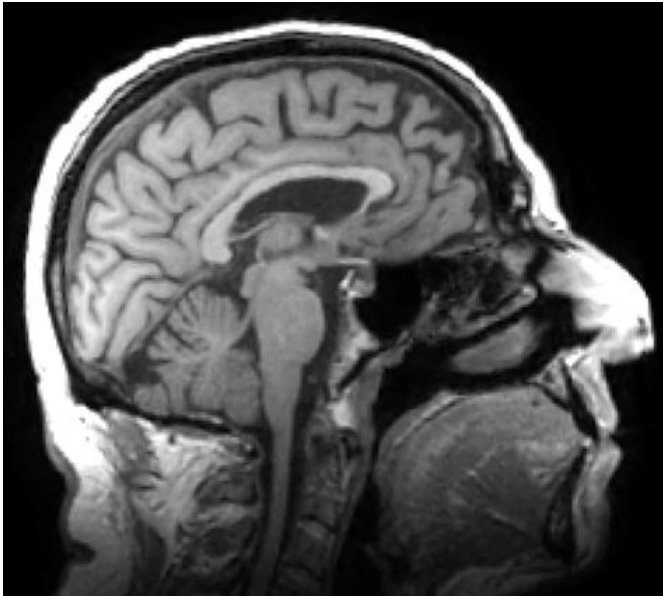➢ **fMRI ANALYSES ON tcMRgFUS PATIENTS**

FLOW CHART OF ANALYSIS PERFORMED

➢ **SEGMENTATION OF THE CEREBRAL CORTEX**

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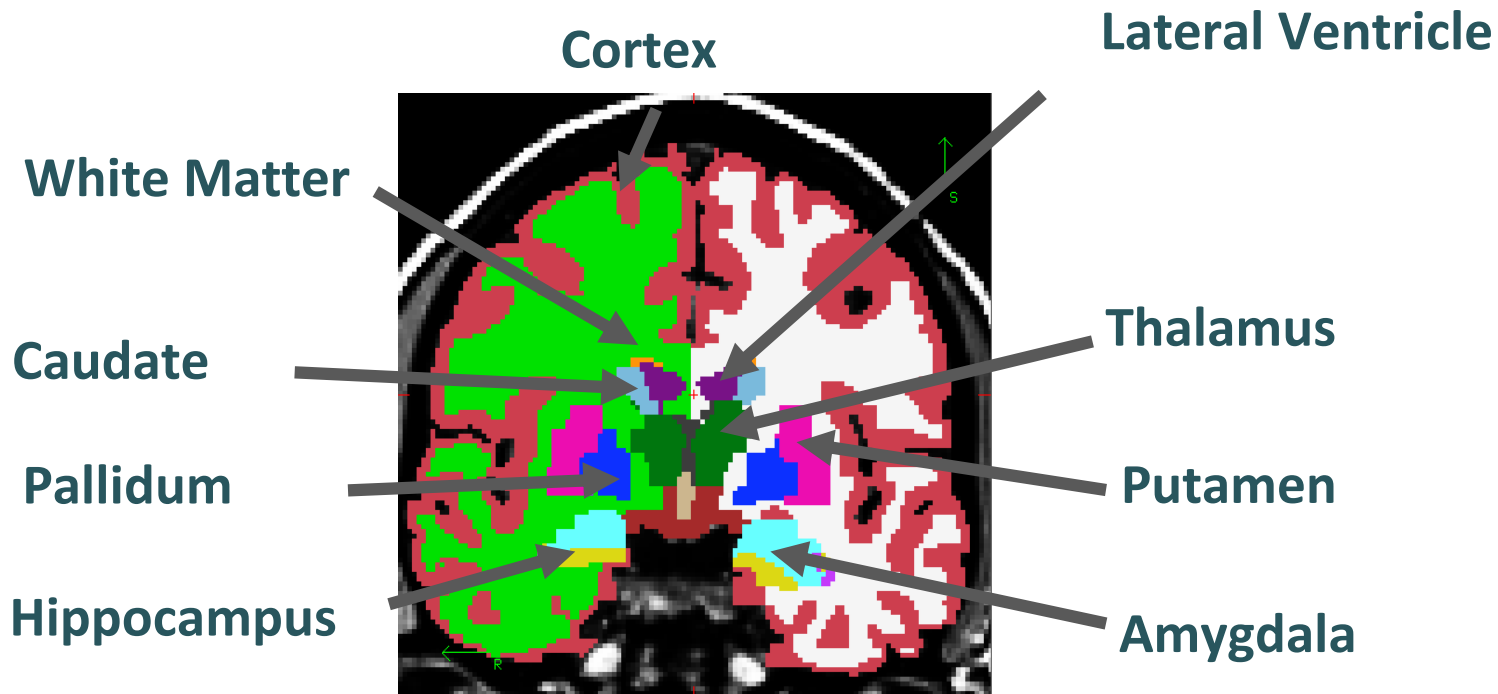
➢ **fMRI ANALYSES ON tcMRgFUS PATIENTS**

CORTICAL SEGMENTATION

CORTICAL SEGMENTATION

SUBCORTICAL SEGMENTATION

SEGMENTATION

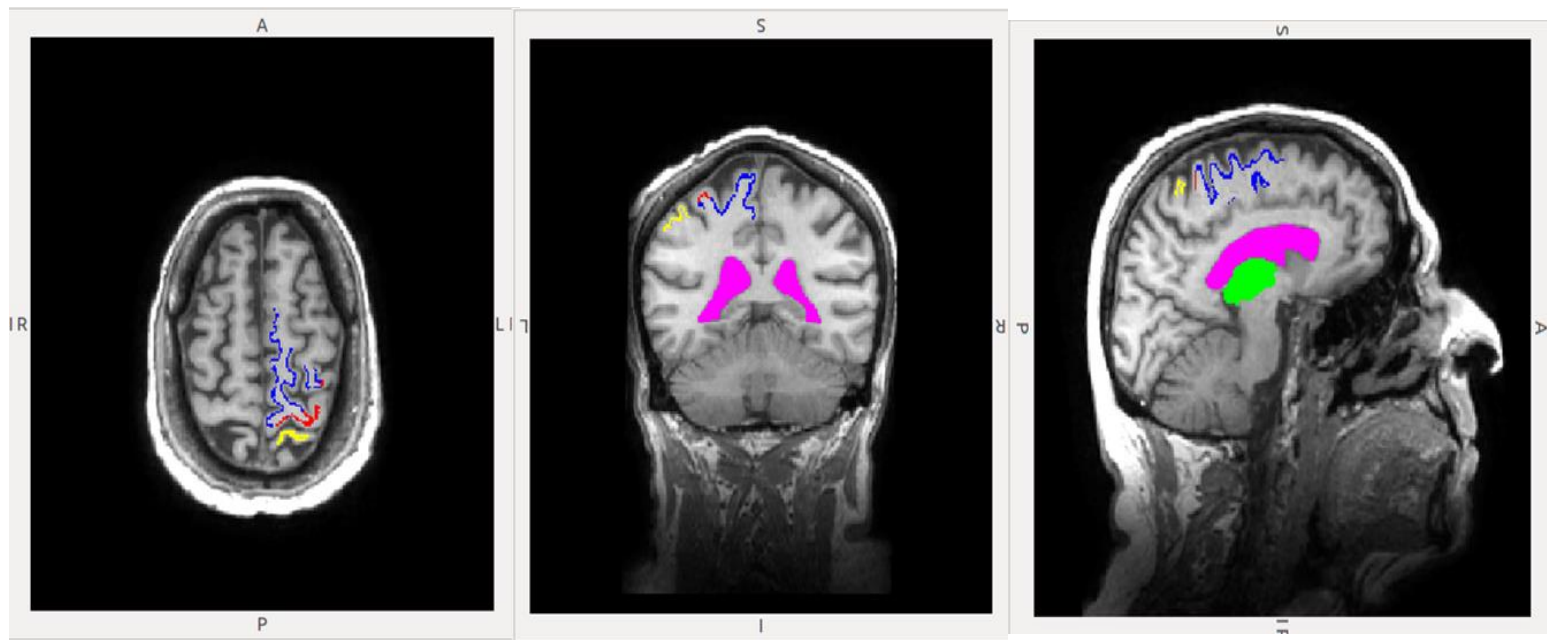**Creation of masks using Python scripts of:**

➢ **thalamus**

➢ **ventricles**

➢ **precentral gyrus**

➢ **postcentral gyrus**

➢ **Brodman area 6**

Nibabel - Neuroimaging in Python

SEGMENTATION

■ VENTRICLES   ■ RIGHT THALAMUS   ■ BRODMAN AREA 6

■ PRECENTRAL GYRUS   ■ POSTCENTRAL GYRUS

FLOW CHART OF ANALYSIS PERFORMED

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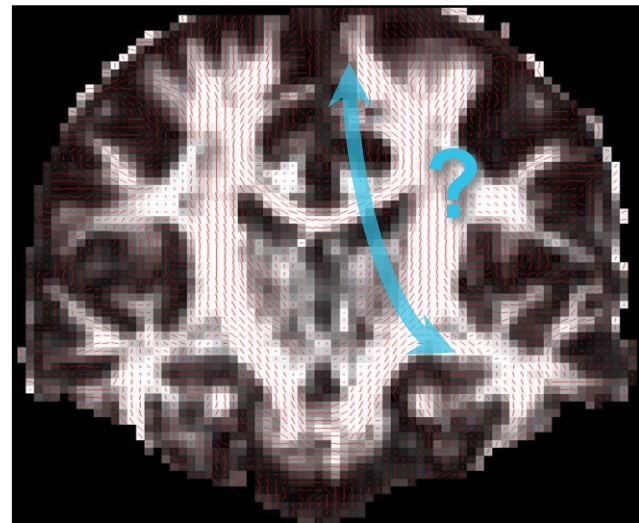
➢ **fMRI ANALYSES ON tcMRgFUS PATIENTS**

TRACTOGRAPHY

- Use at each voxel **local diffusion orientation** to determine **pathway** between distant brain regions
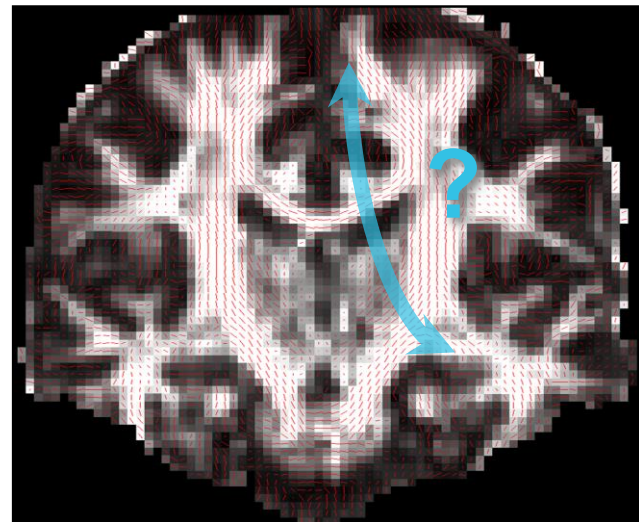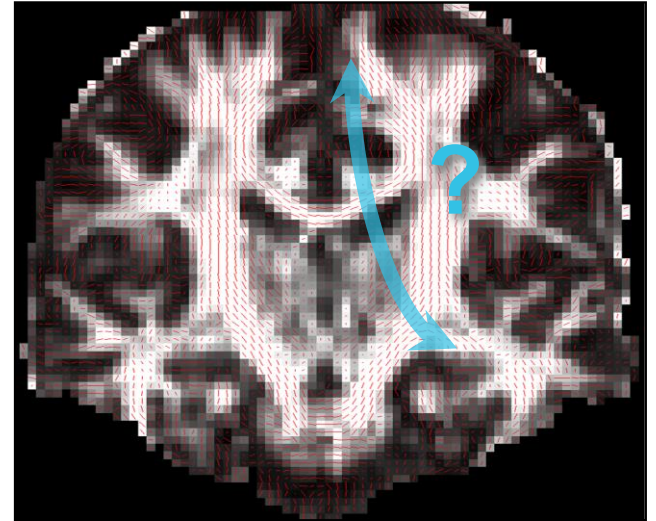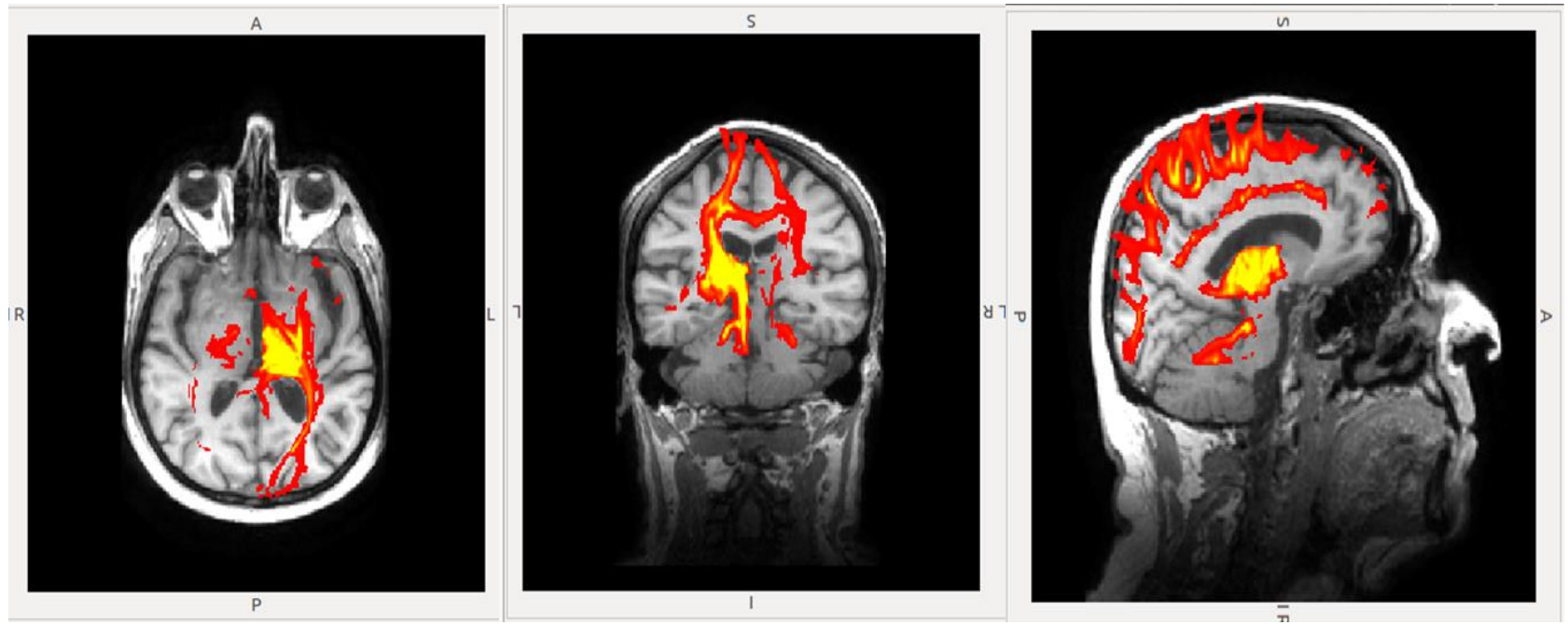
TRACTOGRAPHY

- Use at each voxel **local diffusion orientation** to determine **pathway** between distant brain regions

- Local orientation comes from diffusion model fit (**tensor, ball-and-stick**, etc.)

TRACTOGRAPHY

- Use at each voxel **local diffusion orientation** to determine **pathway** between distant brain regions

- Local orientation comes from diffusion model fit (**tensor, ball-and-stick**, etc.)

- **Deterministic** vs. **probabilistic tractography**:

  -**Deterministic** assumes a single orientation at each voxel

  -**Probabilistic** assumes a distribution of orientations

PROBABILISTIC TRACTOGRAPHY
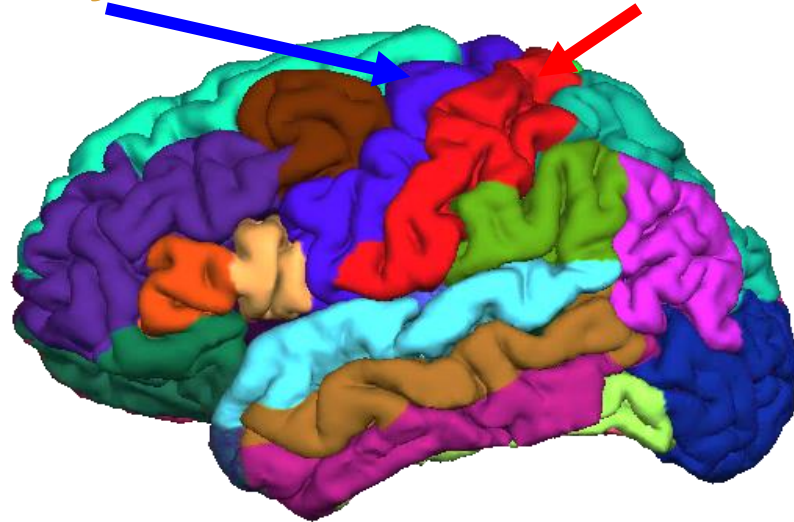
FLOW CHART OF ANALYSIS PERFORMED

➢ **SEGMENTATION OF THE CEREBRAL CORTEX**

➢ **PROBABILISTIC TRACTOGRAPHY**

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➢ **fMRI ANALYSES ON tcMRgFUS PATIENTS**

THALAMIC PARCELLATION

Desikan/Killiany Atlas (35 ROI's)

Precentral Gyrus

Postcentral Gyrus

THALAMIC PARCELLATION

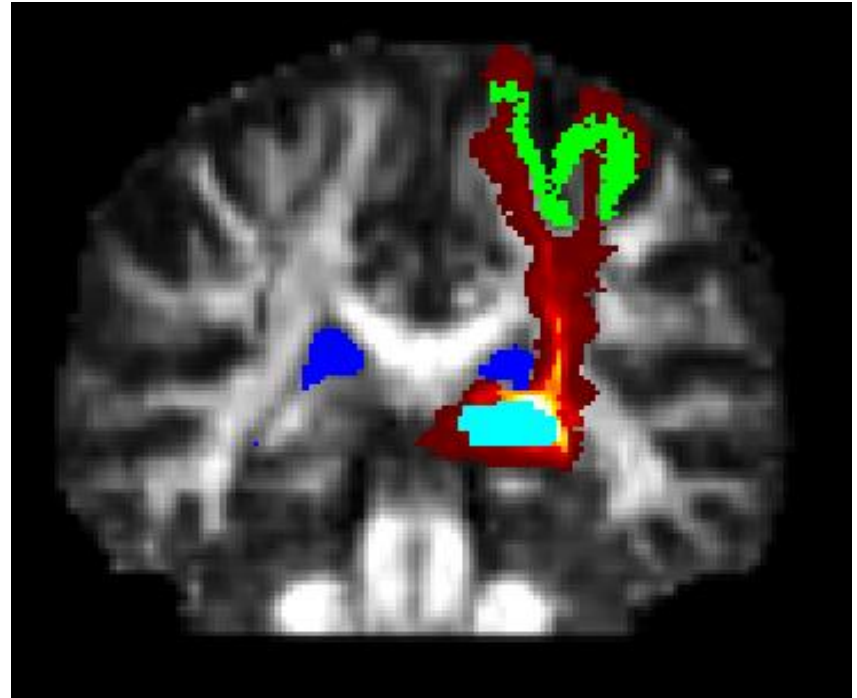Constrained to connection of two specific end regions

Seeds:
➔**Thalamus**
Target:
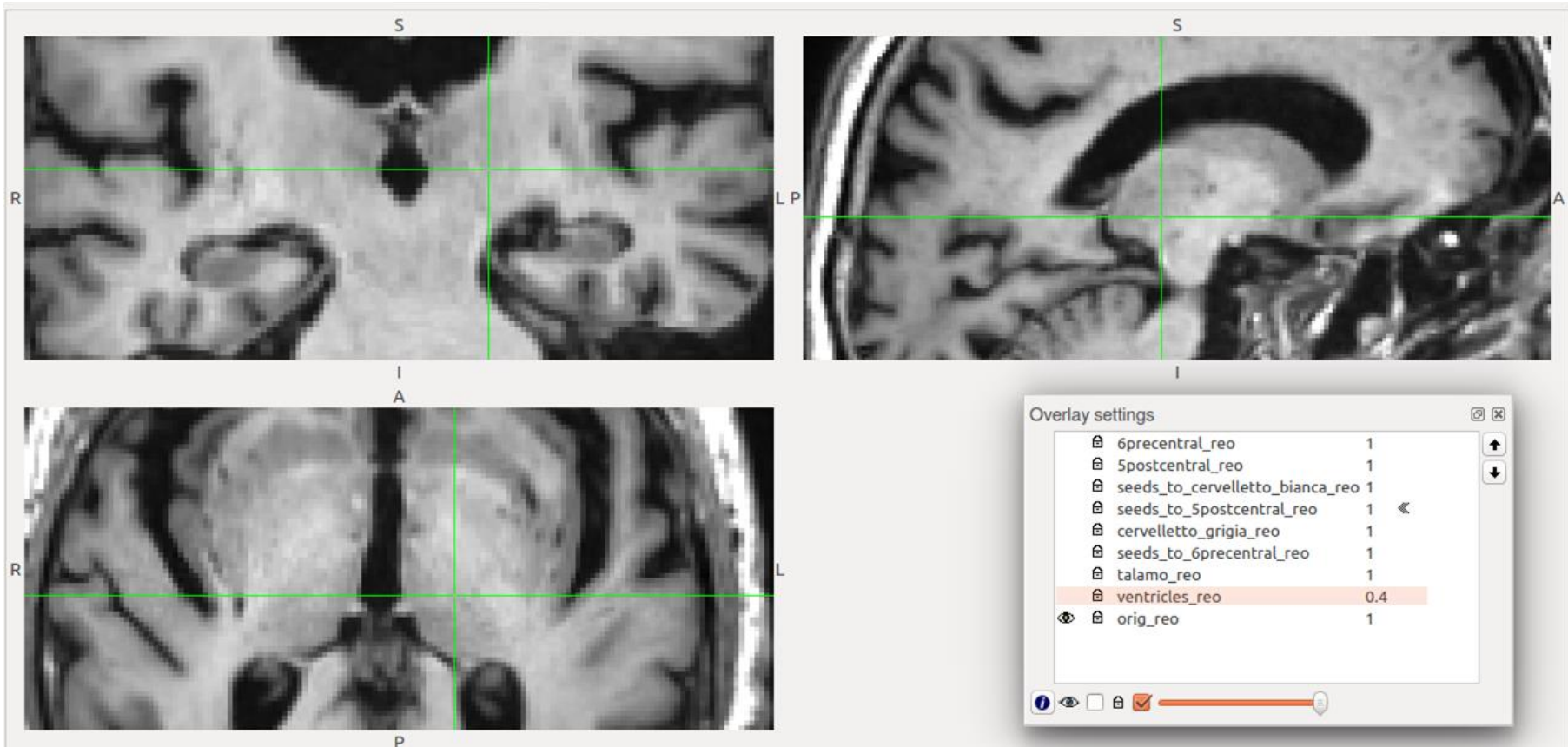➔**pre-central gyrus**
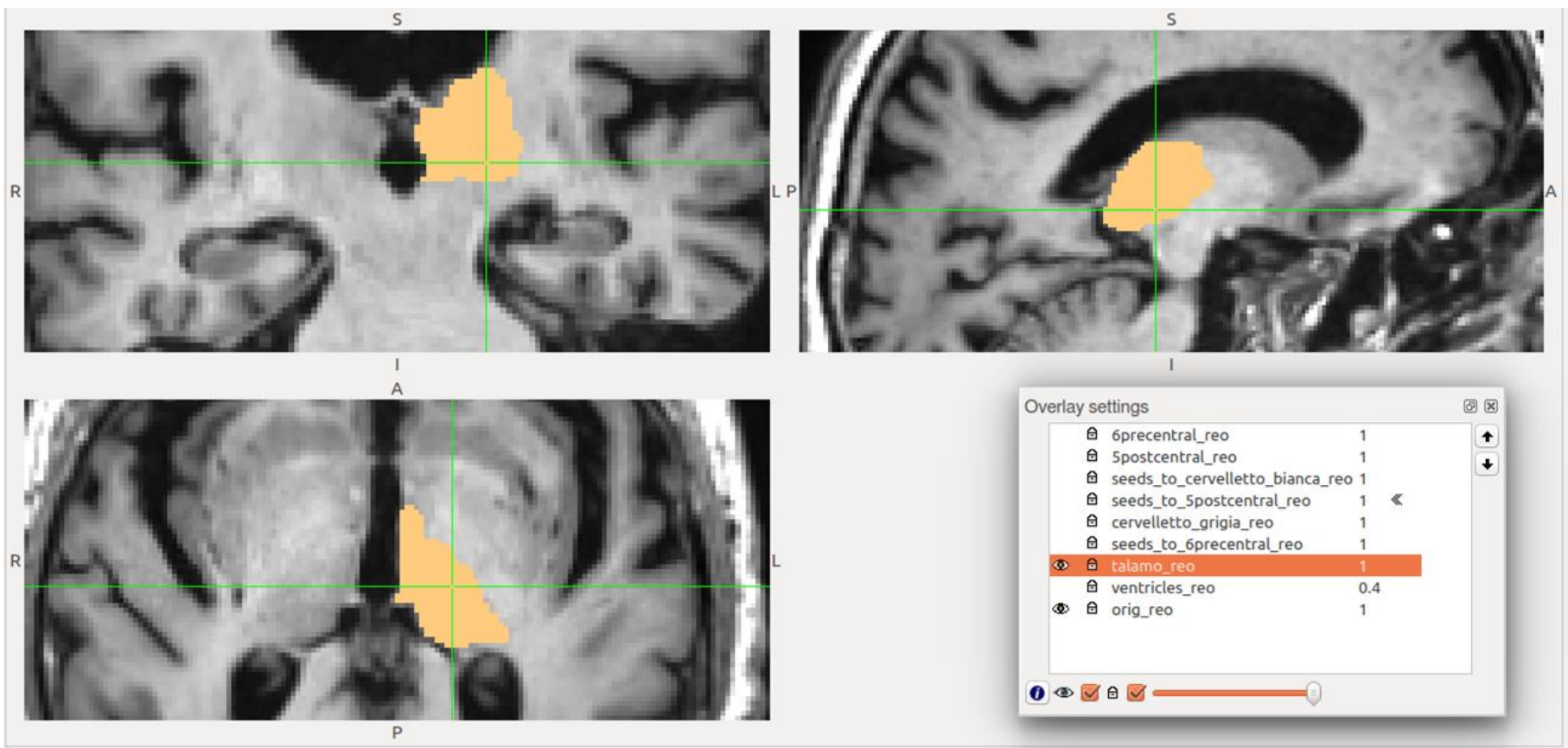➔**post-central gyrus**
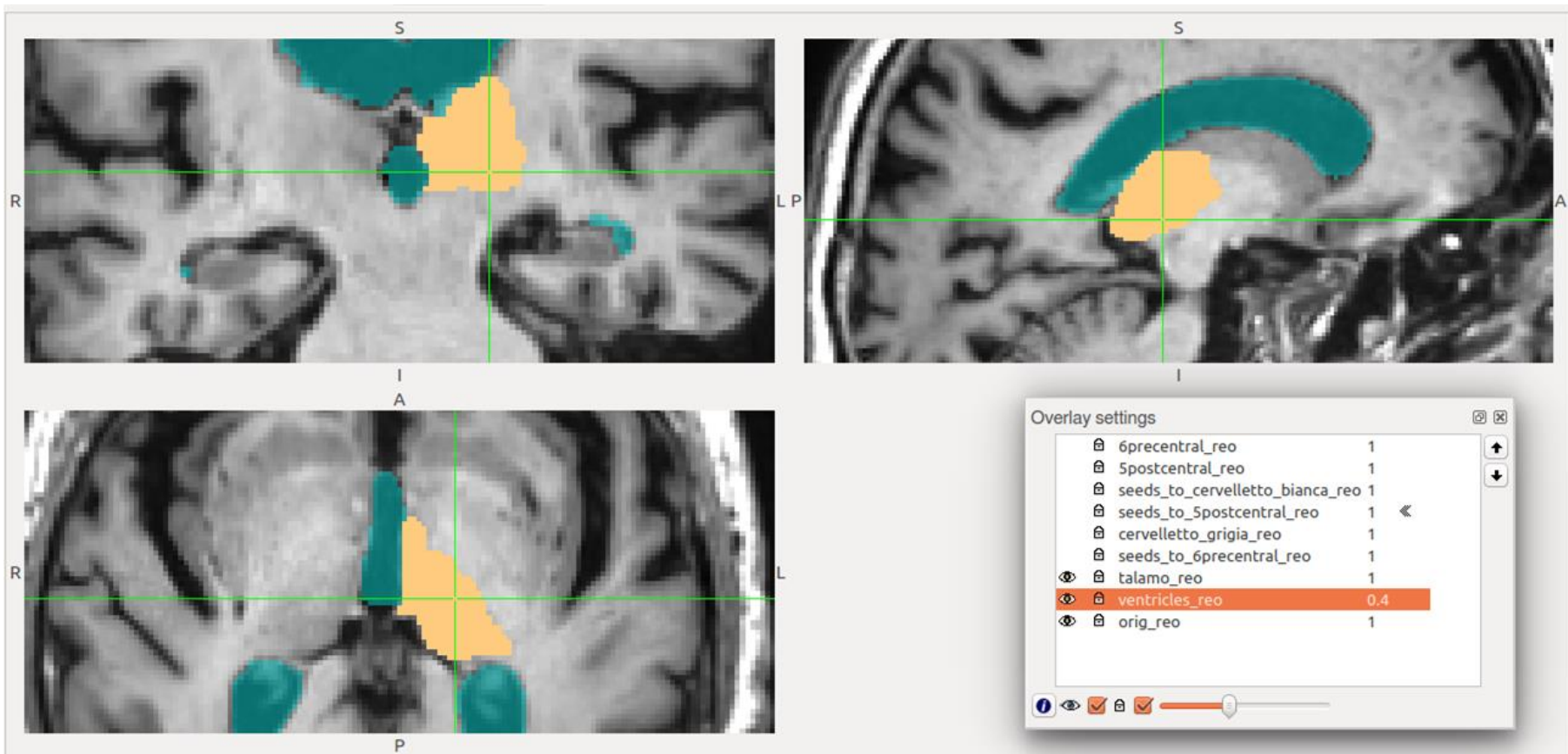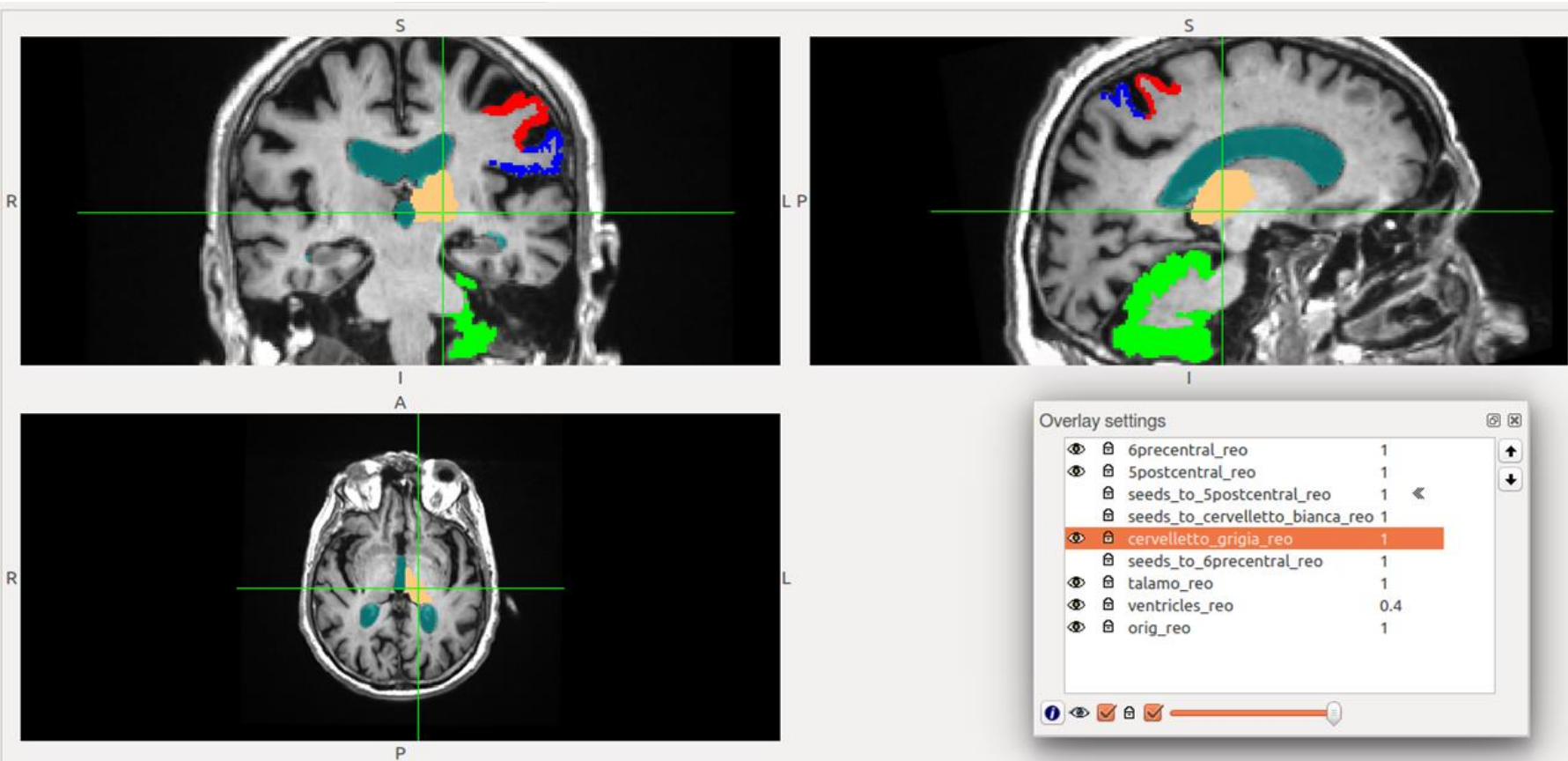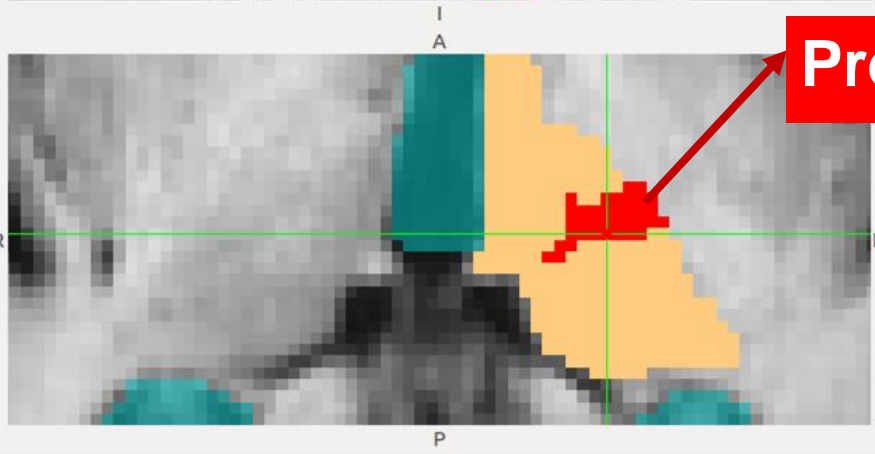➔**Cerebellar cortex**
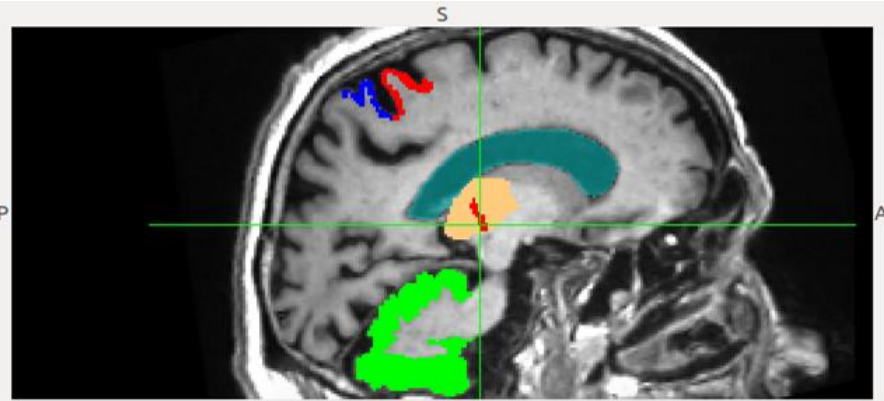 **Regions excluded:**
➔**Ventricles**

THALAMIC PARCELLATION
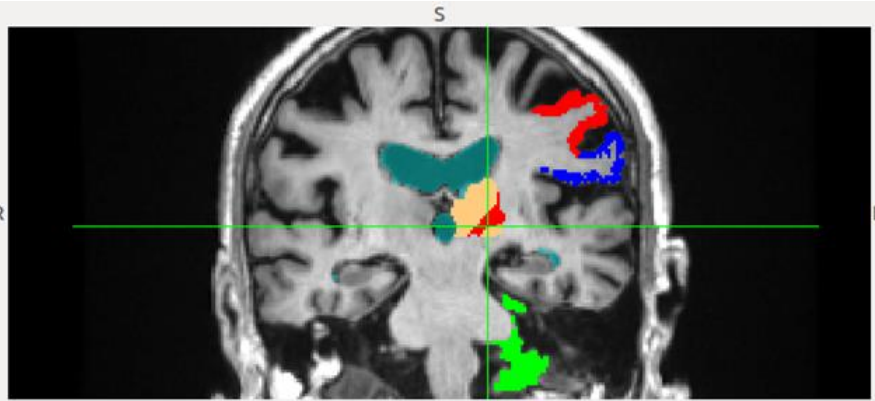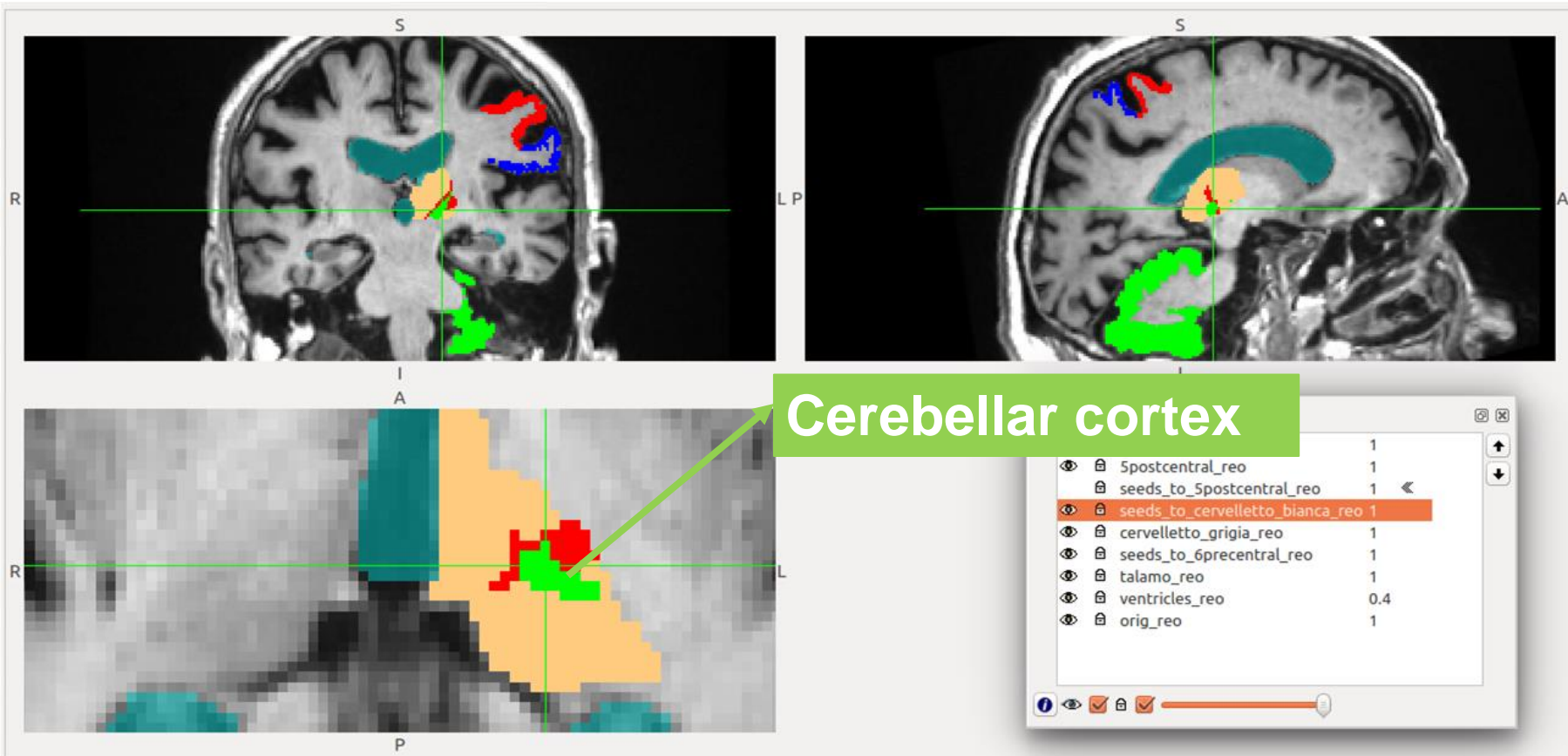
THALAMIC PARCELLATION

THALAMIC PARCELLATION

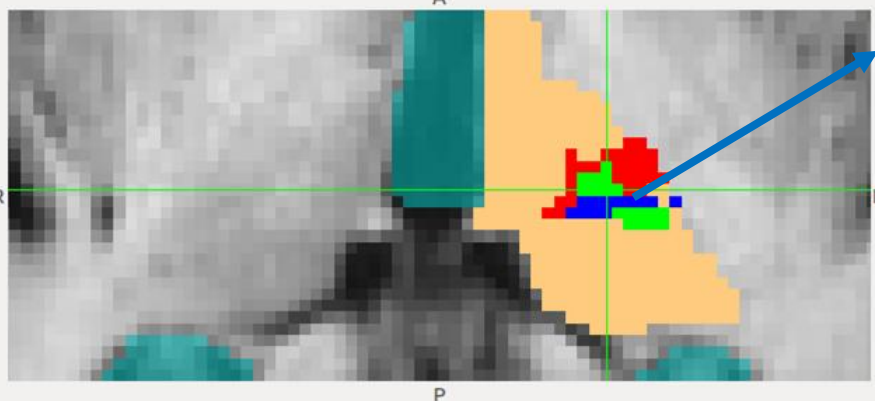# THALAMIC PARCELLATION

THALAMIC PARCELLATION

Precentral cortex

THALAMIC PARCELLATION

Cerebellar cortex

THALAMIC PARCELLATION
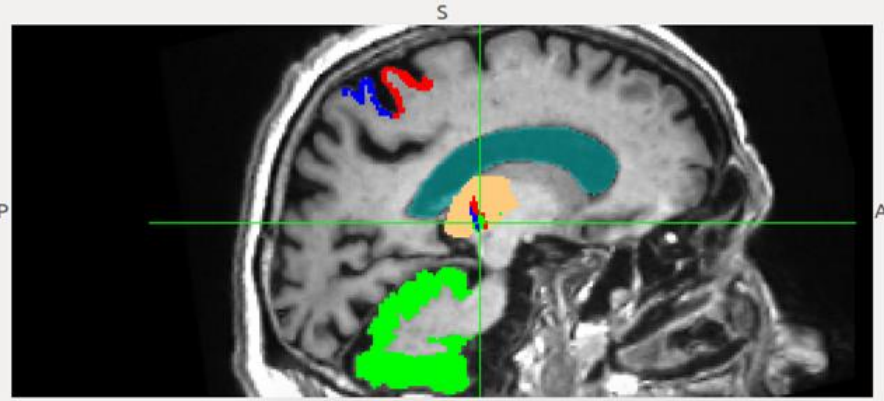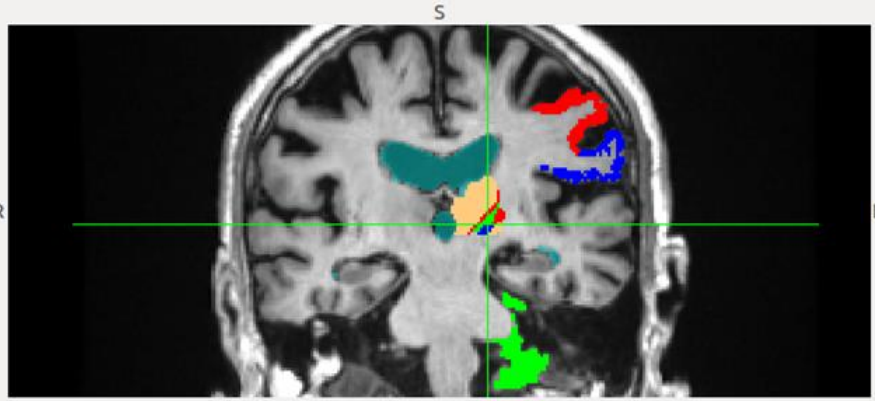
Postcentral cortex

SEGMENTATION OF THALAMIC NUCLEI WITH FREESURFER

This tool produces a parcellation of the thalamus into 25 different nuclei, using a probabilistic atlas built with histological data
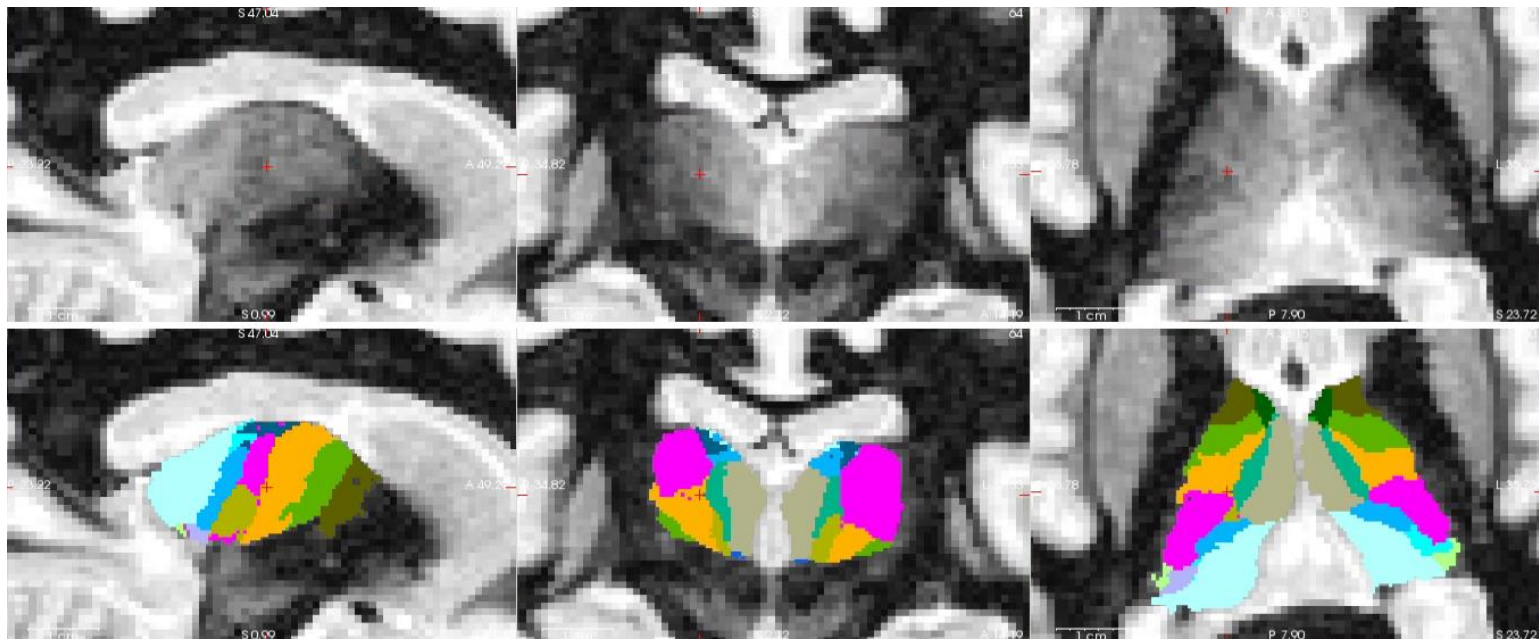
THALAMIC PARCELLATION vs CLASSIC TARGETING
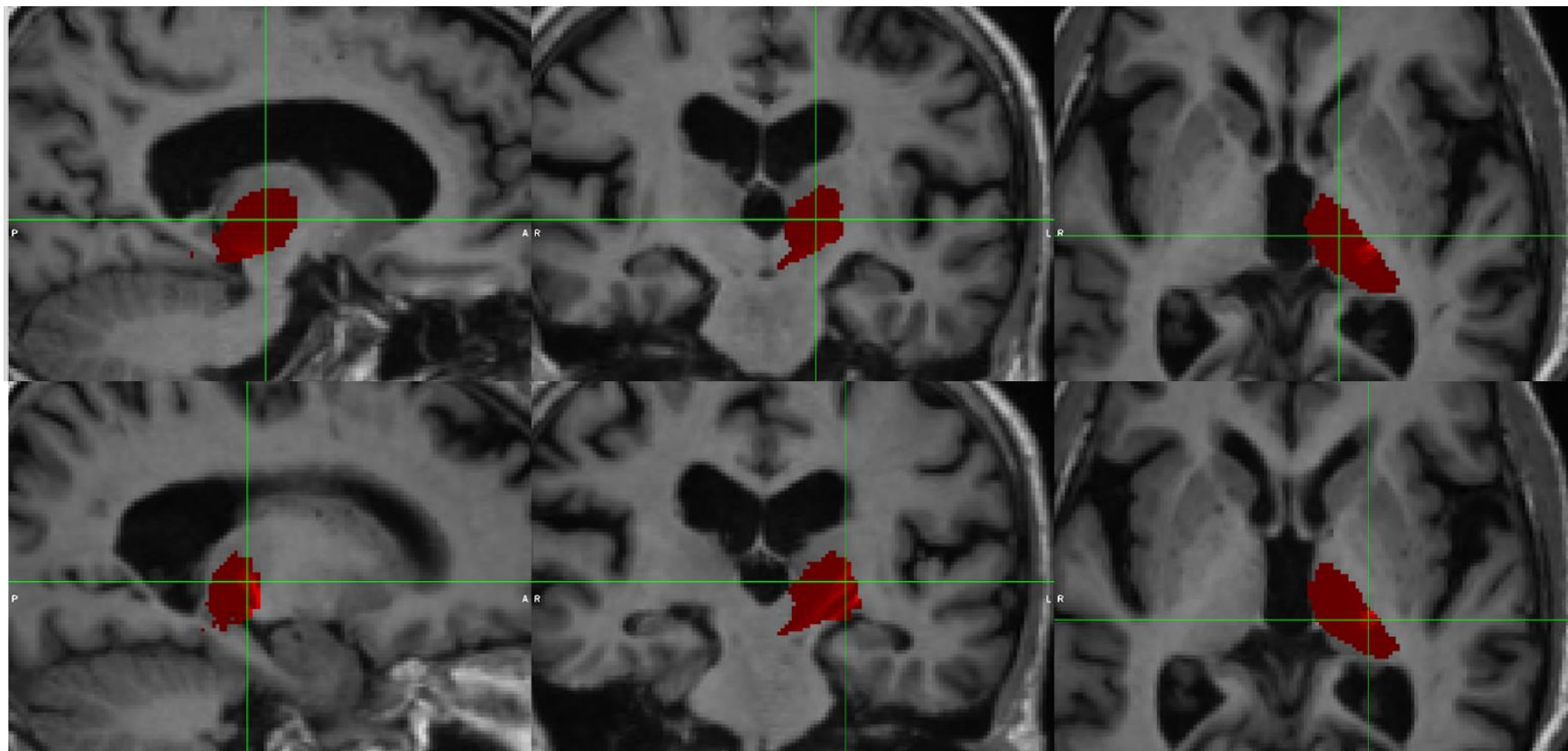
THALAMIC PARCELLATION vs CLASSIC TARGETING

CLASSIC TARGETING
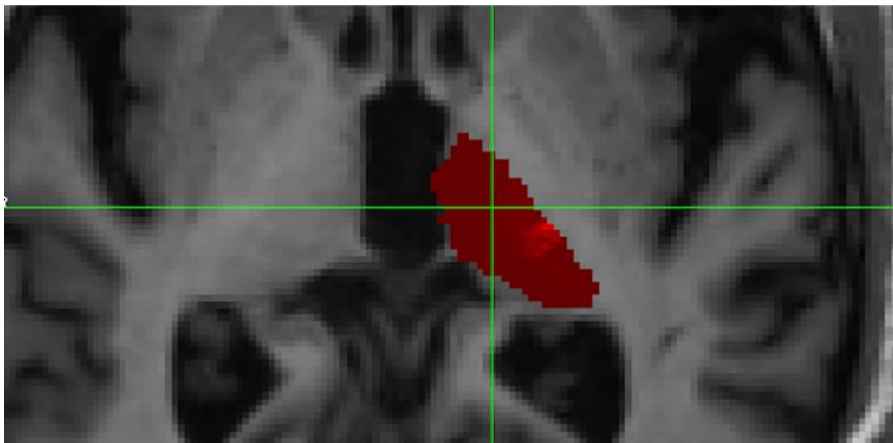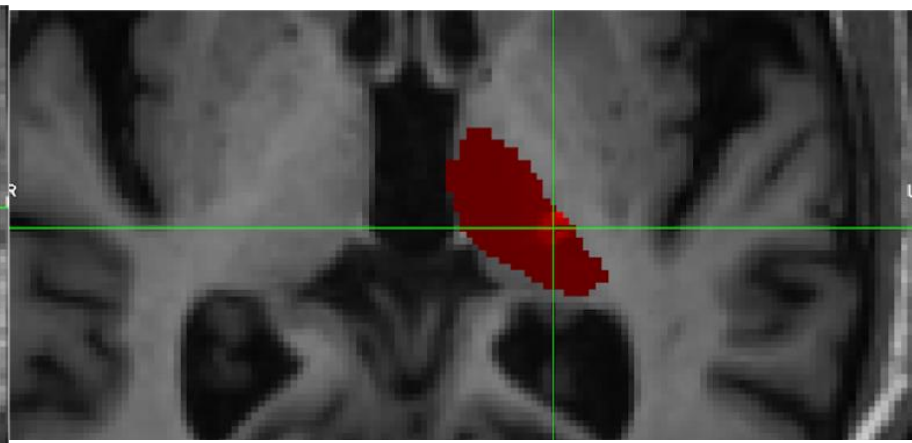
THALAMIC PARCELLATION

FLOW CHART OF ANALYSIS PERFORMED

➤ **SEGMENTATION OF THE CEREBRAL CORTEX**

➤ **PROBABILISTIC TRACTOGRAPHY**

➤ **THALAMIC PARCELLATION**

➤ **COMPARISON *A POSTERIORI* BETWEEN LESION AND PARCELLATION**

➤ **fMRI ANALYSES ON tcMRgFUS PATIENTS**

COMPARISON BETWEEN LESION AND RECONSTRUCTED TARGET

TARGET DETERMINED THROUGH PROBABILISTIC TRACTOGRAPHY
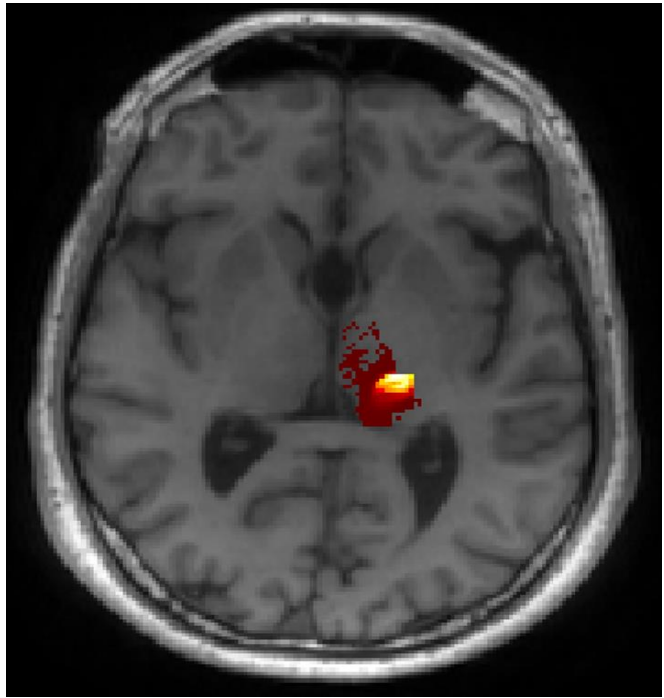
LESION INDUCED BY TREATMENT
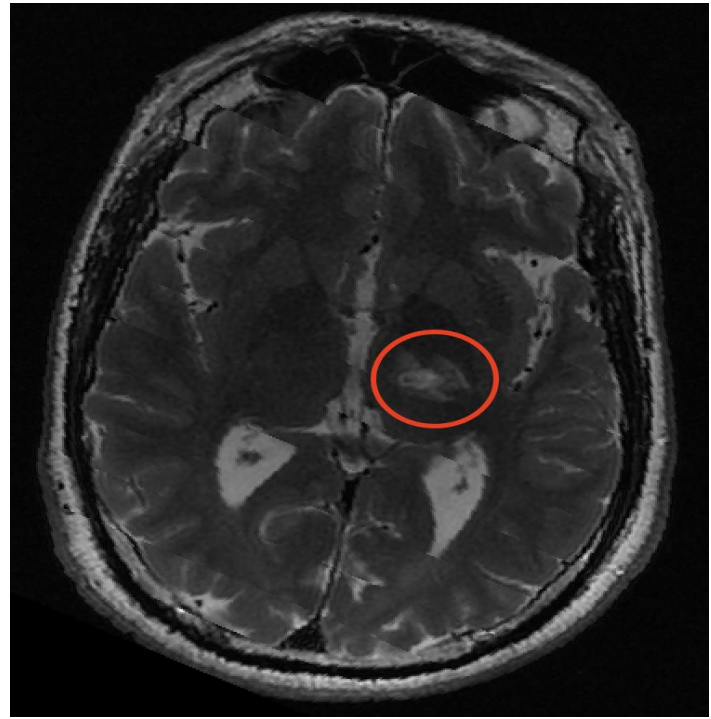
RESULTS OF THE QUANTITATIVE COMPARISON
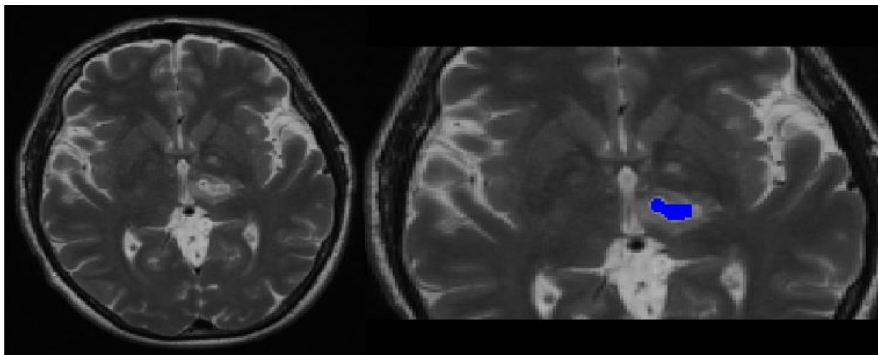
Lesion induced in 2016
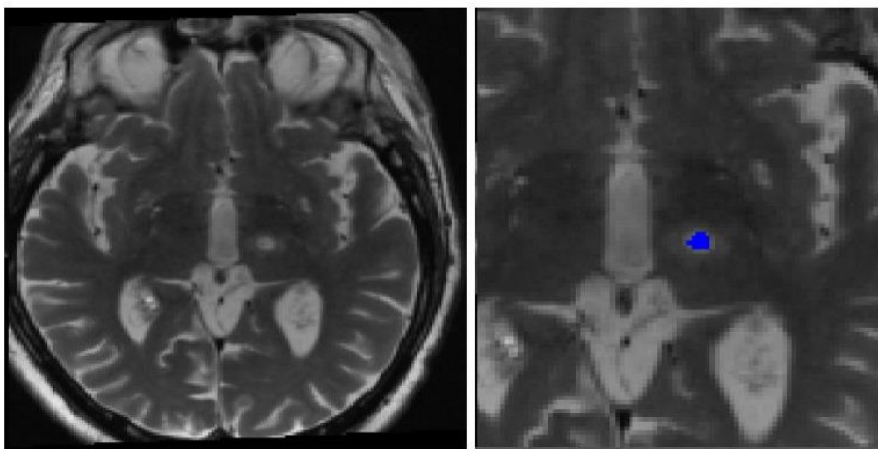
Lesion induced in 2018

RESULTS OF THE QUANTITATIVE COMPARISON

Average lesion volume 55 ± 16 mm^3

Average lesion volume 152 ± 81 mm^3

COMPARISON BETWEEN LESION AND RECONSTRUCTED TARGET

MASK OF THE LESION OBTAINED FROM T$_2$-WEIGHTED IMAGE
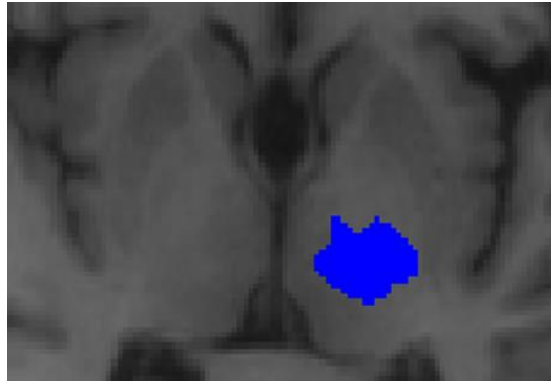
COMPARISON BETWEEN LESION AND RECONSTRUCTED TARGET

**MASK OF THE LESION
OBTAINED FROM
T$_2$-WEIGHTED IMAGE**
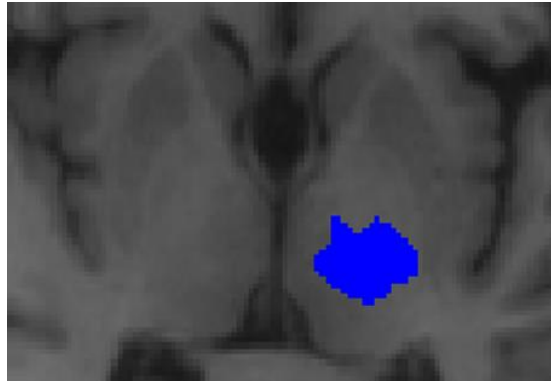
**PROBABILITY
DISTRIBUTION OF
PRECENTRAL GYRUS**

COMPARISON BETWEEN LESION AND RECONSTRUCTED TARGET

MASK OF THE LESION OBTAINED FROM T$_2$-WEIGHTED IMAGE
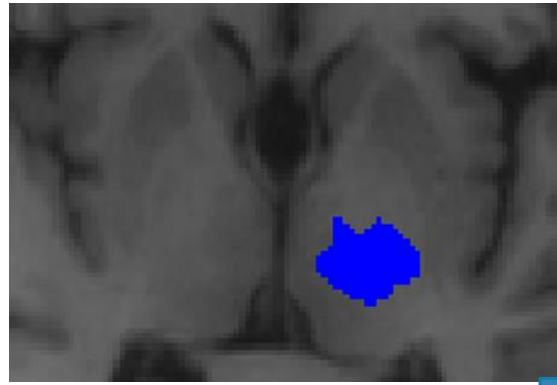
OVERLAP

PROBABILITY DISTRIBUTION OF PRECENTRAL GYRUS
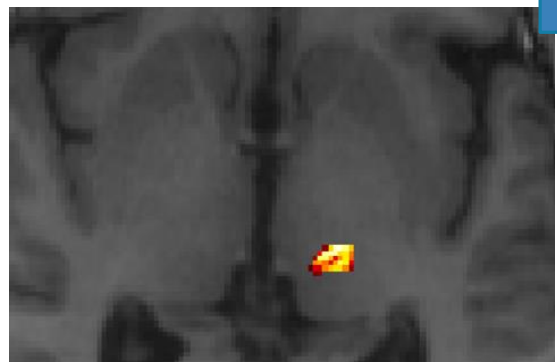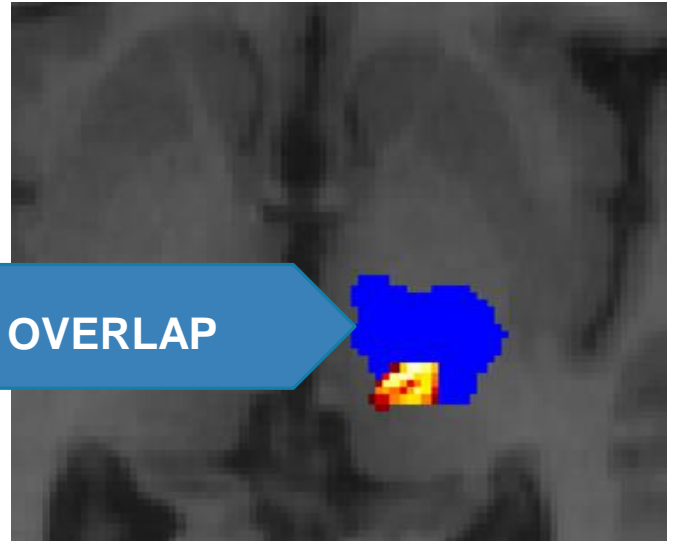
PRELIMINARY RESULTS OF THE QUANTITATIVE COMPARISON

the **degree of overlap** between the **lesion** and that of the **target obtained through thalamic parcellation** was **correlated** with an **index** that measures the **clinical outcome**

1   2   3   4   5   6

Clinical Score Scale

PRELIMINARY RESULTS OF THE QUANTITATIVE COMPARISON

Pre-Central Gyrus

Pearson $R^2 = 0.527$
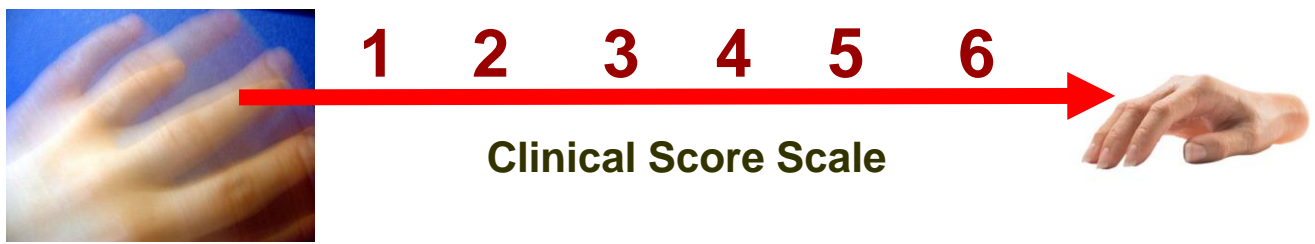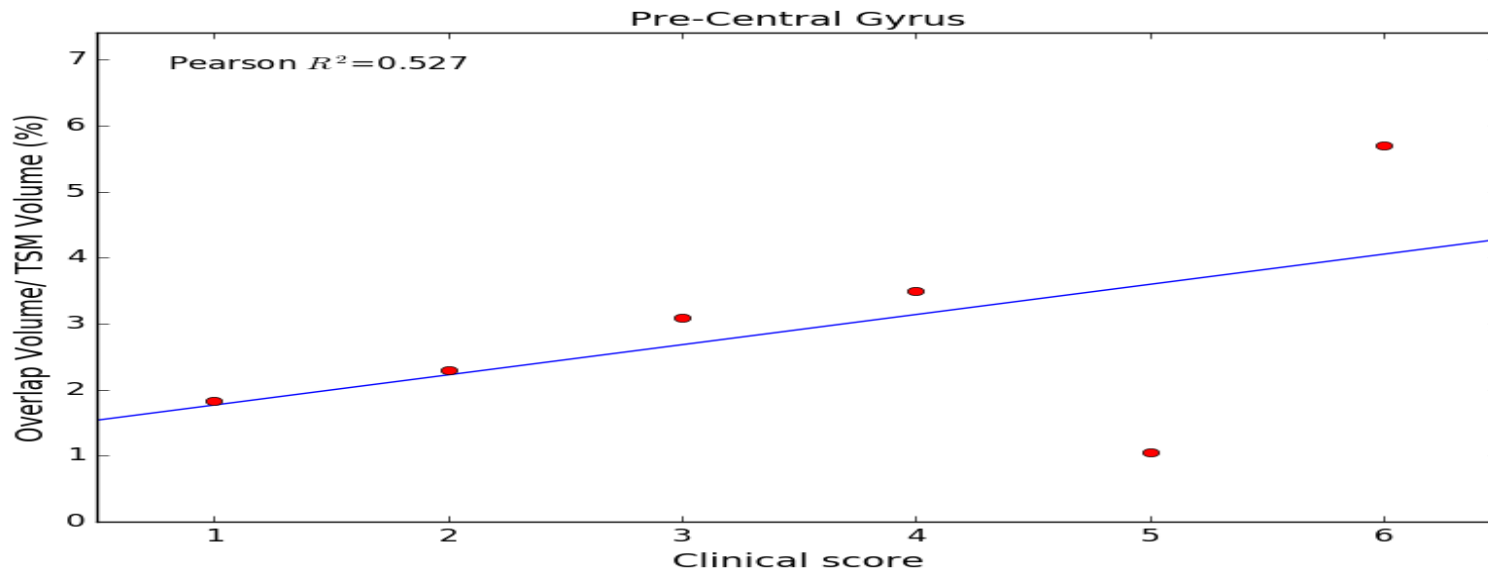
The more the lesion overlaps the thalamus region identified by the thalamic parcellation, the better the outcome of treatment will be.

FLOW CHART OF ANALYSIS PERFORMED

➢ **SEGMENTATION OF THE CEREBRAL CORTEX**

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➢ **fMRI ANALYSES ON tcMRgFUS PATIENTS**

Preliminary results of fMRI analyses on TcMRgFUS patients

Functional magnetic resonance imaging (**fMRI**) is a safe and noninvasive MRI technique, used to estimate and localize neuronal activation in the gray matter.
This technique provides detailed information about the metabolic and functional processes of the human brain.
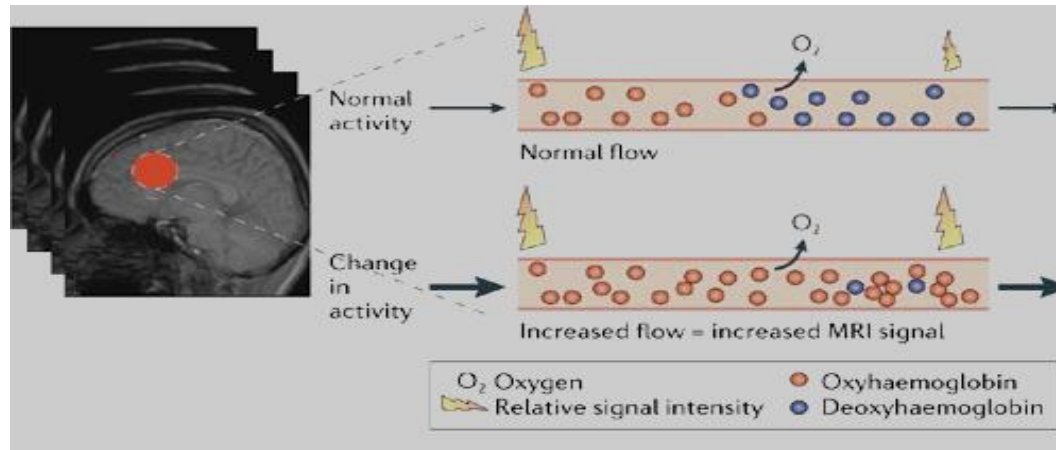
Model-free data Analysis

MELODIC
Multivariate Exploratory Linear Optimised Decomposition into Independent Components

- Decomposes data into a set of statistically independent spatial component maps and associated time courses.

- Can perform multi-subject/multi session analysis.

- Inference on **IC** maps using alternative hypothesis testing

MELODIC
part of FSL

Our Resting State Networks

This picture show network obtained by us like visual, auditory, executive or motor network
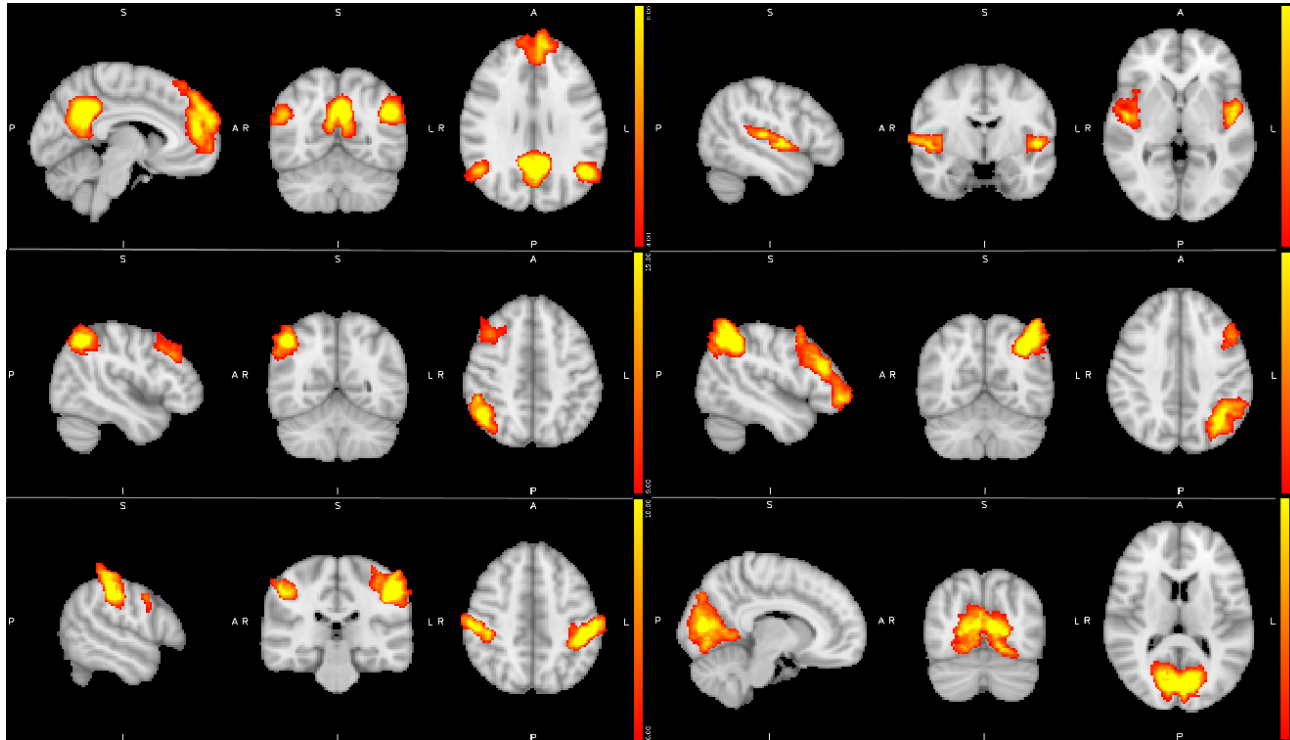
Results
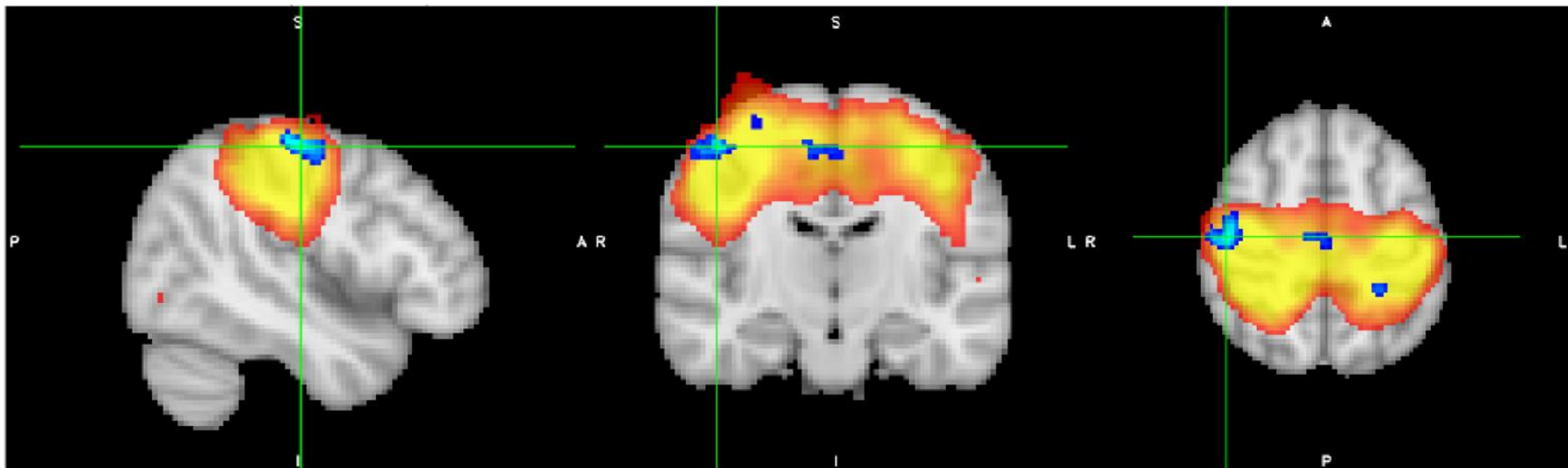
Increased resting state functional connectivity in patients with essential tremor

undergoing left thalamotomy using high intensity focused ultrasound guided by

MRI in right precentral gyrus (primary motor area, M1)

Results

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)

Results

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

Results

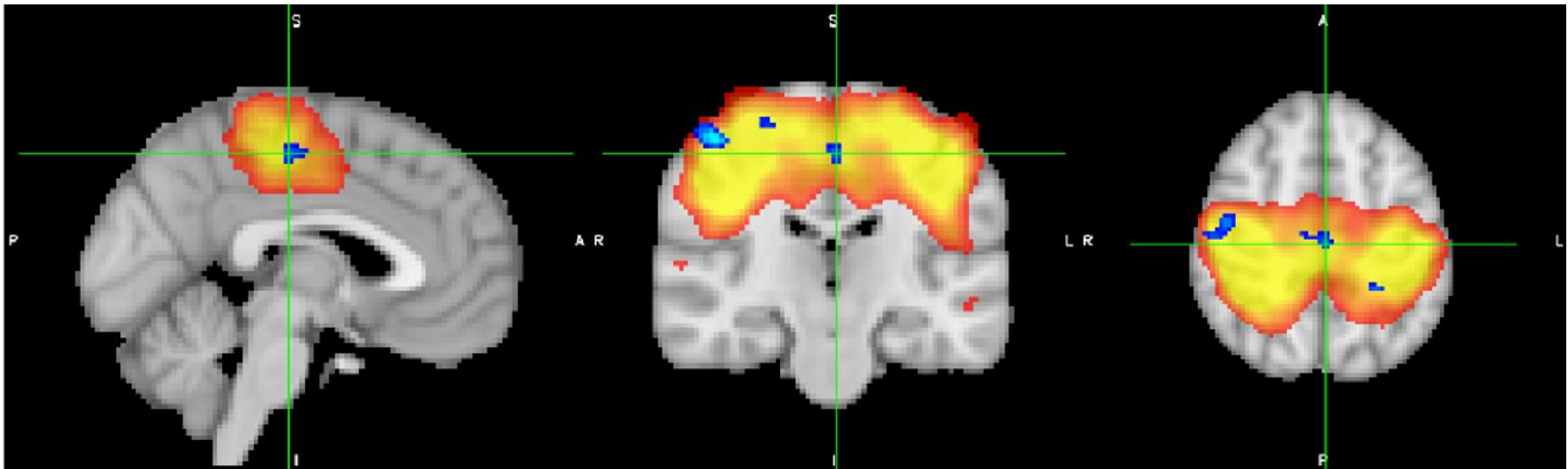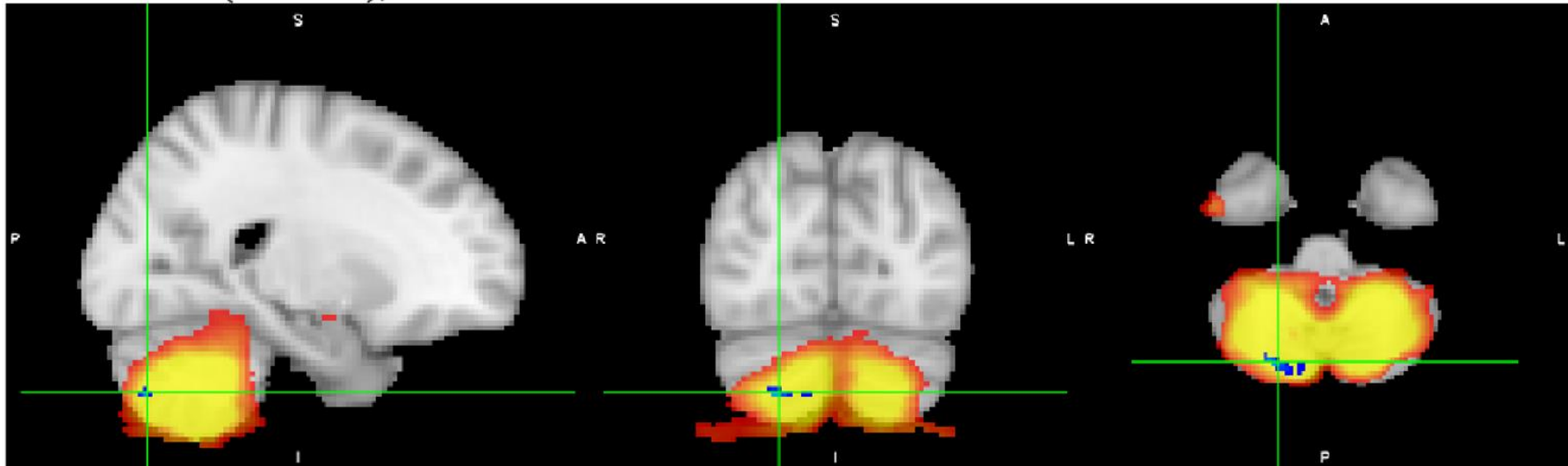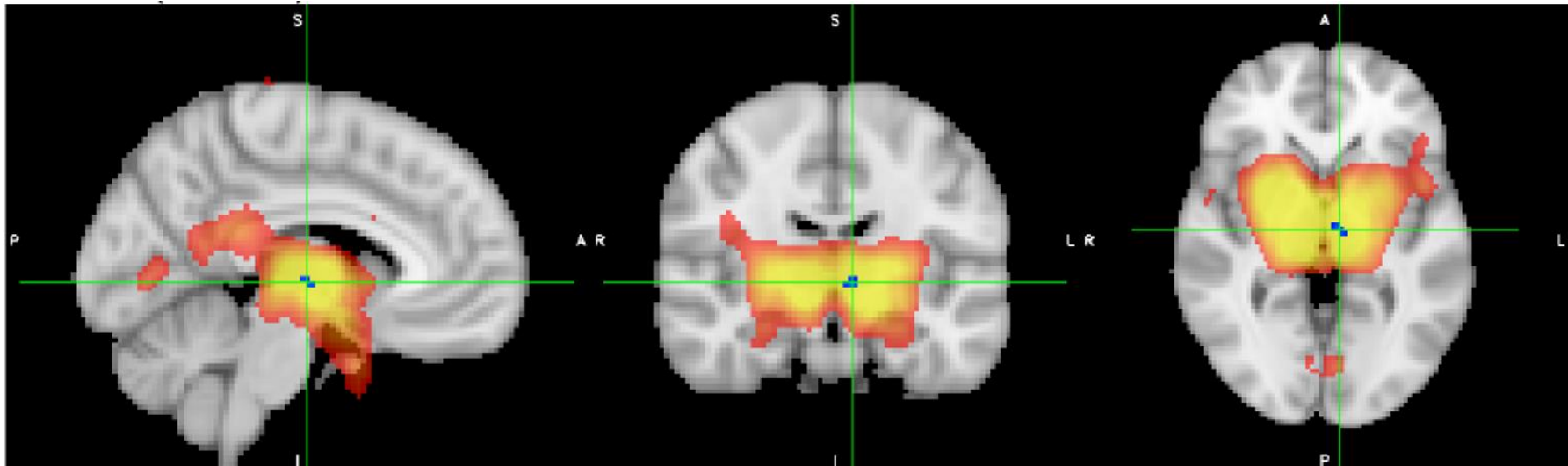Increased resting state functional connectivity in patients with essential tremor undergoing left thalamotomy using high intensity focused ultrasound guided by MRI in left thalamus

Results

We have observed that all the networks, where an increased functional connectivity was found after the tcMRgFUS treatment, belong to the extra-pyramidal circuits responsible for controlling the voluntary movements of the contralateral limb to that treated.

The data obtained, for a correct interpretation, must be correlated with the results of the clinical evaluations.

CONCLUSIONS AND PERSPECTIVES

➢In all cases it was possible to represent the major groups of **thalamic nuclei** that are **connected** to the **cortex**.

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➢ an **rs-fMRI** analysis will be performed on all the dataset acquired

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➤an **rs-fMRI** analysis will be performed on all the dataset acquired

➤These analyses will be applied **in a predictive way** during the planning of the **tcMRgFUS** treatments and could allow the **temporal optimization**

thank you