

Target Visualization in DBS Anatomy, Subregions, and Connectivity

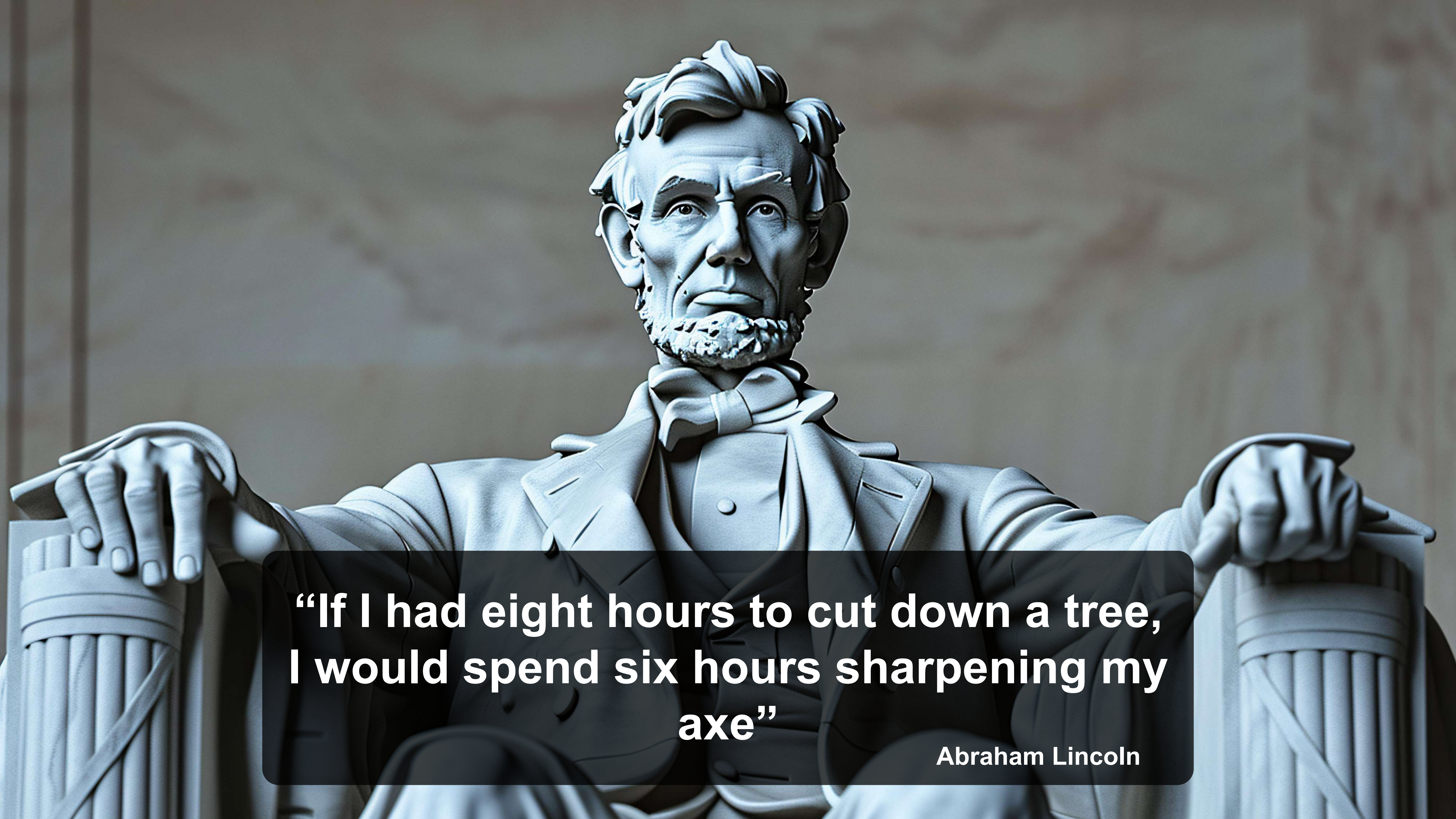
Rubens Cury, MD, PhD

Movement Disorders Center

University of São Paulo, Brazil

Hospital Israelita Albert Einstein

MDS-PAS 5th Neuromodulation School for Movement Disorders (New York, NY, USA)

A detailed, monochromatic statue of Abraham Lincoln, seated and facing forward. He has a full, textured beard and is wearing a high-collared coat with a cravat. His hands are resting on the armrests of his chair. The background is a soft, out-of-focus wall with faint, classical-style murals.

**“If I had eight hours to cut down a tree,
I would spend six hours sharpening my
axe”**

Abraham Lincoln



DBS PRINCIPLES

First = Think WHERE to stimulate

Second = Think HOW to stimulate



How many possible combinations are there in DBS programming?

Polarity + Intensity (1%)
 10^{10} possibilities

Outline

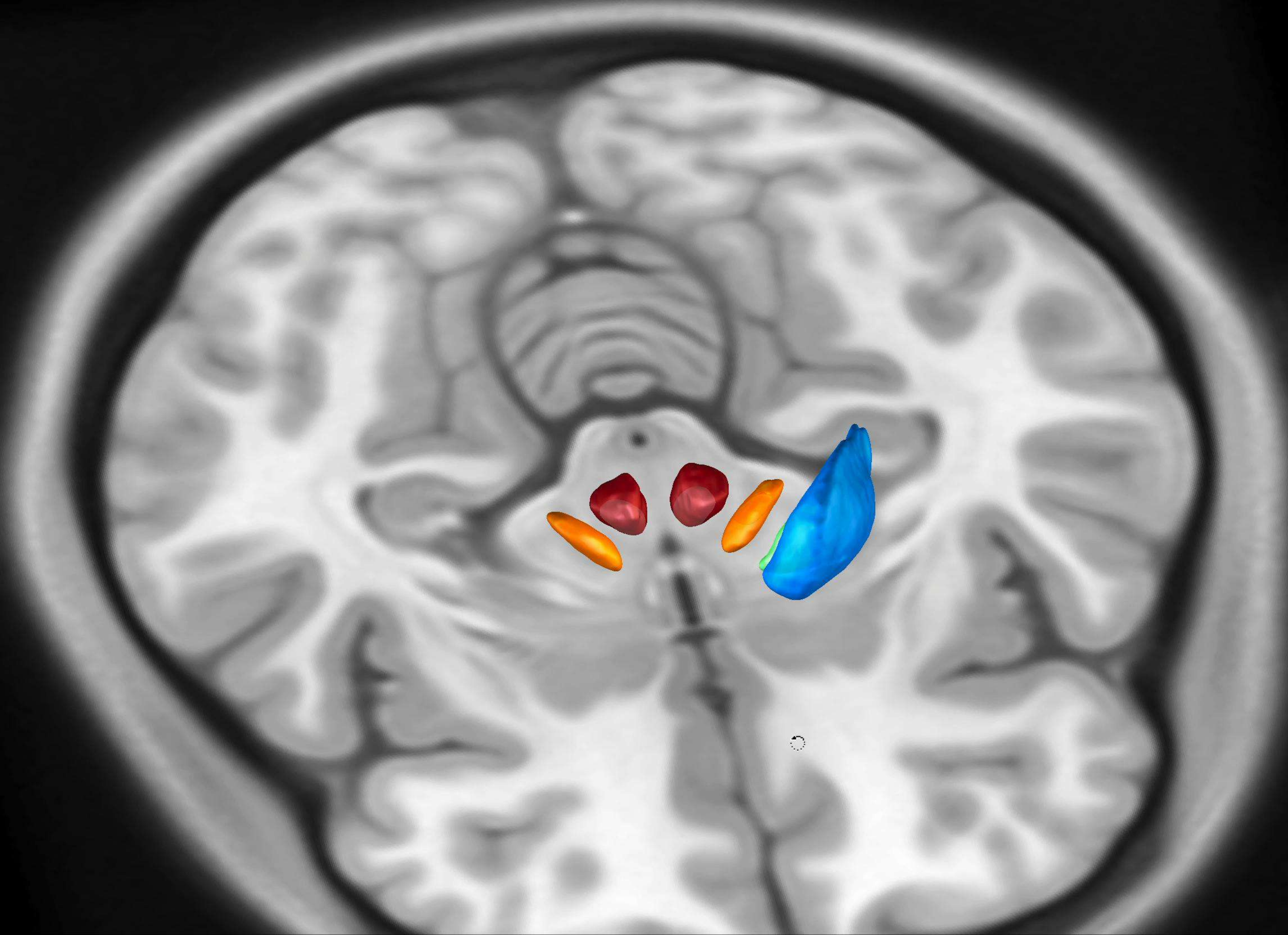
A STN Anatomy, Subregions and Connectivity

B GPi Anatomy, Subregions and Connectivity

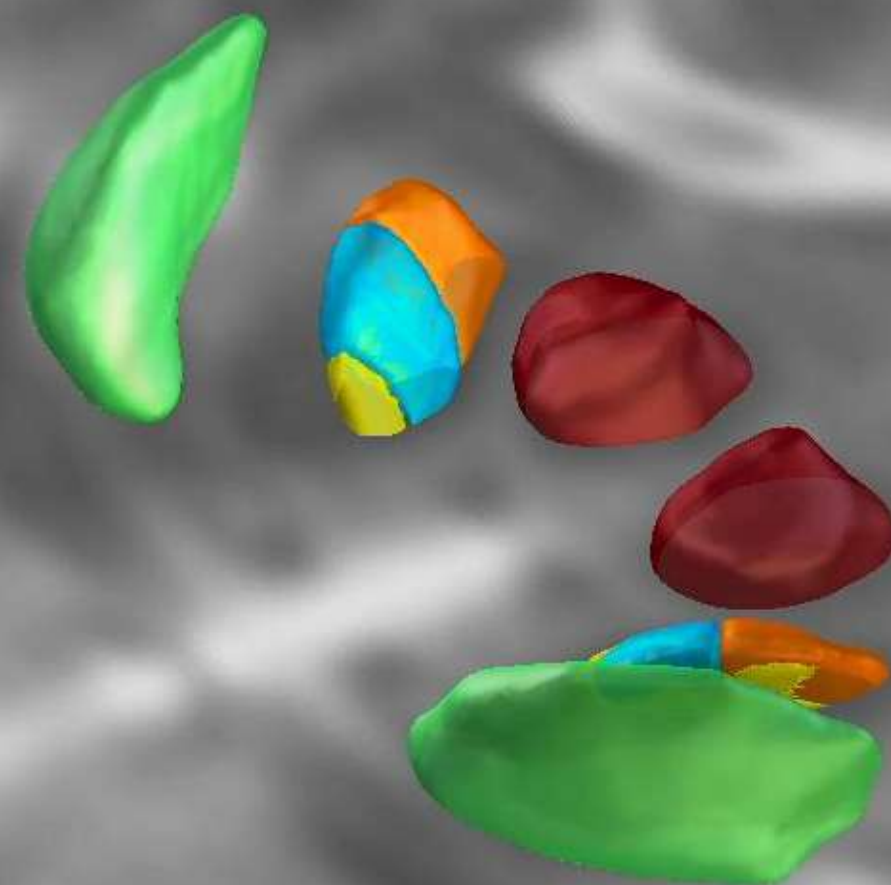
Outline

A STN Anatomy, Subregions and Connectivity

B GPi Anatomy, Subregions and Connectivity



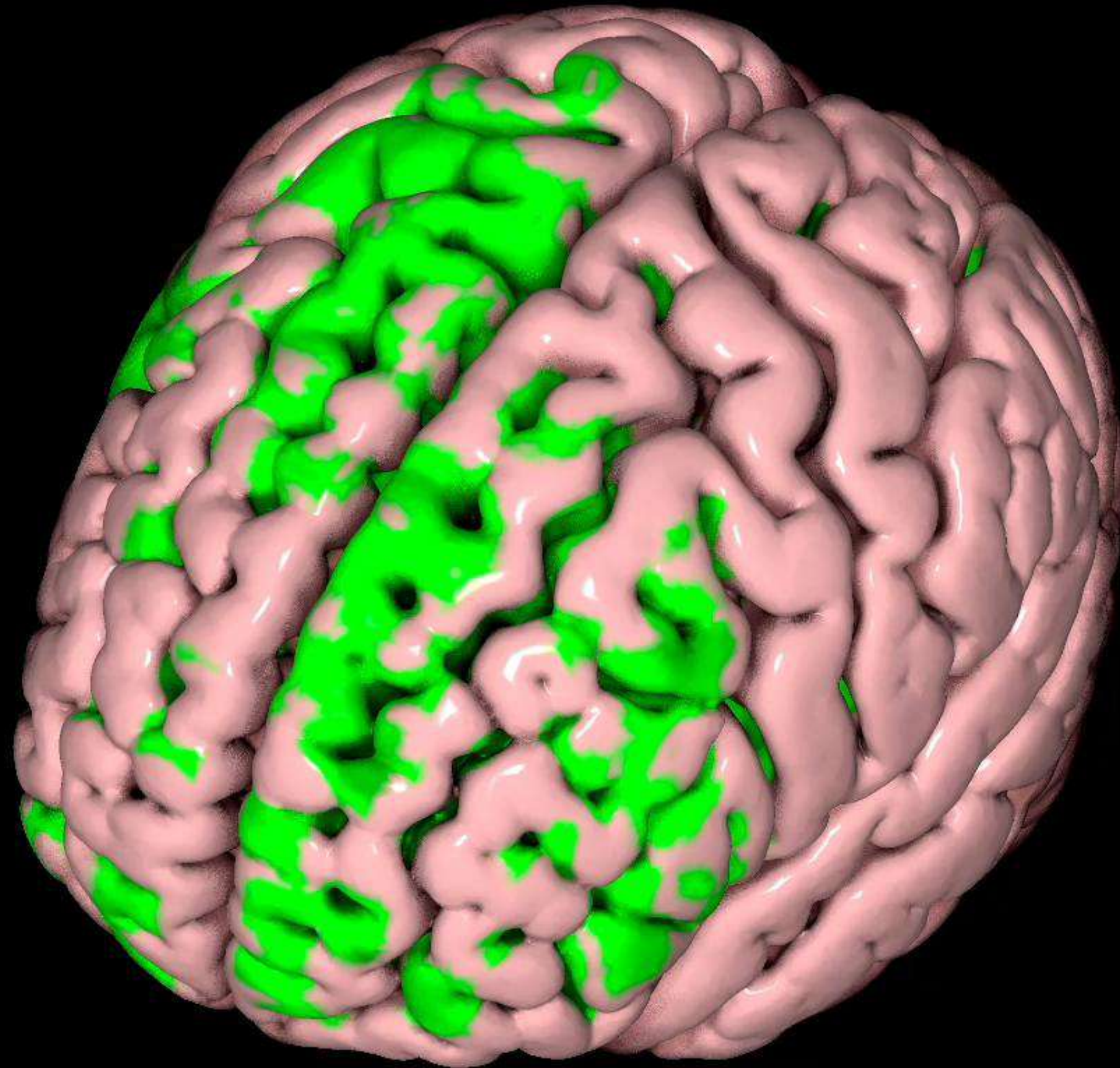
STN subregions and connectivity



69 yo, behaviour changes after STN-DBS

"accelerated, uninhibited, without censorship

he cries easily, he sees a small scene in the soap opera and he starts crying...."



Red-Yellow

Options

Darkest

0

Brightest

0.3

Opacity

Clipping

Depth

Azimuth

Elevation

Background Mesh

XRay

Shader For Background Only

Render

Heidrich-Seidel

AO

Light

Ambient

Diffuse

Specular

Roughness

AnisoRoughness

Overlay 1: mni152_2009.curv

range min..max -0.1949..0.4209

view min..max -0.2..0.4

Overlay 2: sub-EdsonLuizRibeiro_sim-bi

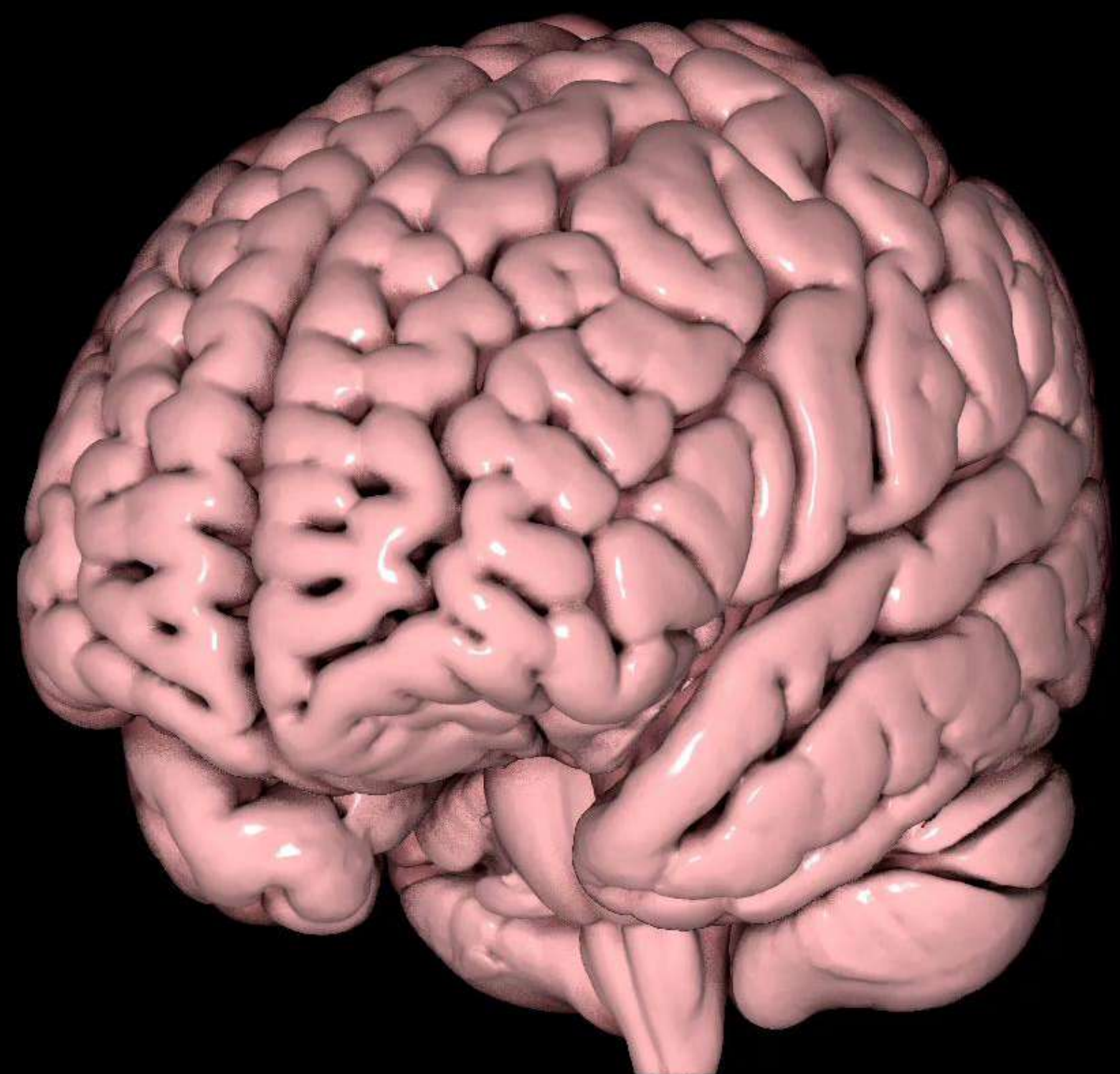
range min..max -0.1148..0.2601

view min..max 0..0.3

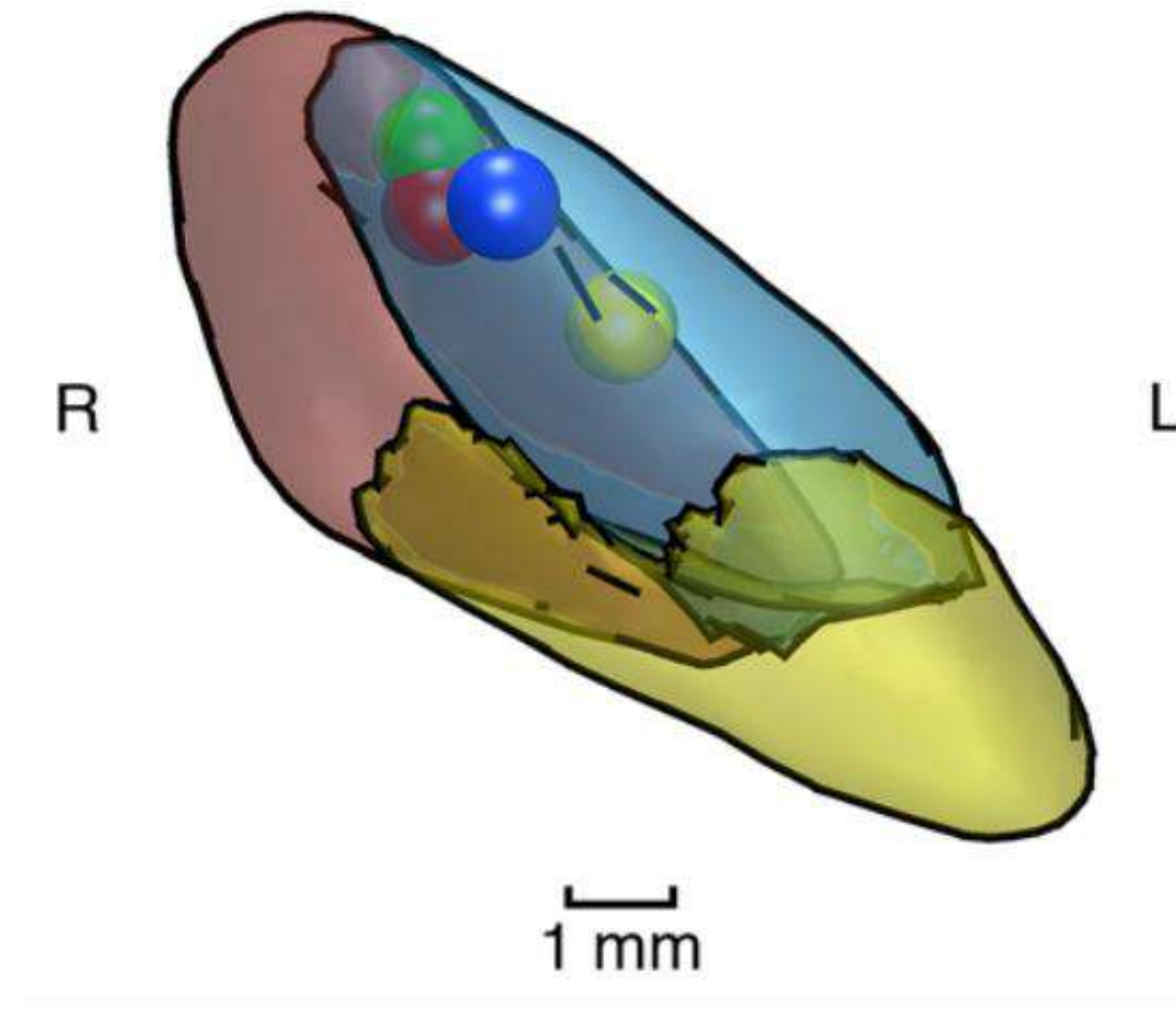
Overlay 3: sub-EdsonLuizRibeiro_sim-bi

range min..max -0.1148..0.2601

view min..max -0.1..-0.0001

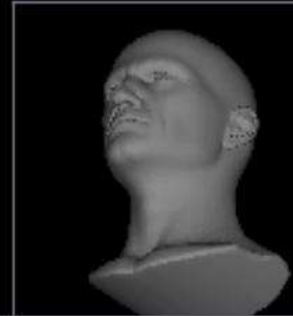
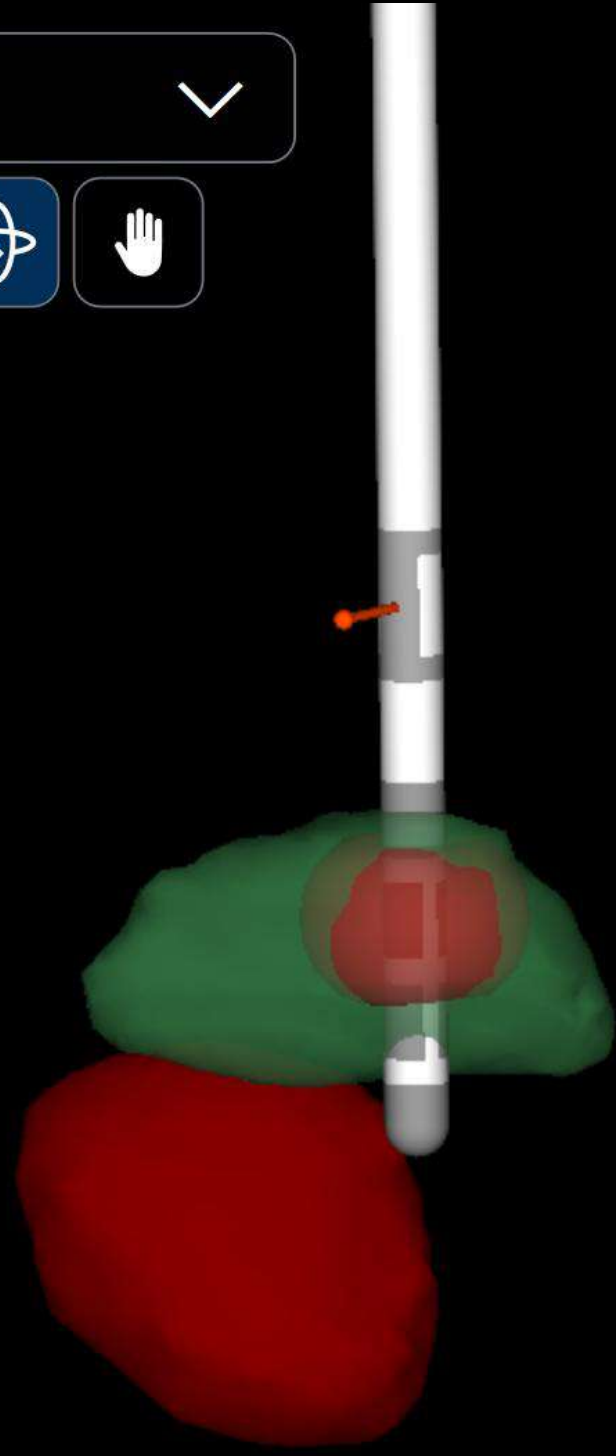


Center of mass of the sweet spot for Parkinson's disease (motor improvement)

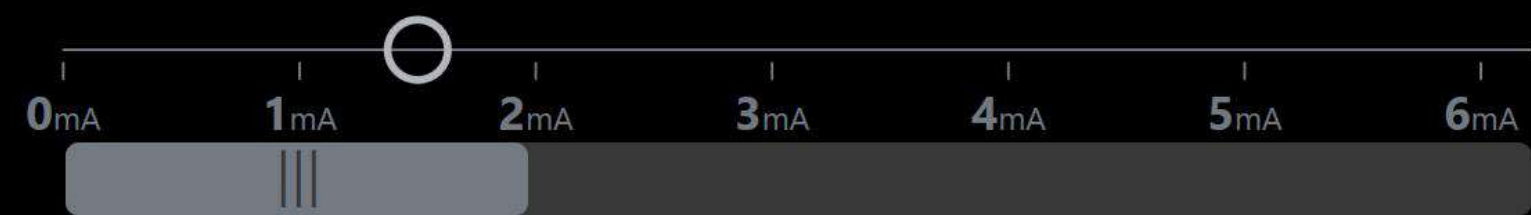


Dembek et al., Annals of Neurology, 2019

3D Overview

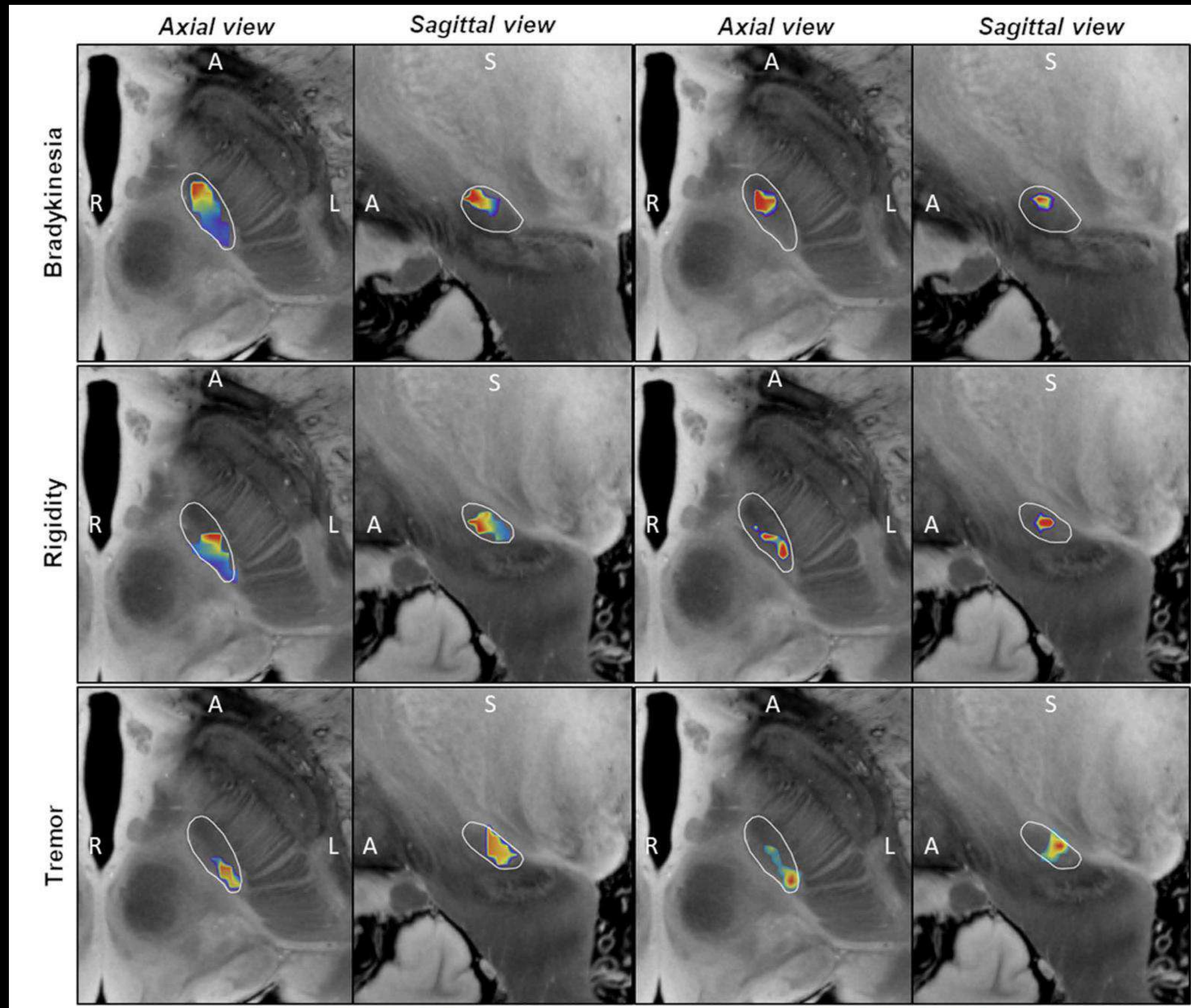


CLINICAL EFFECTS MAP



Tremor: Posterolateral

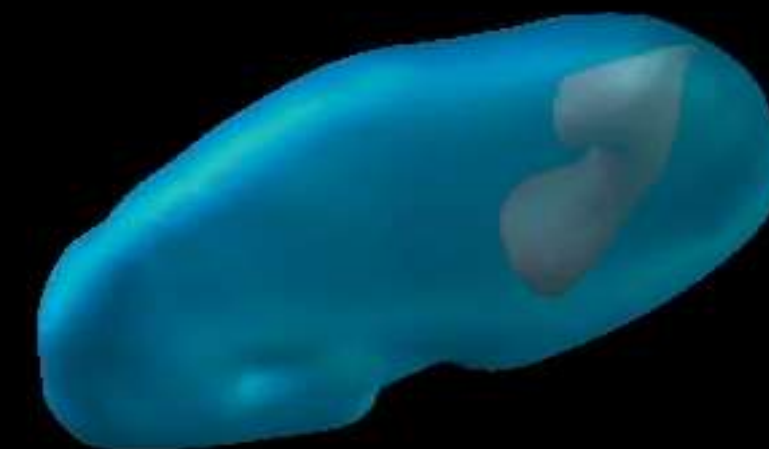
Bradykinesia and Rigidity:
More rostral





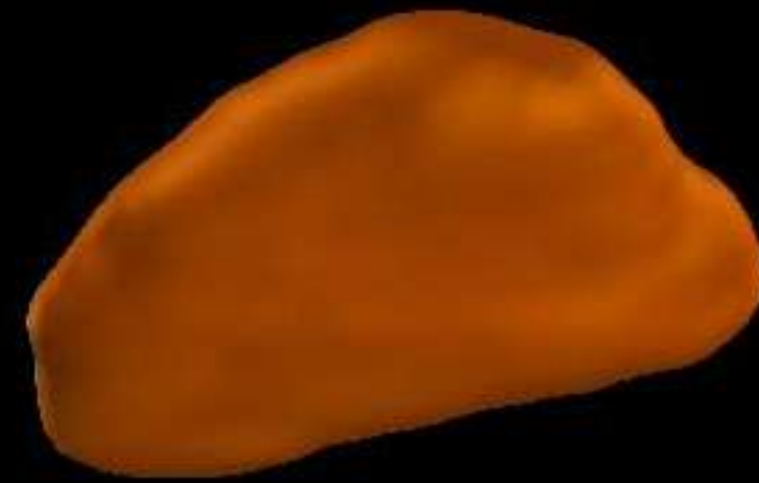


Beta band peak

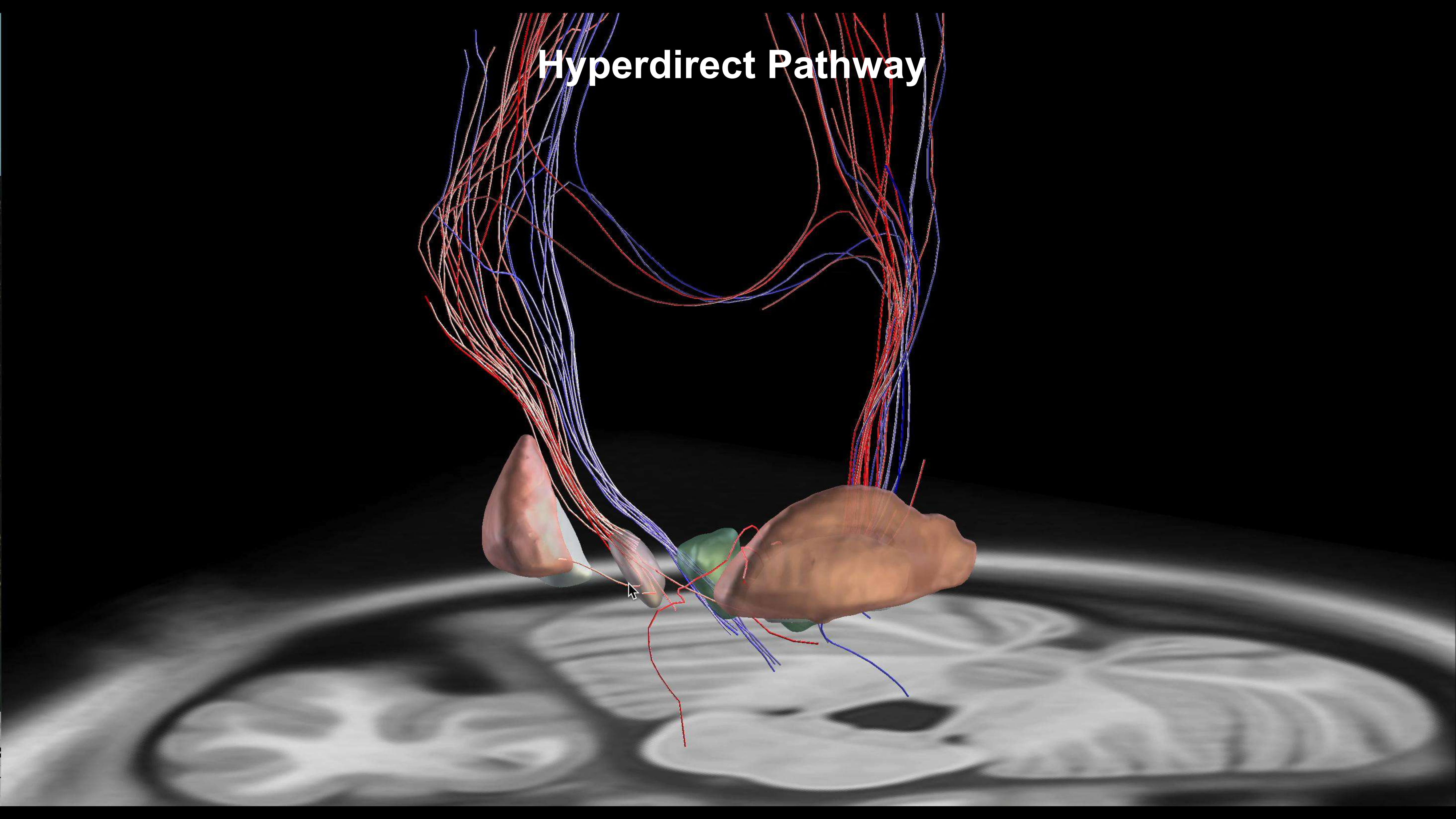


5

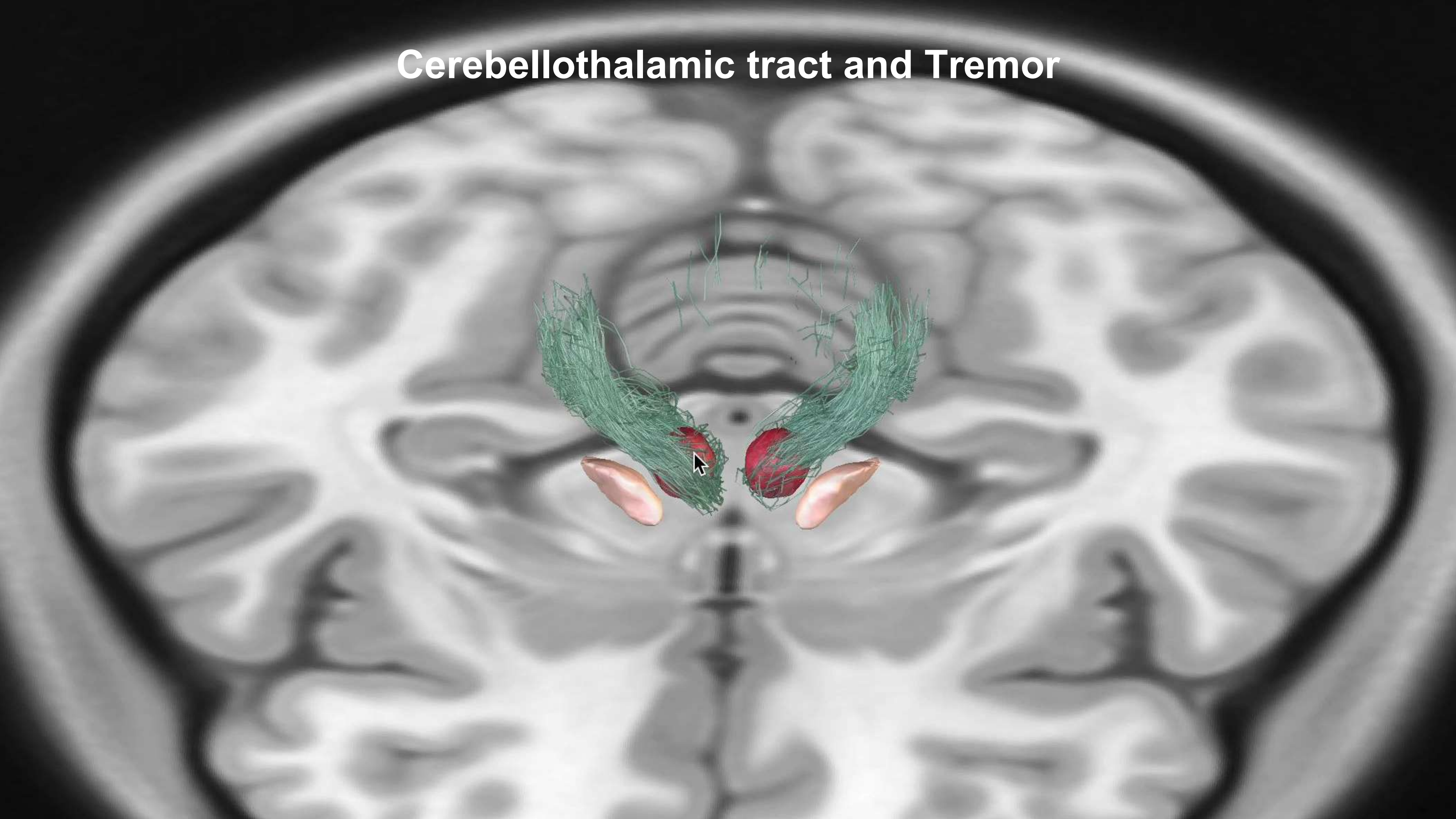
Cluster analysis



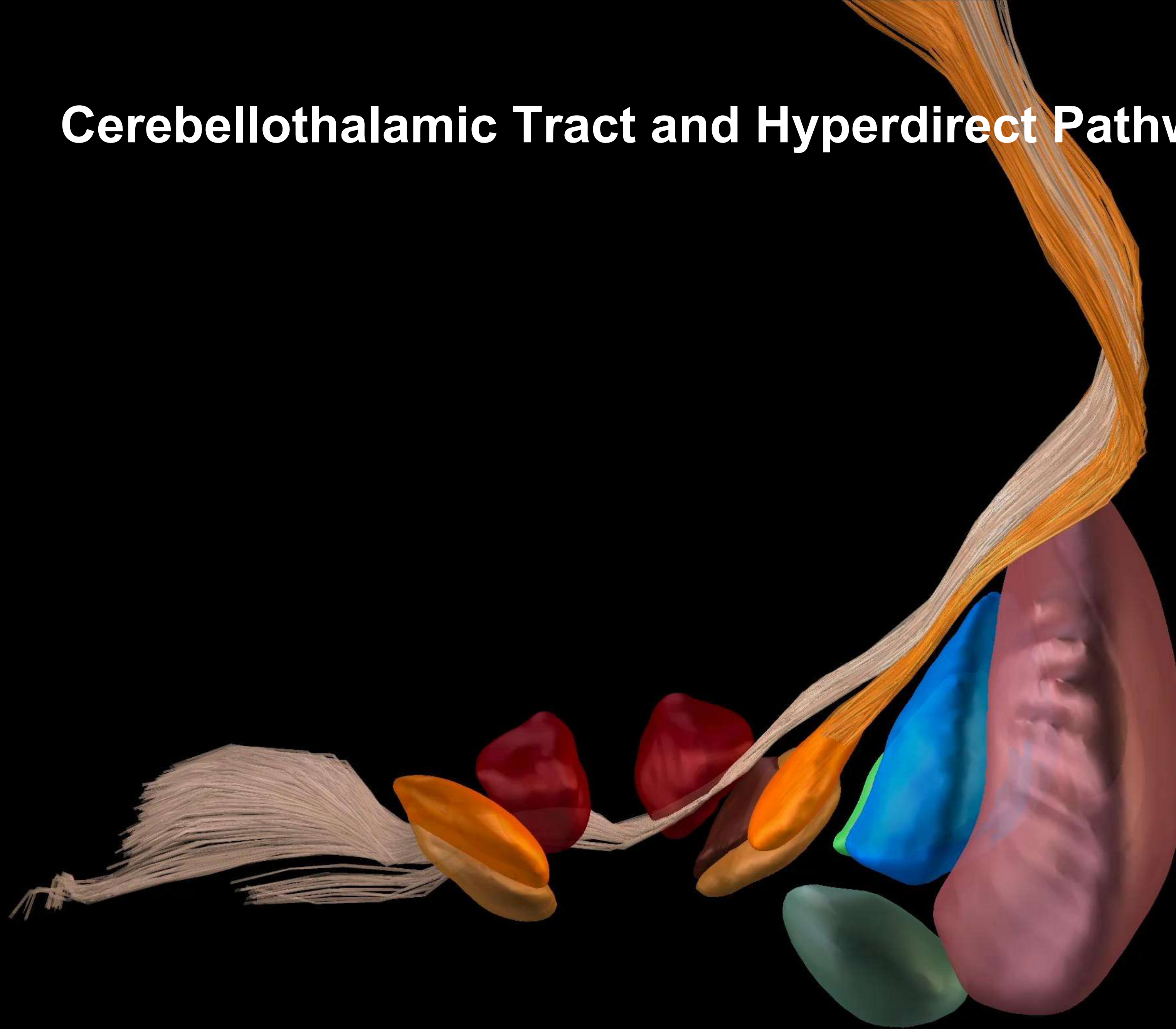
Hyperdirect Pathway



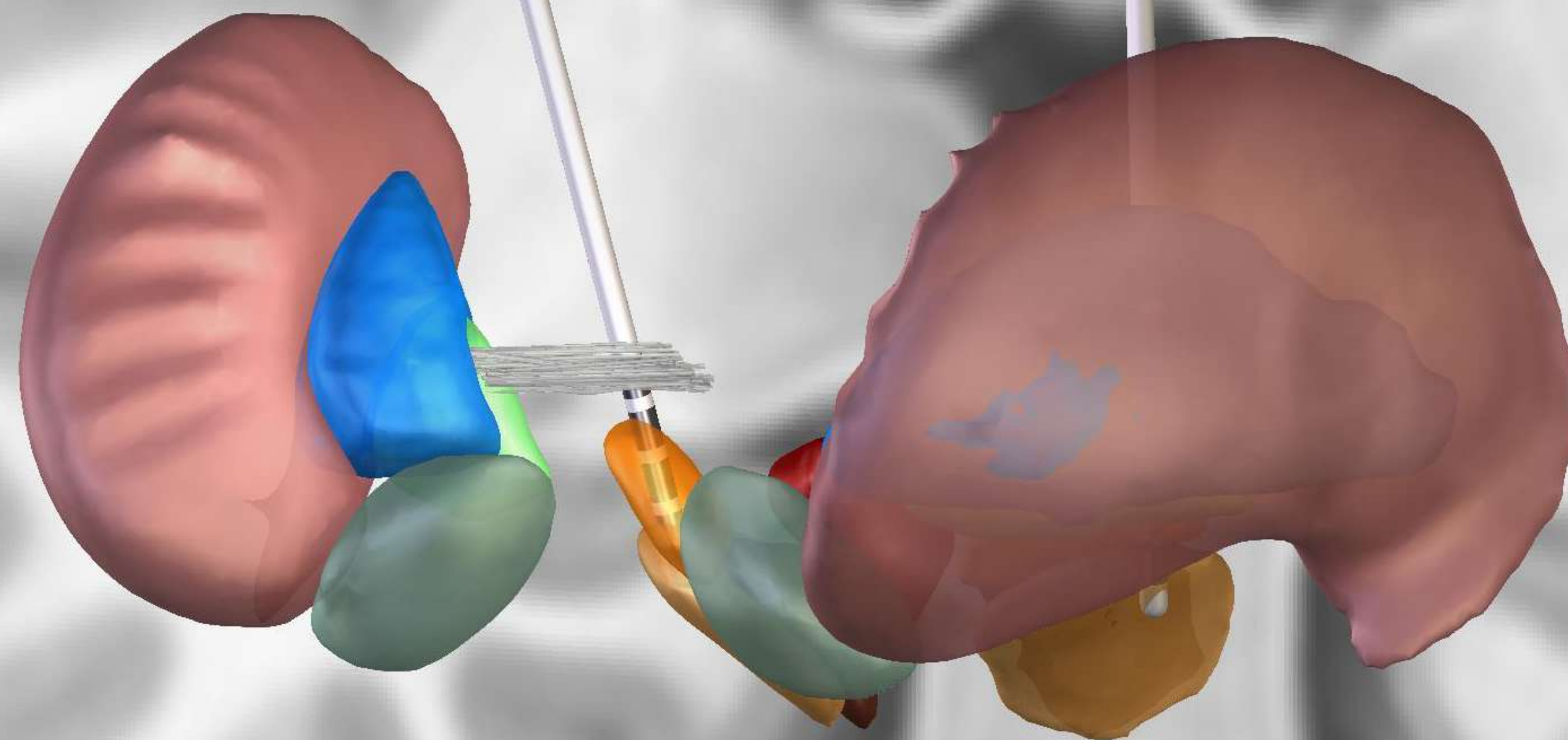
Cerebellothalamic tract and Tremor

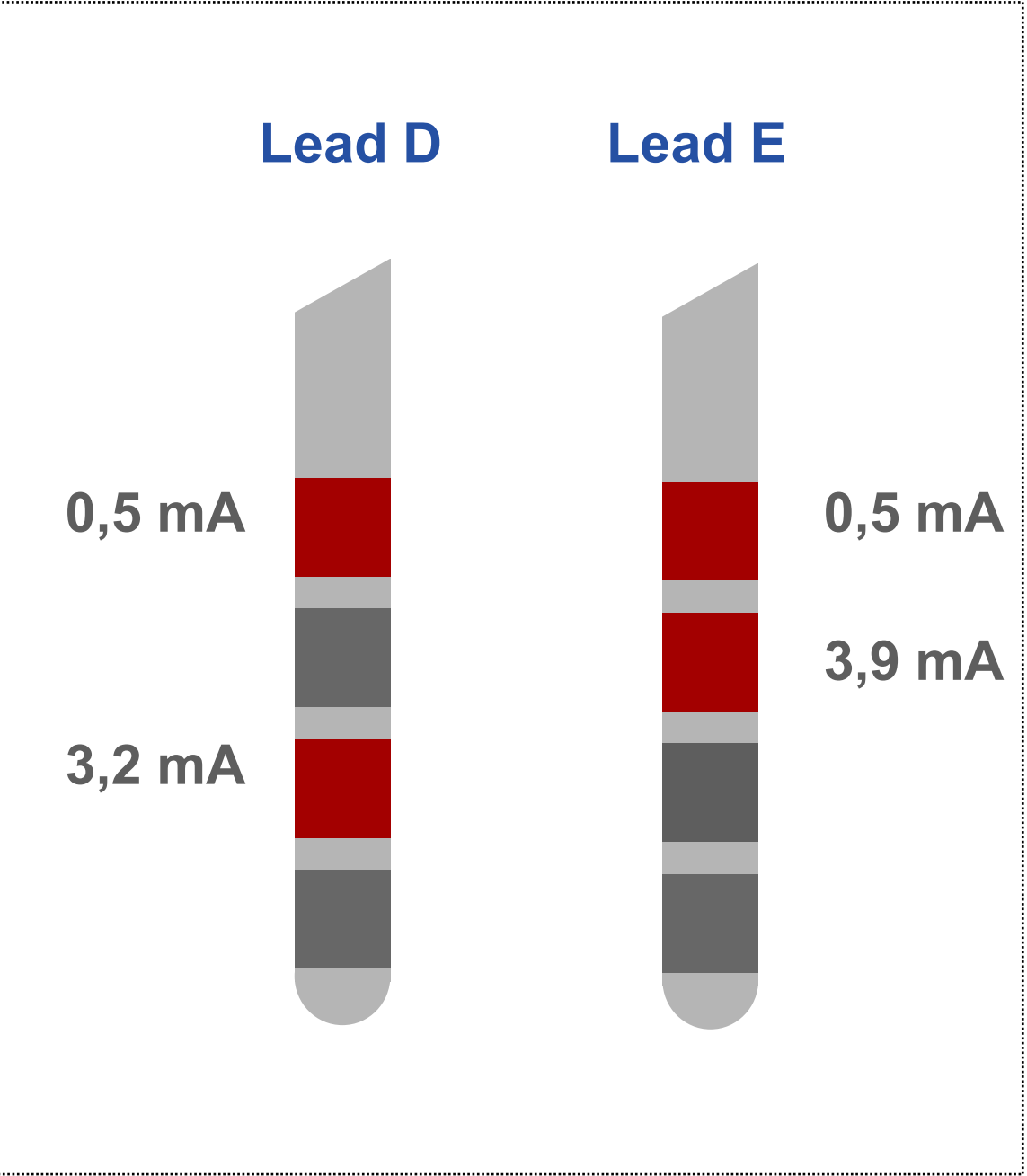
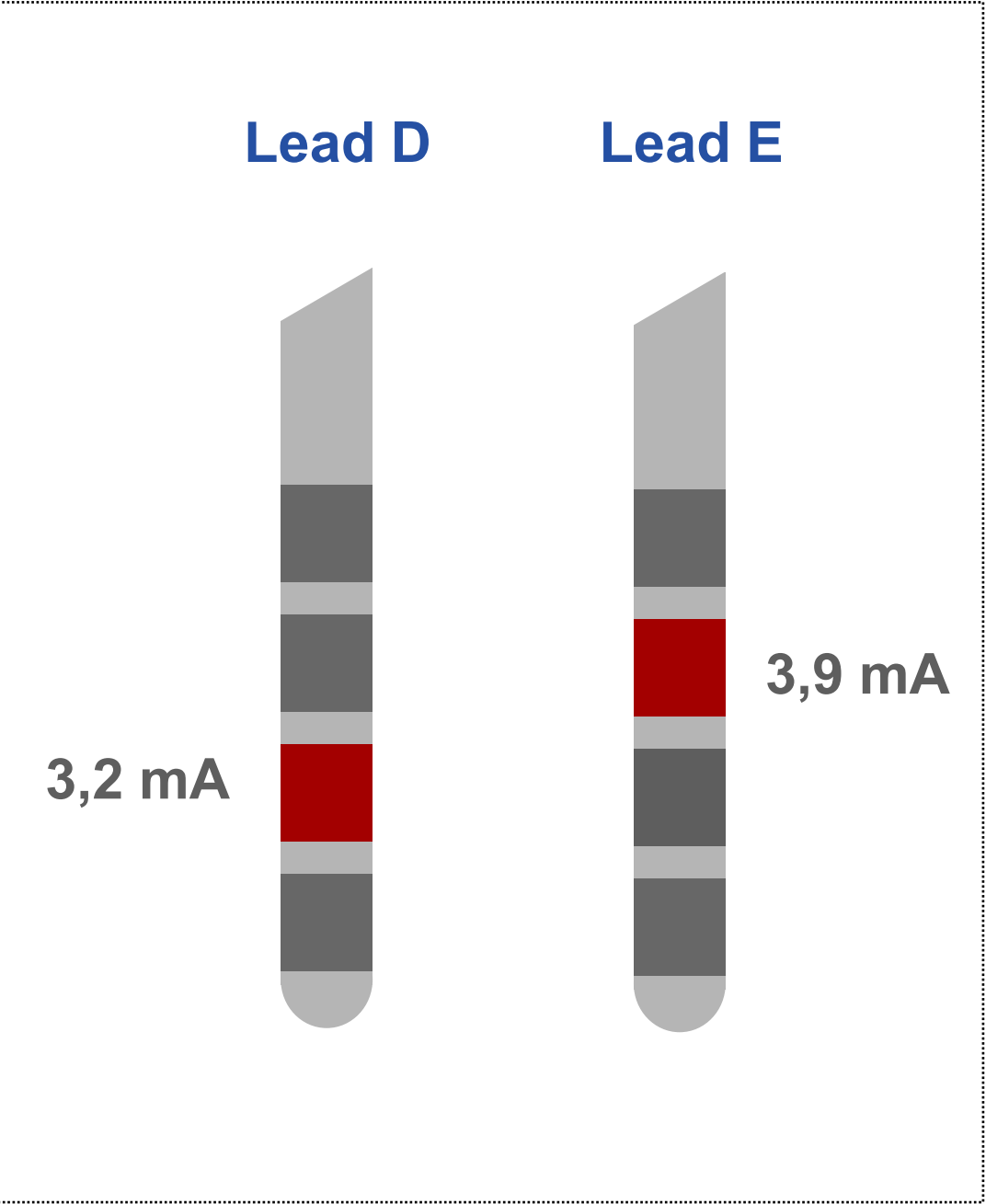


Cerebellothalamic Tract and Hyperdirect Pathway



A way to
alleviate
dyskinesias:
Lenticular
fasciculus





Video autorizado pela paciente

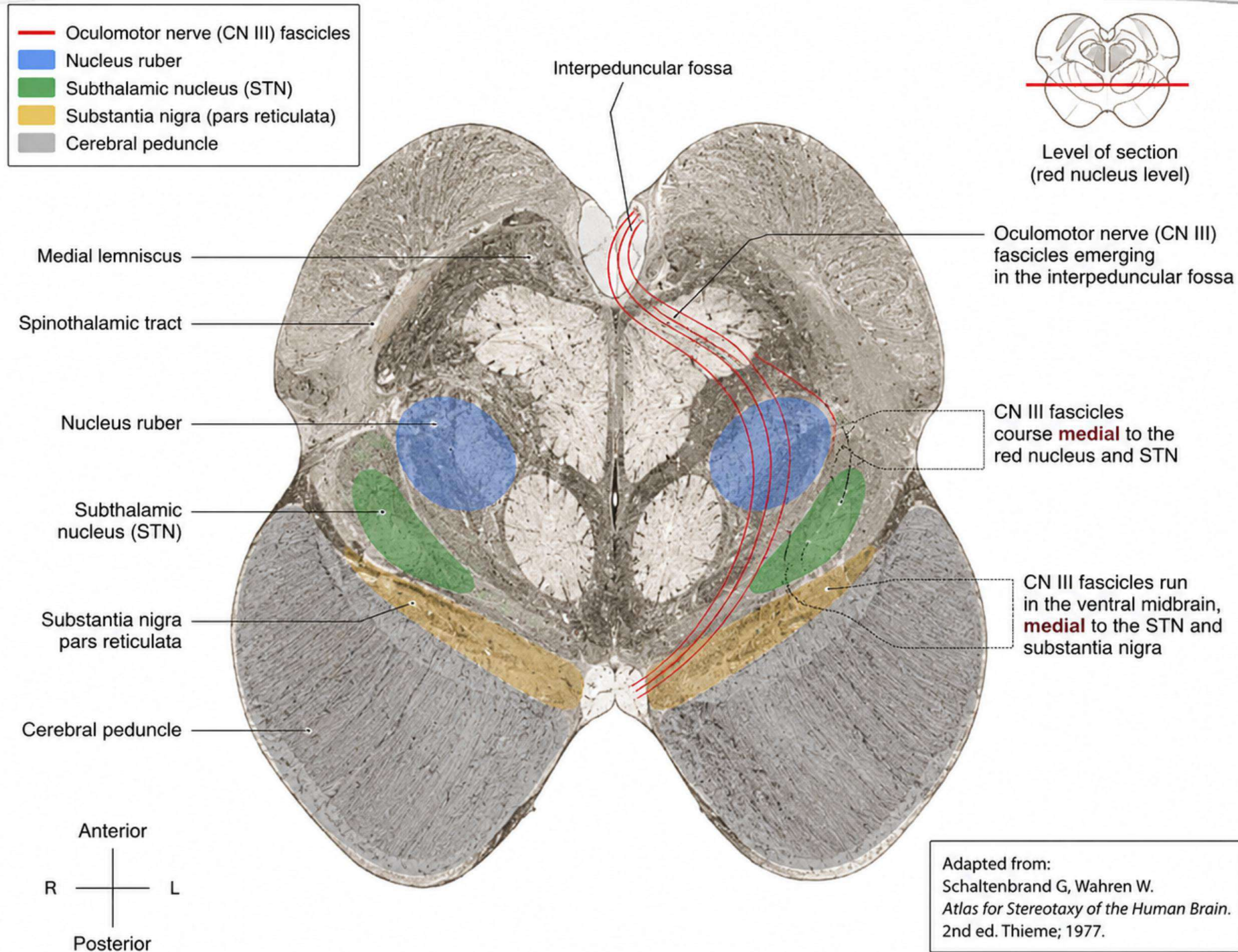


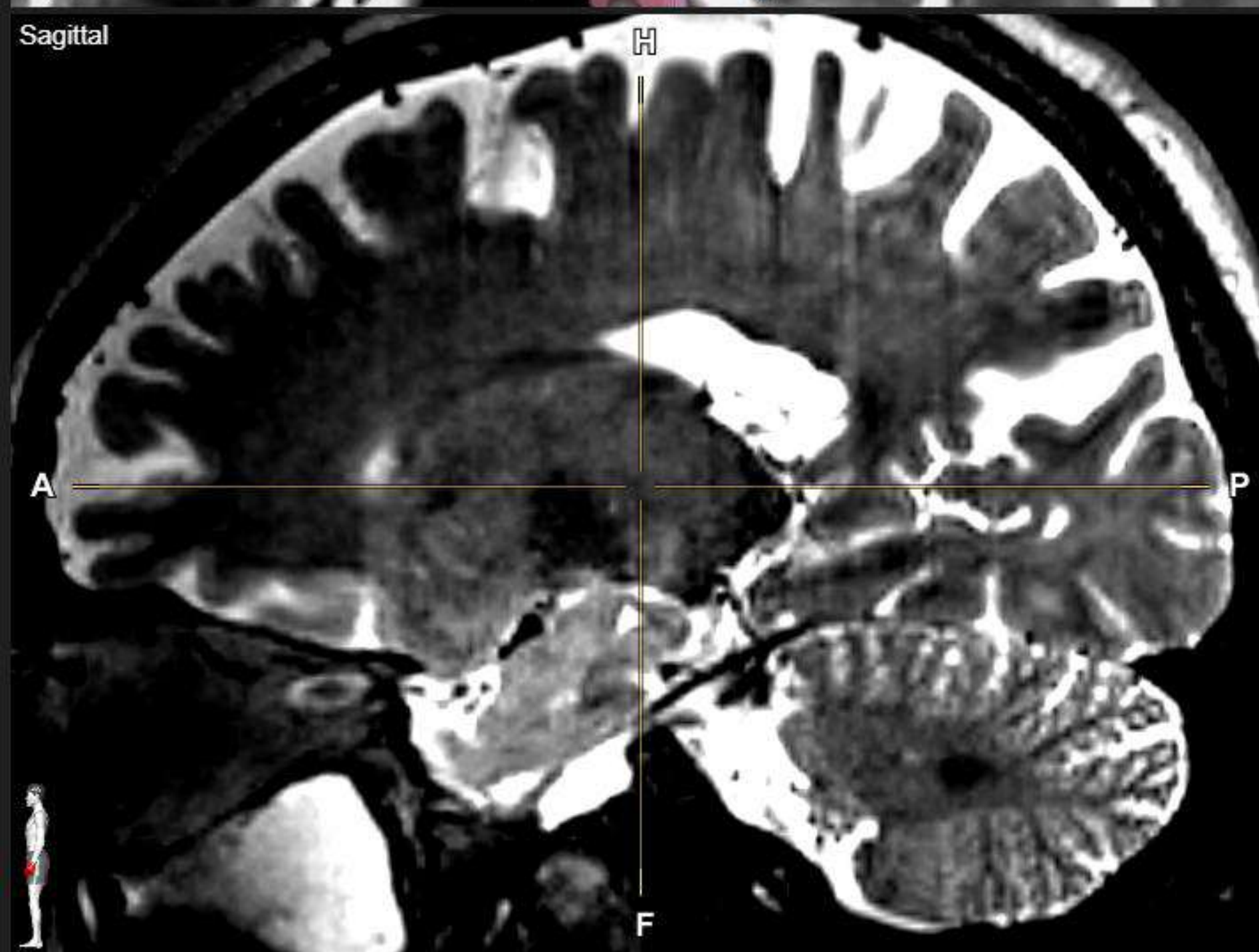
Putting the most important tracts together



Midbrain – oculomotor nerve (CN III) fibers in relation to the STN

Axial section through the rostral midbrain (red nucleus level)





FIBER BUNDLES

Templates

Alerts

Data

Home

PASINATO, MIGUEL
6230051
Modified plan

Fibertracking

01 CST Left

02 ML Left

03 DDRT Left

04 dDRTT

CST 2

CST detministic

Create Fiber Bundle

Scroll

Pan

Draw ROI

Undo

Zoom

Windowing

Remove Fibers

Interactive

ROIs

01 CST Left

02 ML Left

03 DDRT Left

04 dDRTT

Dentate Nucleus Left

Dentate Nucleus Right

Nucleus Ruber Left

Nucleus Ruber Right

Create ROI

Refinement: 10%

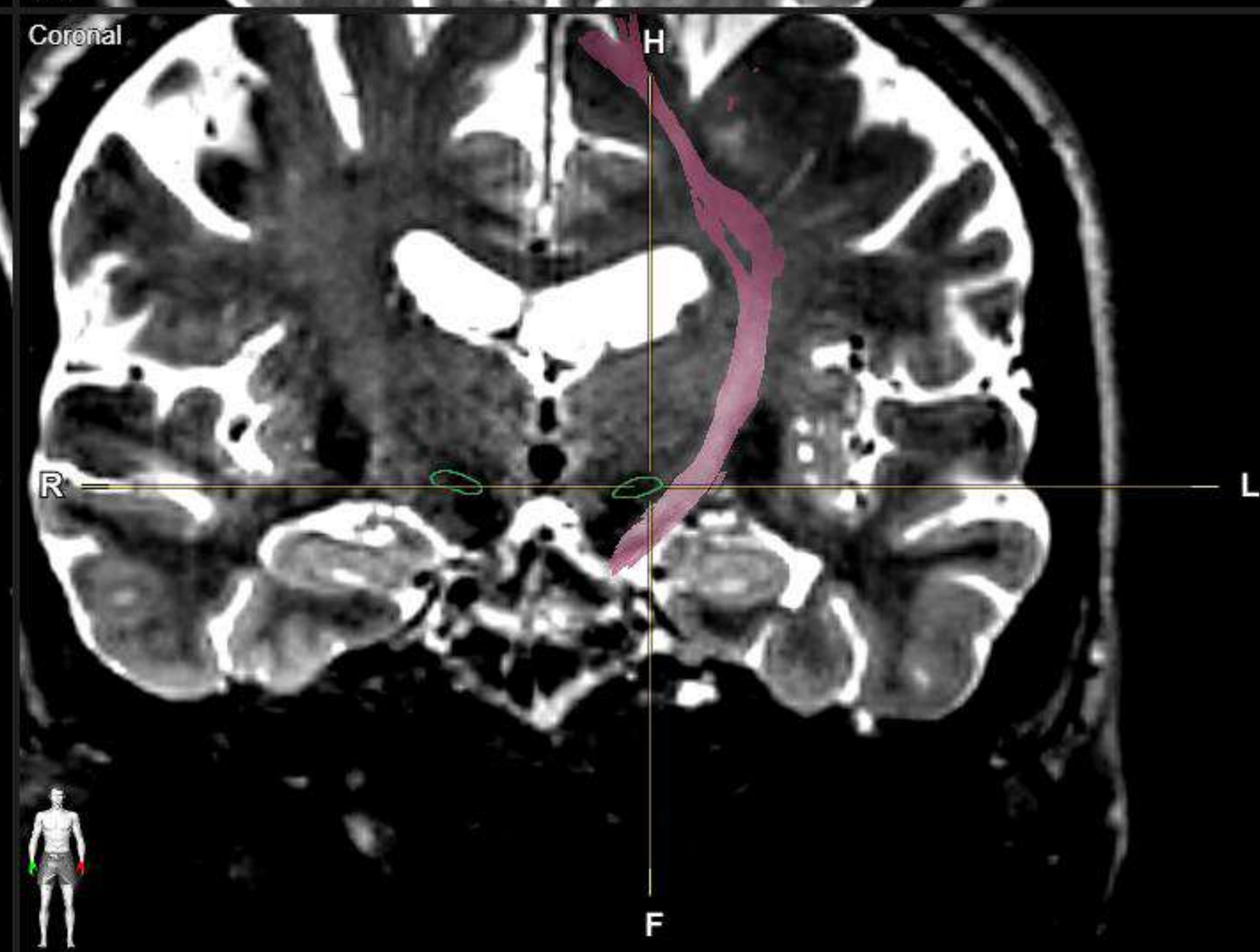
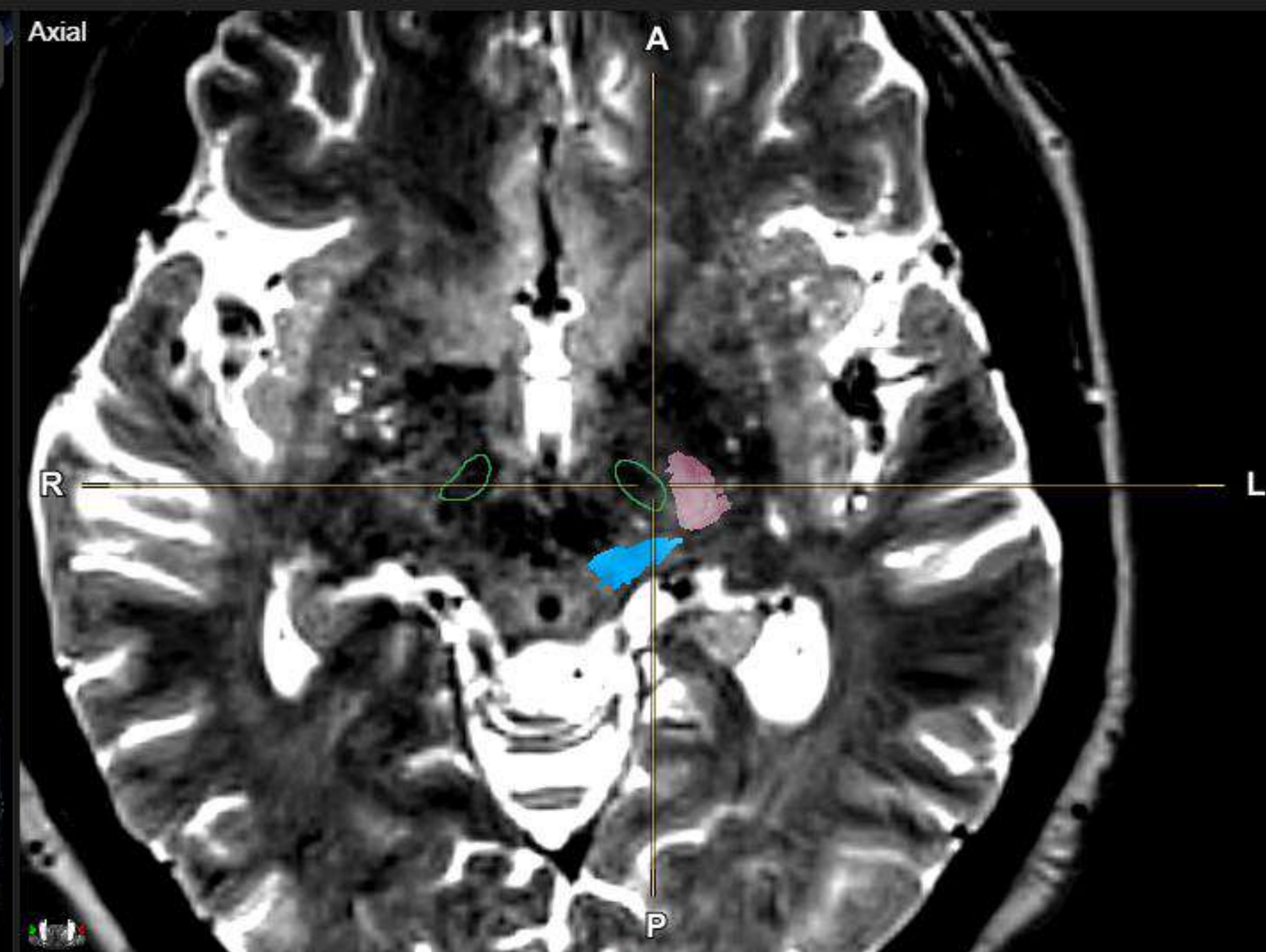
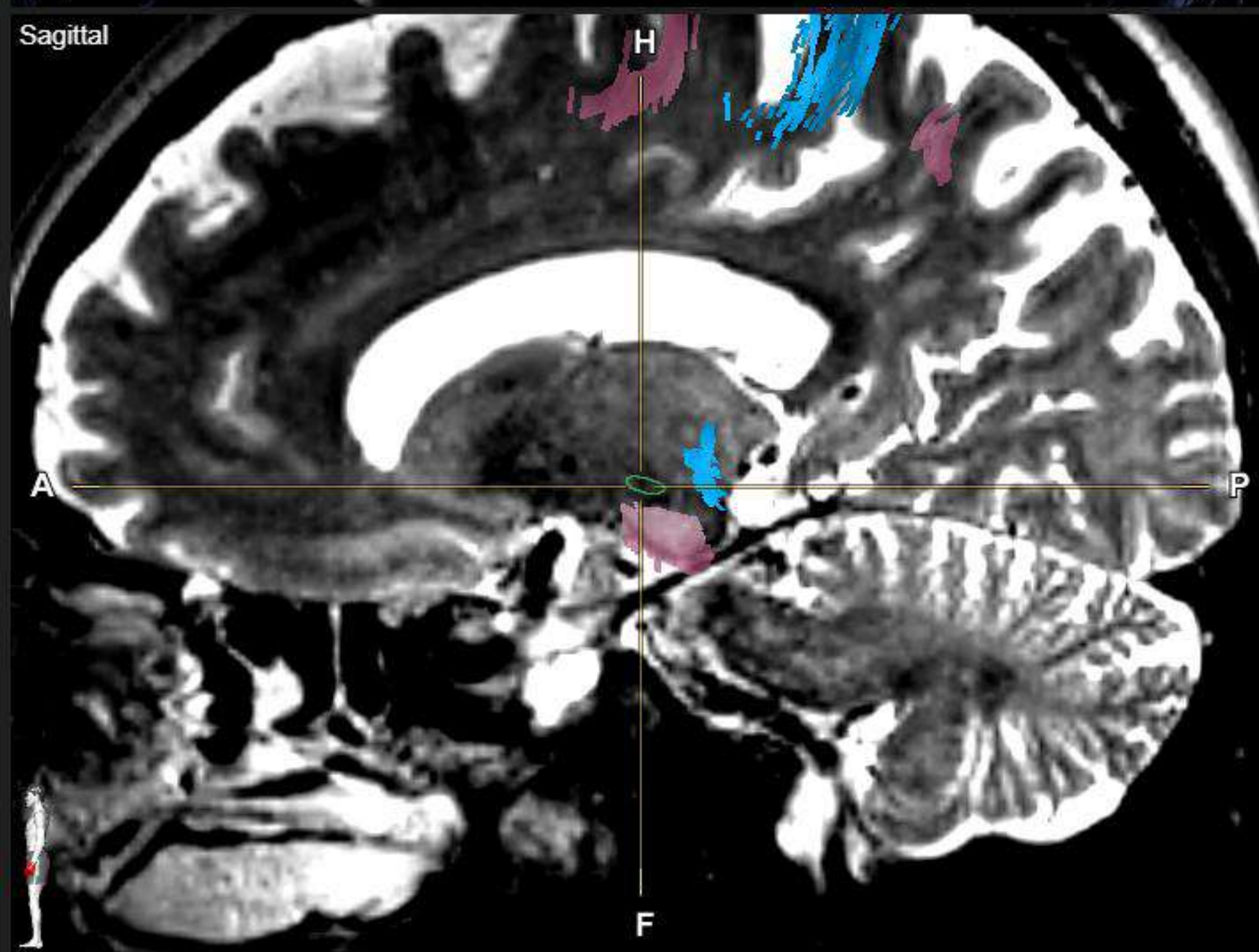
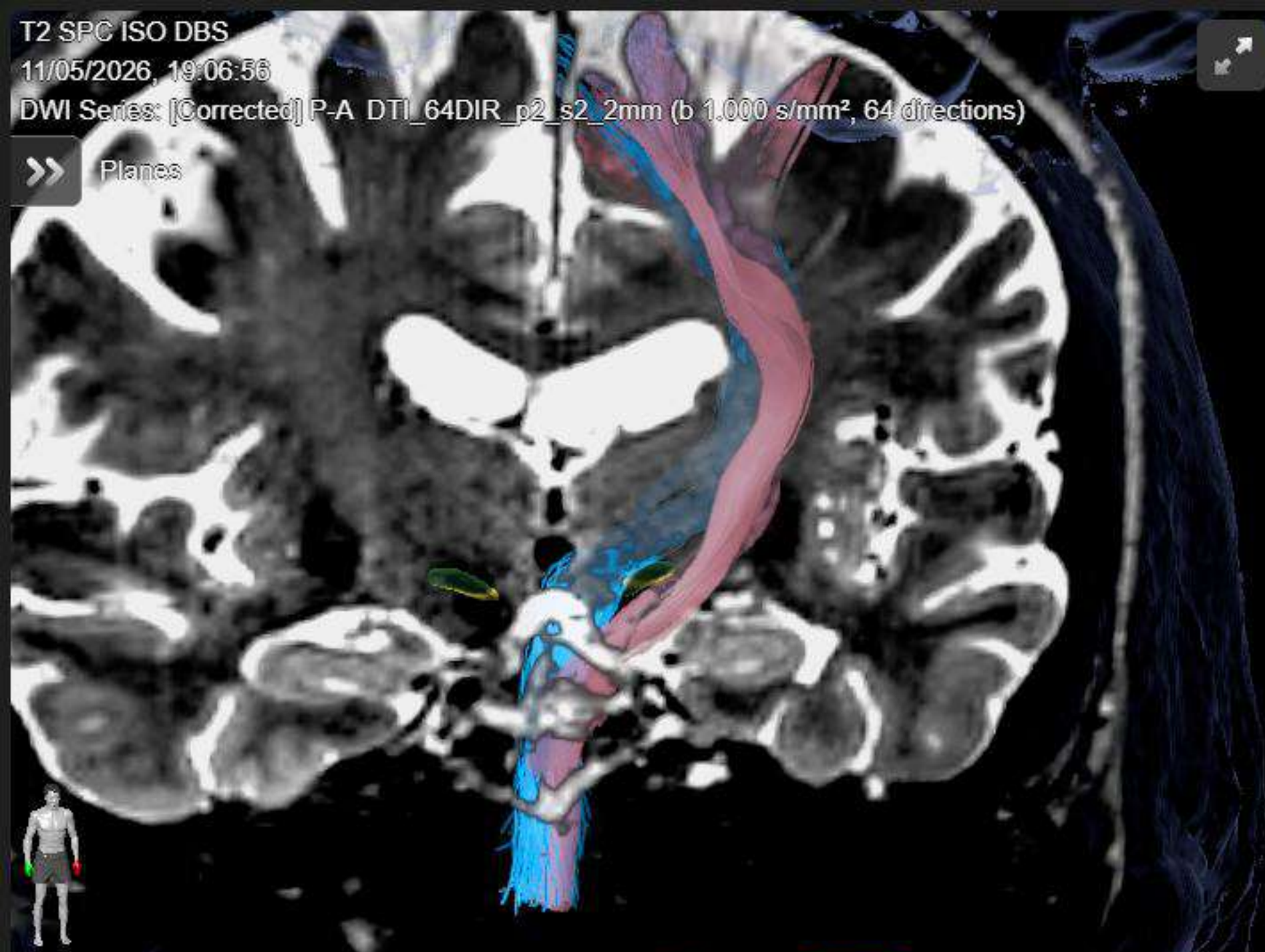
Parameters

Measurement

Back

Done

BRAINLAB



FIBER BUNDLES

Templates

Alerts Data Home

PASINATO, MIGUEL
6230051
Modified plan

Fibertracking

Scroll Zoom

Pan Windowing

Draw ROI Remove Fibers

Undo Interactive

Refinement: 10%

Parameters

Measurement

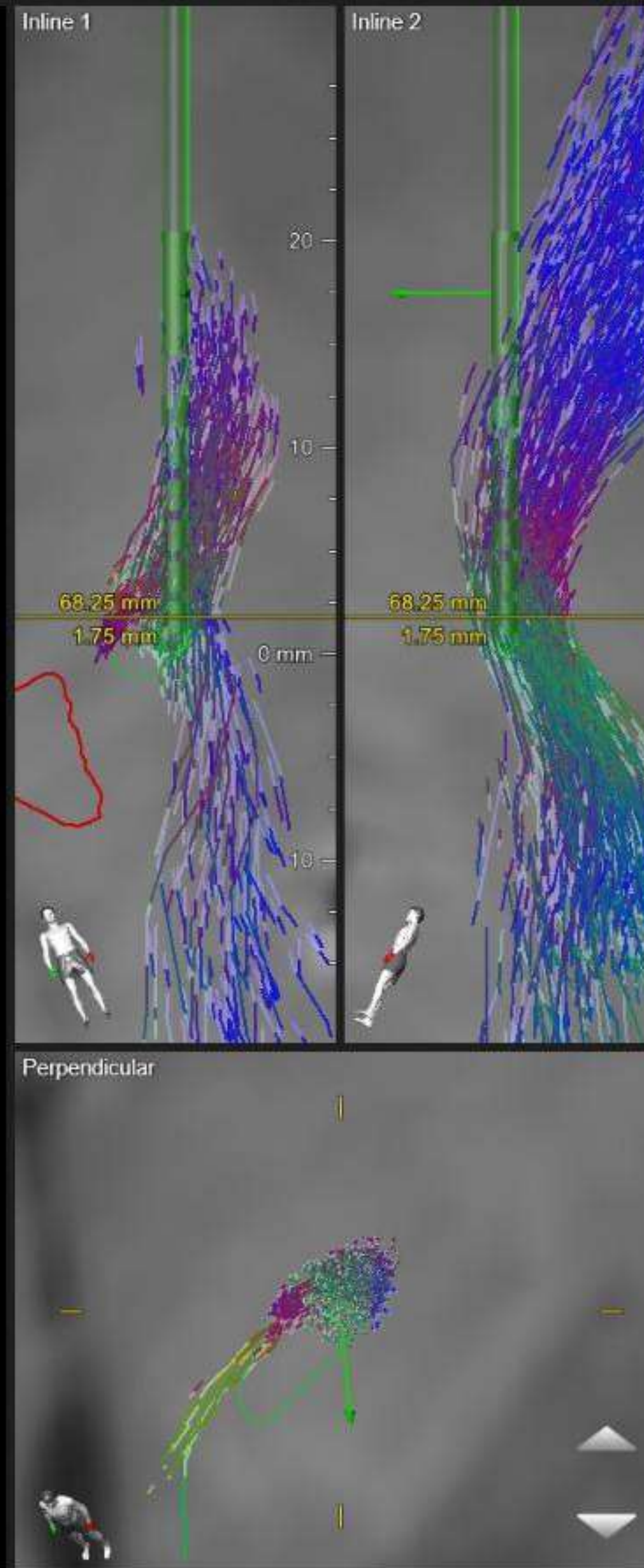
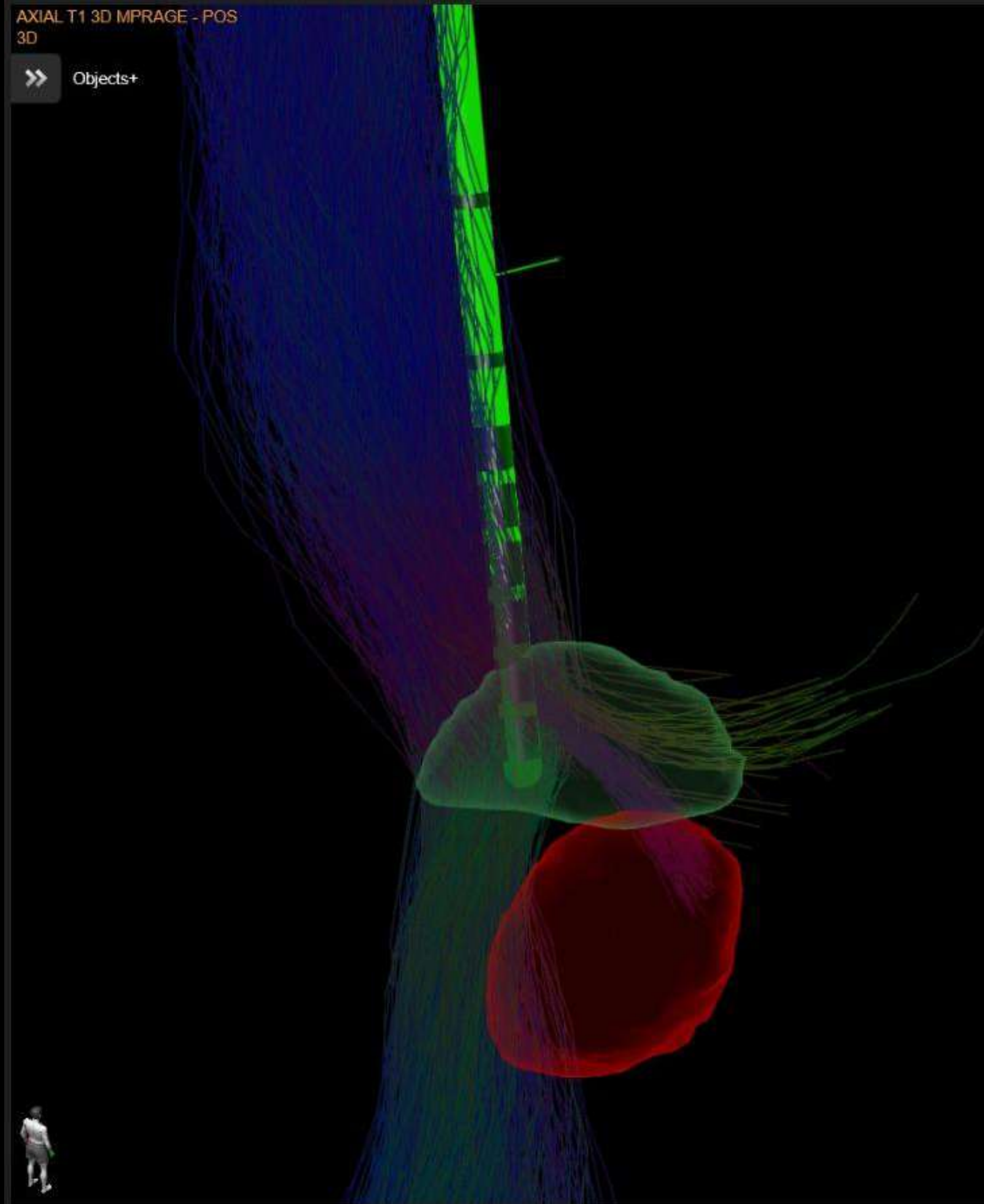
Back Done

BRAINLAB

01 CST Left	
02 ML Left	
03 DDRT Left	
04 dDRTT	
CST 2	
CST deterministic	
Create Fiber Bundle	+

ROIs	
01 CST Left	
02 ML Left	
03 DDRT Left	
04 dDRTT	
Dentate Nucleus Left	
Dentate Nucleus Right	
Nucleus Ruber Left	
Nucleus Ruber Right	
Create ROI	+

>> Objects+



Sim 01 (Trajectory...)

CreateCopy

Parameters

Effects000

IPG100%

16131514101211798455

133%33%34%

Color

SteeringManual

mA%

Pulse (μs)60Rate (Hz)130

Amplitude (mA)Steps-0+0.1

SteeringLevelRotateFocus

Comment

Color

HENRIQUE DE ALVARENG...
7656032
Modified plan

GUIDE XT™

ScrollZoom

PanRotate

Trajectory 01

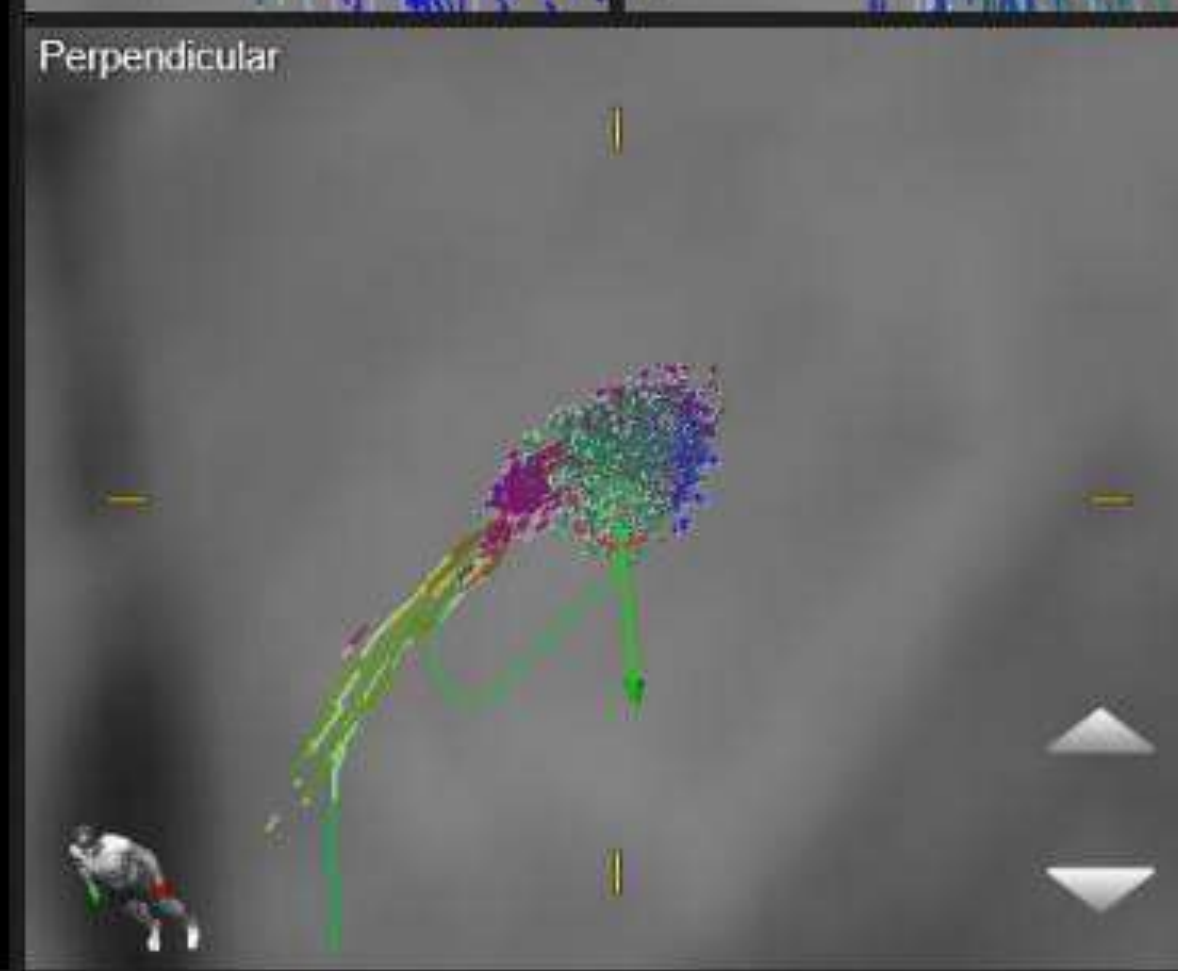
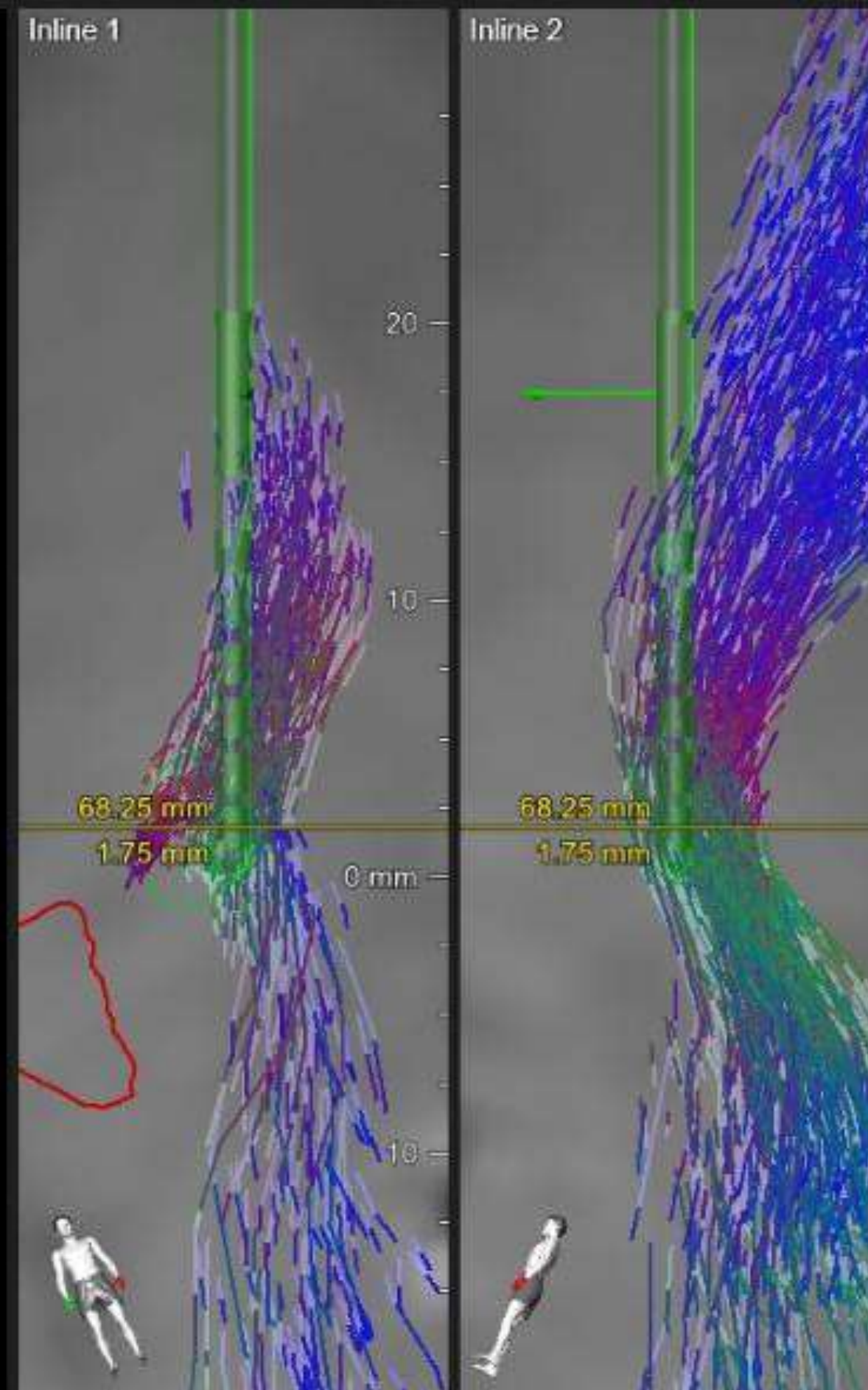
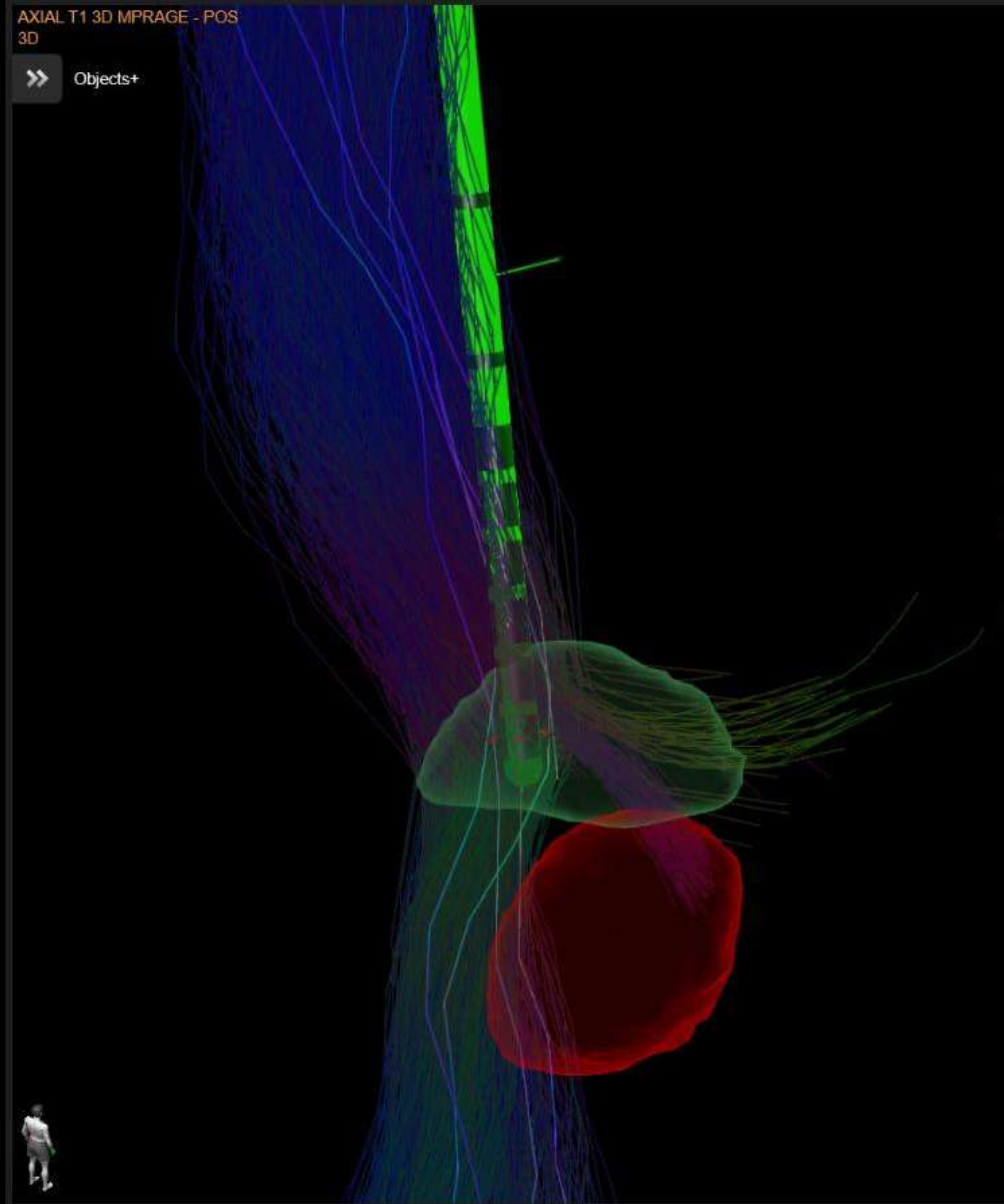
WindowingConfiguration

Center

BackDone

BRAINLAB

Objects+



Sim 01 (Trajectory...)

Create Copy

Alerts Data Home

HENRIQUE DE ALVARENG...
7656032
Modified plan

GUIDE XT™

Scroll Zoom Pan Rotate

Windowing Configuration

Center

Back Done

BRAINLAB

Parameters

Effects 0 0 0 0

IPG 100%

Steering Manual

mA %

Pulse (µs) 60 Rate (Hz) 130

Amplitude (mA) 0.6 Steps 0.1

Steering Level Rotate Focus

Comment

Color

1 33% 33%
2 34%

AXIAL T1 3D MPRAGE - POS
3D

Objects+


 Sim 01 (Trajectory...
 


 Copy

Data

Parameters: Effects 0  0 



Manual

%

Rate (Hz)

130

Steps

0.8

1 ▼

Leve

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te

S

Color



Data

GUIDE XT™



Configuration

Center

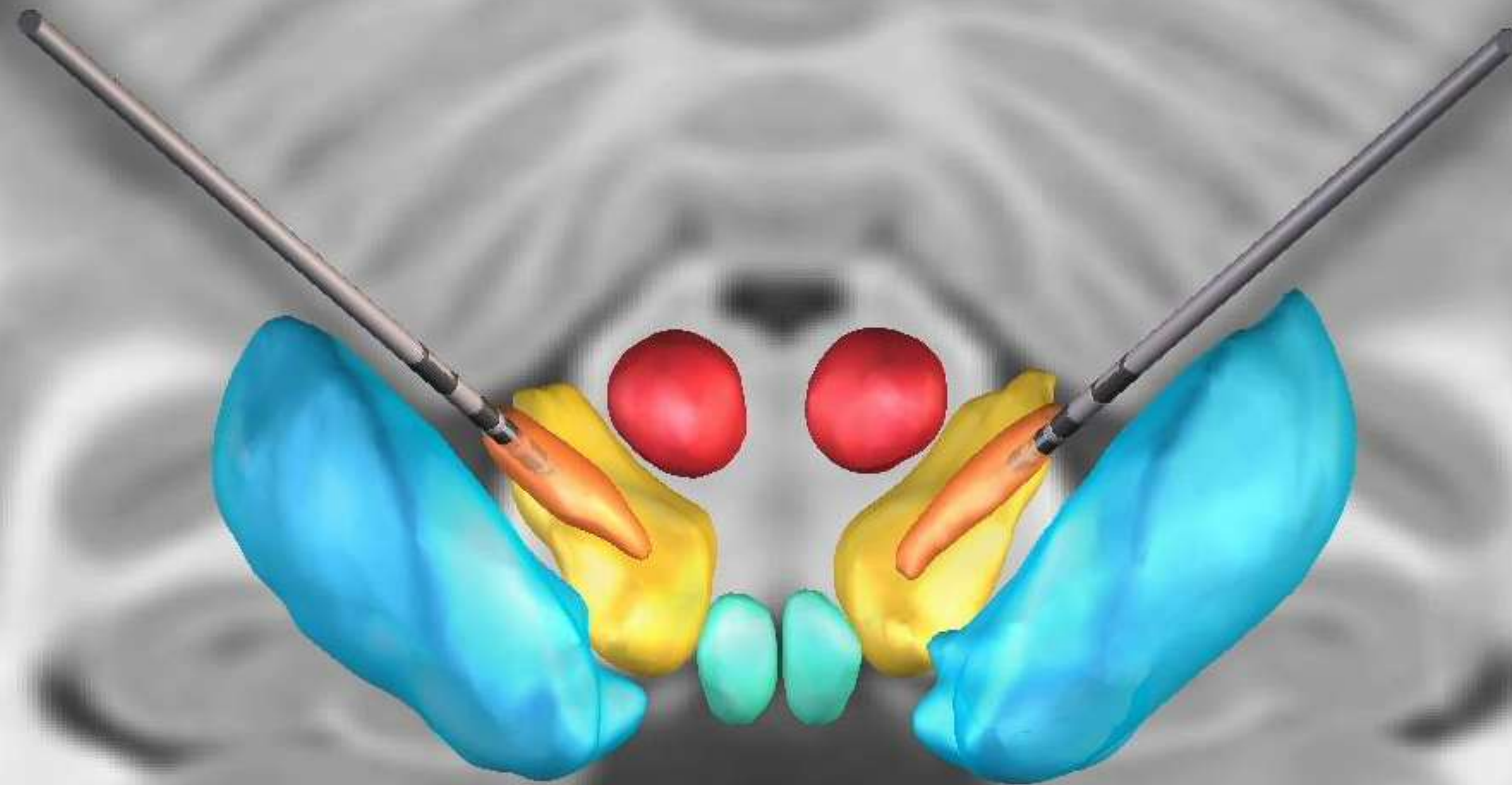
Back

Done



BRAINLAB

Once you are read: start the stimulation





Outline

A STN Anatomy, Subregions and Connectivity

B GPi Anatomy, Subregions and Connectivity

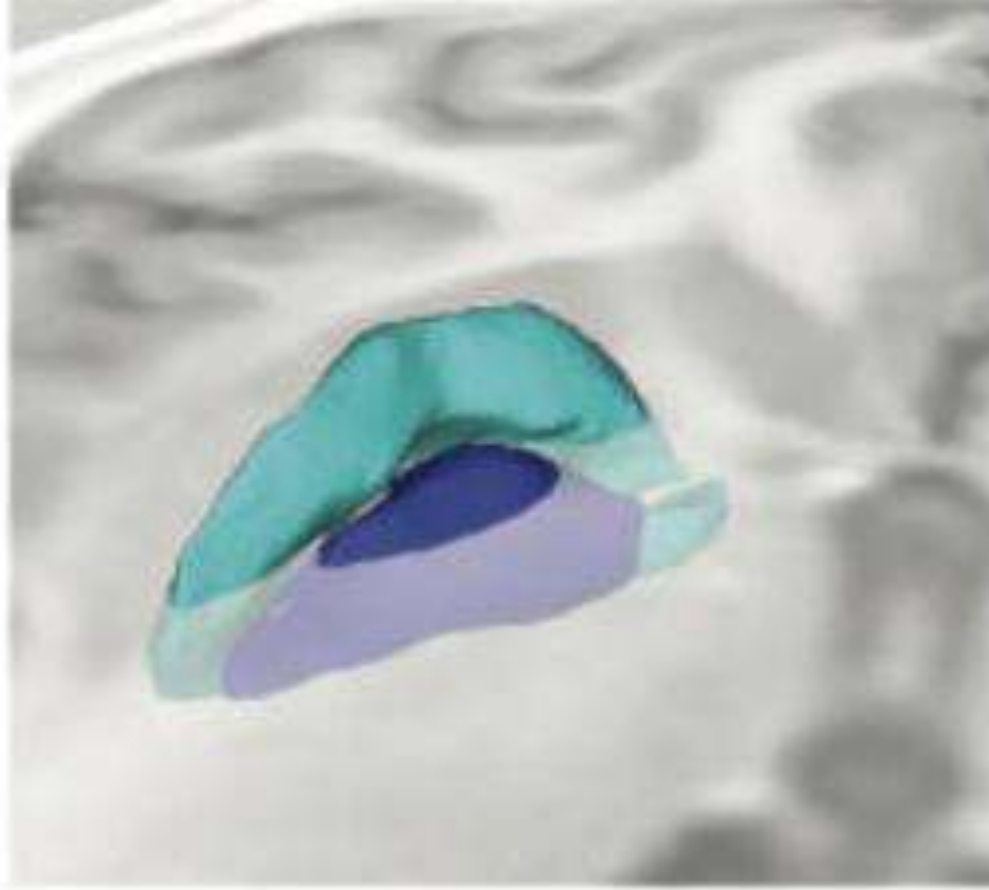


Dystonia GPI

GPI DBS in Dystonia - Hot Spot



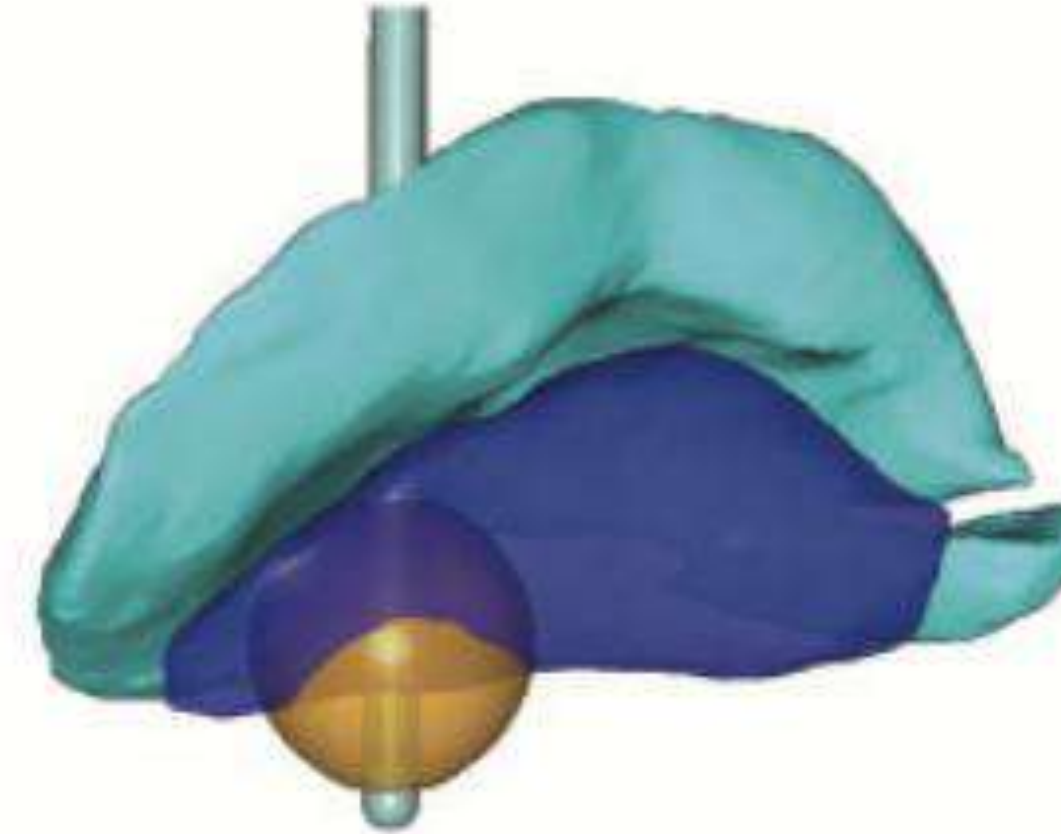
Hot spot - cluster analyzes



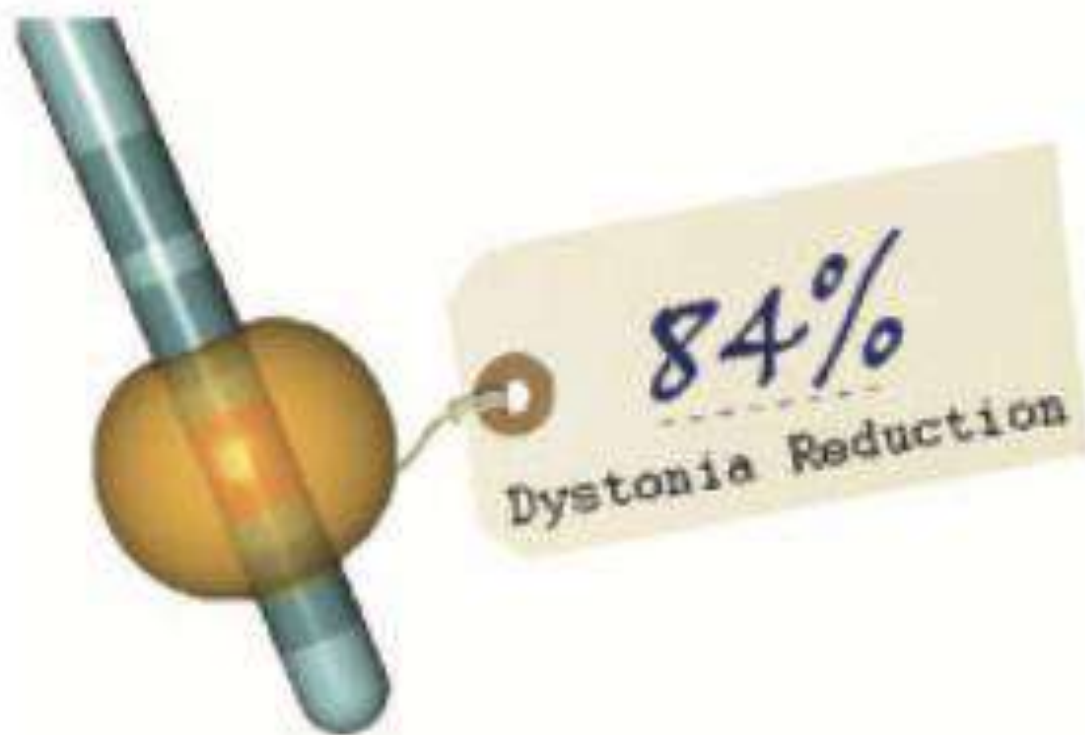
1. Registration of atlas



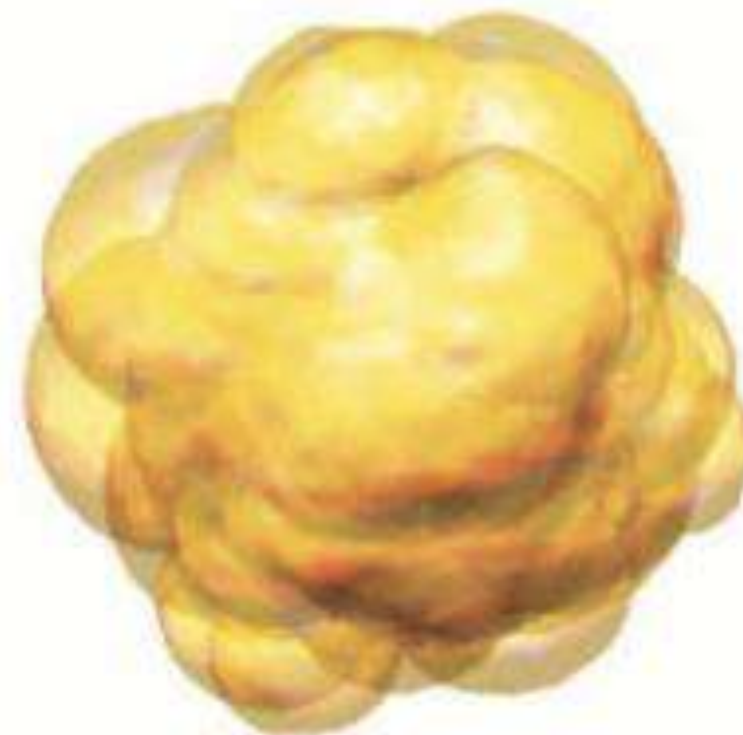
2. Detection of lead



3. Rendering of VTA



4. Scoring of therapy

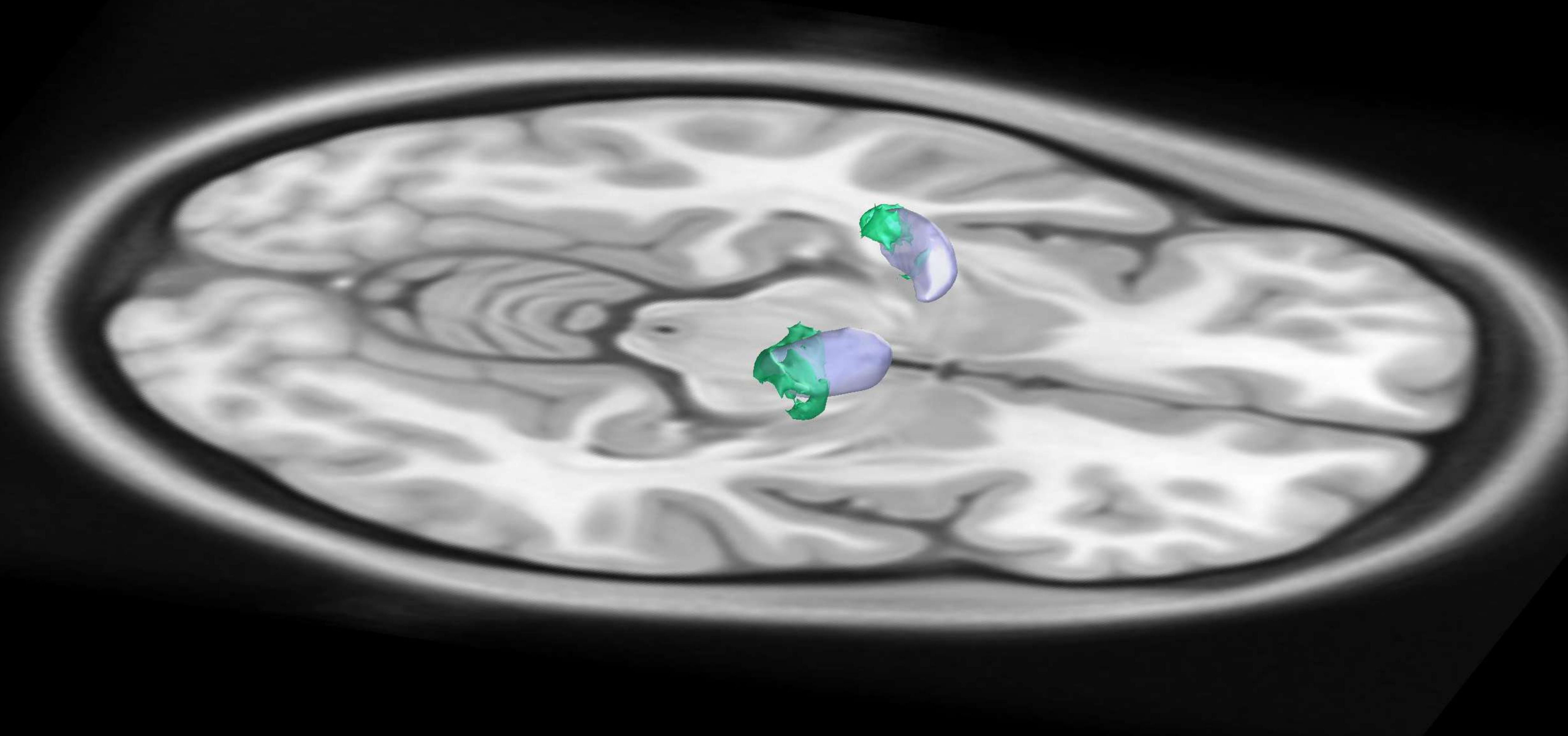


5. Aggregation of data

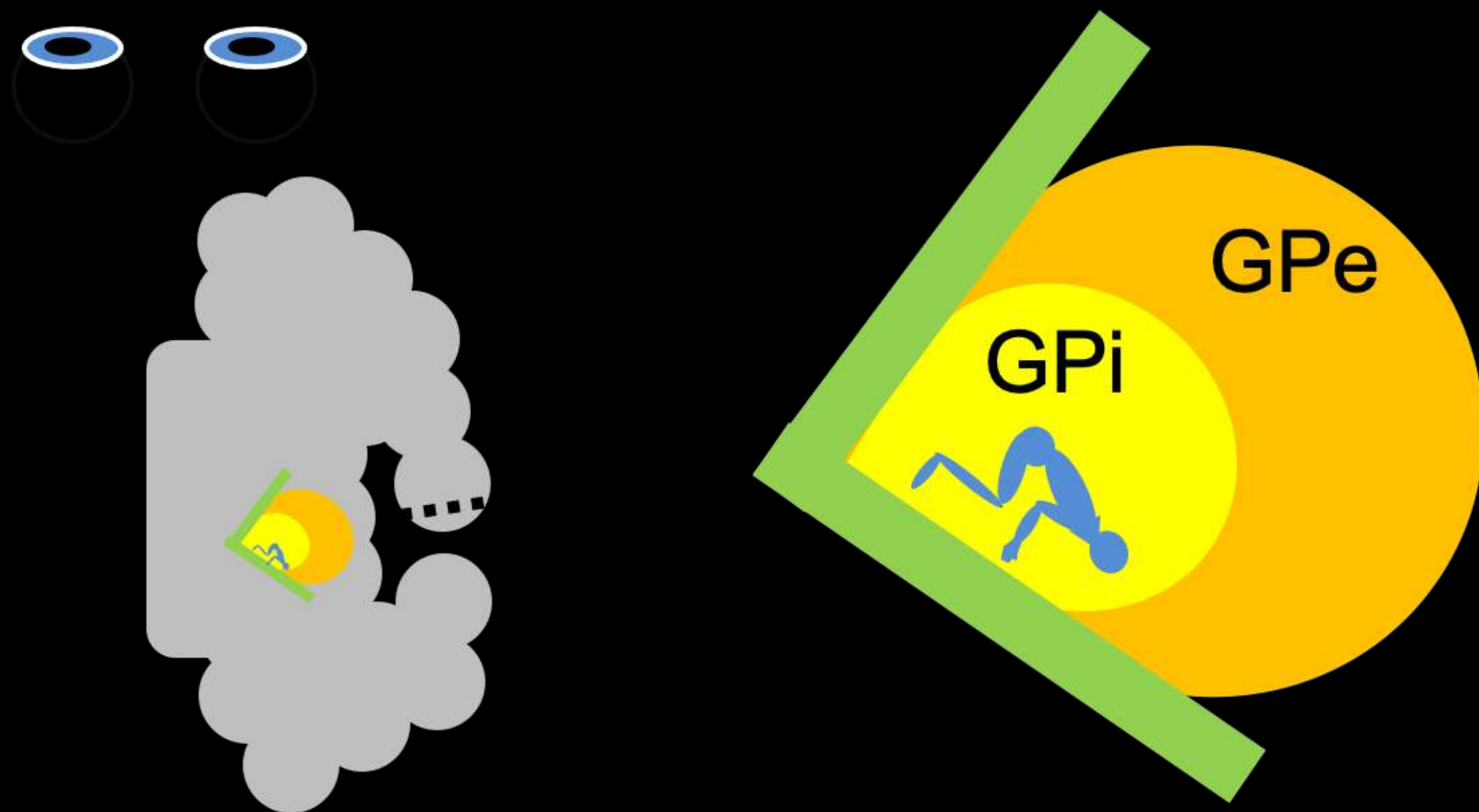


6. Statistical analysis

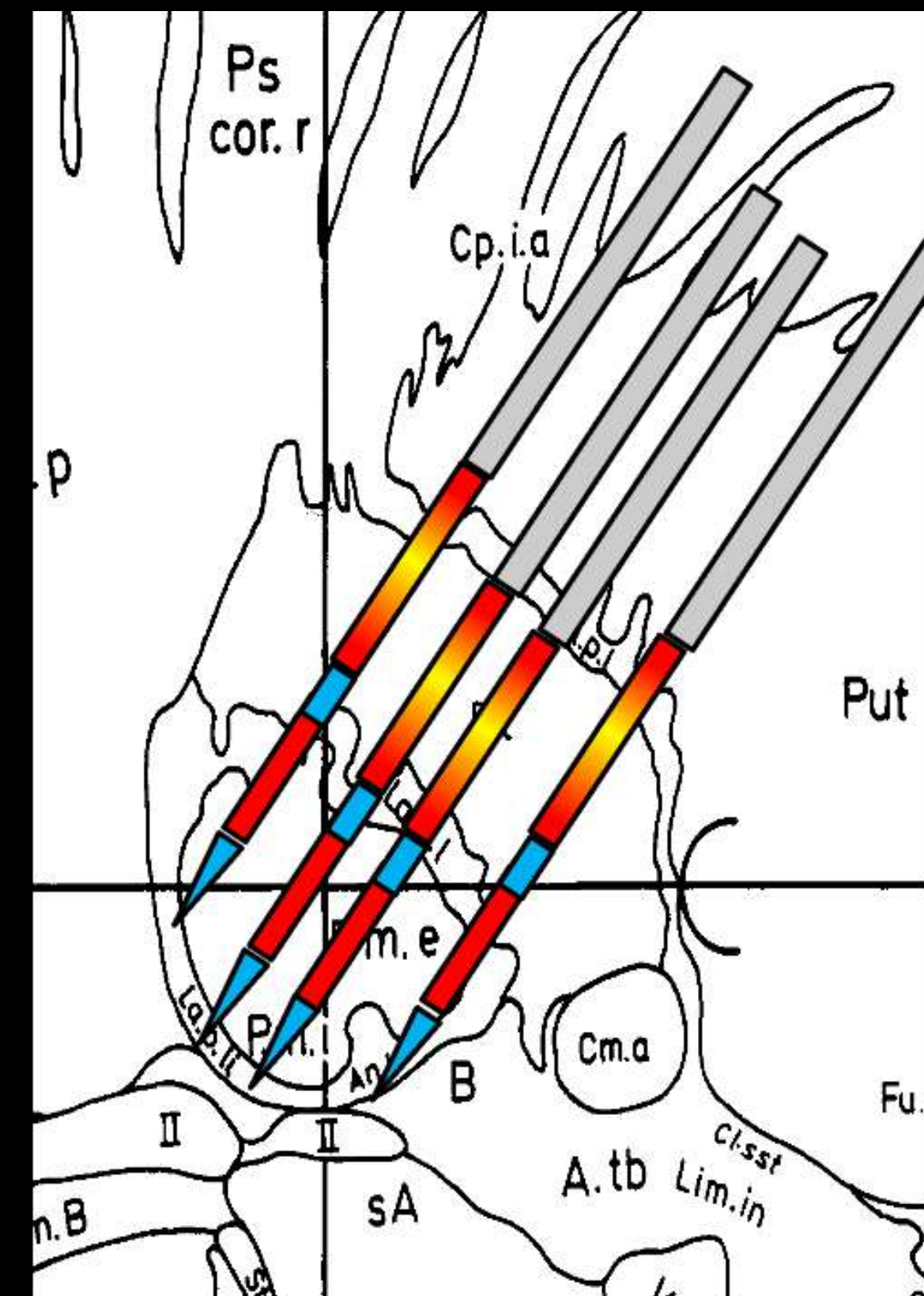
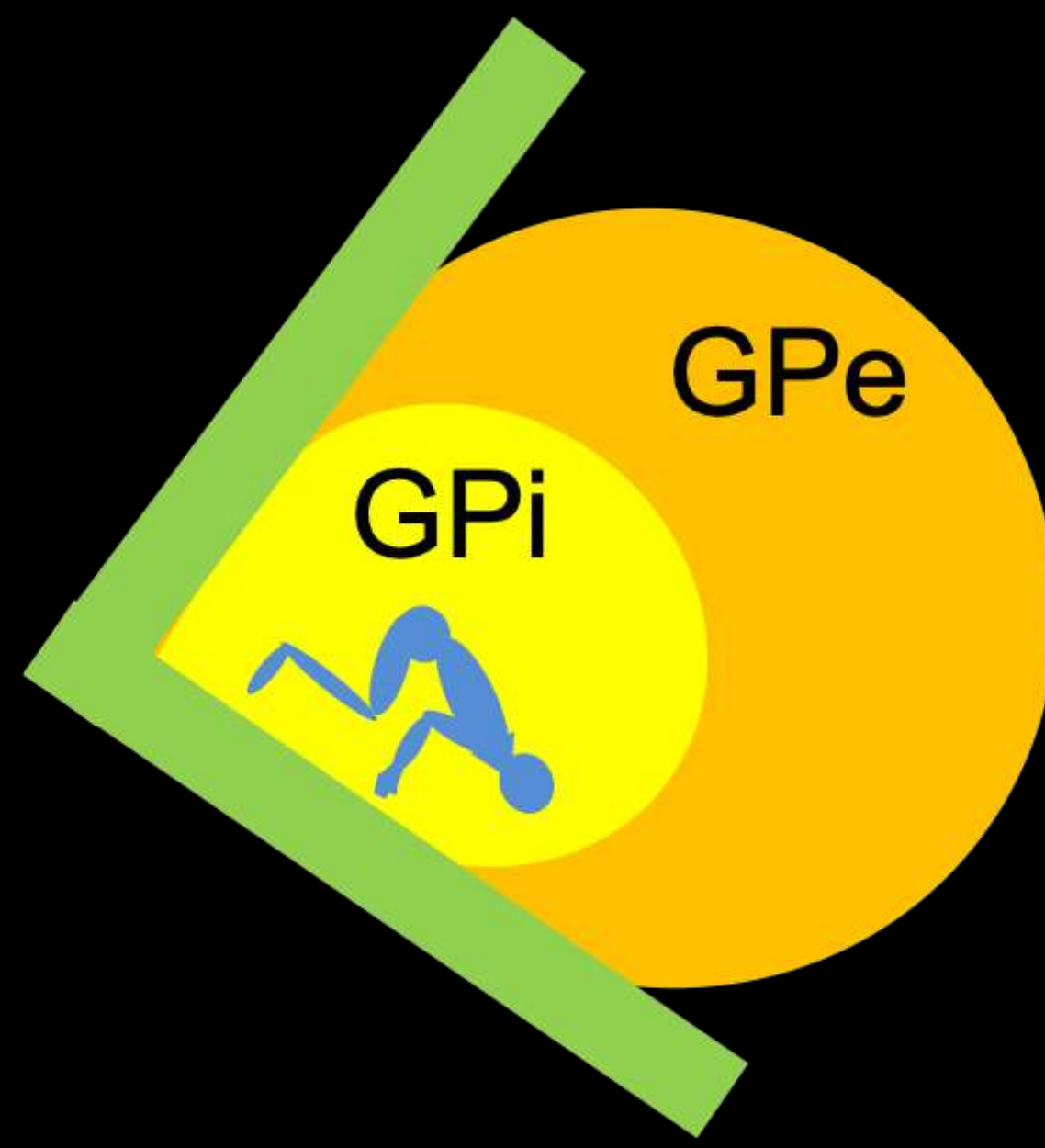
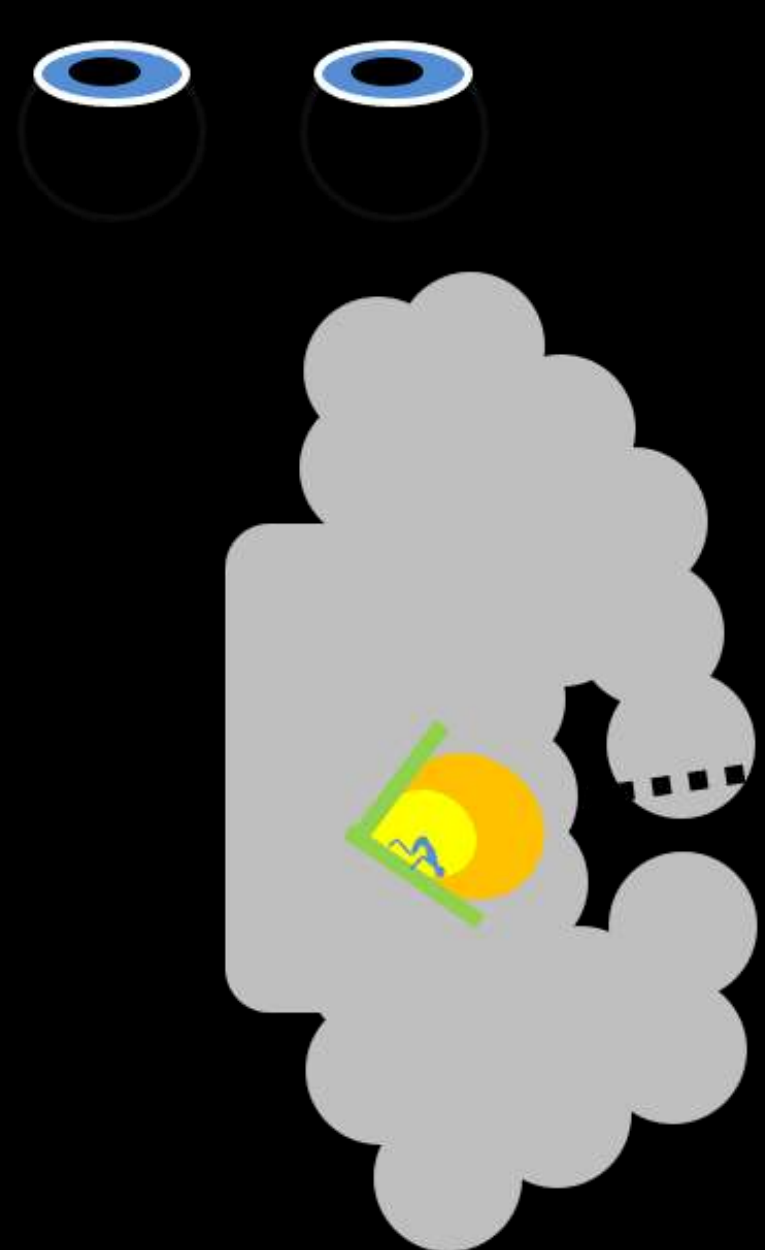
Hot spot - Cluster analyzes



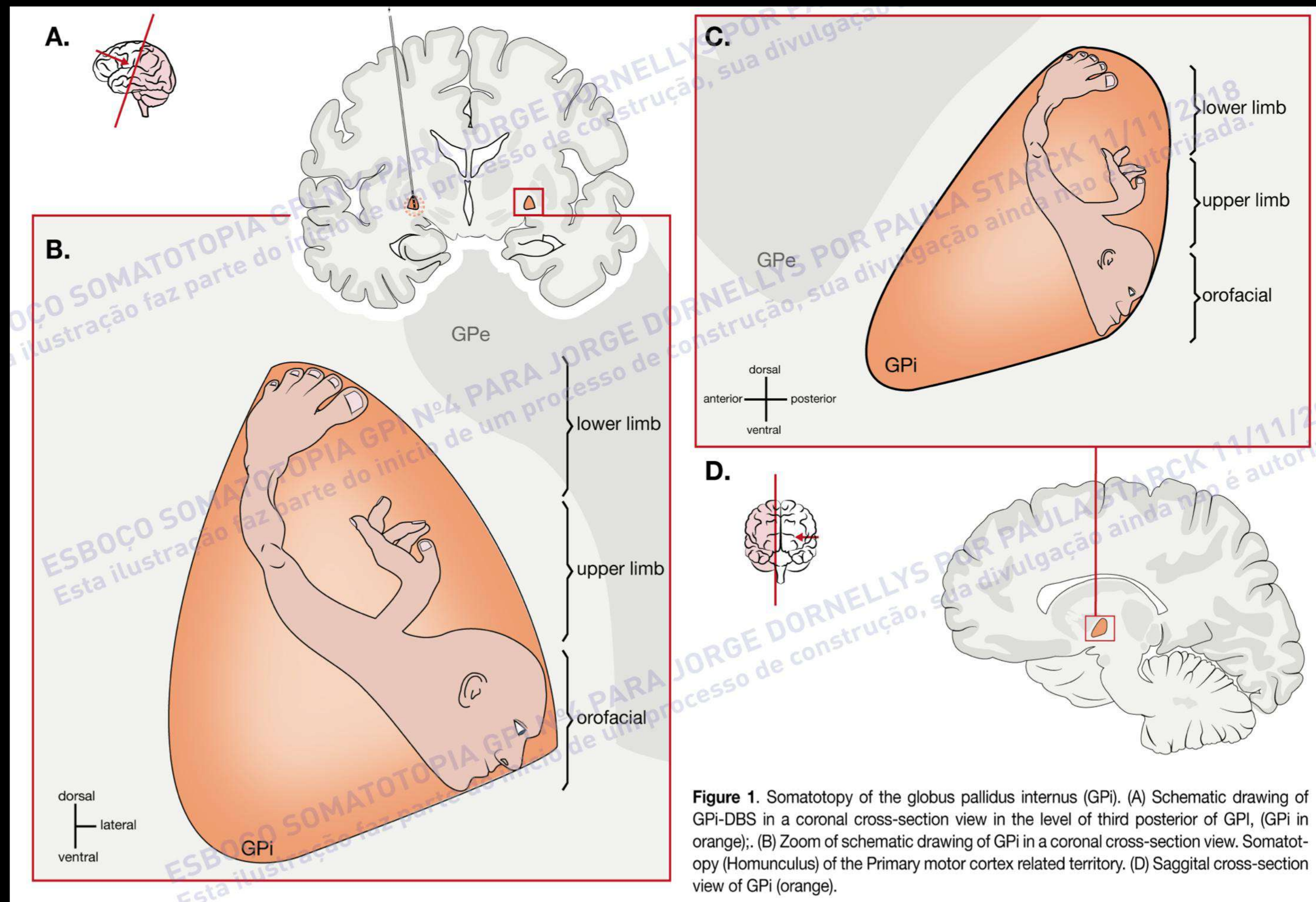
Should we change the target based on the dystonia localization?



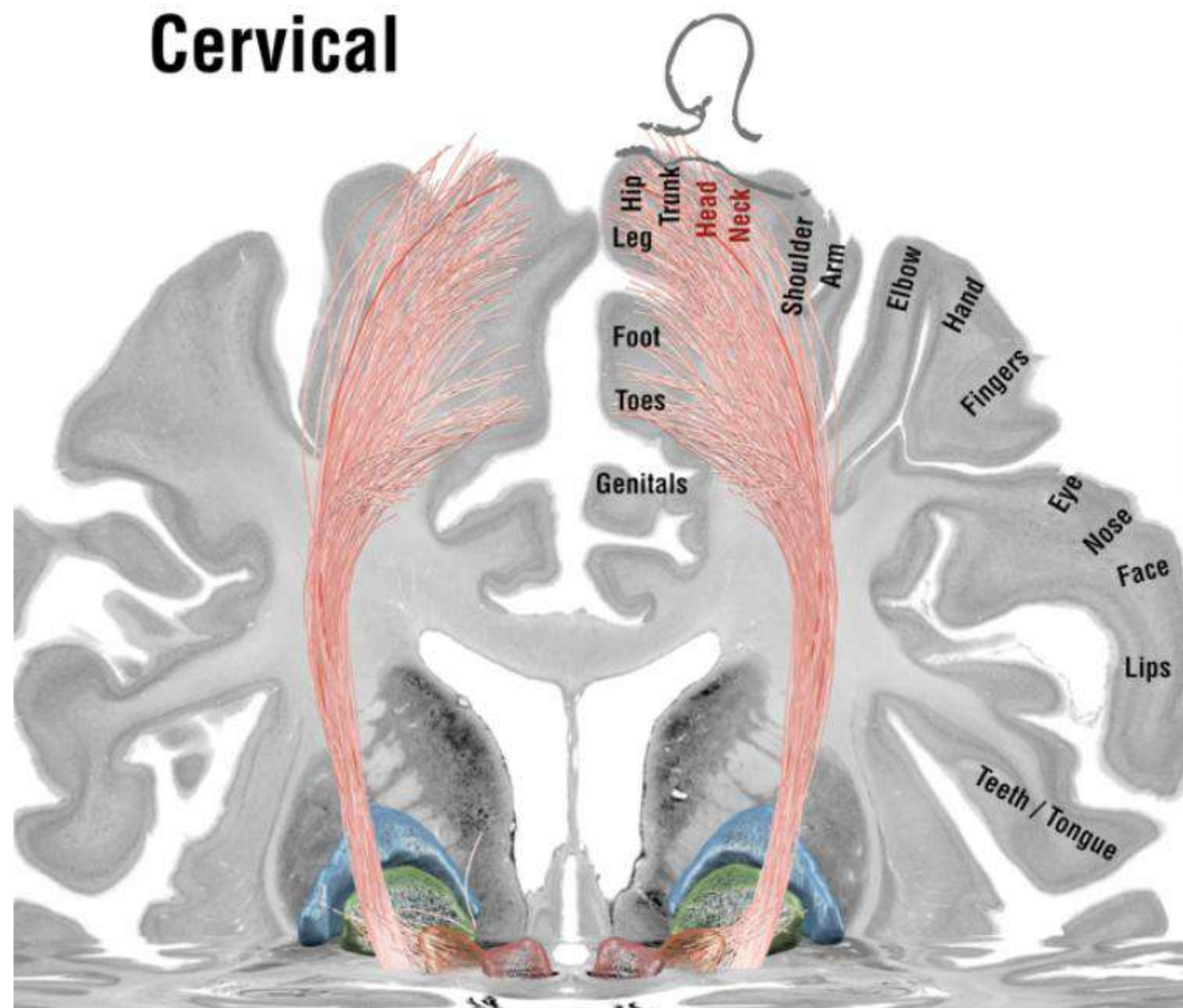
Should we change the target based on the dystonia localization?



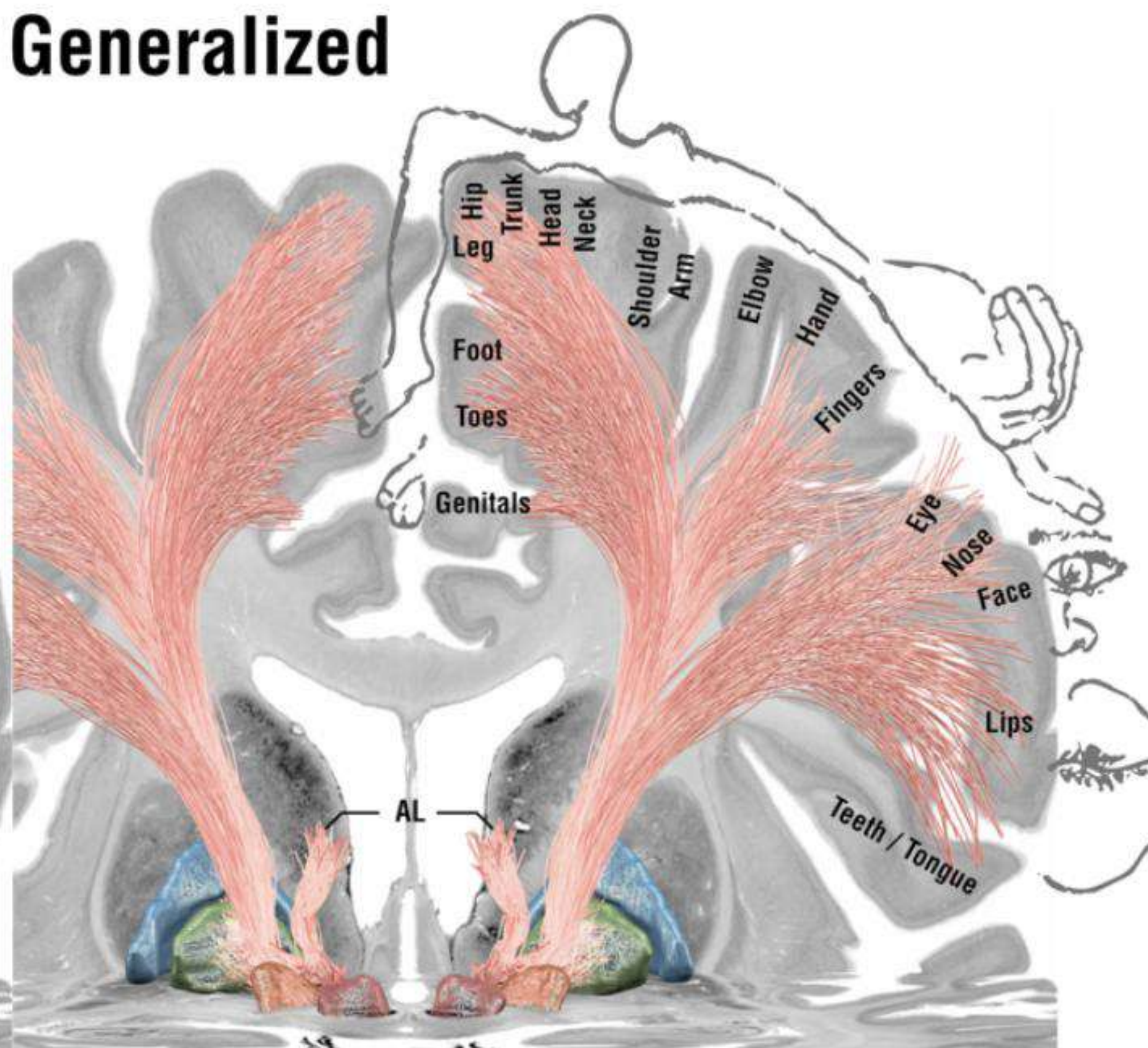
Should we change the target based on the dystonia localization?

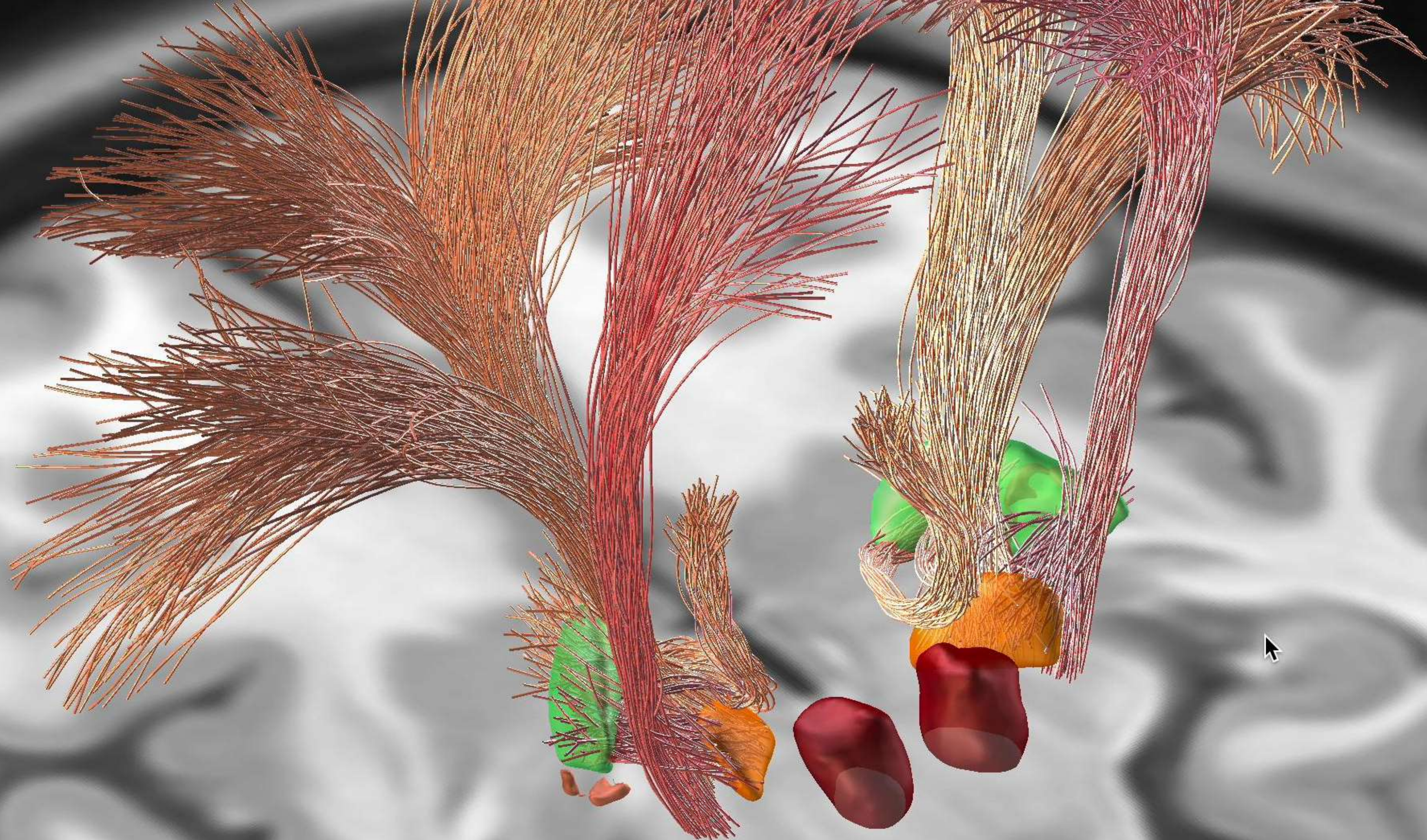


Cervical



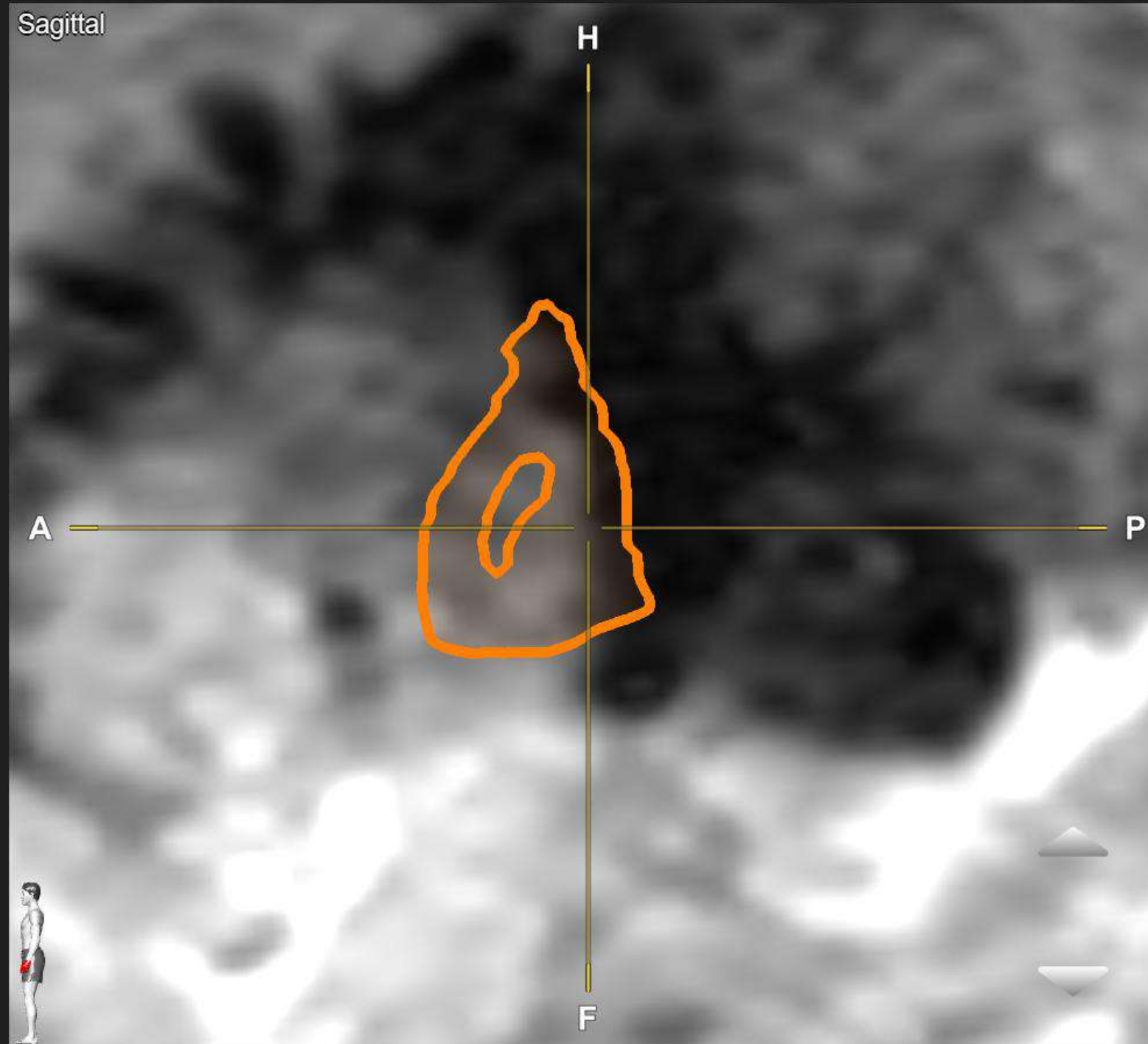
Generalized



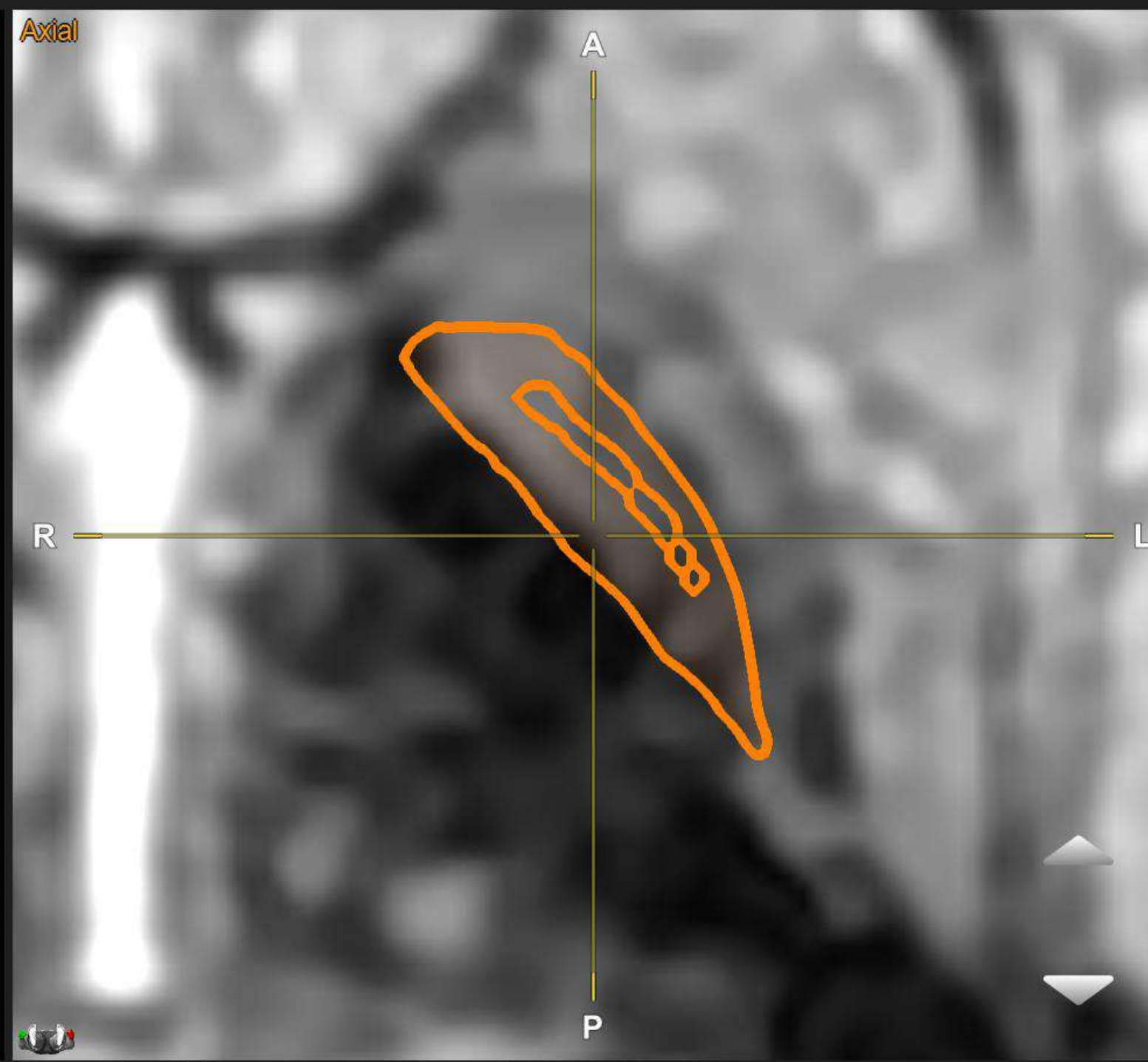


>> Objects

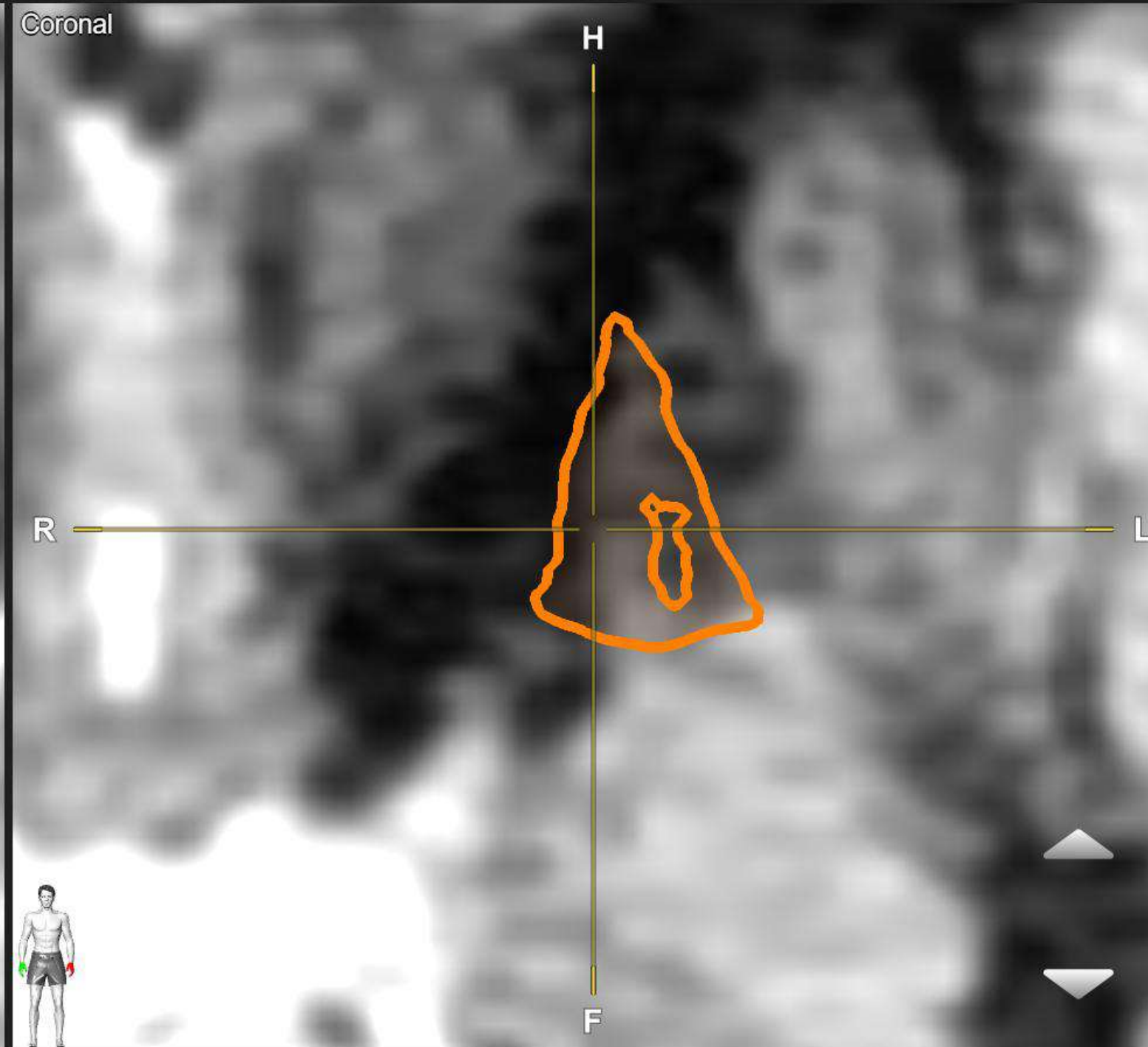
Sagittal



Axial



Coronal



Add Anatomy



NOT REVIEWED

Capsula Interna



☐ Globus Pallidus Exter...



☐ Globus Pallidus Exter...



☒ Globus Pallidus Intern...
0.59 cm³



☐ Globus Pallidus Intern...



☐ Globus Pallidus Intern...



☐ Globus Pallidus Intern...



☐ Globus Pallidus Intern...



☐ Hot Spot GPi D



☐ Nucleus Ruber Left



☐ Nucleus Ruber Right



☐ Subthalamic Nucleus ...



☐ Subthalamic Nucleus ...



Object Management


Scroll


Zoom


Pan


Windowing

Operations


Copy


Union


Intersection


Subtraction


Margin


Smooth


Mirror


Split


Position


Undo

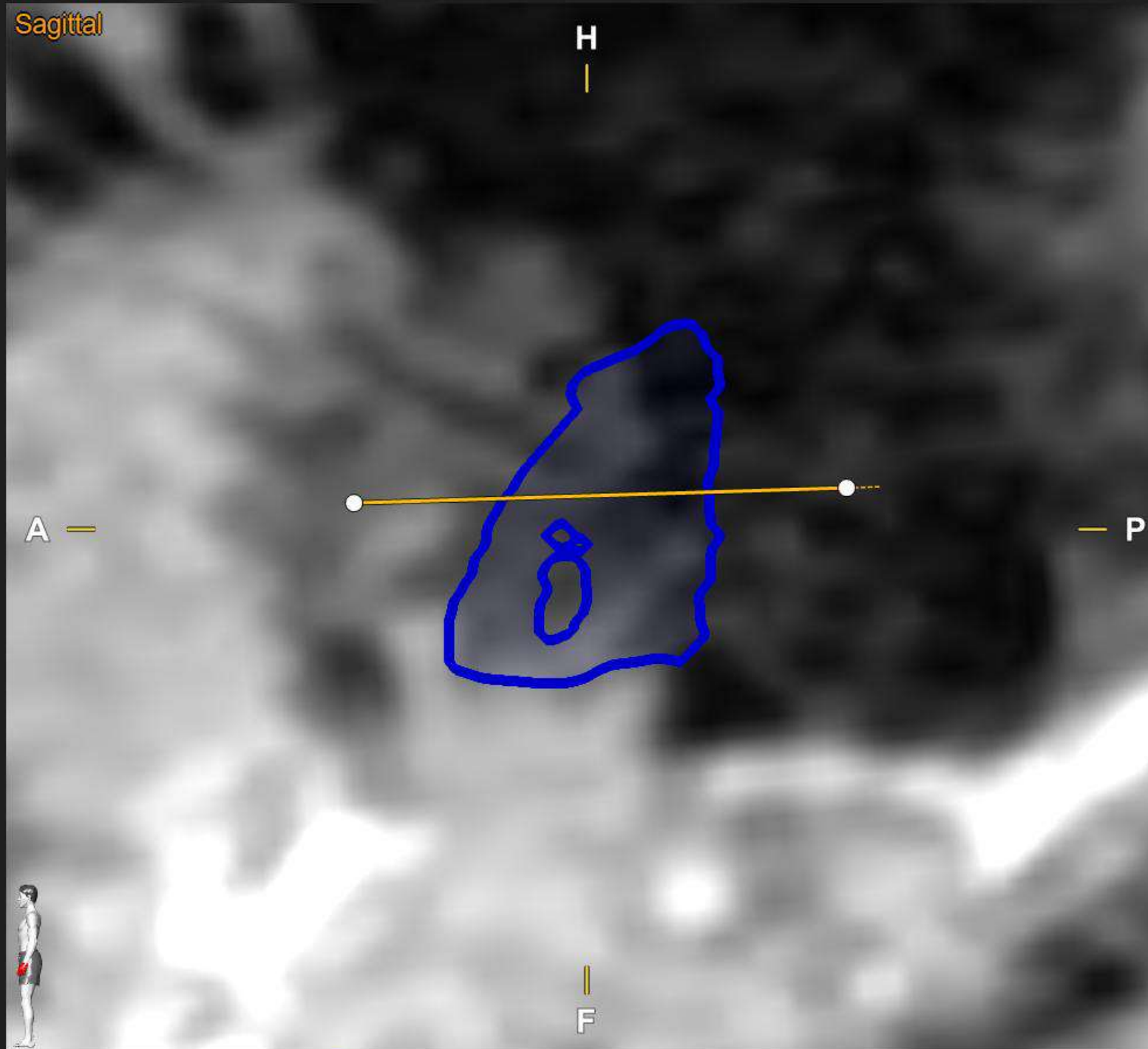

Back


Done

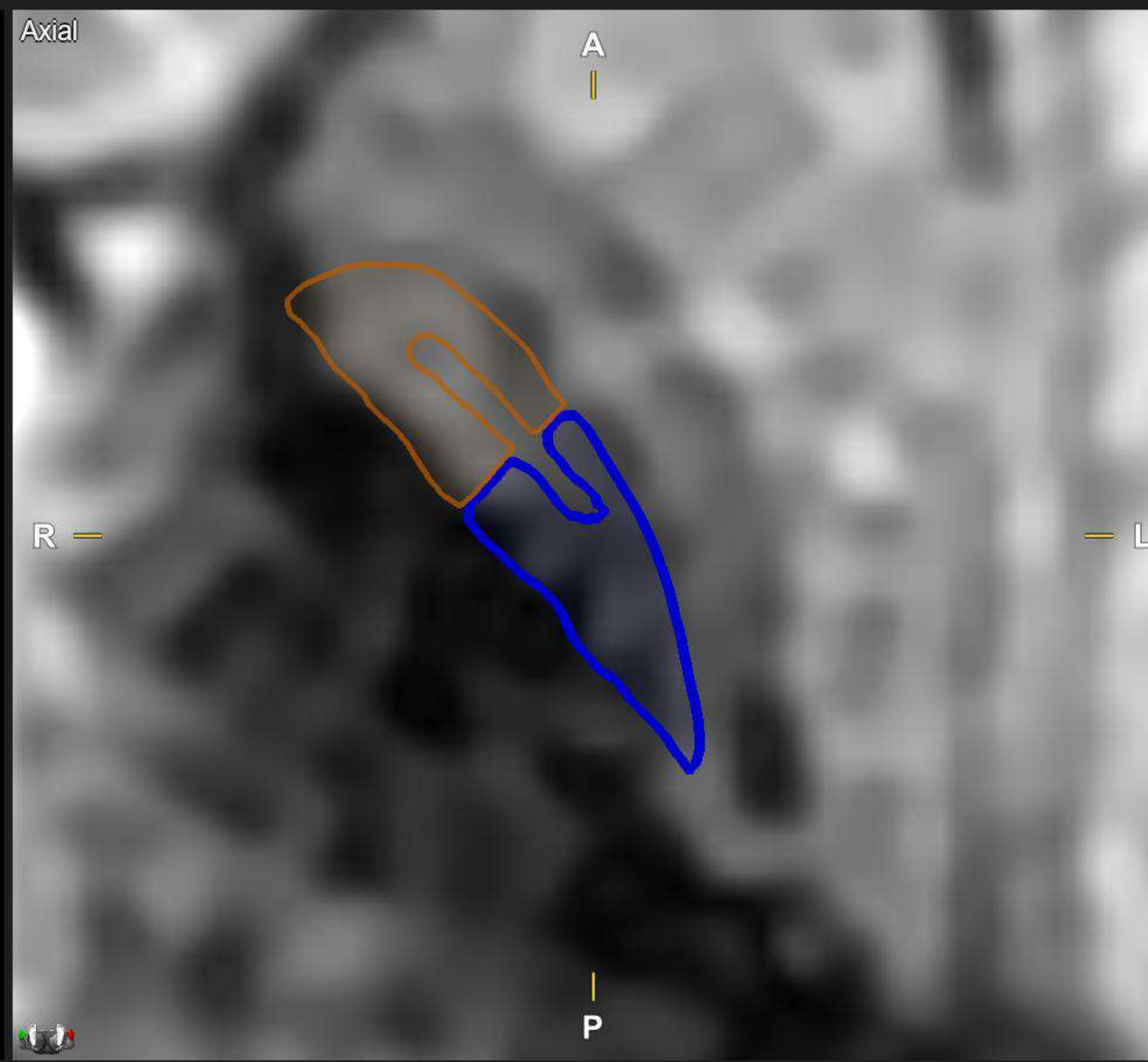


>> Objects

Sagittal



Axial



Coronal



Add Anatomy

NOT REVIEWED

Capsula Interna

☐

Globus Pallidus Exter...

☐

Globus Pallidus Exter...

☐

Globus Pallidus Intern...

☒

Globus Pallidus Intern...

0.31 cm³

☐

Globus Pallidus Intern...

☐

Globus Pallidus Intern...

☐

Globus Pallidus Intern...

☐

Globus Pallidus Intern...

☐

Globus Pallidus Intern...

☐

Hot Spot GPi D

☐

Nucleus Ruber Left

☐

Nucleus Ruber Right

☐

Subthalamic Nucleus ...

☐

Subthalamic Nucleus ...

SPLIT

Split Object

Alerts

Data

Home

Object Management

Scroll

Pan

Zoom

Windowing

Operations

Copy

Union

Intersection

Subtraction

Margin

Smooth

Mirror

Split

Position

Undo

Back

Done

BRAINLAB

» Objects



A sagittal CT scan of the pelvis. A vertical line is labeled 'H' at the top and 'F' at the bottom. A horizontal line is labeled 'A' on the left and 'P' on the right. A blue outline represents a tumor in the pelvic region. A small human figure is visible in the bottom left corner, and navigation arrows are in the bottom right corner.

Axial

A

R

L

P

P

F



Capsula Interna

 Subthalamus



Data

 Home

Windowing



Smooth



Split



B-I

Back

E 44



BRAINLAB



PROGRAM

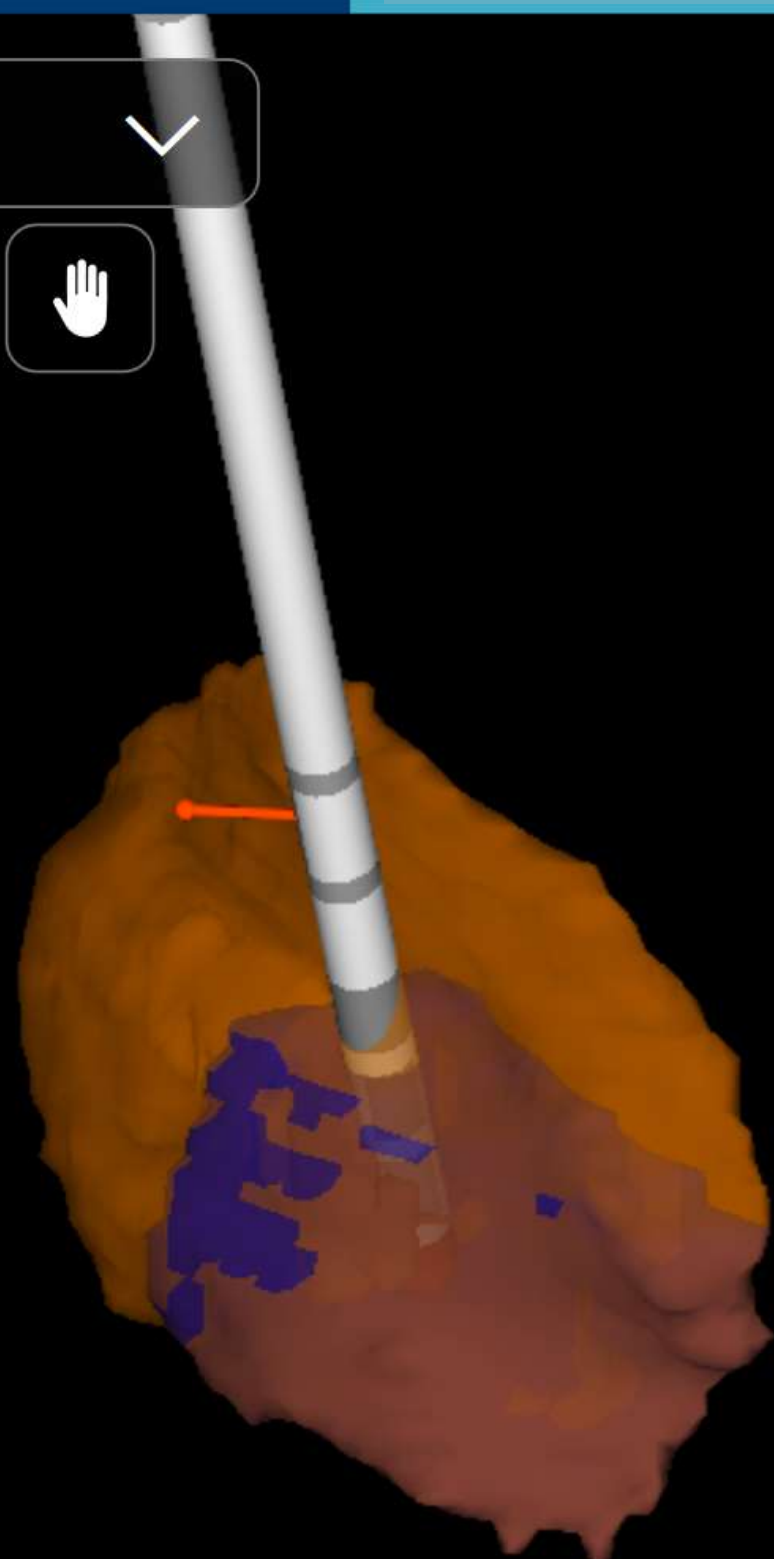
IPG12913



06:26 PM



3D Overview



- PROGRAM
- All Object
- Program 1
- AREAS
- Globus Pallidus External Left
- Globus Pallidus Internal Left
- 0.0 mA
- Globus Pallidus Internal Left (Split 1)
- Right stn
- Globus Pallidus Internal Left (Split 1) (...)
- Globus Pallidus Internal Left (Split 2)
- + Area
- Hot Spot GPi E
- + Area
- Nucleus Ruber Left
- Subthalamic Nucleus Left

IPG
+100%

PROGRAMMING MODE

Steering



STIMULATION

☐ OFF

0.1 Step

0.0
mA



+

-

60 μ s

130 Hz

STEERING



LEVEL
L1.0



DIRECTION
Ring



FOCUS
0%



PATIENT CONTROL

Disabled

CLINICAL EFFECT

Benefit

Side Effect

Details

CLINICAL EFFECTS MAP



0mA

1mA

2mA

3mA

4mA

5mA

6mA



Check

STOP ALL

L2

L1

1

-100%



PROGRAM

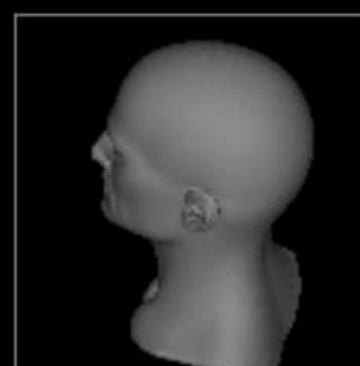
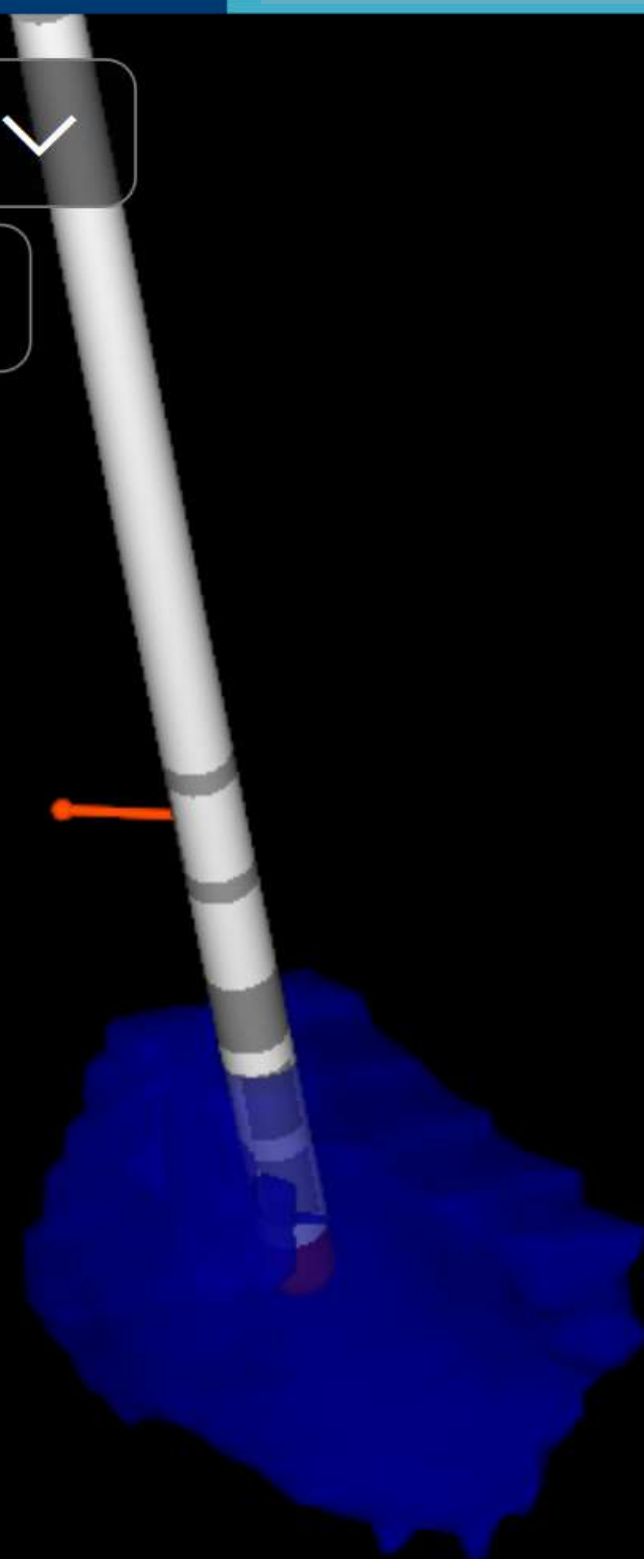
IPG12913



06:26 PM



3D Overview



CLINICAL EFFECTS MAP



0mA

1mA

2mA

3mA

4mA

5mA

6mA



- PROGRAM
- Program 1
- AREAS
- Globus Pallidus External Left
- Globus Pallidus Internal Left
- Globus Pallidus Internal Left (Split 1)
- Globus Pallidus Internal Left (Split 1) (...)
- Globus Pallidus Internal Left (Split 2)
- Hot Spot GPi E
- Nucleus Ruber Left
- Subthalamic Nucleus Left



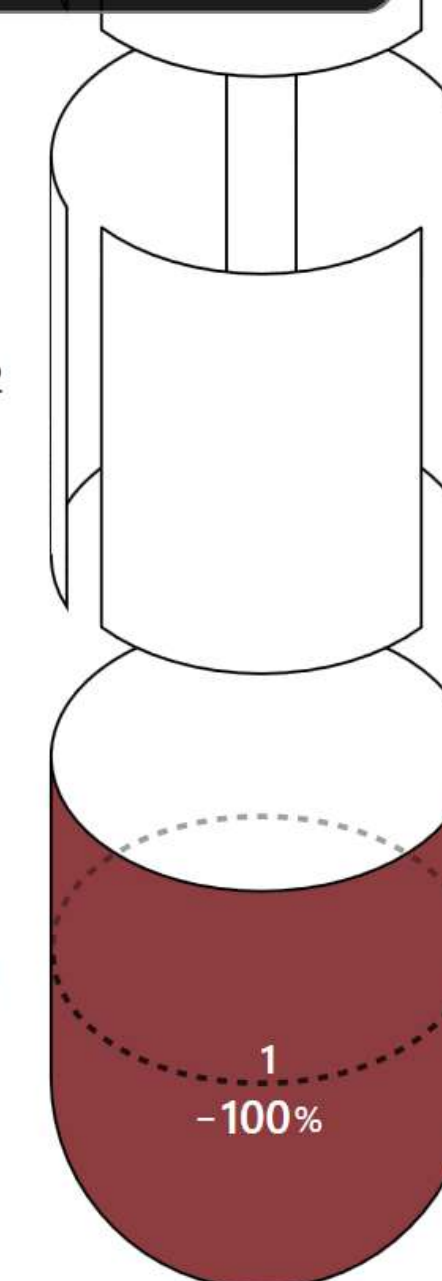
Check



STOP ALL

L2

L1



IPG
+100%

PROGRAMMING MODE

Steering



STIMULATION



OFF

0.1 Step

0.0

mA

+

-



60 μ s

130 Hz

STEERING



LEVEL
L1.0



DIRECTION
Ring



FOCUS
0%



PATIENT CONTROL



Disabled

CLINICAL EFFECT

Benefit

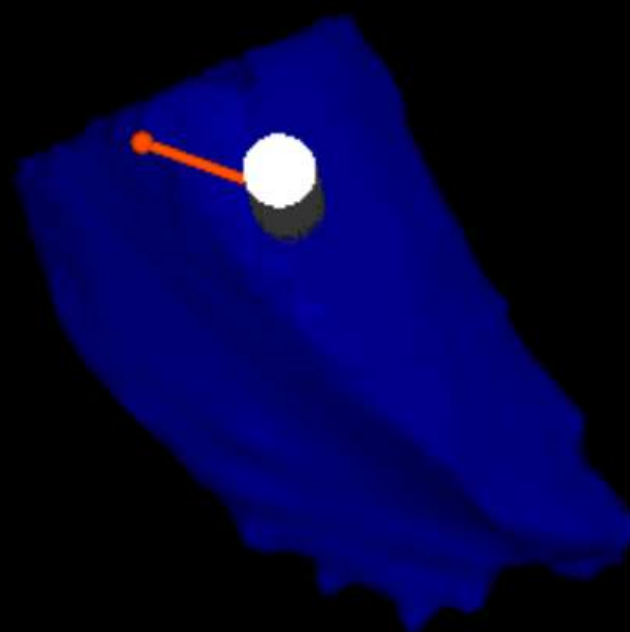
Side Effect

Details



PROGRAM

3D Overview



CLINICAL EFFECTS MAP



0mA

1mA

2mA

3mA

4mA

5mA

6mA



PROGRAM

Program 1



AREAS

Left

0.0 mA



Right

0.0 mA



+ Area

+ Area

Check

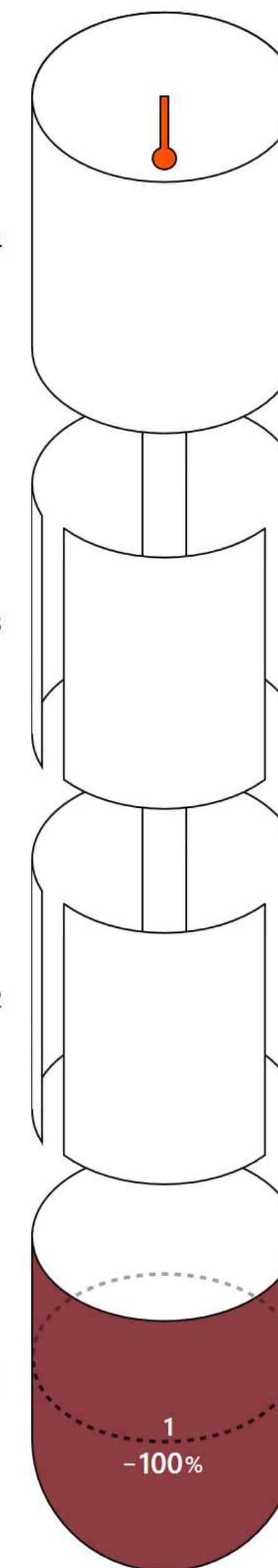
STOP ALL

L4

L3

L2

L1



IPG
+100%

PROGRAMMING MODE

Steering



STIMULATION

☐ OFF

0.1 Step

0.0

mA



+

-

60 μ s

130 Hz

STEERING



LEVEL
L1.0



DIRECTION
Ring



FOCUS
0%



PATIENT CONTROL

Disabled

CLINICAL EFFECT

Benefit

Side Effect

Details



PROGRAM

IPG12913



06:31 PM



3D Overview



PROGRAM

Program 1



AREAS

Left

0.0 mA



Right

0.0 mA



+ Area

+ Area

Ω Check

STOP ALL



Create Illumina 3D™ Simulation

Select Target and Avoidance Regions to Create an Illumina 3D™ Simulation

Select Target Region

Globus Pallidus External Left

Globus Pallidus Internal Left

Globus Pallidus Internal Left (Split 1)

Globus Pallidus Internal Left (Split 1) (Split 2)

Globus Pallidus Internal Left (Split 2)

Hot Spot GPi E

Nucleus Ruber Left

Subthalamic Nucleus Left

Select Avoid Region(s)

Globus Pallidus External Left

Globus Pallidus Internal Left

Globus Pallidus Internal Left (Split 1)

Globus Pallidus Internal Left (Split 1) (Split 2)

Globus Pallidus Internal Left (Split 2)

Hot Spot GPi E

Nucleus Ruber Left

Subthalamic Nucleus Left

Fill/Spill Weighting



Target/Avoidance Weighting



Calculate

Load Settings

CLINICAL EFFECTS MAP



0mA

1mA

2mA

3mA

4mA

5mA

6mA



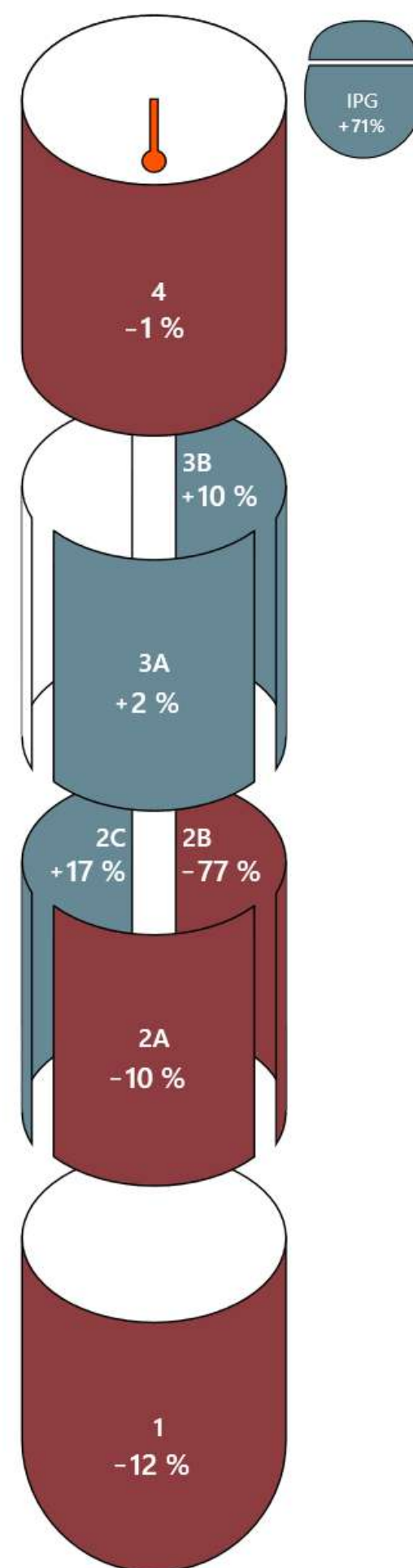


3D Overview



Load Simulation Settings

Program 1 > Left



SIMULATION

7.1 mA

60 μ s

130 Hz

RAMP SPEED

Slow (0.1 mA/sec)



i Amplitude adjustment will occur in 0.1 mA increments each second.

Accept

CLINICAL EFFECTS MAP



0mA

1mA

2mA

3mA

4mA

5mA

6mA



STOP ALL

Calculate

Load Settings

ons to Create an

ect Avoid Region(s)

obus Pallidus External Left

obus Pallidus Internal Left

obus Pallidus Internal Left
plit 1)obus Pallidus Internal Left
plit 1) (Split 2)obus Pallidus Internal Left
plit 2)

ot Spot GPi E

ucleus Ruber Left

bthalamic Nucleus Left

get/Avoidance Weighting

et

Avoidance

plitude: 7.1 mA



PROGRAM

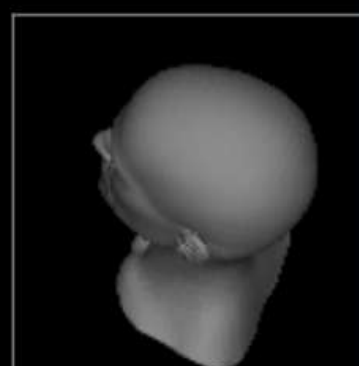
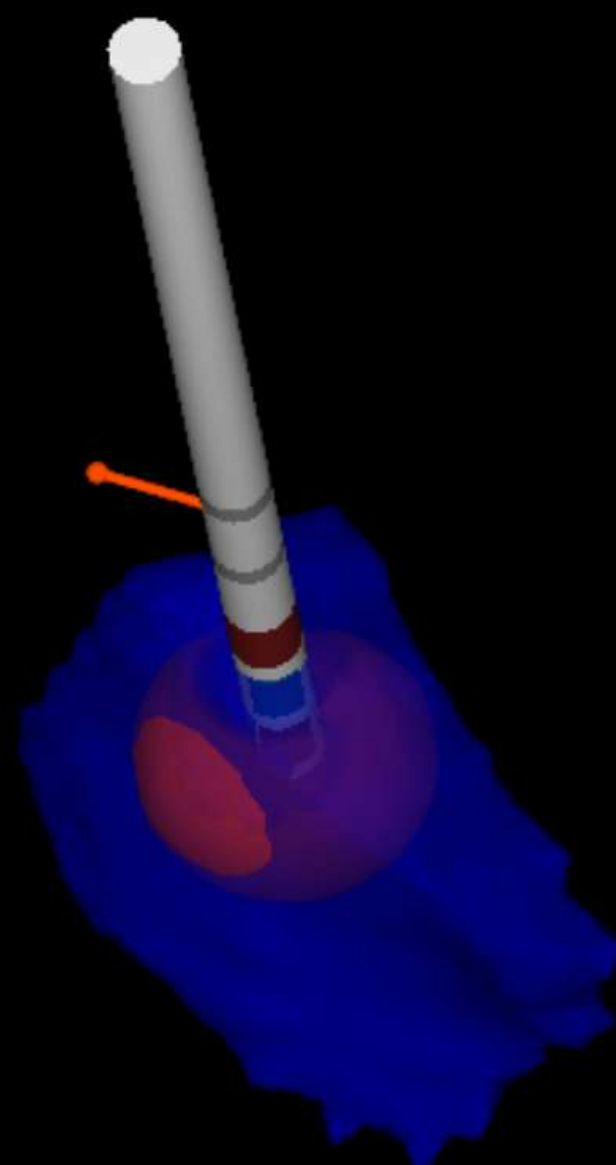
IPG12913



06:32 PM



3D Overview



CLINICAL EFFECTS MAP



PROGRAM

Program 1



AREAS

Left

2.5 mA



Right

0.0 mA



+ Area

+ Area

Ω Check

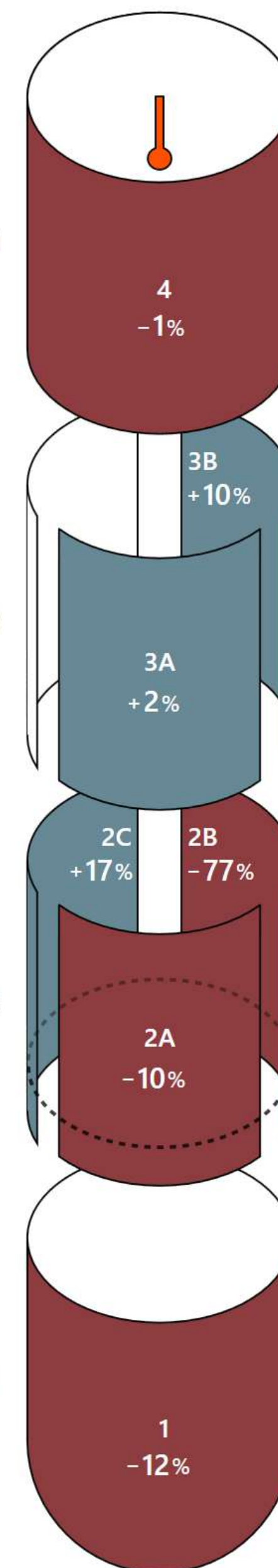
STOP ALL

L4

L3

L2

L1



IPG
+71%

PROGRAMMING MODE

Steering



STIMULATION

ON

0.5 Step

2.5
mA

+

-



60 μs

130 Hz

STEERING

Illumina 3D™



LEVEL
L1.8



DIRECTION
Ant-Lat



Solution
7.1 mA, 60 μs

PATIENT CONTROL



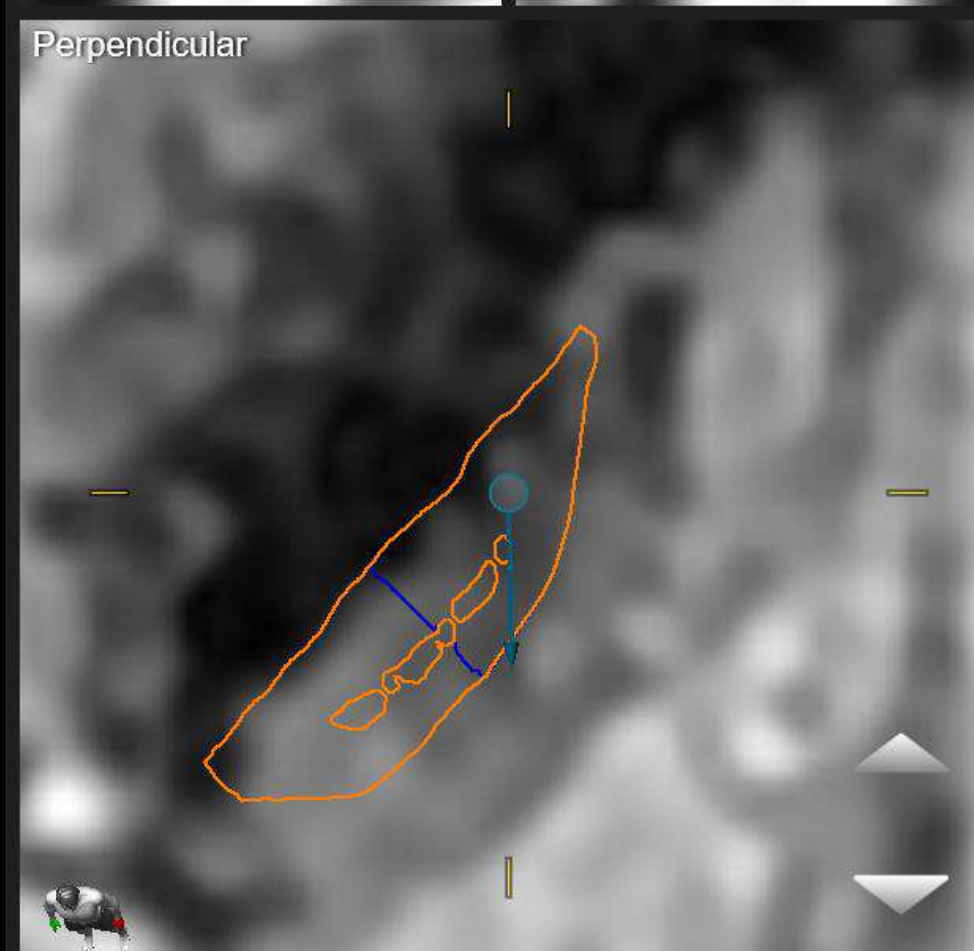
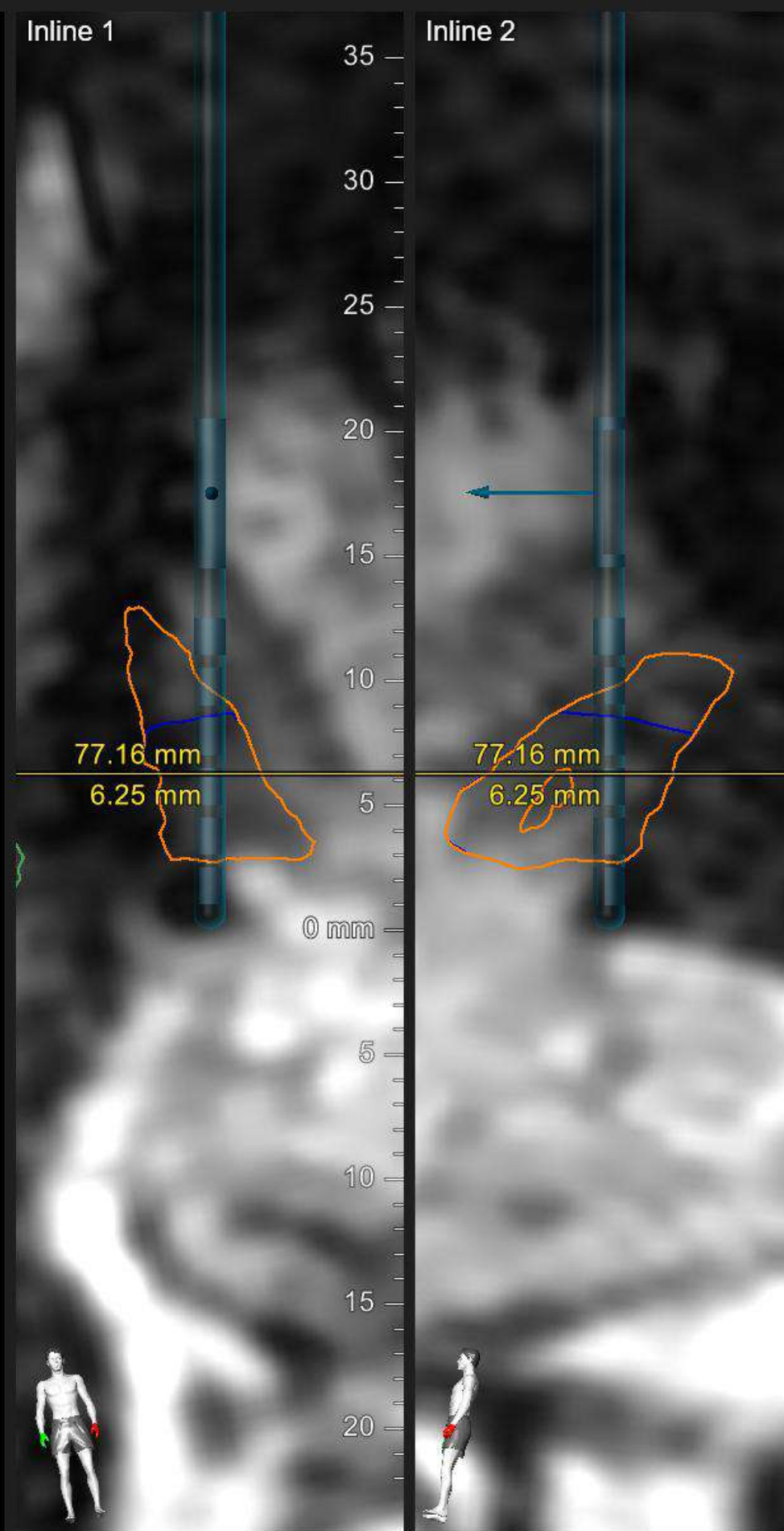
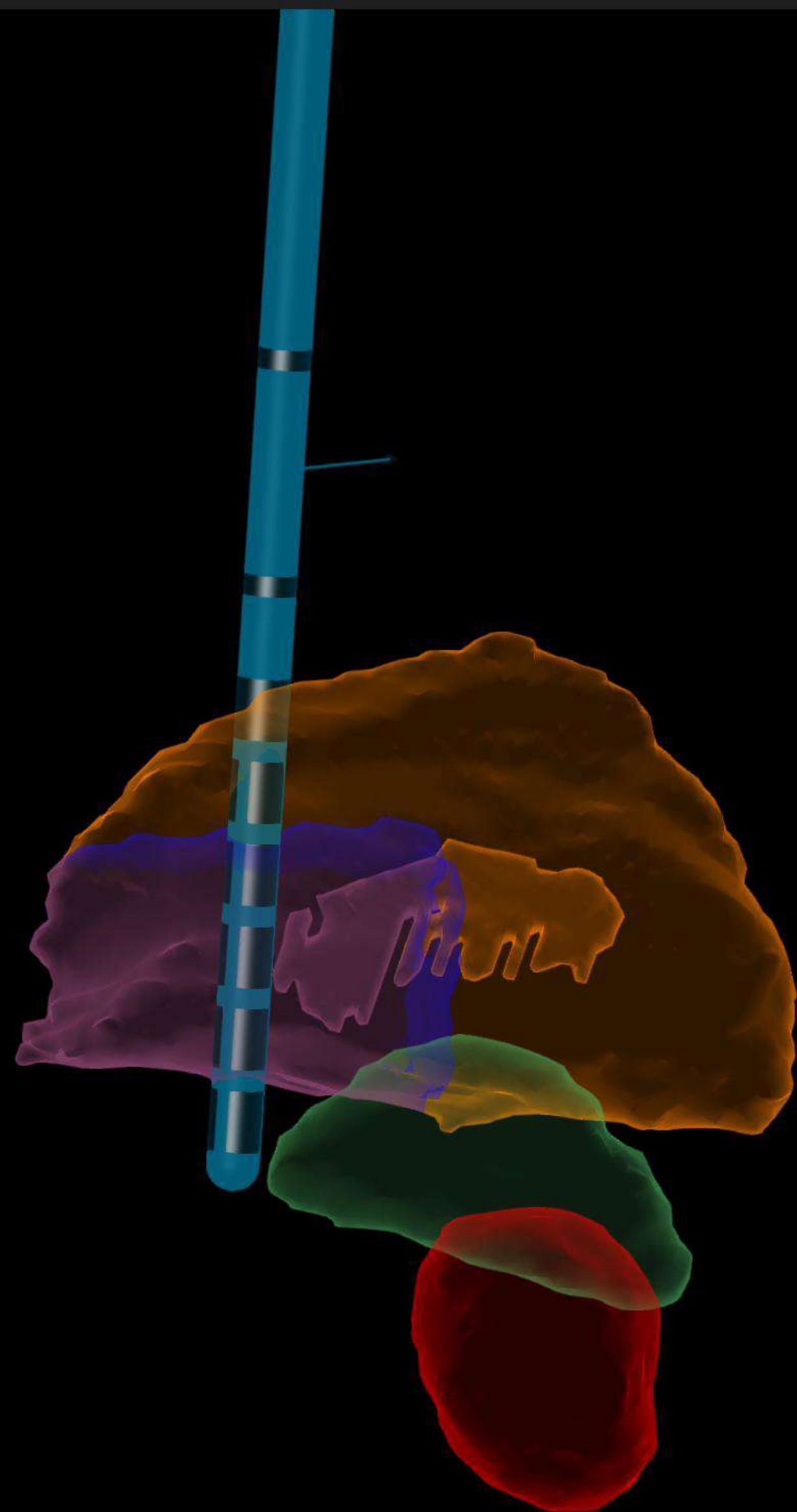
Disabled

CLINICAL EFFECT

Benefit

Side Effect

Details



Alerts Data Home

Parameters Effects 0 0

Steering Manual

mA %

Pulse (μs) Rate (Hz)

Amplitude (mA) Steps

Contact %

Comment

Color

GUIDE XT™

Scroll Zoom

Pan Rotate

Lead Gpi e

Windowing Configuration

Center

Back Done

BRAINLAB



Parkinson's disease

GPI

Clinical Case



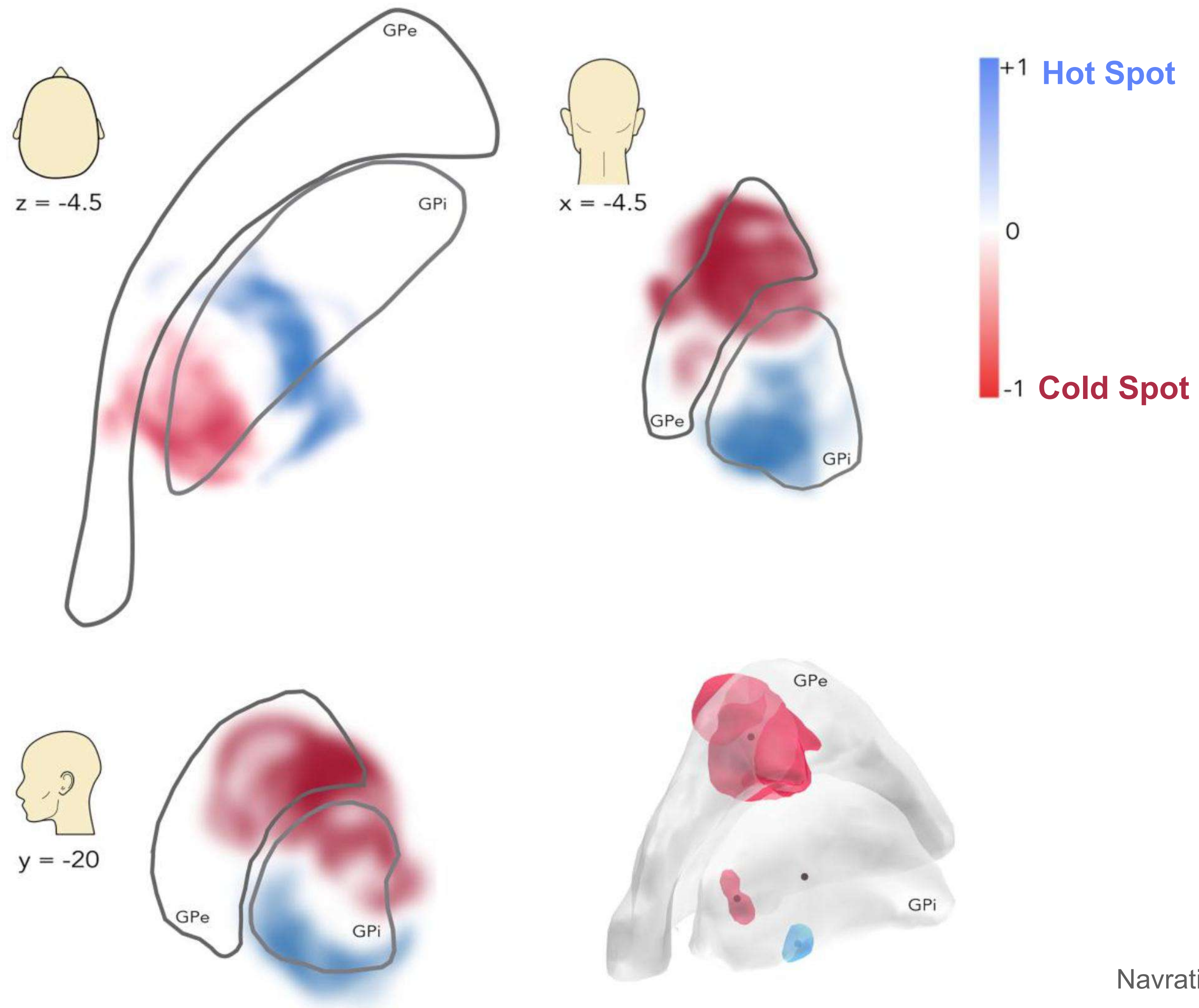
Female, 65 years-old, Parkinson's disease for 17 years



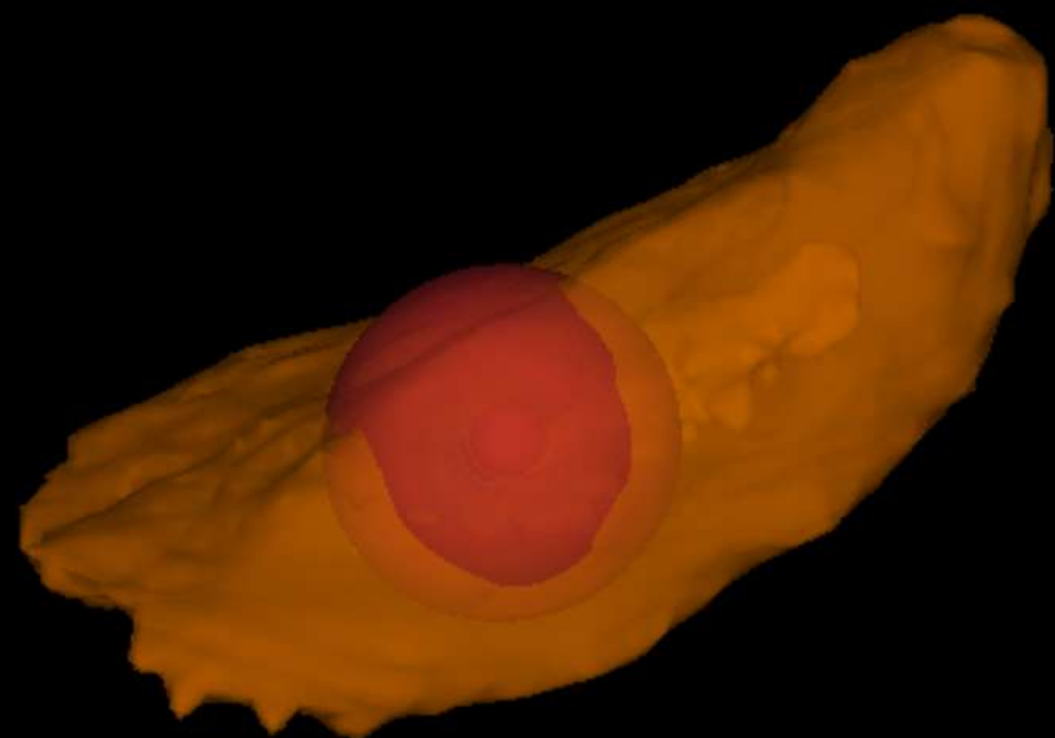
Off-med/ Off-stim



Off-med/On-stim GPi



3D Overview



CLINICAL EFFECTS MAP



PROGRAM

Program 3

AREAS

Left Gpi
3.1 mA

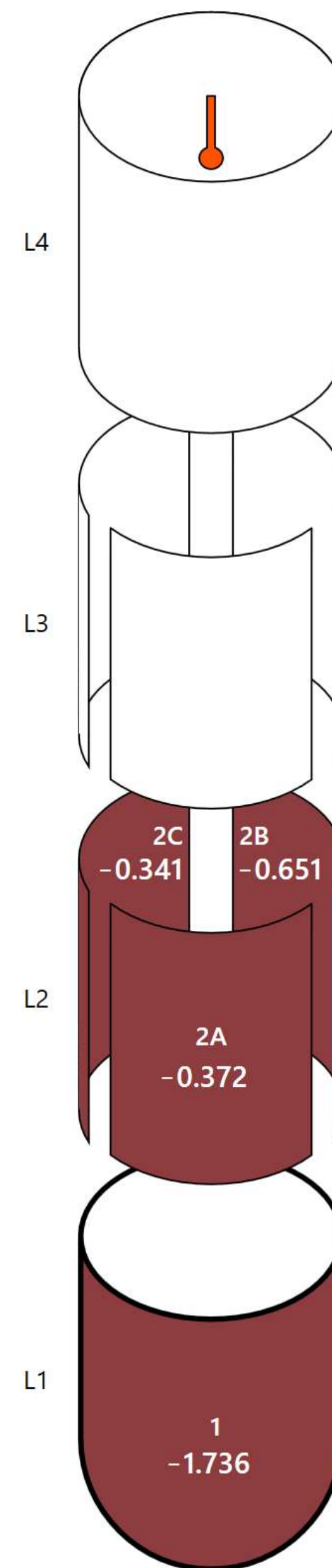
Right Gpi
1.6 mA

+ Area

+ Area

Ω Check

STOP ALL



IPG
+3.1

PROGRAMMING MODE

Custom

STIMULATION

ON

0.1 Step

3.1
mA

...

70 μs

130 Hz

CONTACT CONTROL

1% Step

1
-1.736

Equalize

Clear All

PATIENT CONTROL

0.0 mA - 4.0 mA

CLINICAL EFFECT

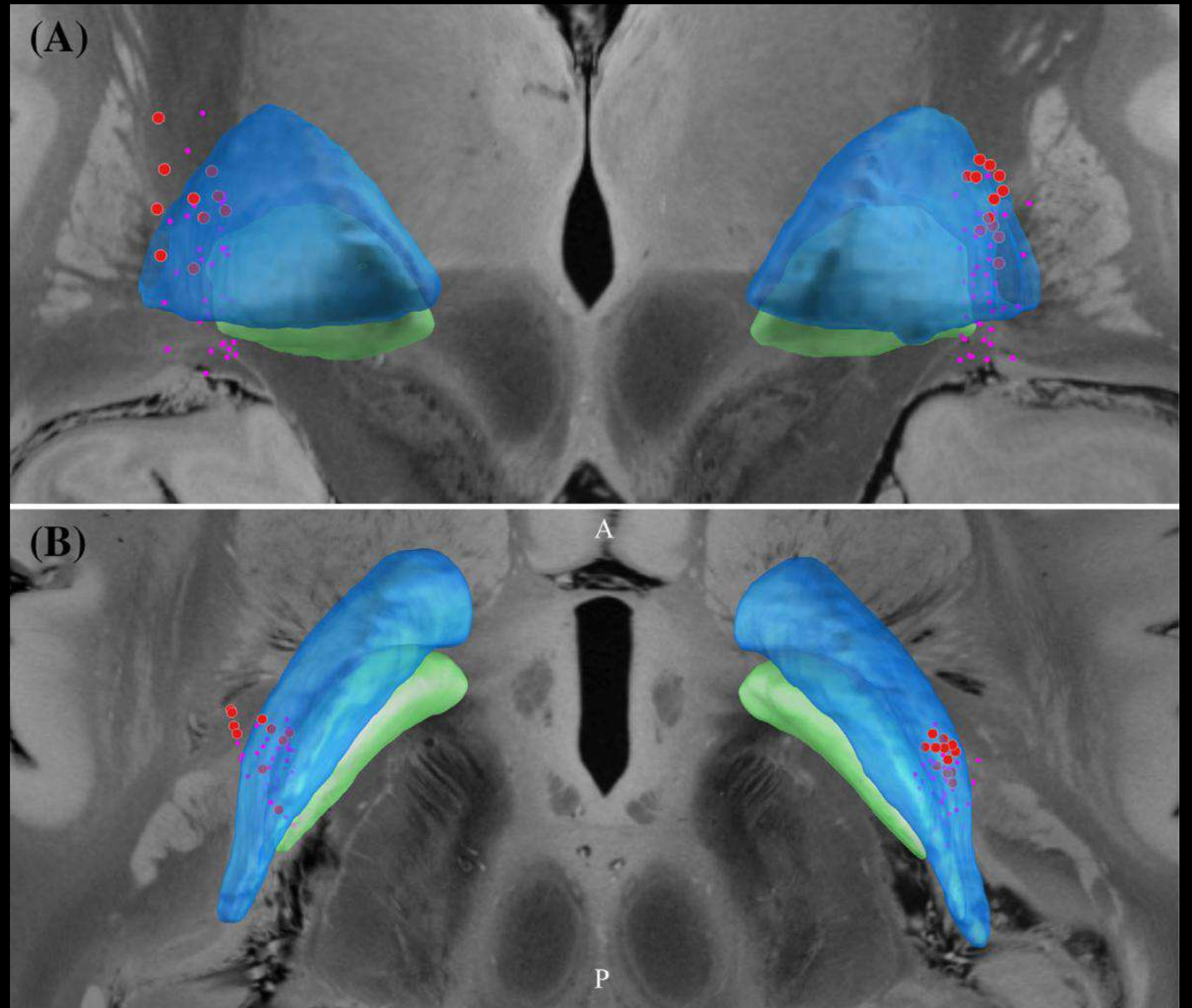
Benefit

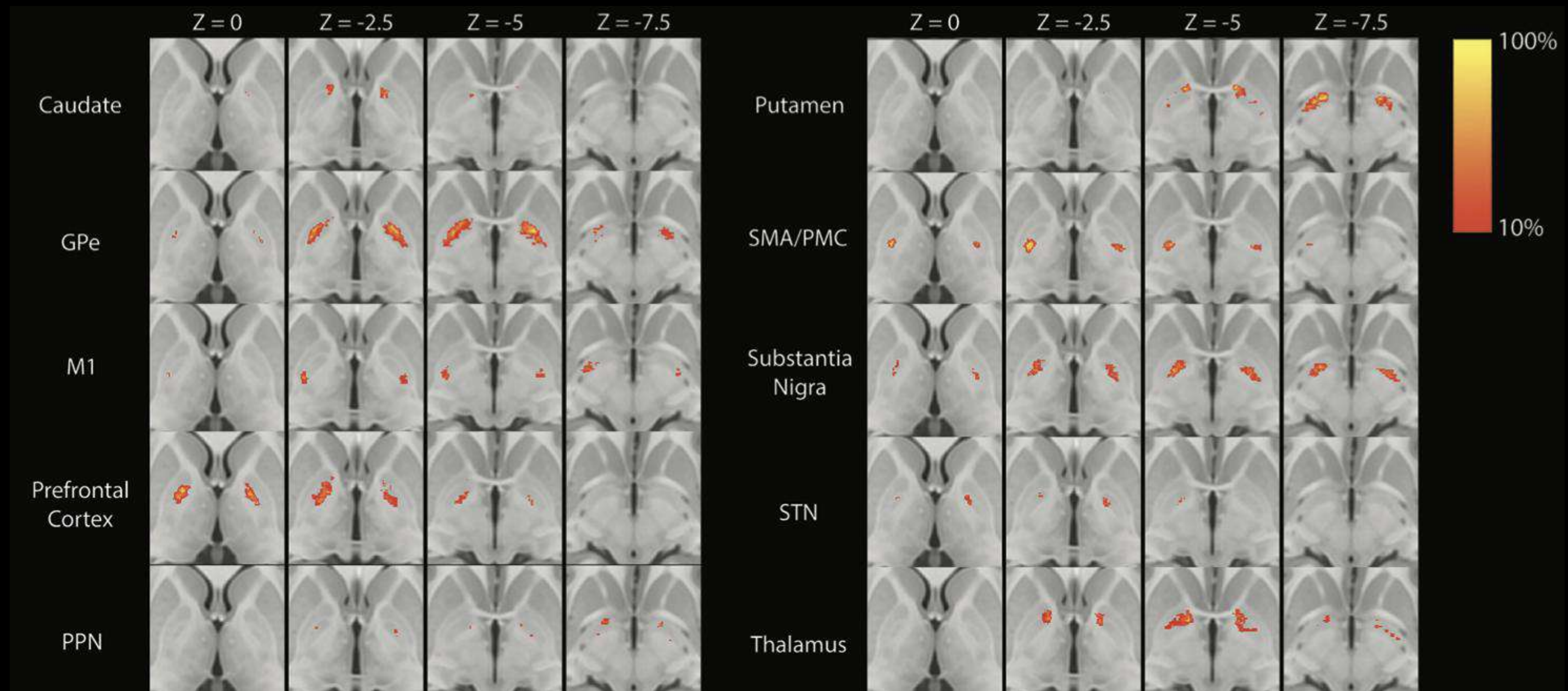
Side Effect

Details

Pallidal Connectivity Profiling of Stimulation- Induced Dyskinesia

Tsuboi et al., 2021





Higher the connectivity with M1 and SMA, higher the UPDRS-III improvement



In Dystonia: M1 and SMA, cerebellum, sensory cortex



GPi posteroventral

Parkinson's
disease

Dystonia



Target Visualization in DBS Anatomy, Subregions, and Connectivity

Rubens Cury, MD, PhD

Movement Disorders Center

University of São Paulo, Brazil

Hospital Israelita Albert Einstein

MDS-PAS 5th Neuromodulation School for Movement Disorders (New York, NY, USA)