Julius-Maximilians-
UNIVERSITÄT
WÜRZBURG

visualDBSlab
Würzburg

# invasive Deep Brain Stimulation

Neuro-X Master course **Nx-436**
*'Advanced methods for human neuromodulation'*

Martin M. Reich

27.11.2024

@MartinMReich1

# Invasive Deep Brain Stimulation

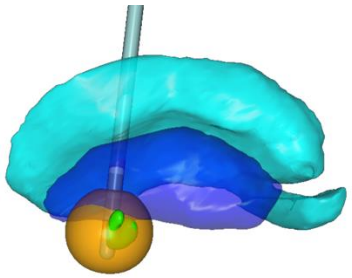
STN-DBS Off

STN-DBS on

# Overview

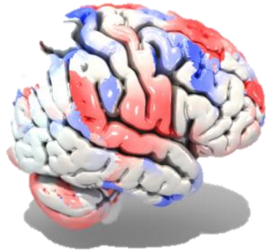
**General aspects:**

Indications
Procedure
Programming
Contact / Amplitude
Pulse width



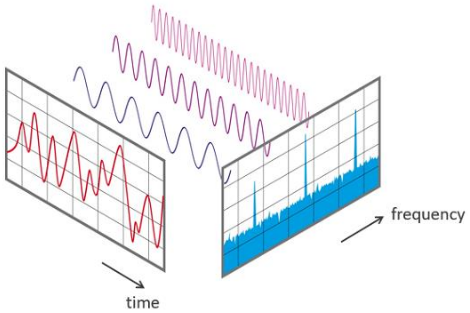
**Computational and Imagaing methodes:**

Probabilistic mapping
Connectomics

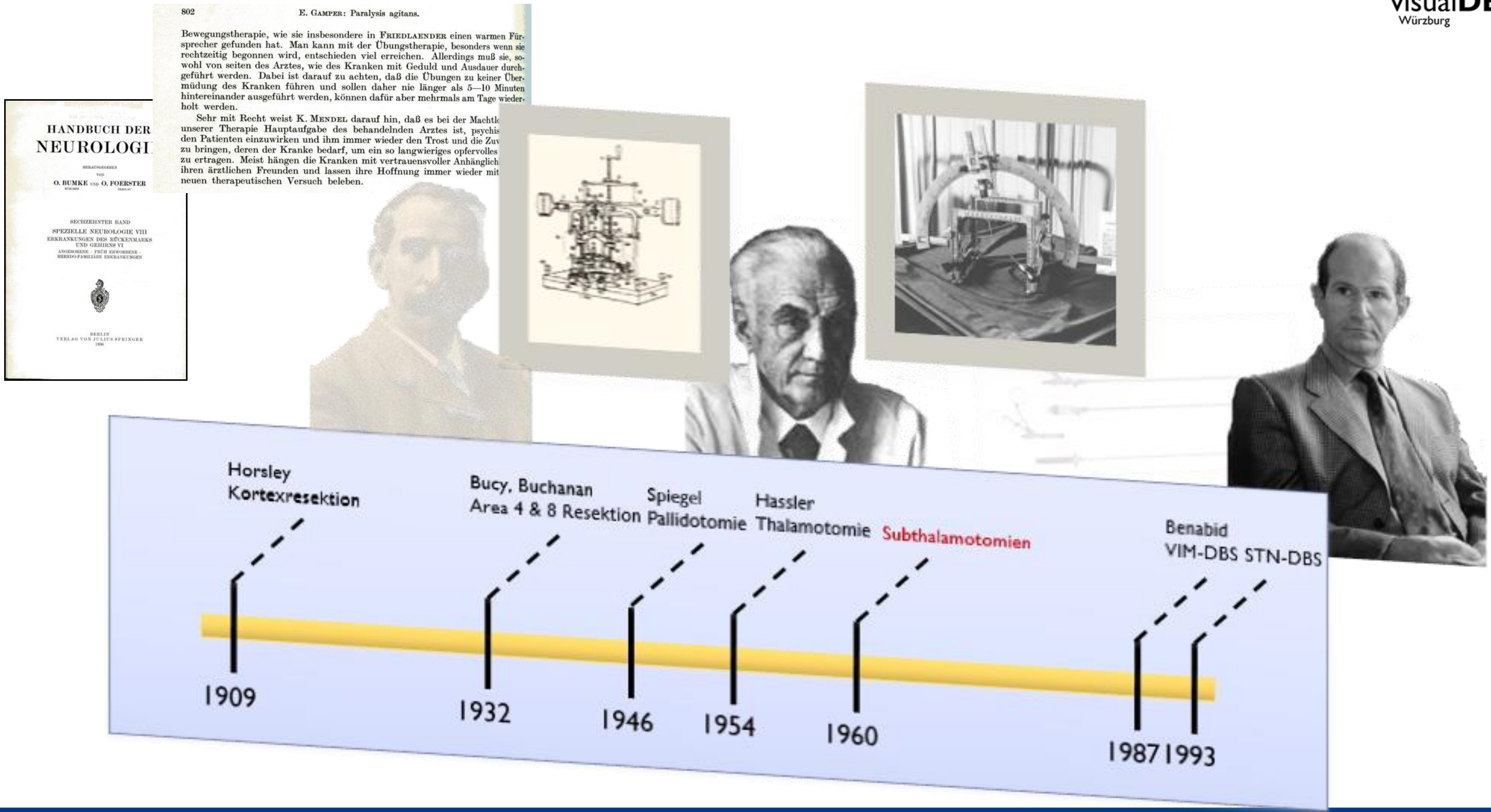


**Oscillatory activity and closed-loop DBS:**

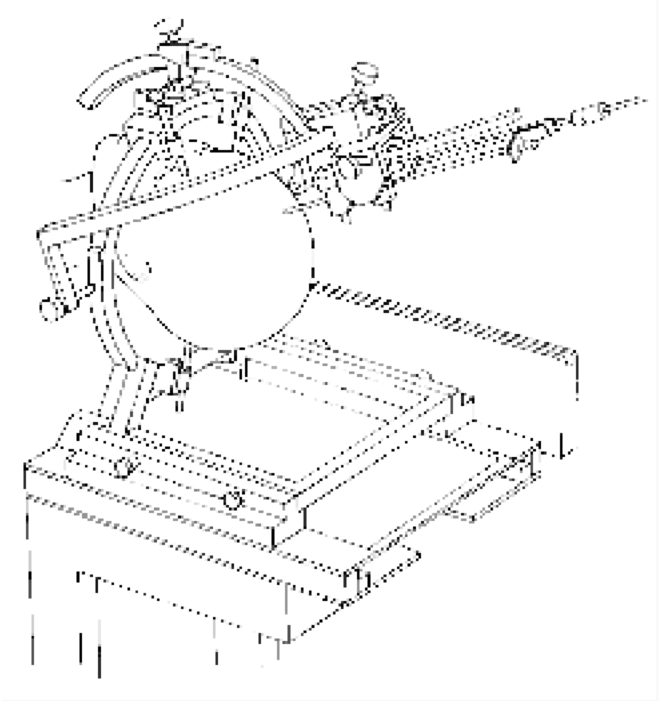
LFPs
adaptive Concepts



# Parkinson's surgery



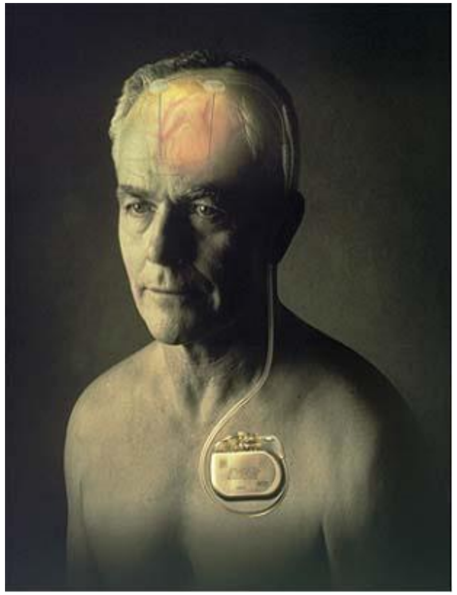
# General principle of stereotactic brain surgeries



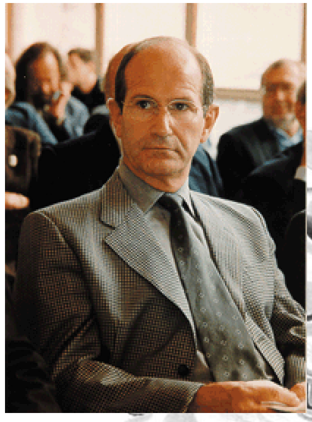
Targeted "elimination" of dysfunctional nerve tissue using a frame system, anatomical reference images, and physiological additional information

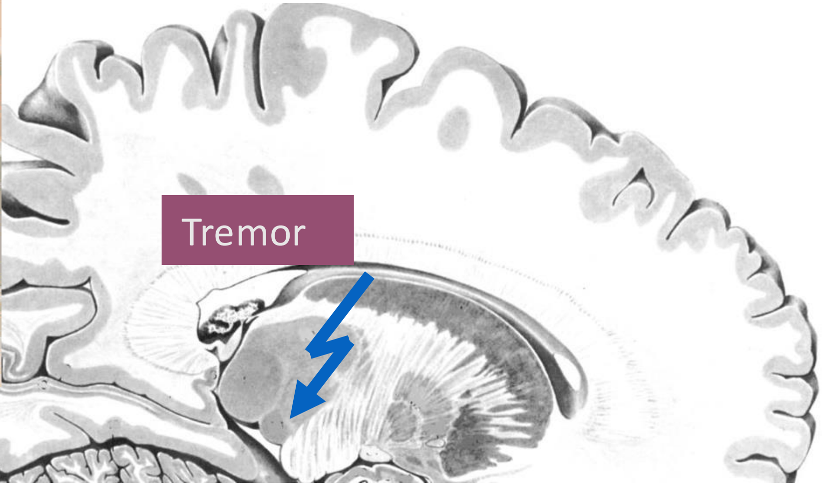
**Läsion**

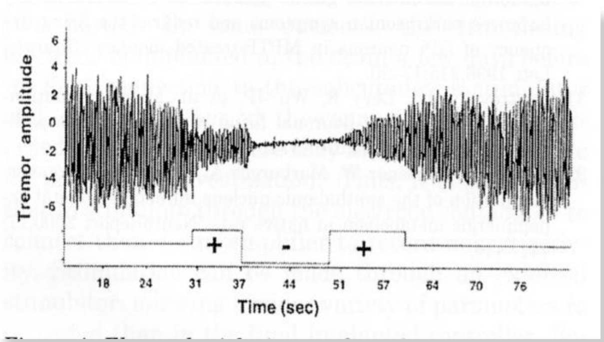
**Stimulation**

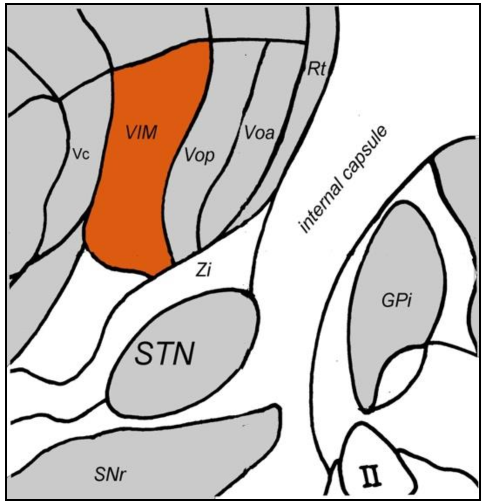


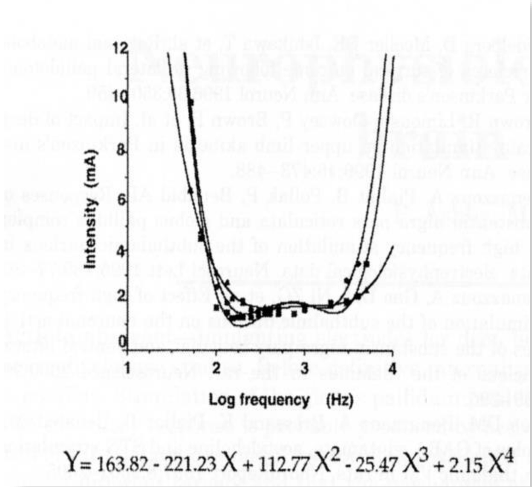
# Deep Brain Stimulation of Thalamus





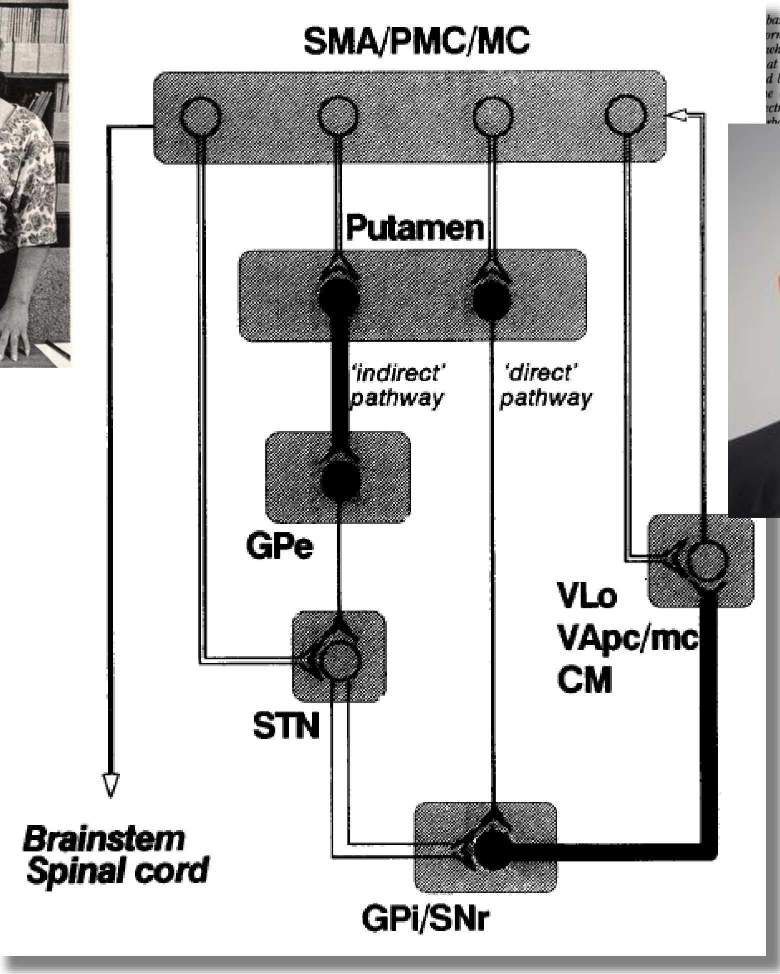




Benabid et al., J. Neurosurg., 84, 1996

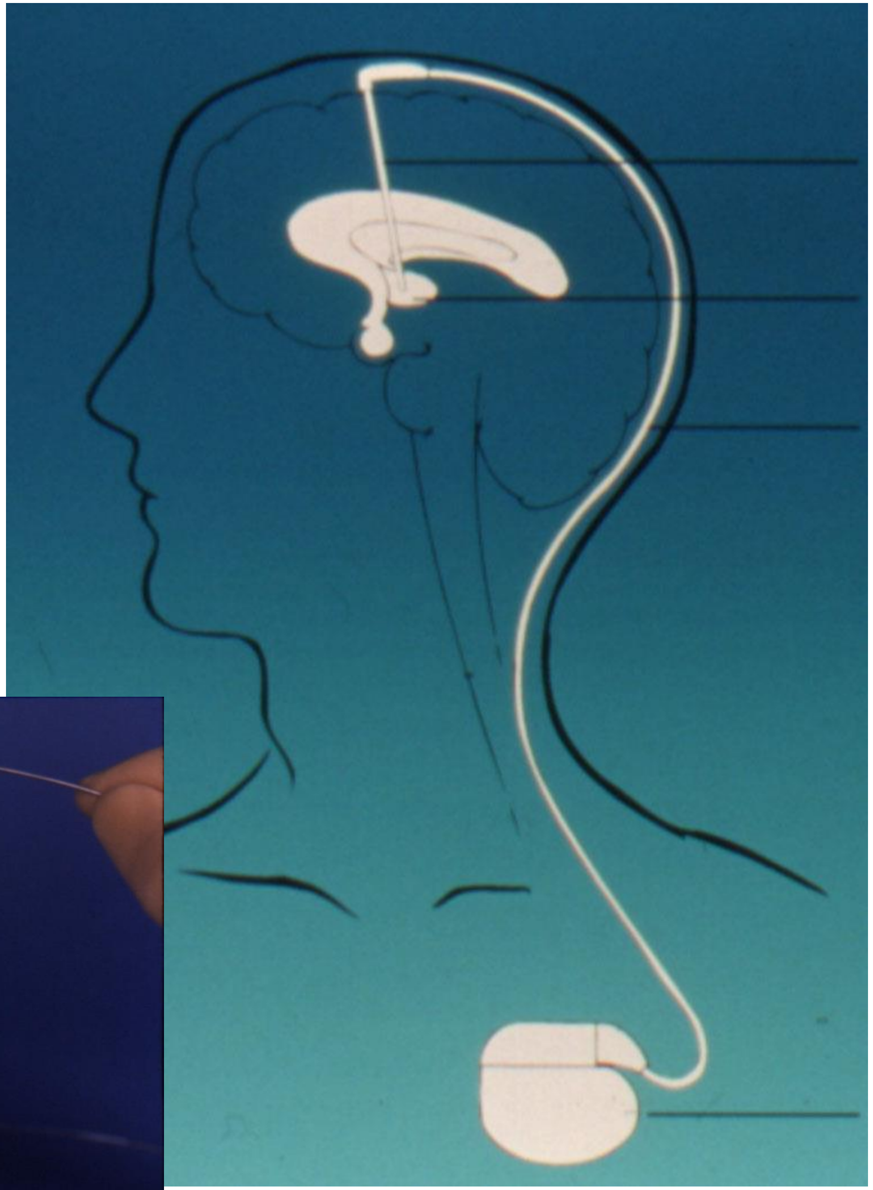
# New basal ganglia model





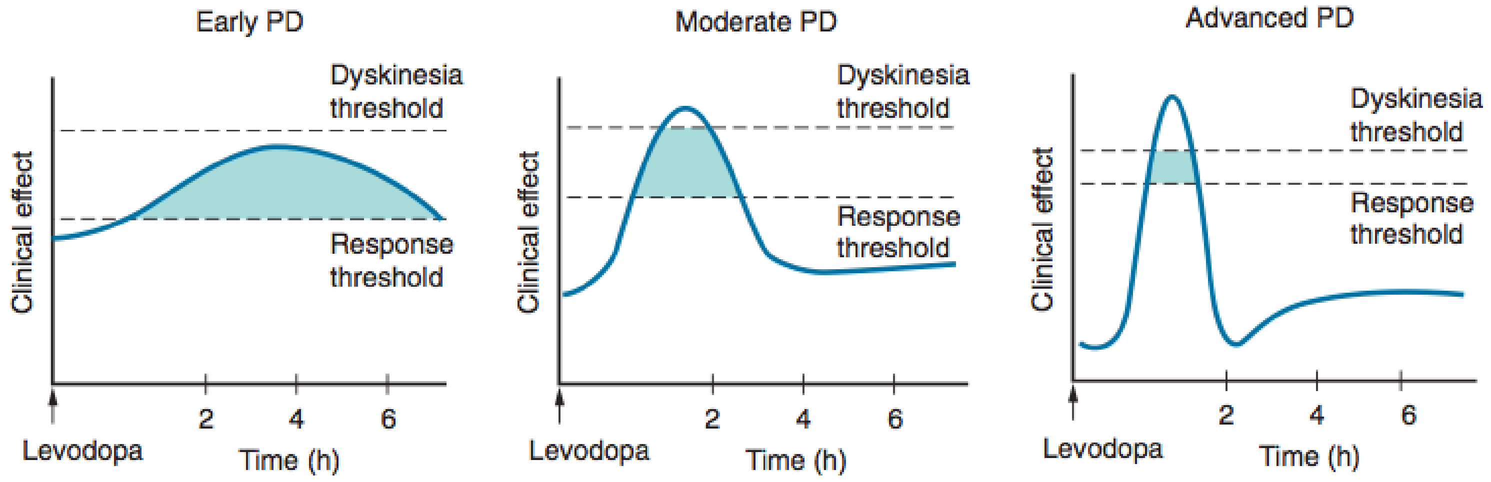
Delong, TINS, 1990

# Prinzip der DBS (Deep Brain Stimulation)



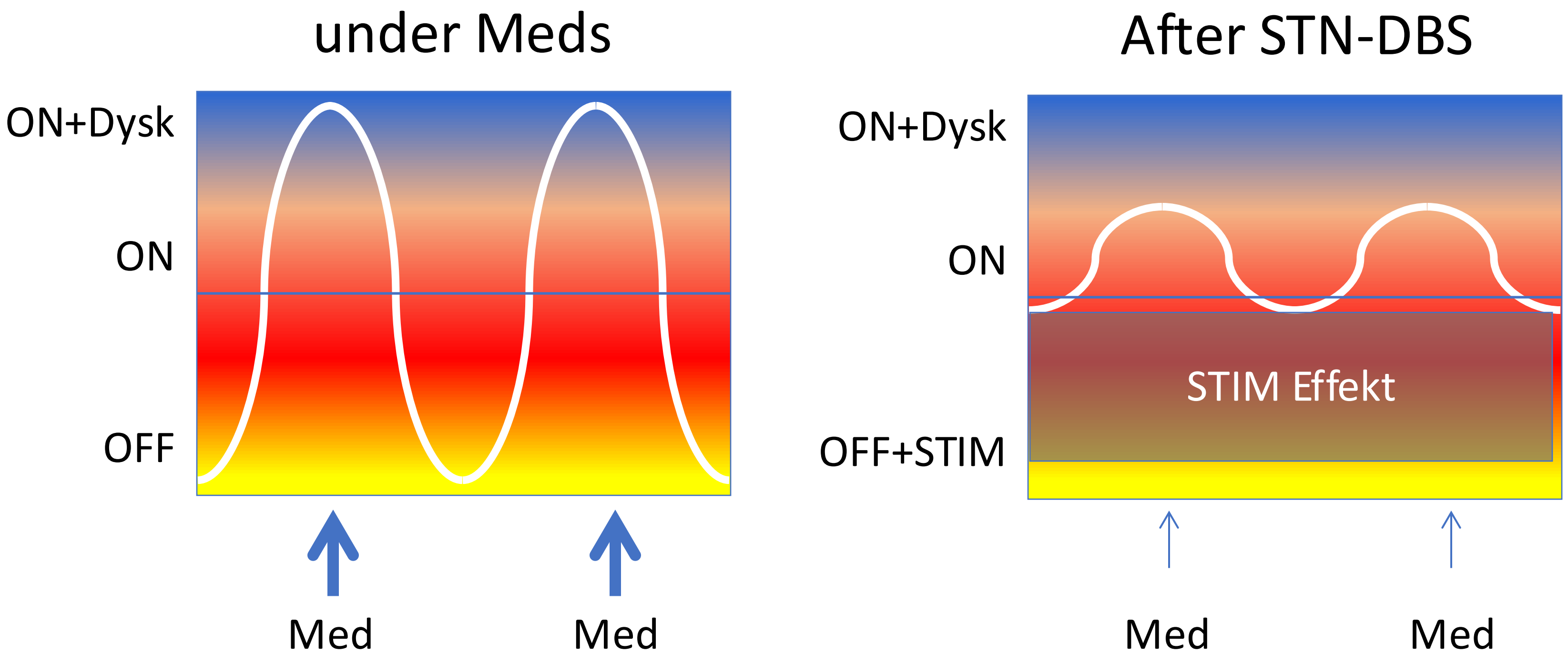
# Indications of DBS

# Parkinsons Disease

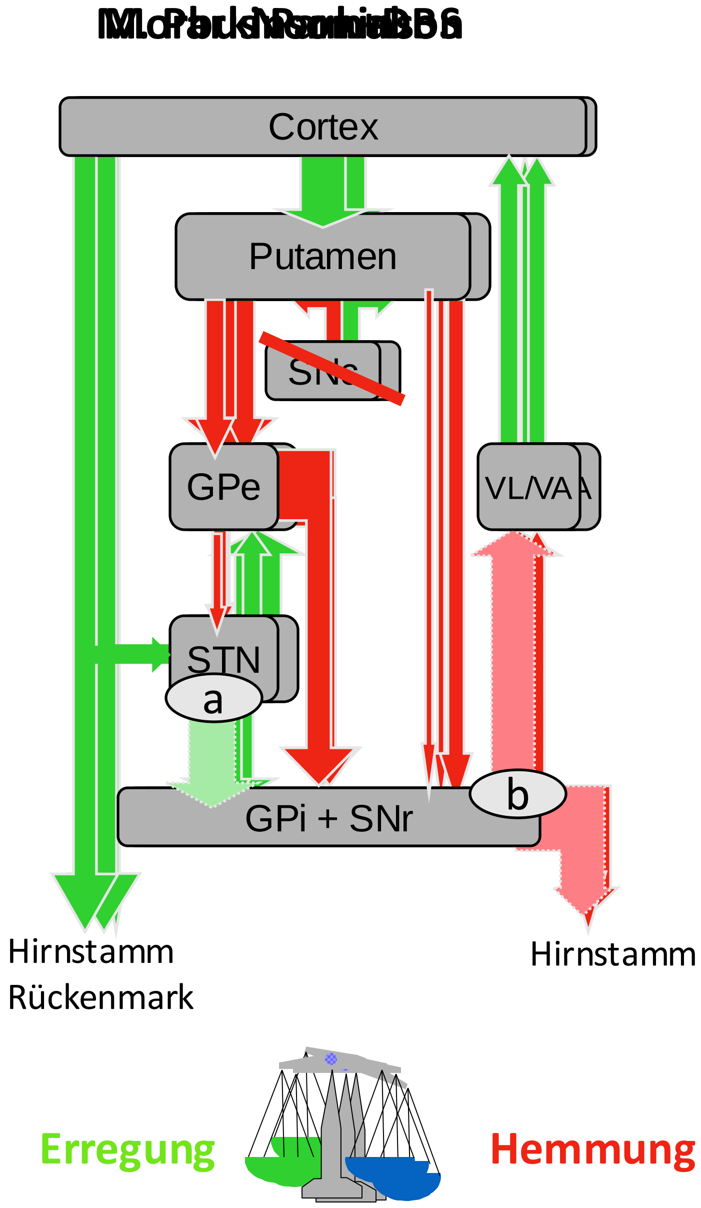



ON (mit peak-dose Dyskinesien)

# Effect of DBS



Negative feedback model of the basal ganglia.
*(Alexander and DeLong)*



# Class I Evidence in Advanced Parkinson's Disease


STN-DBS Off

STN-DBS on

Indication for patients with motor fluctuations, dyskinesias, severe tremor

# thalamic DBS in Essential Tremor

DBS off

DBS on

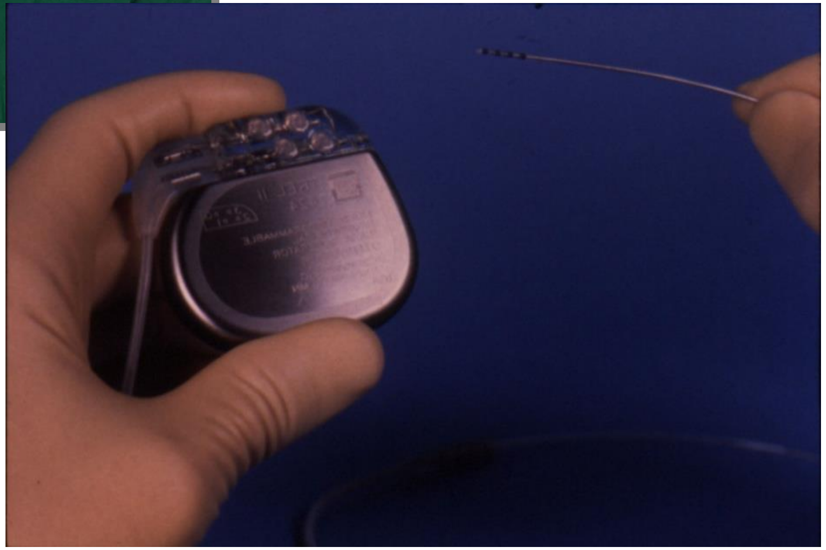
# GPi DBS in Dystonia

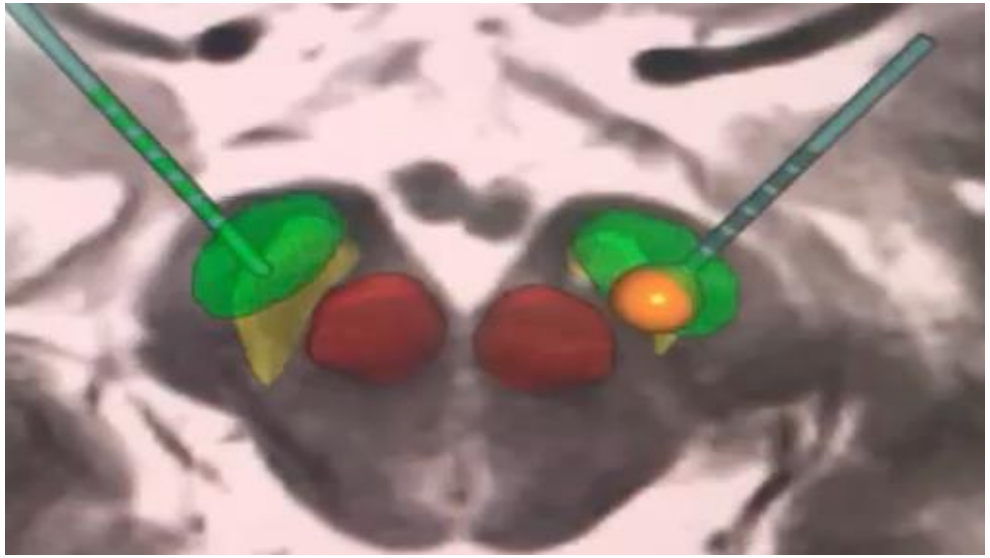
under Meds

After DBS

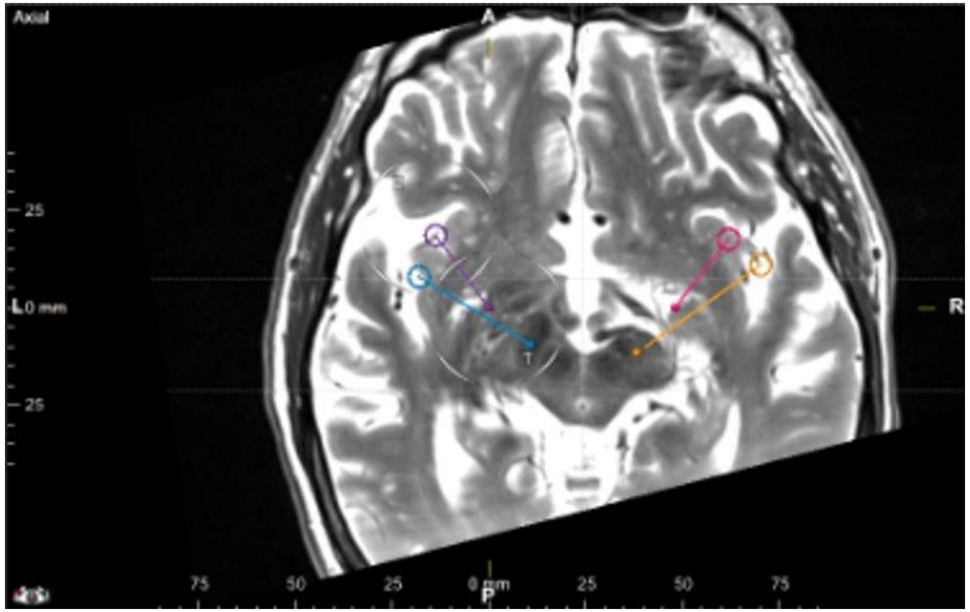
# Procedure of invasive DBS

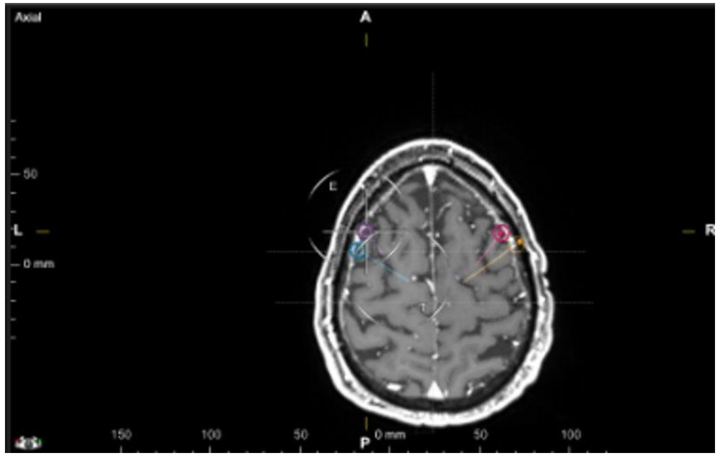
# Implantation der Elektroden

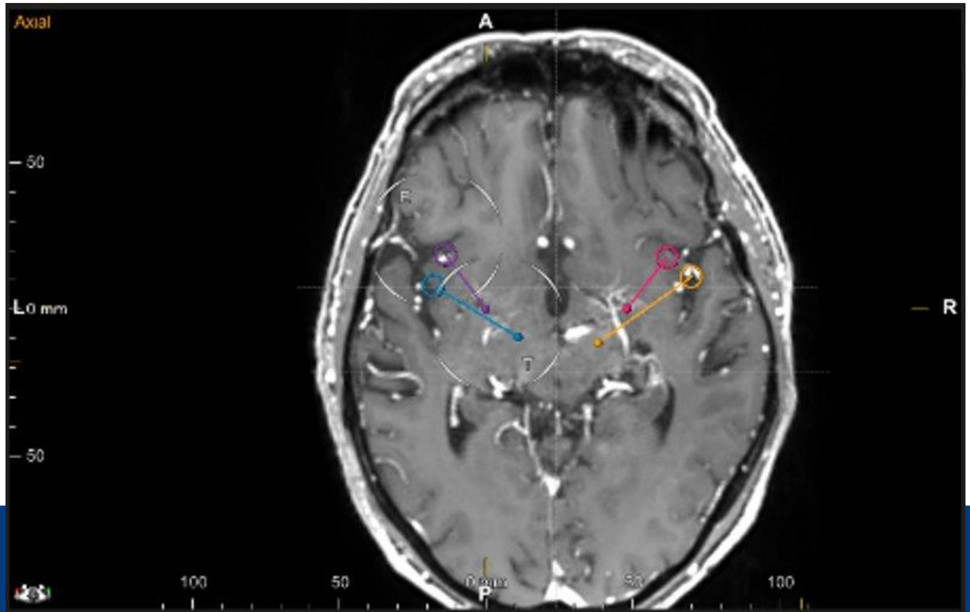




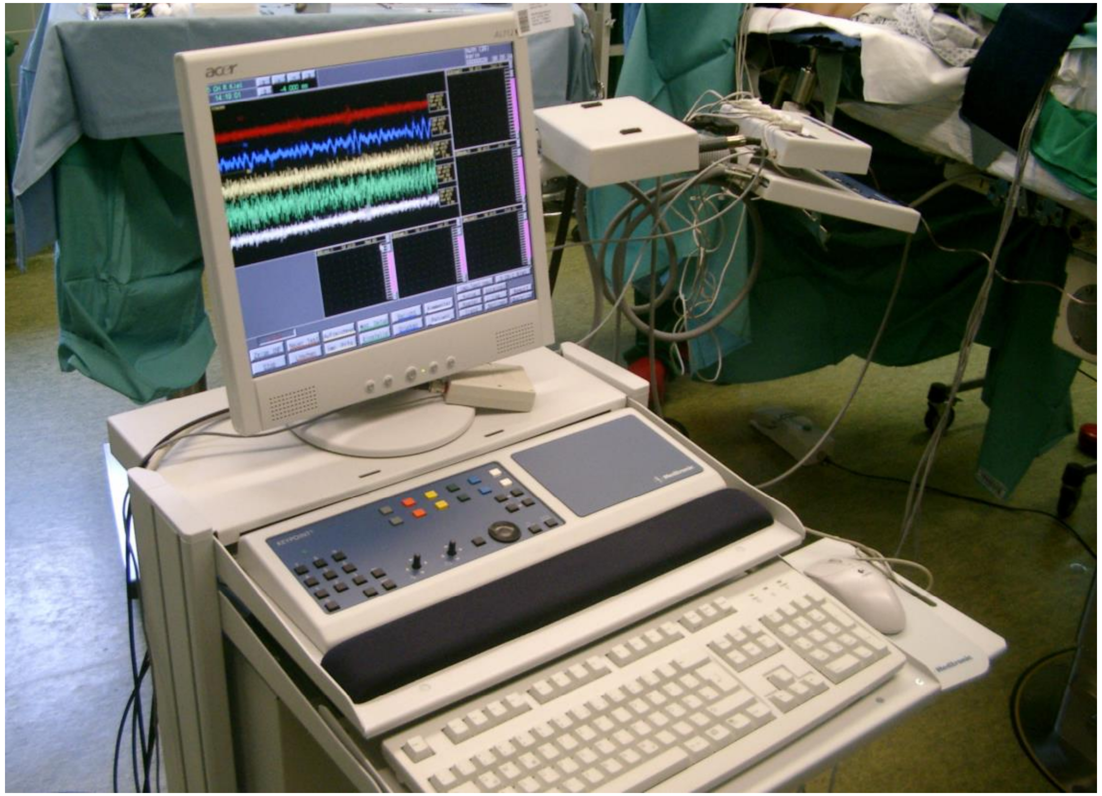
# Planing of the Implantation



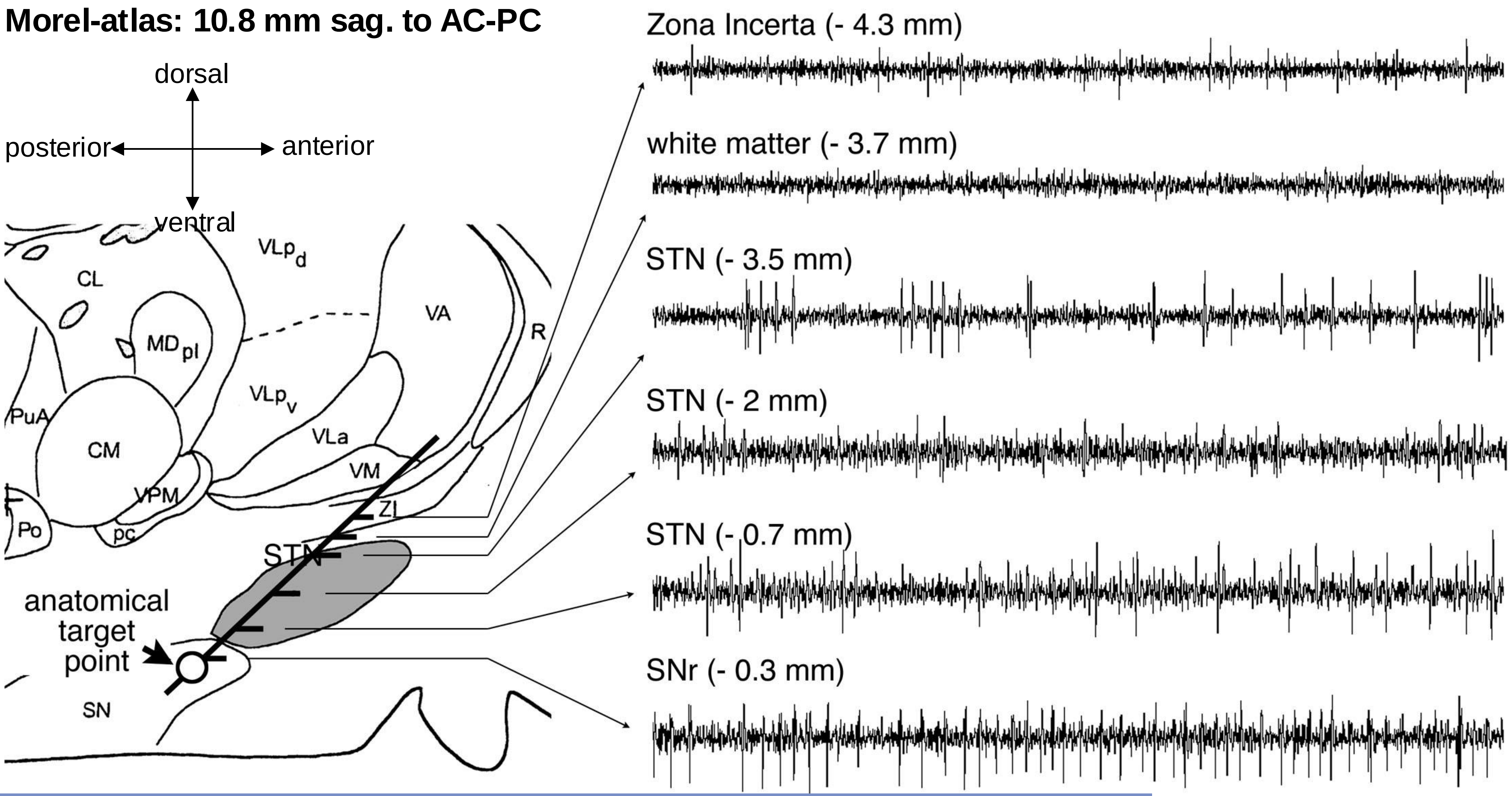



# Implantation of the electrodes



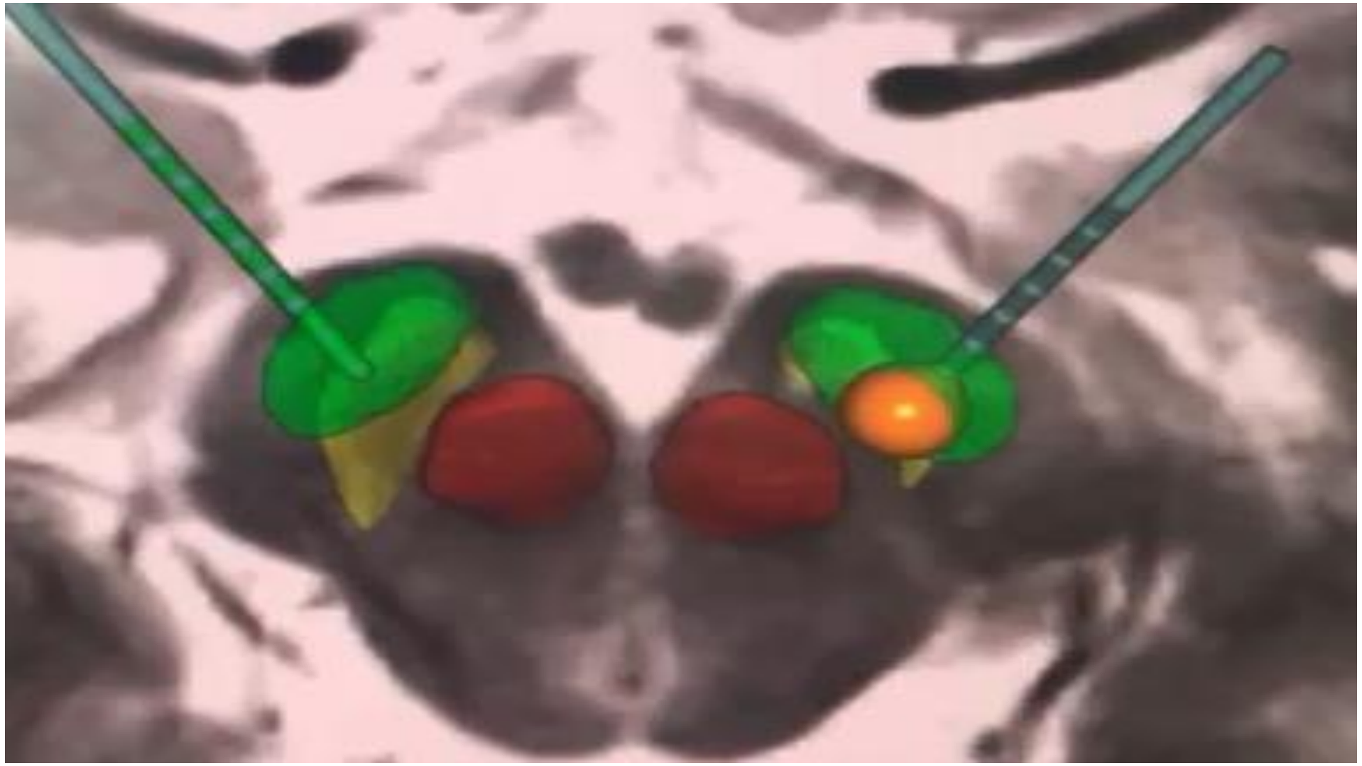
# Firing patterns along STN-trajectory (PD)




- Zona incerta: sparse firing, low background
- STN: irregular firing (30 Hz), high background
- SNr: tonic firing at higher rate (60 Hz)

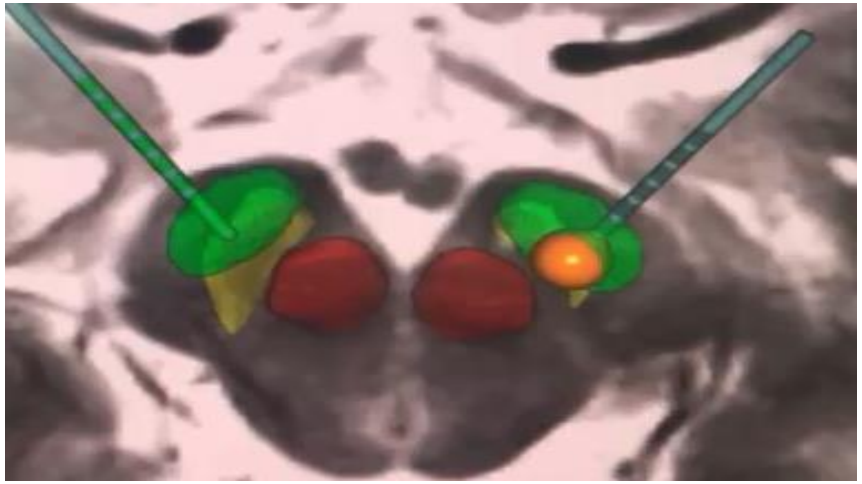
# Testing of the electrodes

# Tuning the therapy



# Tuning the therapy

- Active Contact
- Current (0.5-6.0 mA)



- Pulse duration (30-210 µs)
- Frequency (60-210 Hz)

# Monopolar review

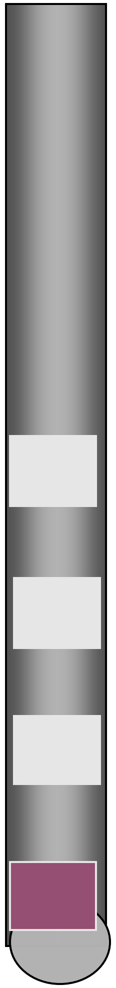
Movement Disorders
Vol. 21, Suppl. 14, 2006, pp. S284–S289
© 2006 Movement Disorder Society

Basic Algorithms for the Programming of Deep Brain Stimulation in Parkinson's Disease

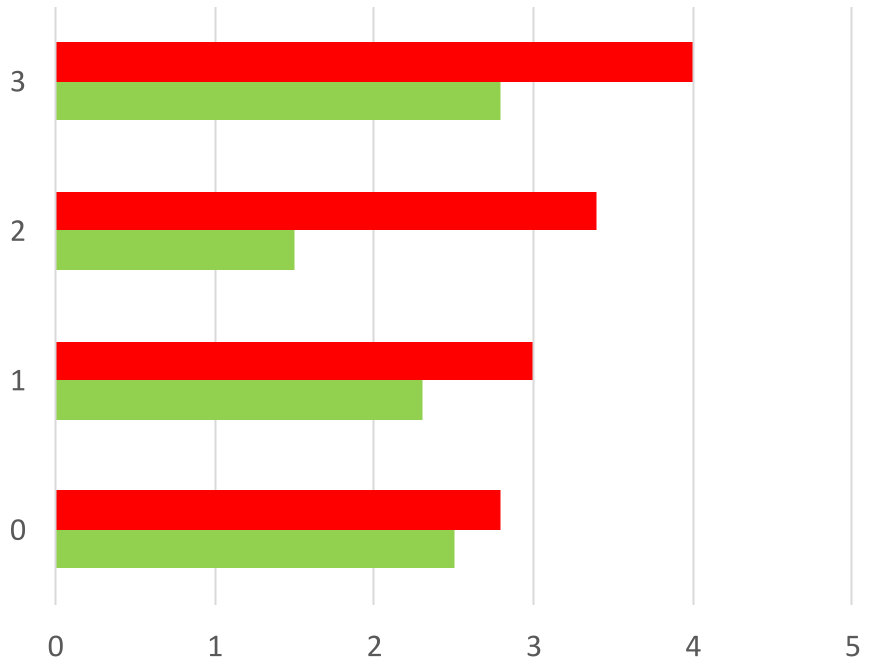
Jens Volkmann, MD,[1*] Elena Moro, MD,[2] and Rajesh Pahwa, MD[3]

[1]Department of Neurology, Christian-Albrechts-Universität Kiel, Kiel, Germany
[2]Department of Neurology, Toronto Western Hospital, and University of Toronto, Toronto, Canada
[3]Parkinson Disease and Movement Disorder Center, University of Kansas, Kansas City, Kansas, USA

3
2
1
0



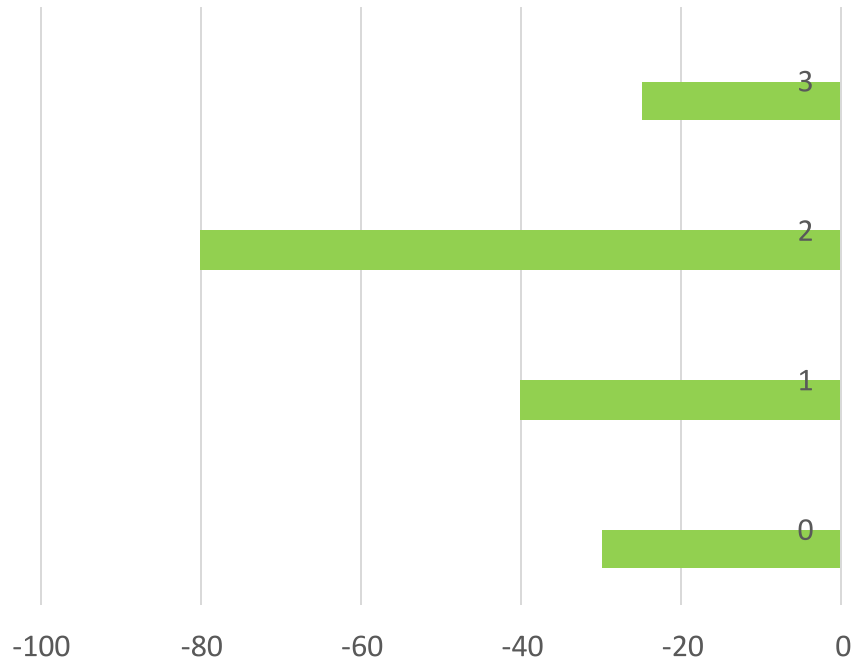
## a) Threshold detection




Current (mA)

## a) Clinical response assessment

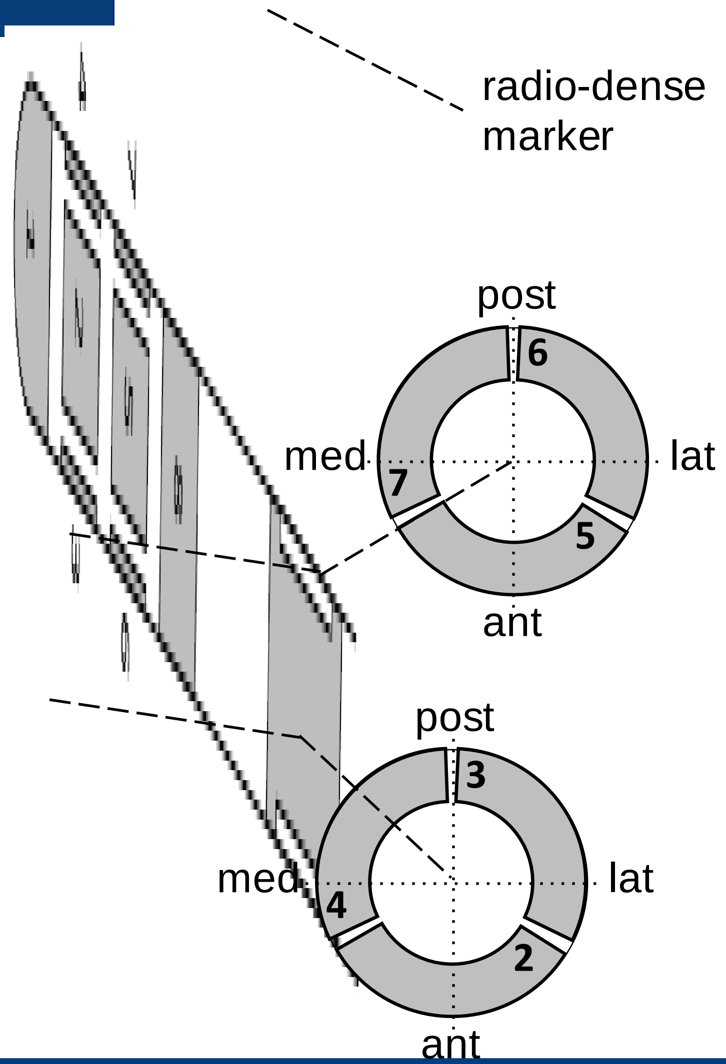
Fixed amplitude (e.g. 1.5 mA)



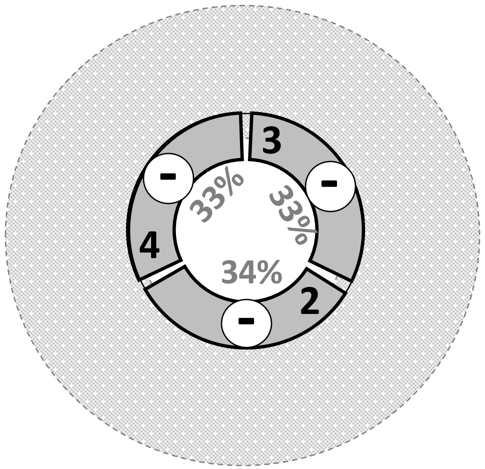

Symptom reduction (%)

# Using clinical response as a benchmark for DBS


# Directional Platform

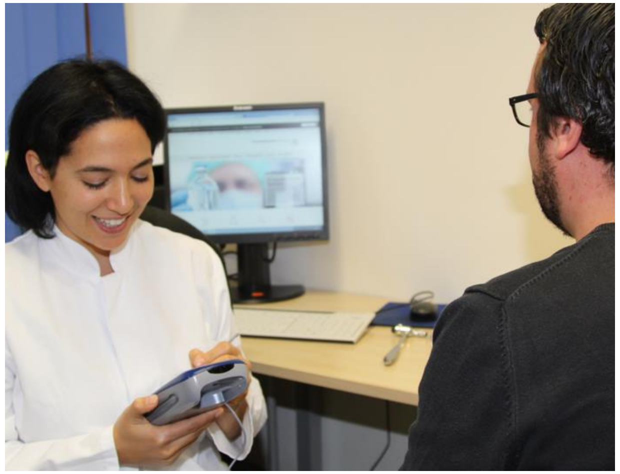



## conventional ring stimulation



# Programming time?

| Reprogramming sessions | | |
|---|---|---|
| Inpatient days | Outpatient appointments | Hours |
| 28 | 8 | 96 |
| 12 | / | 36 |
| 26 | / | 78 |
| 8 | 7 | 34.5 |
| 38 | 4 | 120 |
| 10 | 2 | 33 |
| 15 | 1 | 46.5 |
| 28 | 4 | 90 |
| 19 | 2 | 60 |
| 12 | 4 | 60 |

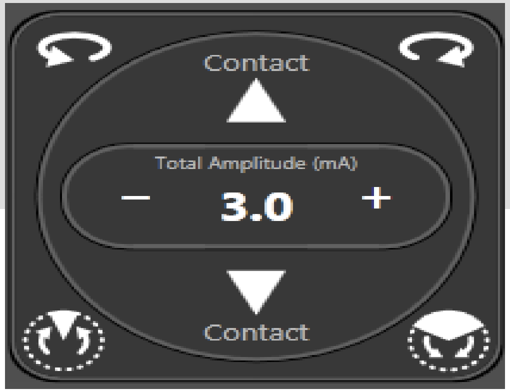


12,964
combinations of
PW, F and mA
65 contact
combinations

Millions of
combinations

Nickl et al. 2019 Neurosurgery

# Programming workflow



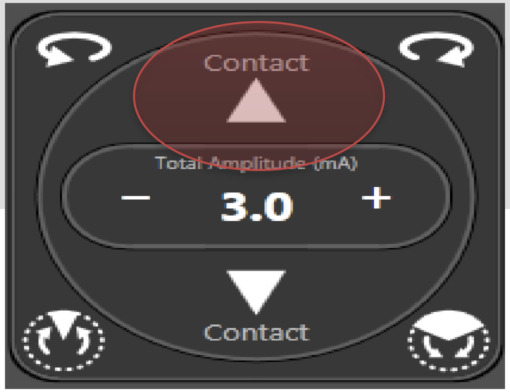

- Monopolar review including „vertical“ steering to find optimal stimulation site in z-Axis
  - highest efficacy

60 µs
130 Hz

vertical
steering

# Programming workflow

- Monopolar review including „vertical“ steering to find optimal stimulation site in z-Axis
  - highest efficacy

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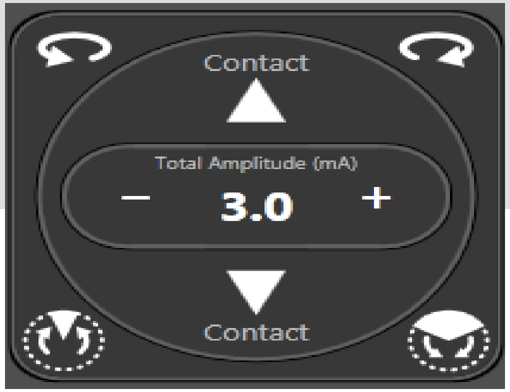


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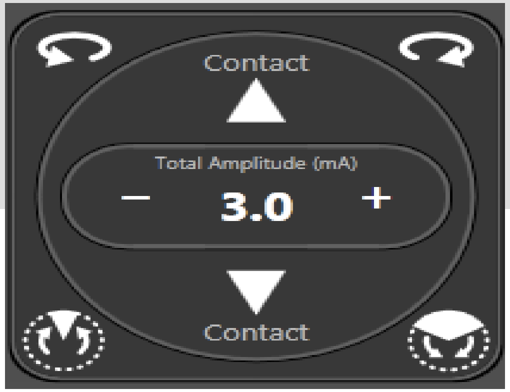


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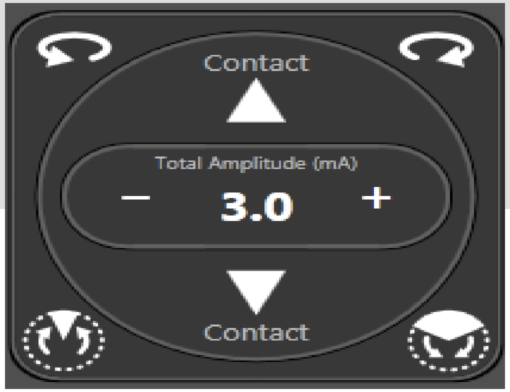
# Programming workflow

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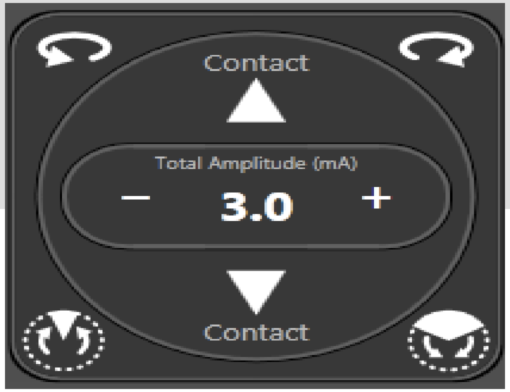


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# Programming workflow

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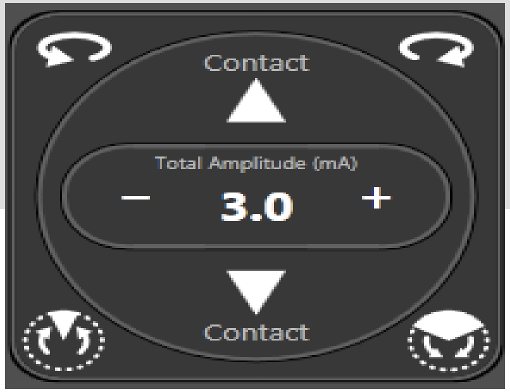


60 µs
130 Hz

vertical
steering

# Programming workflow

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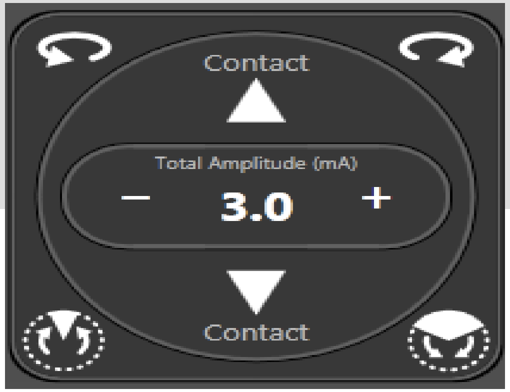
  - highest efficacy

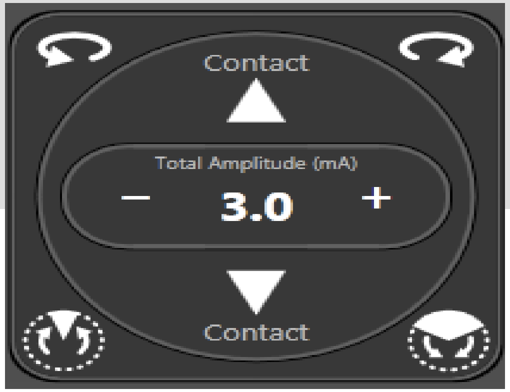


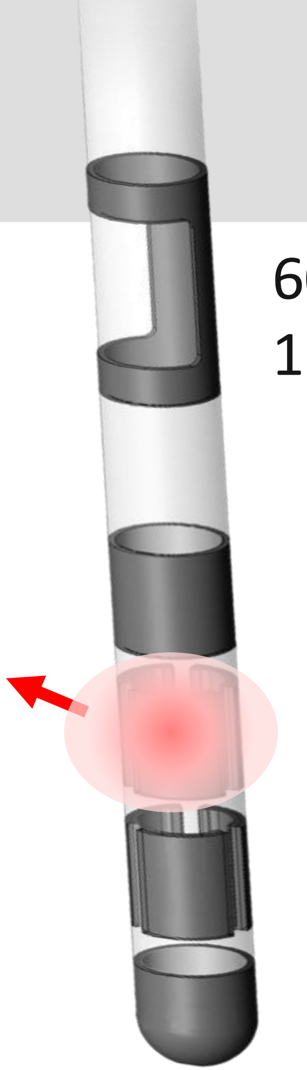

60 µs
130 Hz

vertical steering

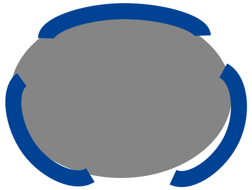
# Programming workflow

- Monopolar review of 3-6 directions including „directional“ steering to find optimal direction
- highest efficacy



60 µs
130 Hz

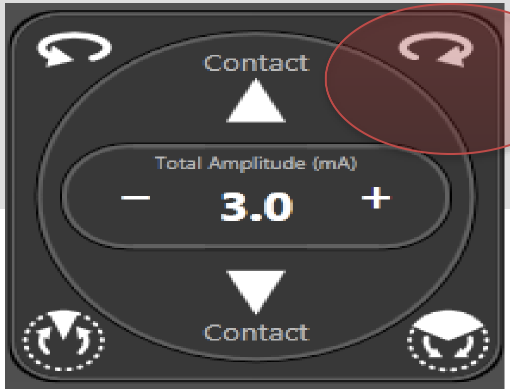


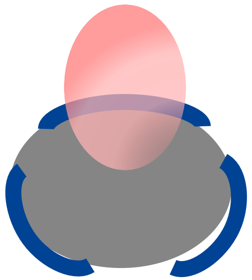
Directional (rotational) steering

vertical steering

# Programming workflow

- Monopolar review of 3-6 directions including „directional“ steering to find optimal direction
- highest efficacy



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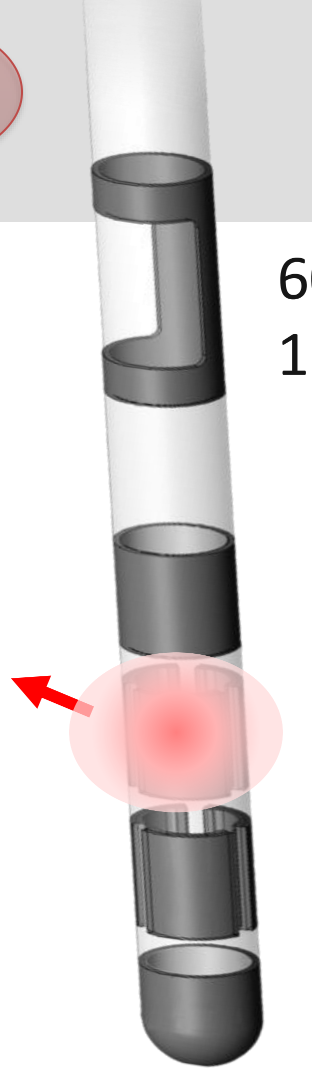

60 µs
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vertical steering

# Programming workflow

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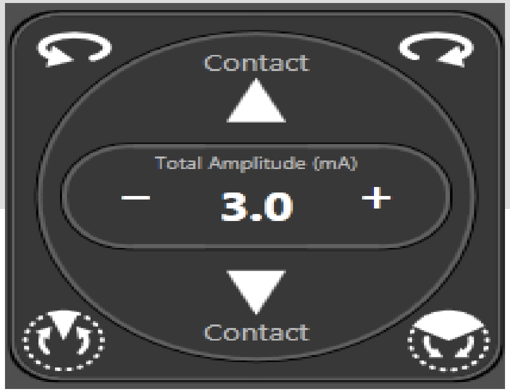
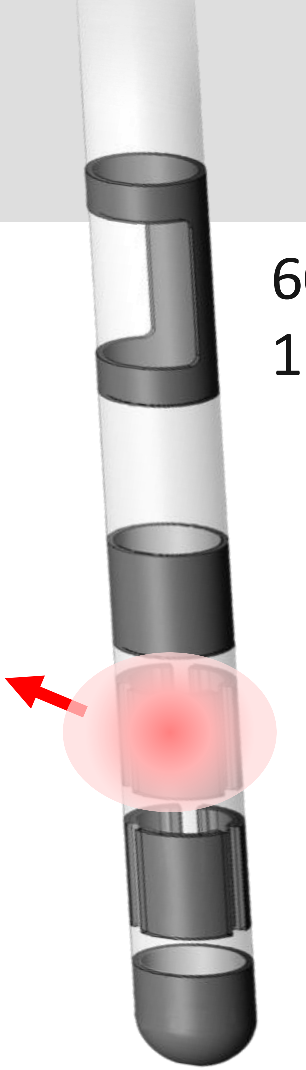
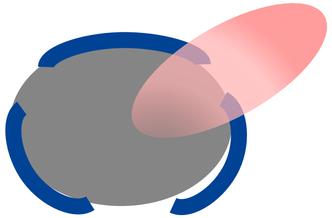


60 µs
130 Hz



Directional (rotational) steering

vertical steering

# Programming workflow

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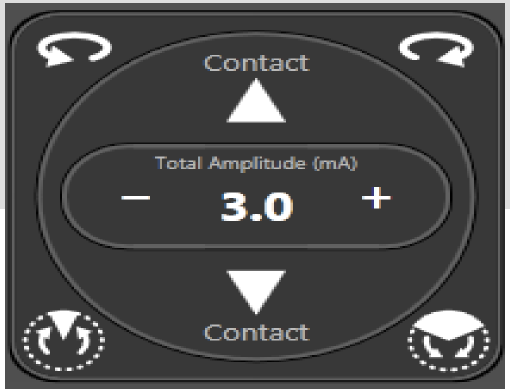
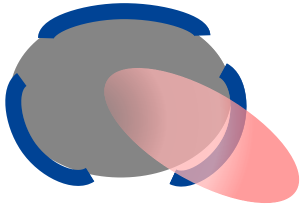
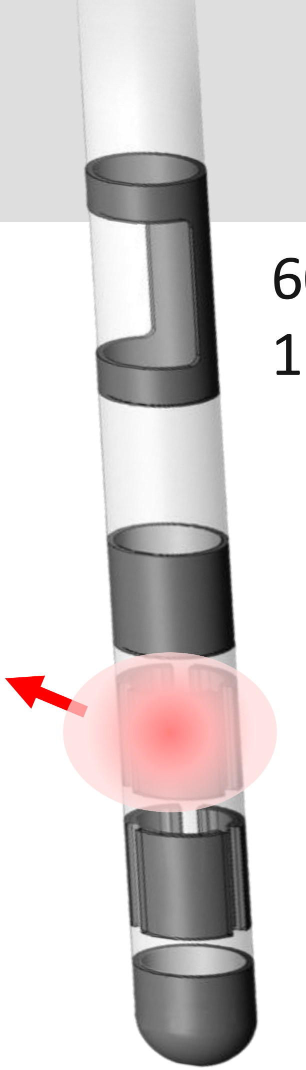


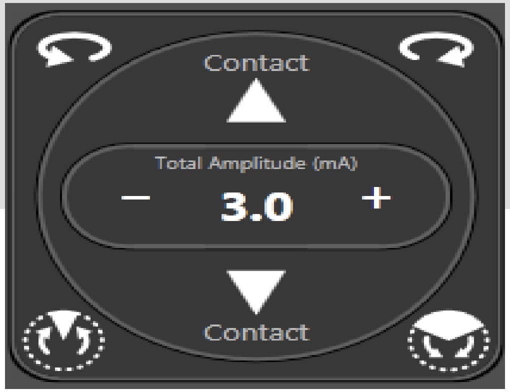
Directional (rotational) steering



60 µs
130 Hz

vertical steering

# Programming workflow

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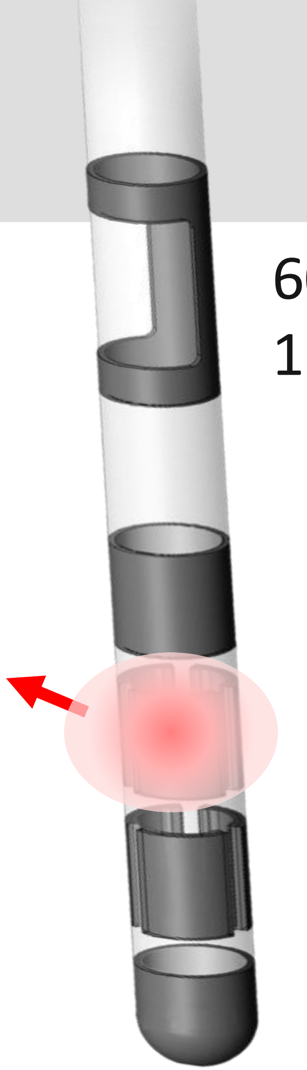

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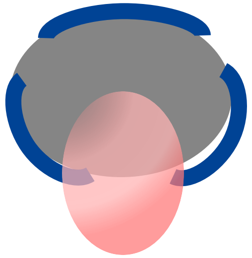
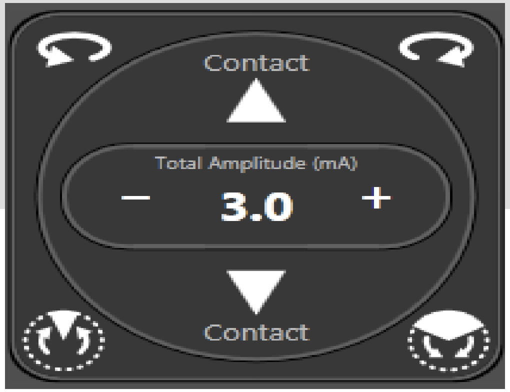


Directional (rotational) steering

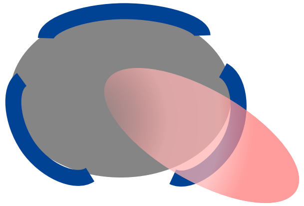
vertical steering

# Programming workflow

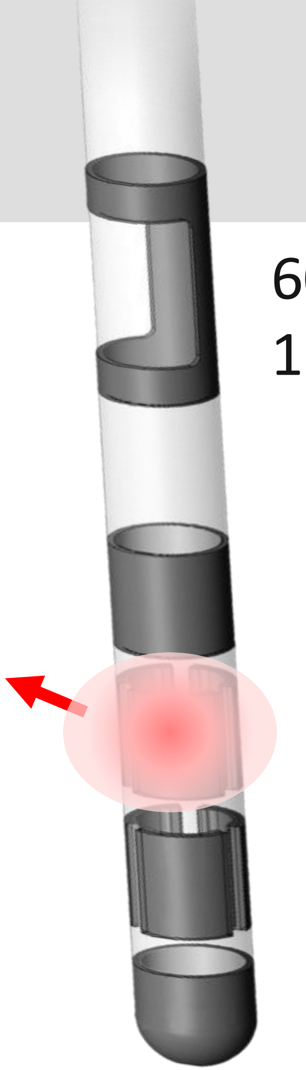
- Check the therapeutic window on the most effective contact combination




Efficacy/AE threshold (mA)



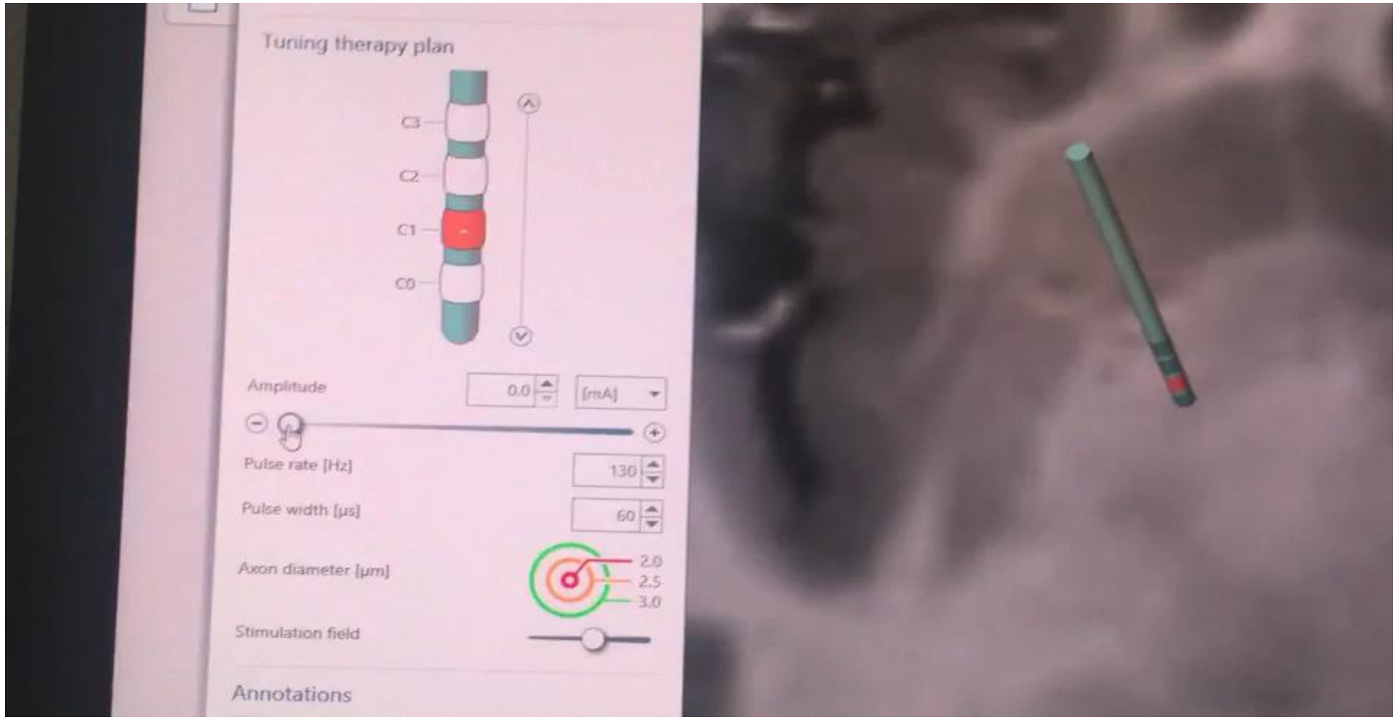
Directional (rotational) steering

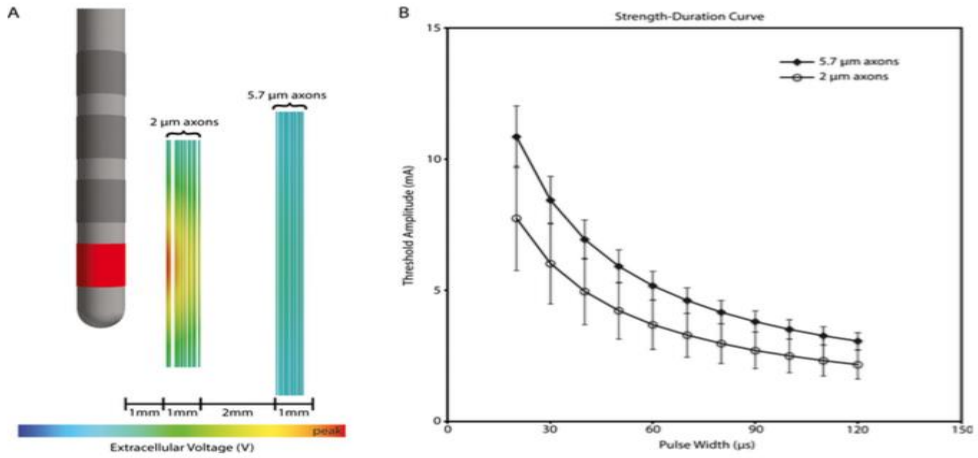


60 µs
130 Hz

vertical steering

# Pulse width




VTA assumes that the primary effect of DBS is to activate myelinated axons, which was proved by several studies [Holsheimer et al. 2000; Groppa et a. 2014; Reich et al. 2015].

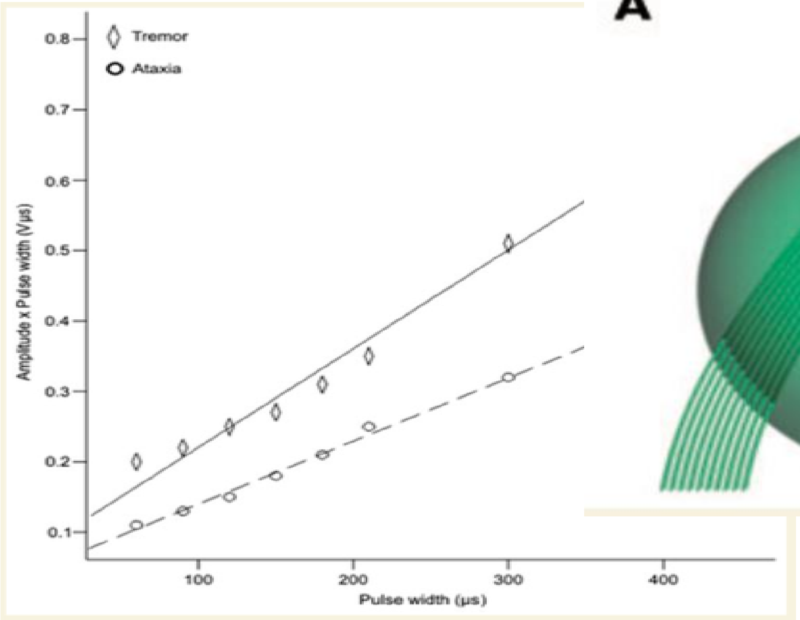
# therapeutic window outcomes by altering pulse width

doi:10.1093/brain/awt304 Brain 2014: 137; 109–121 | 109

BRAIN
A JOURNAL OF NEUROLOGY

**Physiological and anatomical decomposition of subthalamic neurostimulation effects in essential tremor**

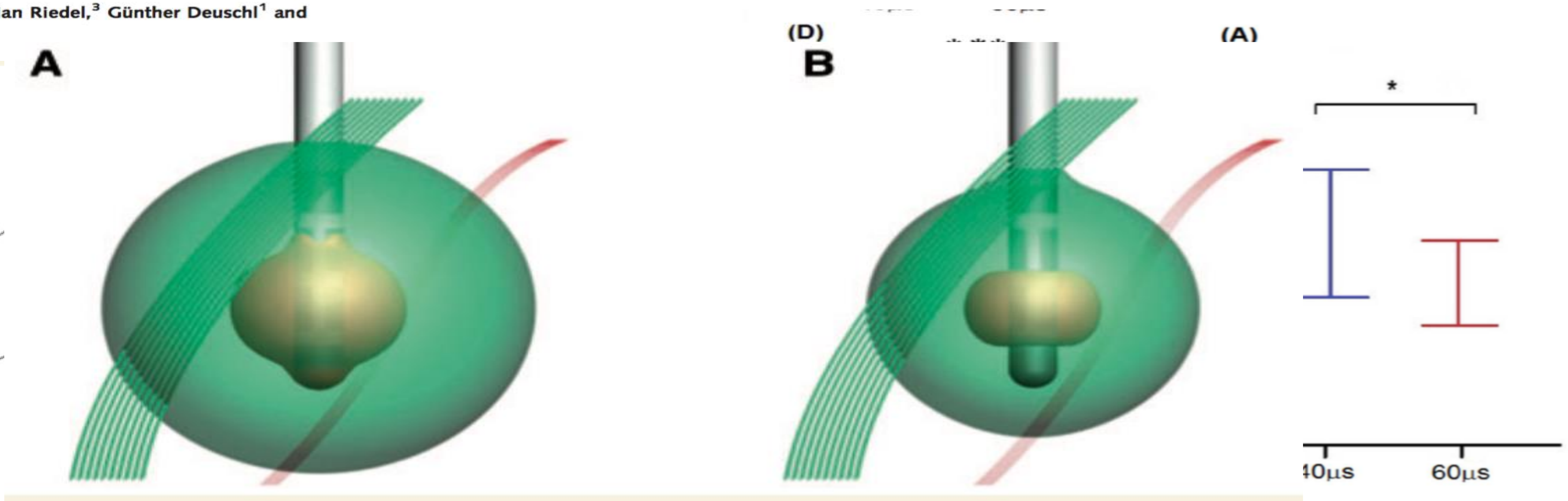
Sergiu Groppa,[1,*] Jan Herzog,[1,*] Daniela Falk,[2] Christian Riedel,[3] Günther Deuschl[1] and Jens Volkmann[1,4]




Accepted Manuscript


Less is more - Pulse width dependent therapeutic window in deep brain stimulation for essential tremor

Alexia-Sabine Moldovan, Christian Johannes Hartmann, Carlos Trenado, Nicola Meumertzheim, Philipp Jörg Slotty, Jan Vesper, Alfons Schnitzler, Stefan Jun Groiss




**I. Chronaxie of the fibers**

...observed chronaxies of 27µs for tremor-reduction and 52µs for dysmetria induction...

# therapeutic window outcomes by altering pulse width

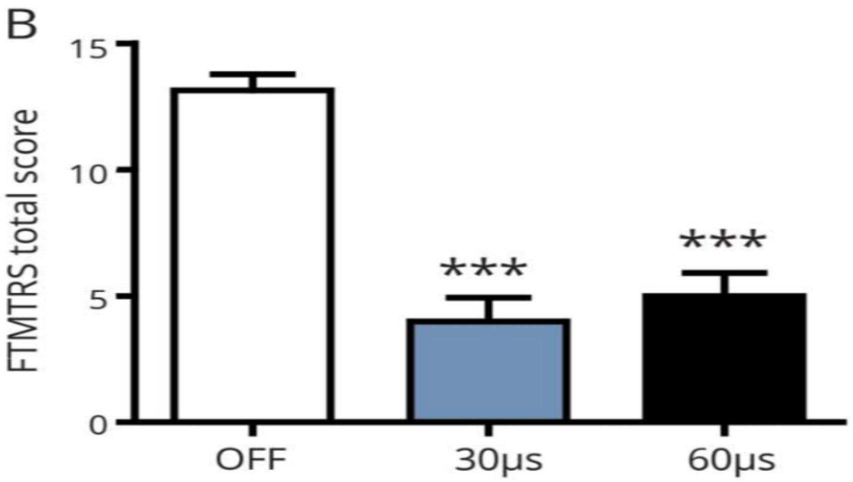
ARTICLE CLASS OF EVIDENCE

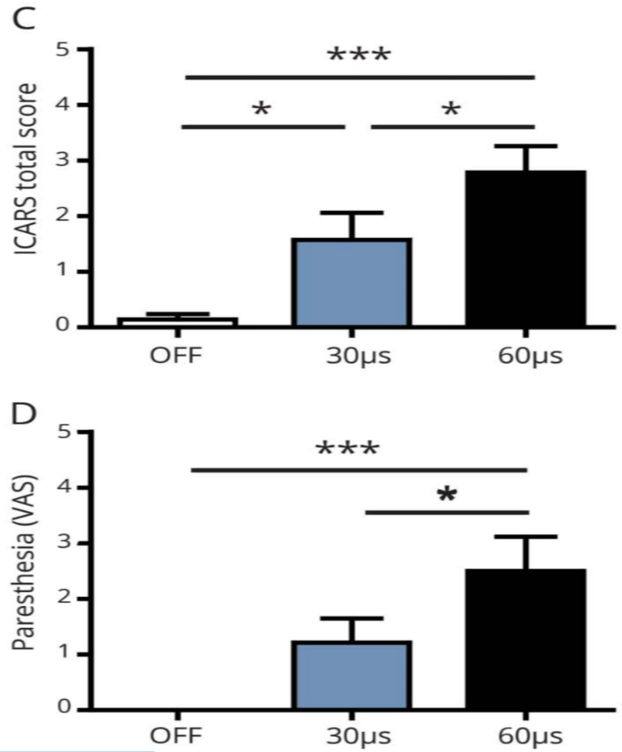
## Thalamic short pulse stimulation diminishes adverse effects in essential tremor patients

Chi-un Choe, MD,* Ute Hidding, MD,* Miriam Schaper, MD, Alessandro Gulberti, PhD, Johannes Köppen, MD, Carsten Buhmann, MD, Christian Gerloff, MD, Christian K.E. Moll, MD, Wolfgang Hamel, MD, and Monika Pötter-Nerger, MD

**Correspondence**
Dr. Choe
cchoe@uke.de

*Neurology*® 2018;91:e704-e713. doi:10.1212/WNL.0000000000006033




**I. Chronaxie of the fibers**

...observed chronaxies of 27μs for tremor-reduction and 52μs for dysmetria induction...

# Delayed-onset adverse effect of thalamic DBS

1 - /2.5 mA / 90 us / 130 Hz

9- / 2.7 mA / 90 us / 130 Hz

# Delayed-onset adverse effect of thalamic DBS

After pausing and re-programming

1 - /3.3 mA / **30 us** / 130 Hz

9- / 3.5 mA / **30 us** / 130 Hz

# Re-programming to 30 µs

doi:10.1093/brain/awx038 BRAIN 2017: Page 1 of 3 | e1

BRAIN
A JOURNAL OF NEUROLOGY

LETTER TO THE EDITOR

**Reply: Clinical approach to delayed-onset cerebellar impairment following deep brain stimulation for tremor**

Martin M. Reich,[1] Nicolò G. Pozzi,[1] Joachim Brumberg,[2] Mattias Åström,[3,4] Jens Volkmann[1] and Ioannis U. Isaias[1]

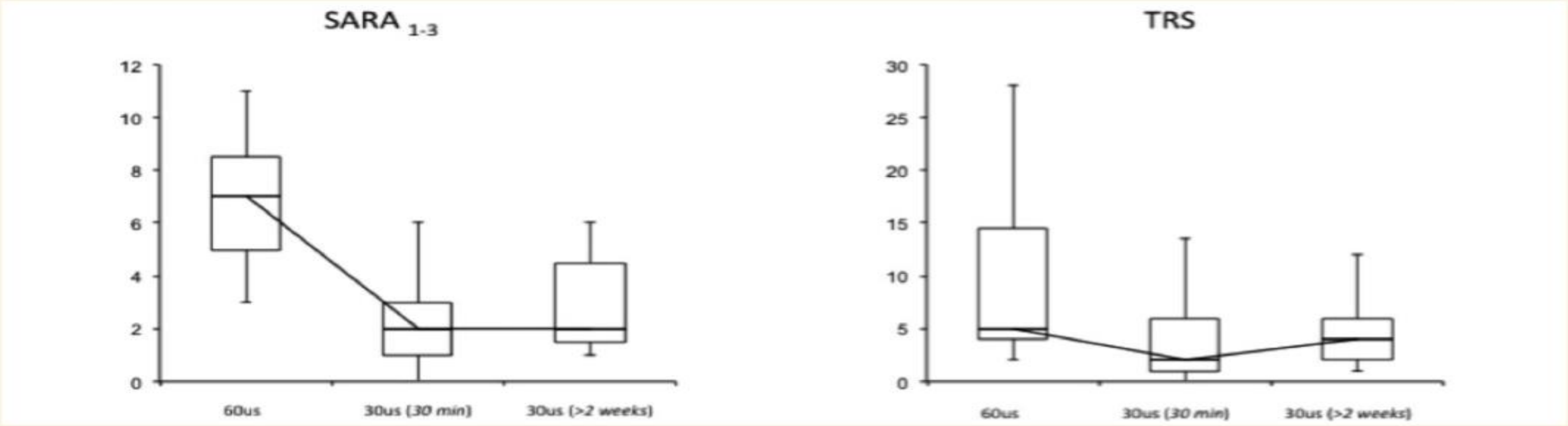



**Figure 1** Severity scores of tremor (TRS) and ataxia (SARA scale, items 1 to 3, $SARA_{1-3}$) with 60 µs pulse duration, acutely (30 min) after changing to 30 µs pulse duration and after at least 2 weeks of stimulation with 30 µs pulse duration.

# therapeutic window outcomes by altering pulse width

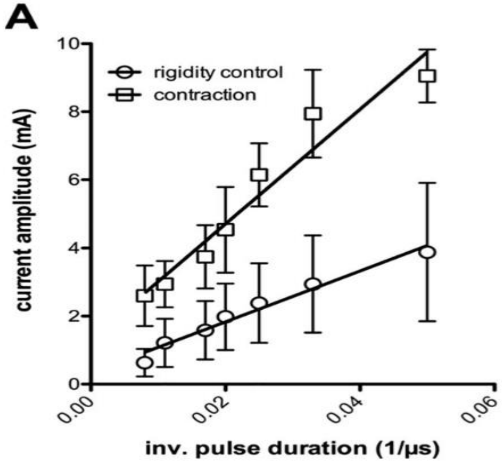
ANNALS of Clinical and Translational Neurology
Open Access

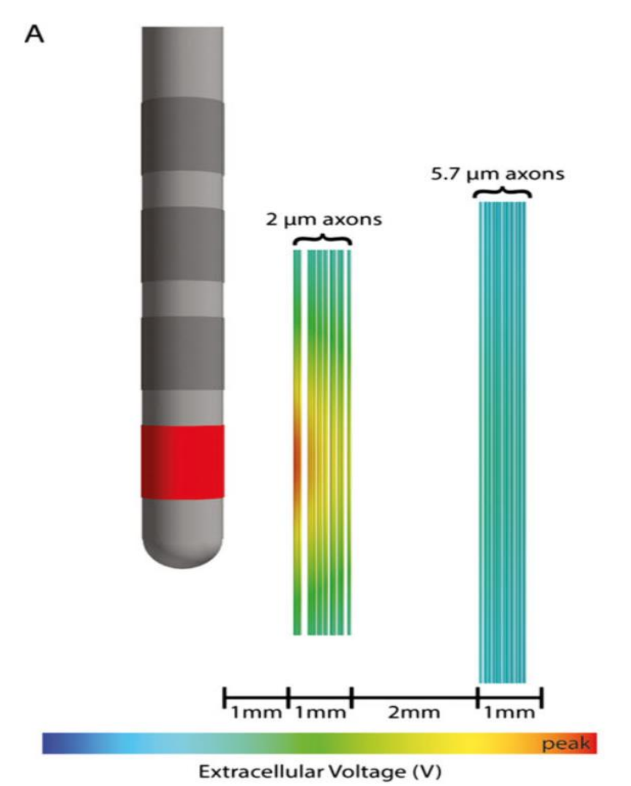
BRIEF COMMUNICATION

**Short pulse width widens the therapeutic window o subthalamic neurostimulation**

Martin M. Reich[1,a], Frank Steigerwald[1,a], Anna D. Sawalhe[1], Rene Reese[1], Kabilar Gun Johannes[3], Robert Nickl[3], Cordula Matthies[3], Cameron C. McIntyre[2] & Jens Volkmann[1]

[1]Department of Neurology, Julius-Maximilians-University, Würzburg, Germany
[2]Department of Biomedical Engineering, Case Western Reserve University, Cleveland, Ohio
[3]Department of Neurosurgery, Julius-Maximilans-University, Würzburg, Germany

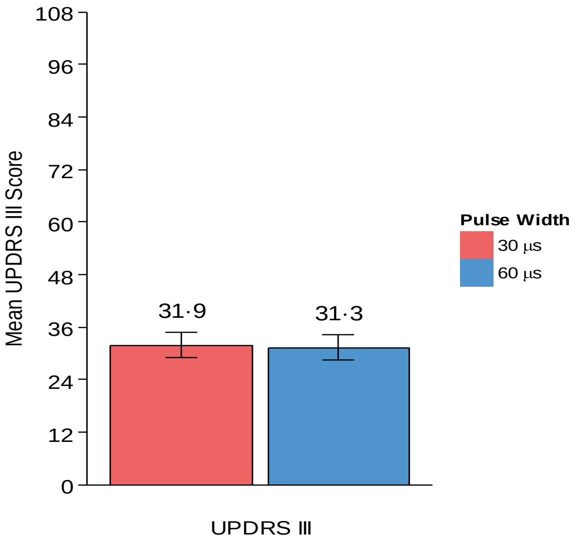



BRIEF REPORT

**Pulse Duration Settings in Subthalamic Stimulation for Parkinson's Disease**

Frank Steigerwald, MD,[1] Lars Timmermann, MD,[2] Andrea Kühn, MD,[3] Alfons Schnitzler, MD,[4] Martin M. Reich, MD,[1] Anna Dalal Kirsch, MD,[1] Michael Thomas Barbe, MD,[2] Veerle Visser-Vandewalle, MD,[2] Julius Hübl, MD,[3] Christoph van Riesen, MD,[3] Stefan Jun Groiss, MD,[4] Alexia-Sabine Moldovan, MD,[4] Sherry Lin, PhD,[5] Stephen Carcieri, PhD,[5] Ljubomir Manola, PhD,[6] and Jens Volkmann, MD[1*]


## II. Distance of fibers to electrode

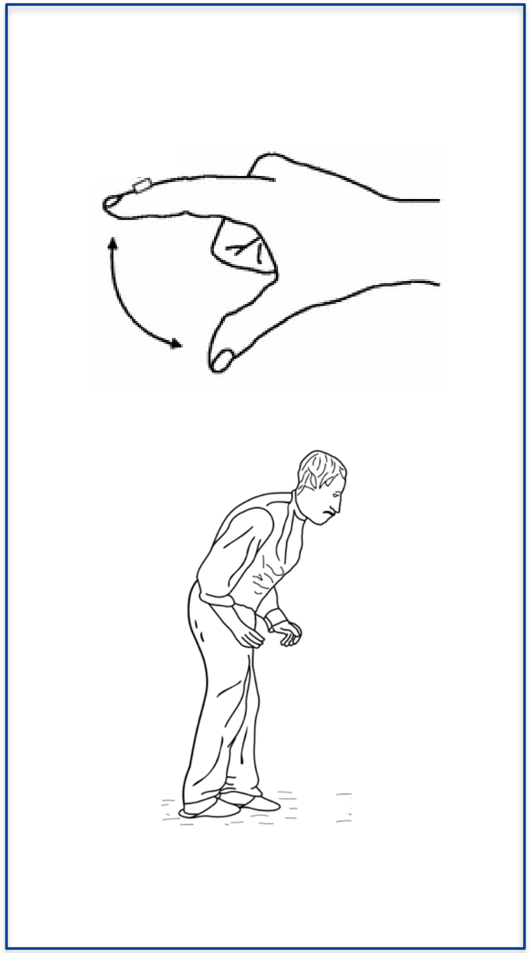
...explained by focusing on excitation of *(smaller myelinated)* axons near the electrode and a steeper falloff for activation of *(thick myelinated)* axons with increasing radius of current spread...

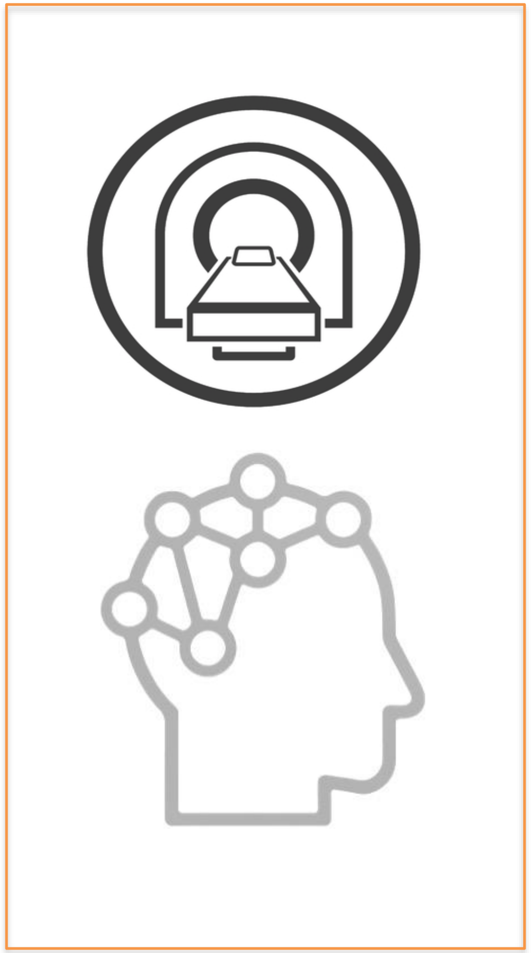
# ... searching in the dark

Tapping in the dark
„Inching“ distances

# Ideas?

# DBS programming of > 12.000 options



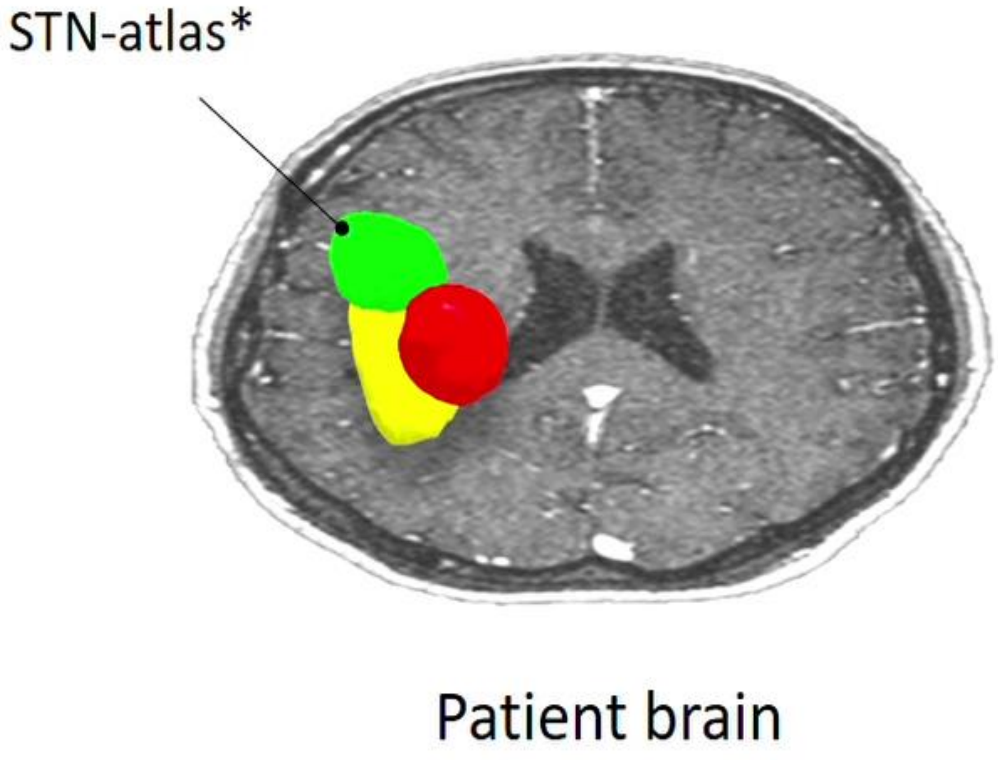


# Computational modelling for DBS programming with imaging


1. Registration of atlas 2. Detection of lead 3. Rendering of VTA

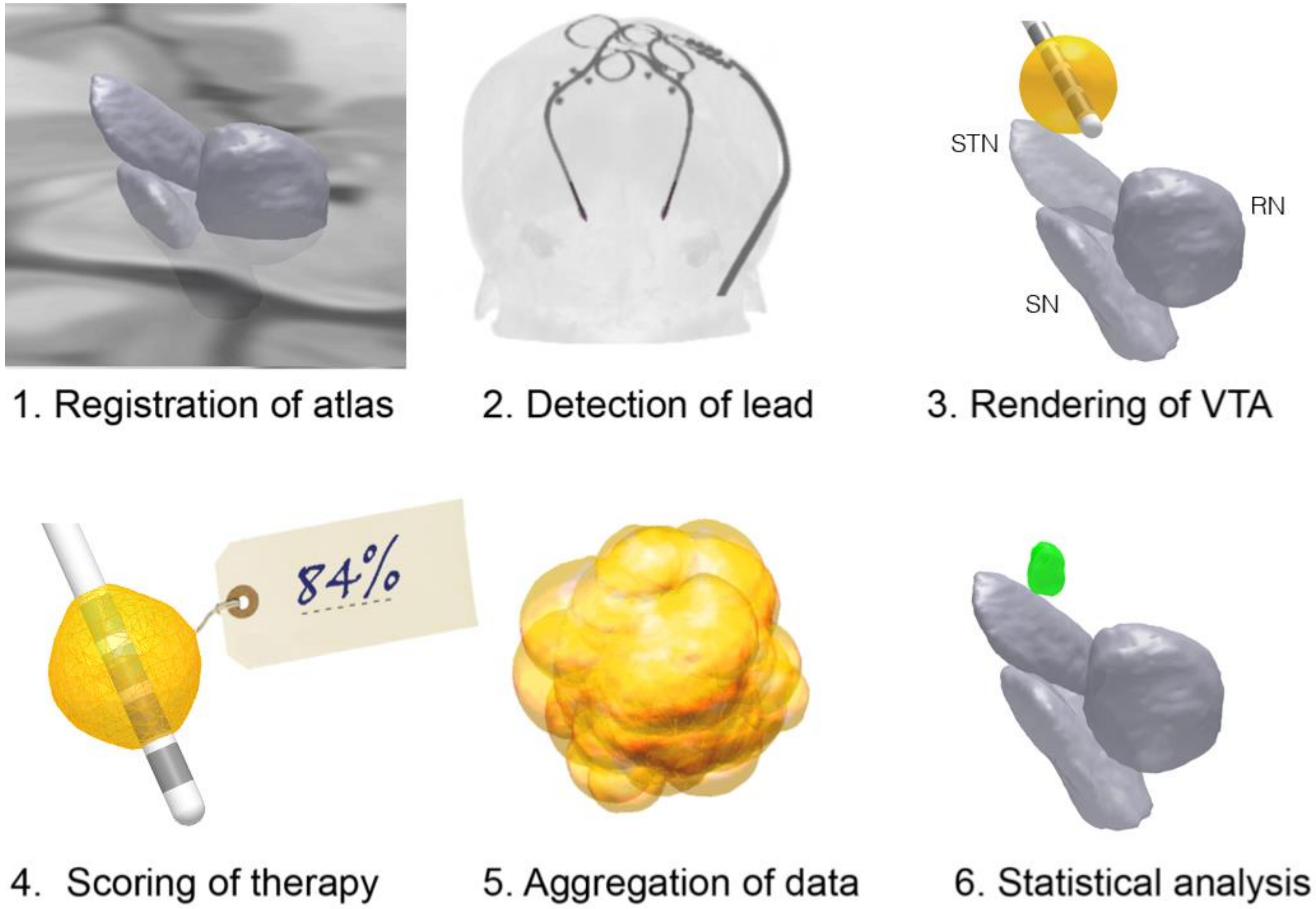

4. Scoring of therapy 5. Aggregation of data

# imaging methods

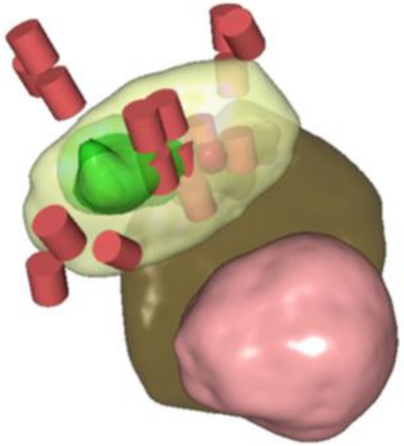


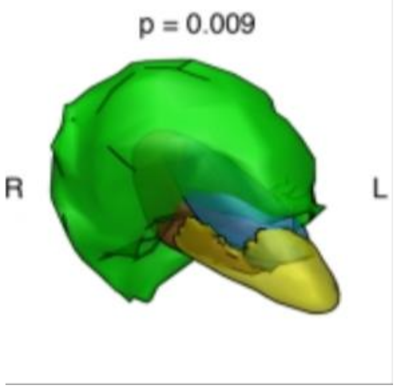

*Not to scale

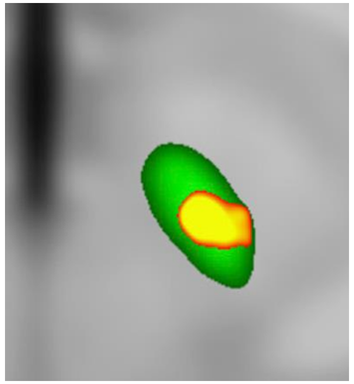
# Computational modelling for DBS programming with imaging

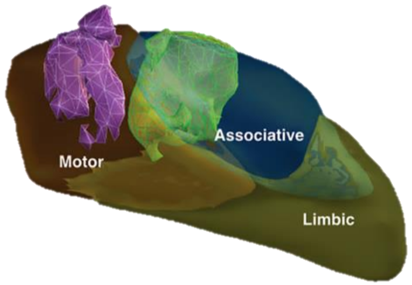


# Sweetspot(s) of STN DBS in PD








n = 9

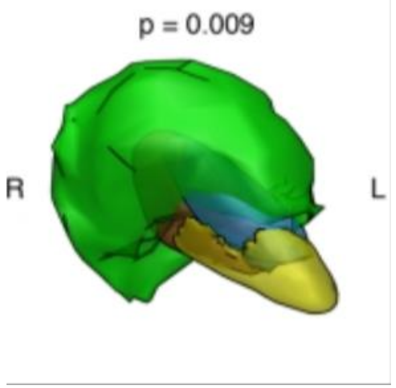
n = 21
449 settings

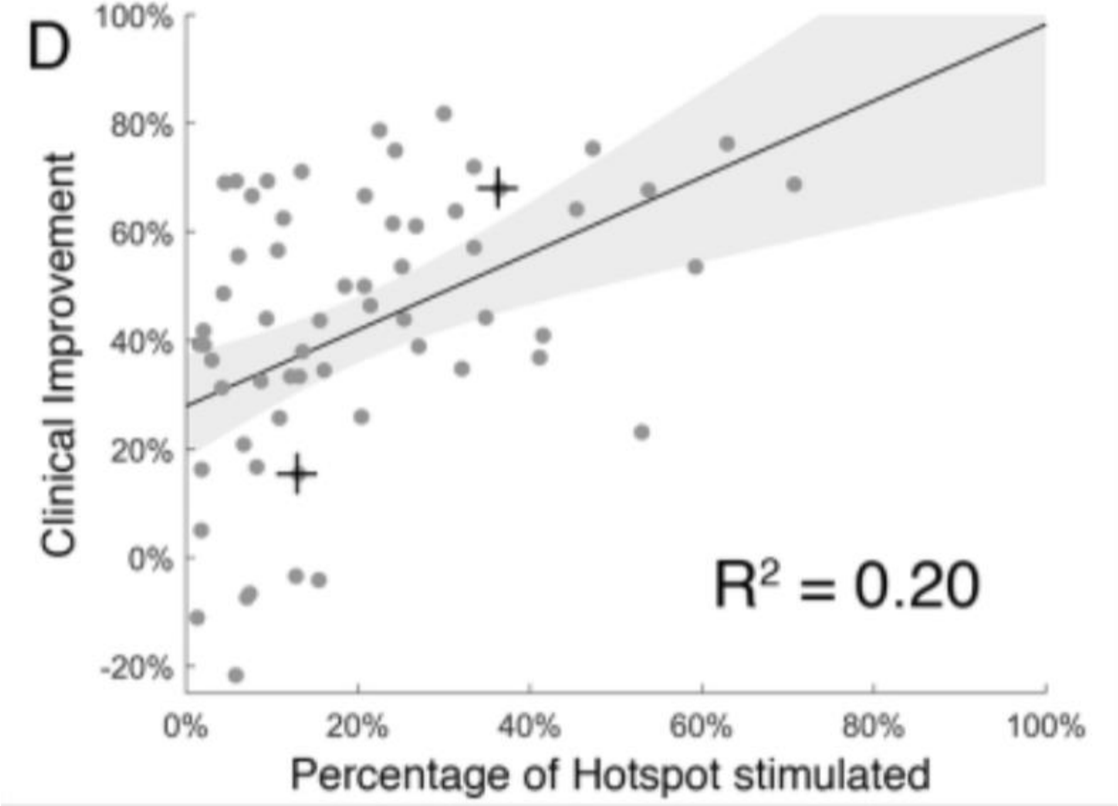
n = 12
192 settings

n = 69

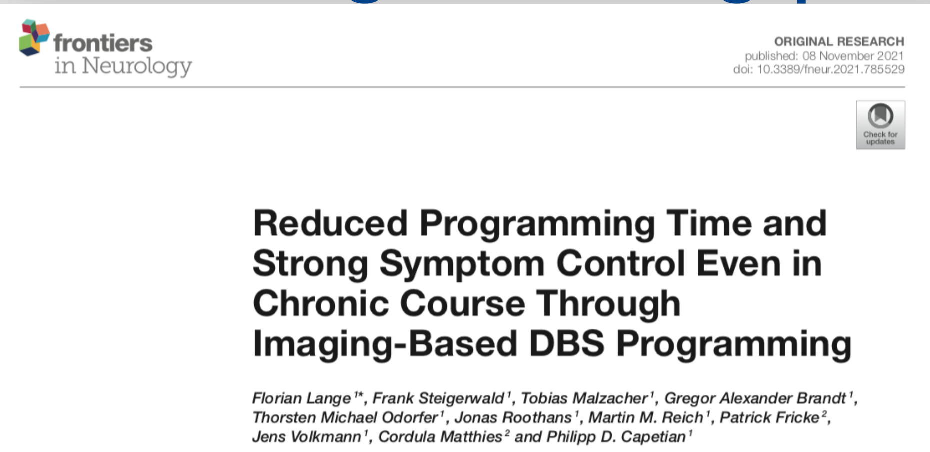
Nickl et al. 2019 Dembek et al. 2019 Akram et al. 2017 Tödt et al. 2022

# Sweetspot(s) of STN DBS in PD



# Programming patients on Sweetspot



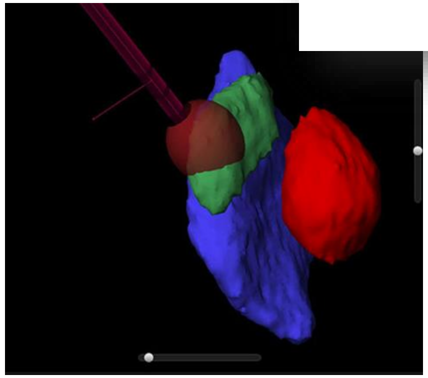
frontiers in Neurology

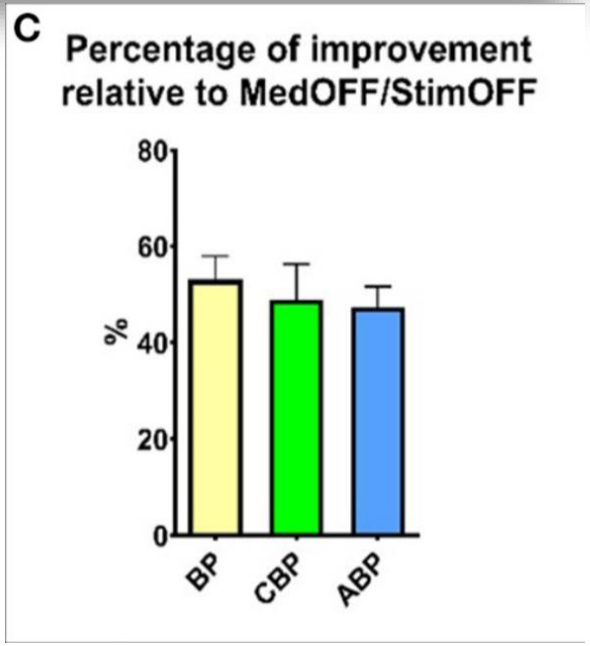
ORIGINAL RESEARCH
published: 08 November 2021
doi: 10.3389/fneur.2021.785529

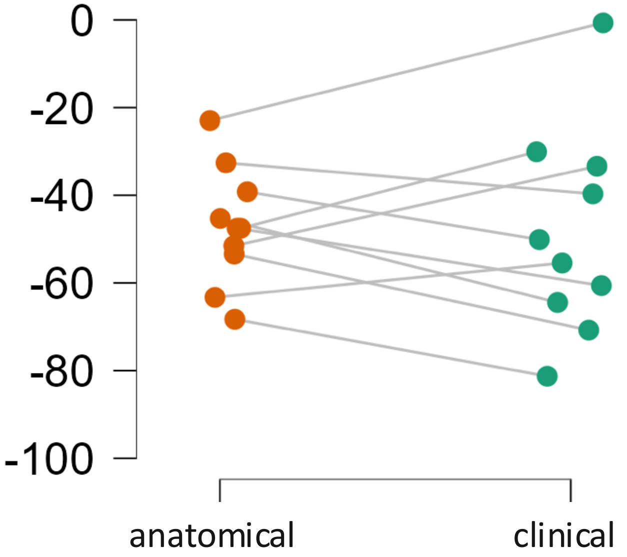
Check for updates

**Reduced Programming Time and Strong Symptom Control Even in Chronic Course Through Imaging-Based DBS Programming**

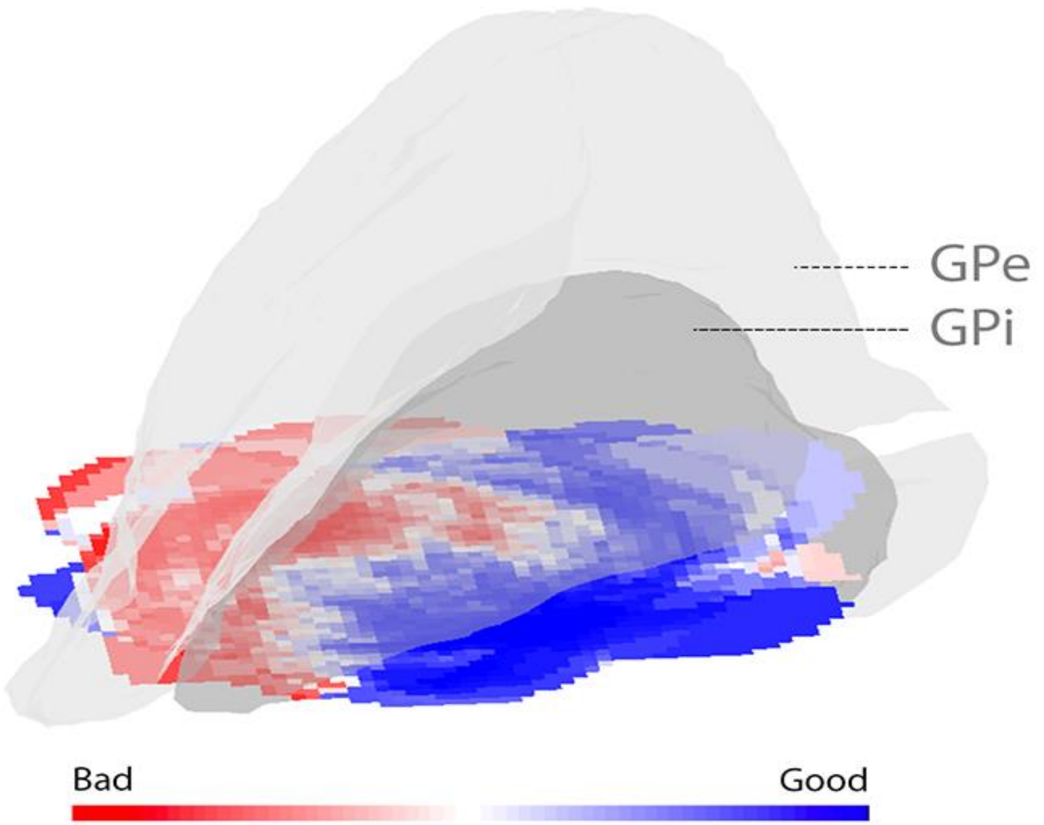
*Florian Lange[1]*, Frank Steigerwald[1], Tobias Malzacher[1], Gregor Alexander Brandt[1], Thorsten Michael Odorfer[1], Jonas Roothans[1], Martin M. Reich[1], Patrick Fricke[2], Jens Volkmann[1], Cordula Matthies[2] and Philipp D. Capetian[1]*





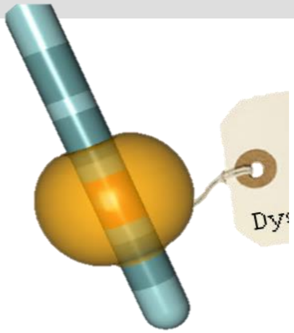



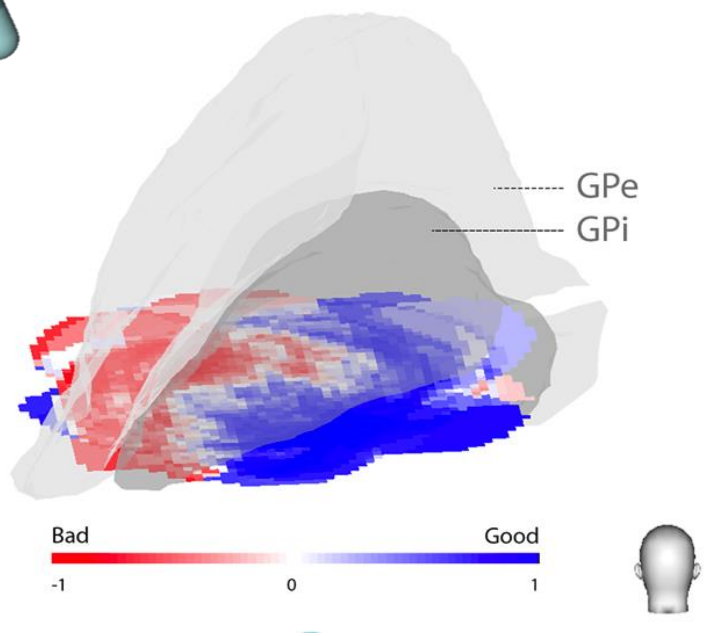
# Taking the whole statistical map

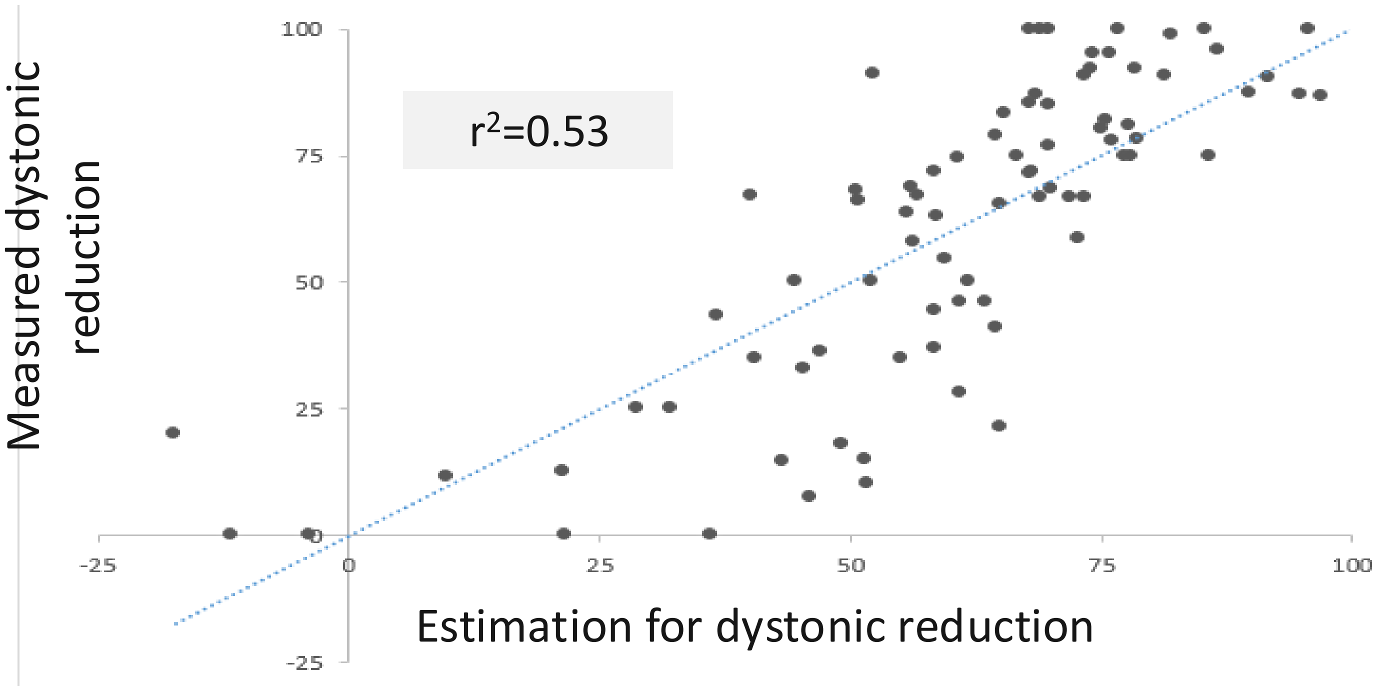



n = 87

# Probabilistic mapping and VTAs

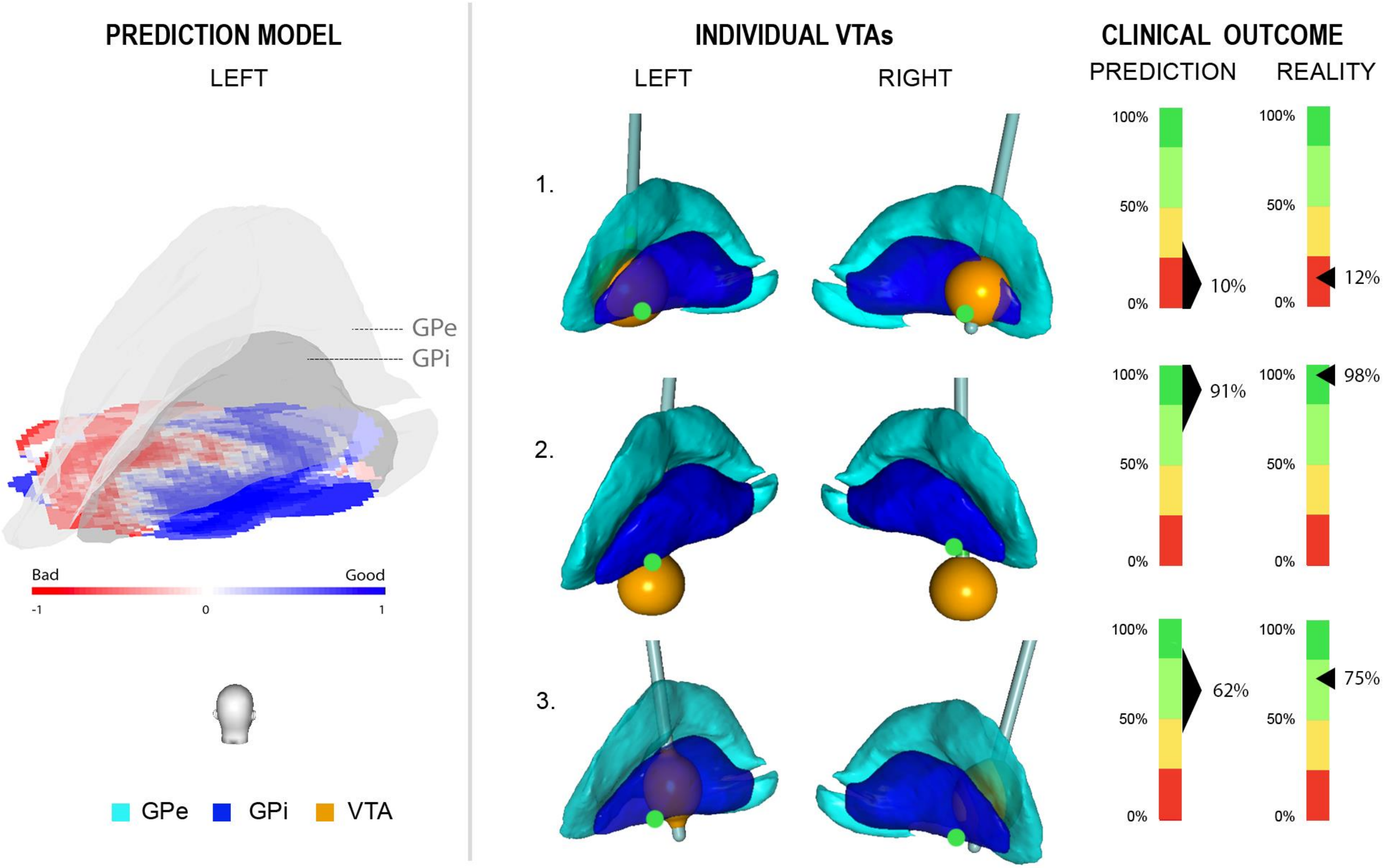


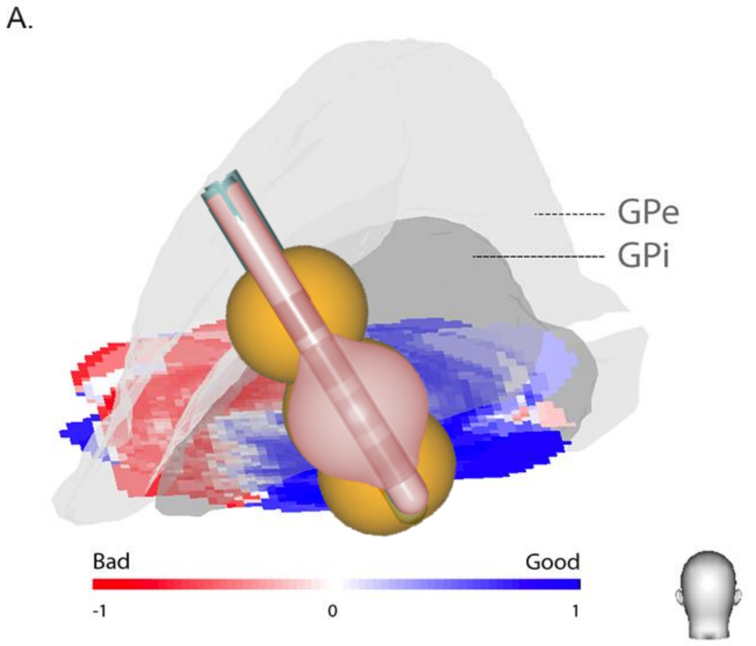



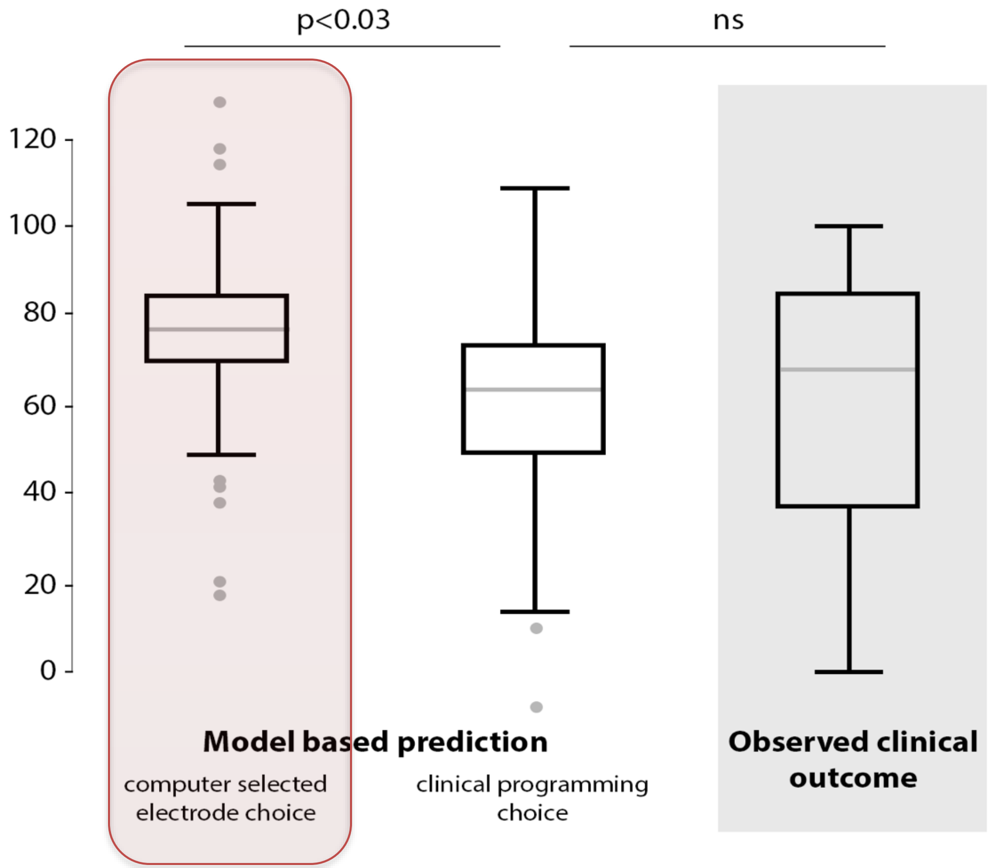

Correlation between **estimation** and **clinical measurements**

# Individual predictions on local maps

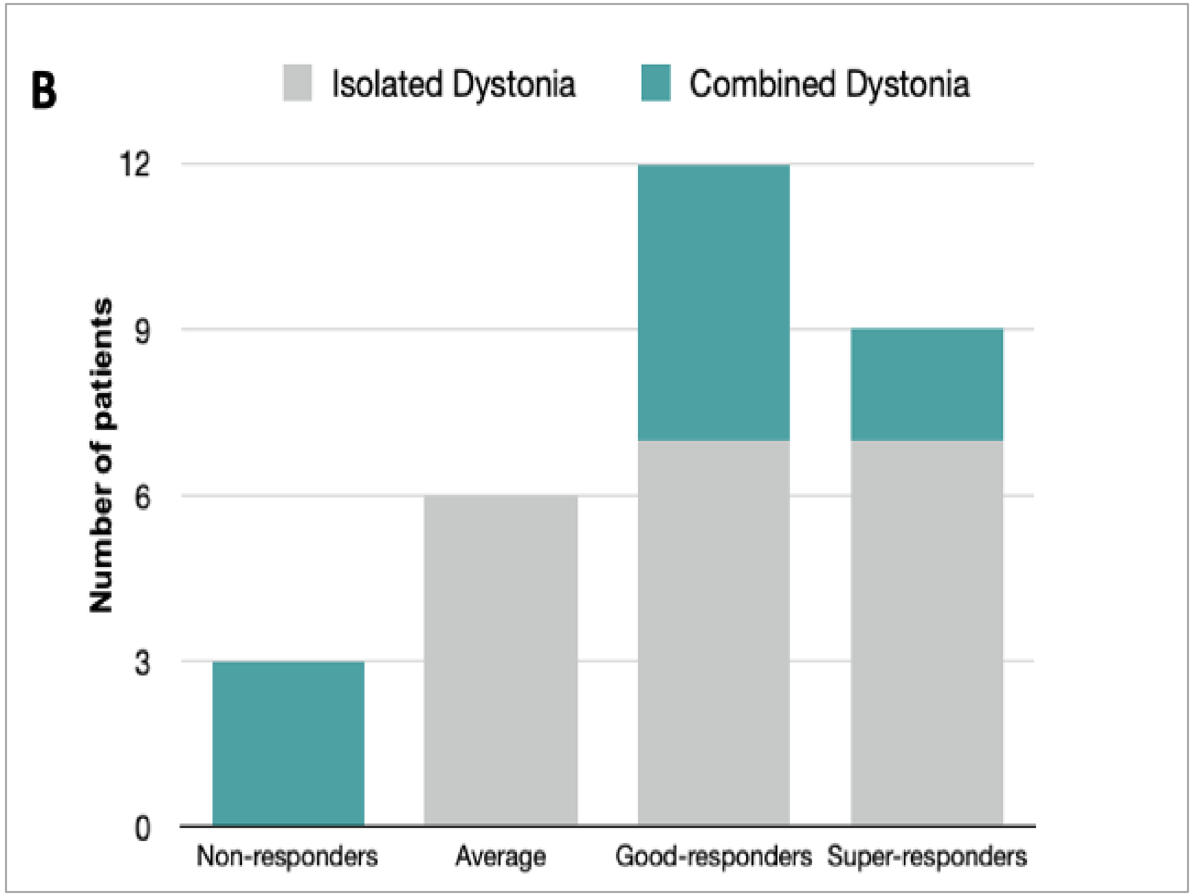


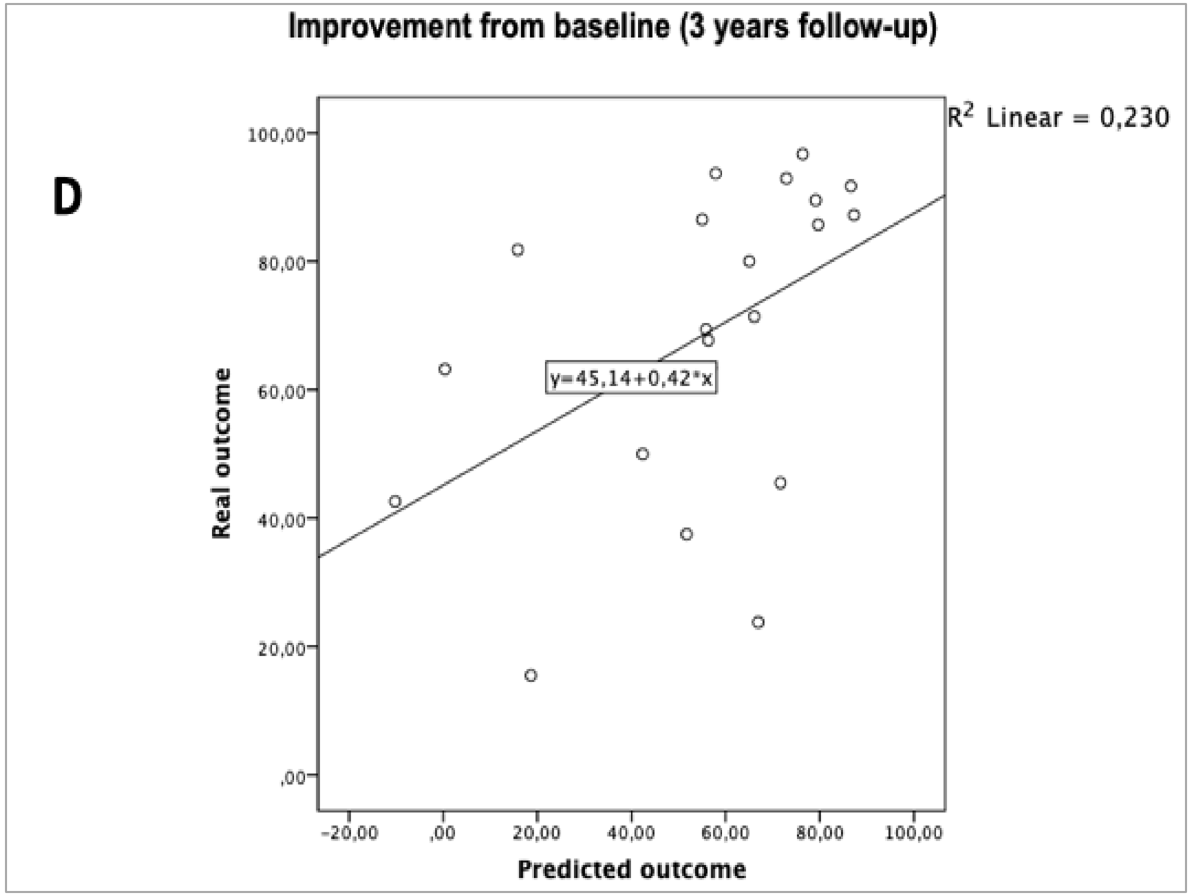
# In silico testing of all possible monopolar electrode choices with a predefined VTA (3.0 mA; 90 µs)



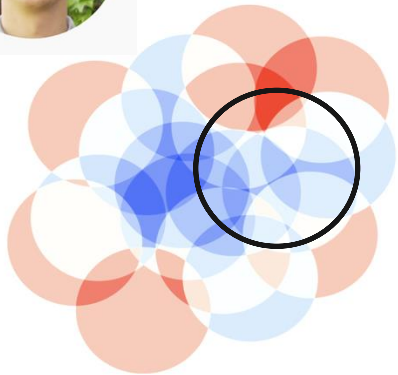



# Conformation study with a independent cohort of isolated and combined dystonia (Soares et al. *2021*)



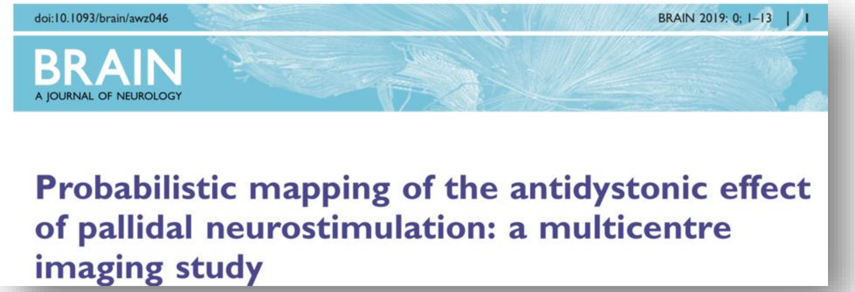



# Prediction modelling of individual DBS settings



| | |
|---|---|
| Fix Amplitude ? | No |
| Fix pulse duration? | **120 µs** (mean 117.5 µs ± 44.2 µs; Brain 2019) |
| How to handle Frequency? | Individual chosen once |
| Overlap of VTA with probablistic map? | > 50 % regarding Soares *et al. 2021* |

# Prediction modelling of individual DBS settings


doi:10.1093/brain/awz046 BRAIN 2019: 0; 1–13 | 1

BRAIN
A JOURNAL OF NEUROLOGY

**Probabilistic mapping of the antidystonic effect of pallidal neurostimulation: a multicentre imaging study**

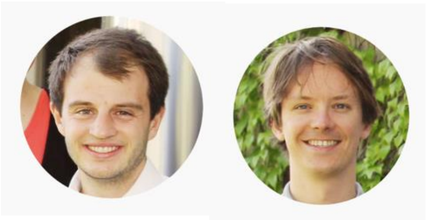
| | | |
|---|---|---|
| mean | 3,41294118 | |
| std | 1,10172412 | |
| | lower | upper |
| 1 sigma | 2,31121706 | 4,51466529 |
| 2 sigma | 1,20949294 | 5,61638941 |

Clinician has +/- 0.5 mA selection freedom

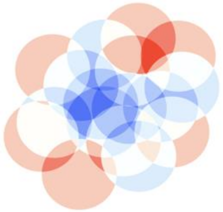
So the range for **CSURF** is:

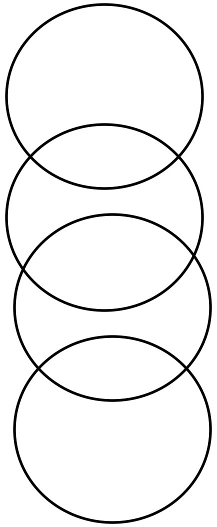
**1.5** (1.0 - 2.0) **until 5.5** (5.0 - 6.0)

# Proof of Concept Study



$b_0$: 0
$b_1$: -1
$b_2$: +2
$b_3$: +3





(4 contacts x 8 amplitudes ) $^{2 \text{ sides}}$

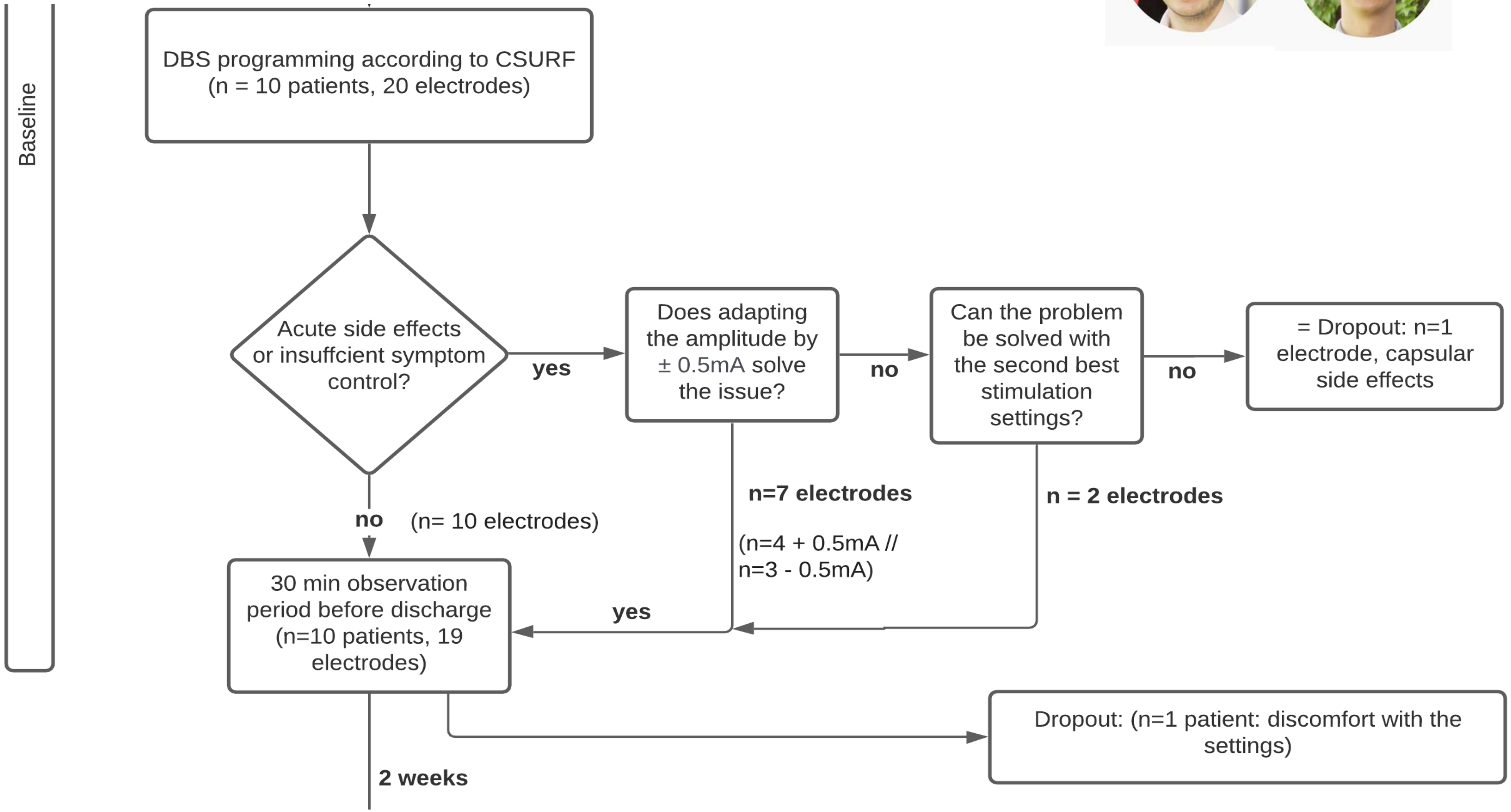
**1024 combinations!**

1024 predictions. → TOP 1 and 2

(5 minutes per setting, would be 3.5 days non stop programming)

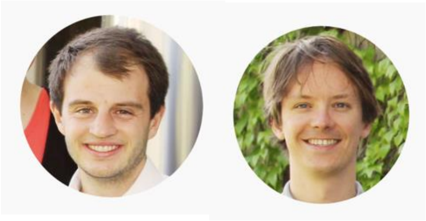
F. Lange , C. Soares, J. Roothans , R. Raimundo, H. Eldebakey , B. Weigl, C. Daniels, T. Musacchio, J. Volkmann, M. Rosas, MM. Reich . (2023) „**C-Surf: Artificial intelligent DBS programming results of a prospective feasibility study “, Brain Stimulation**

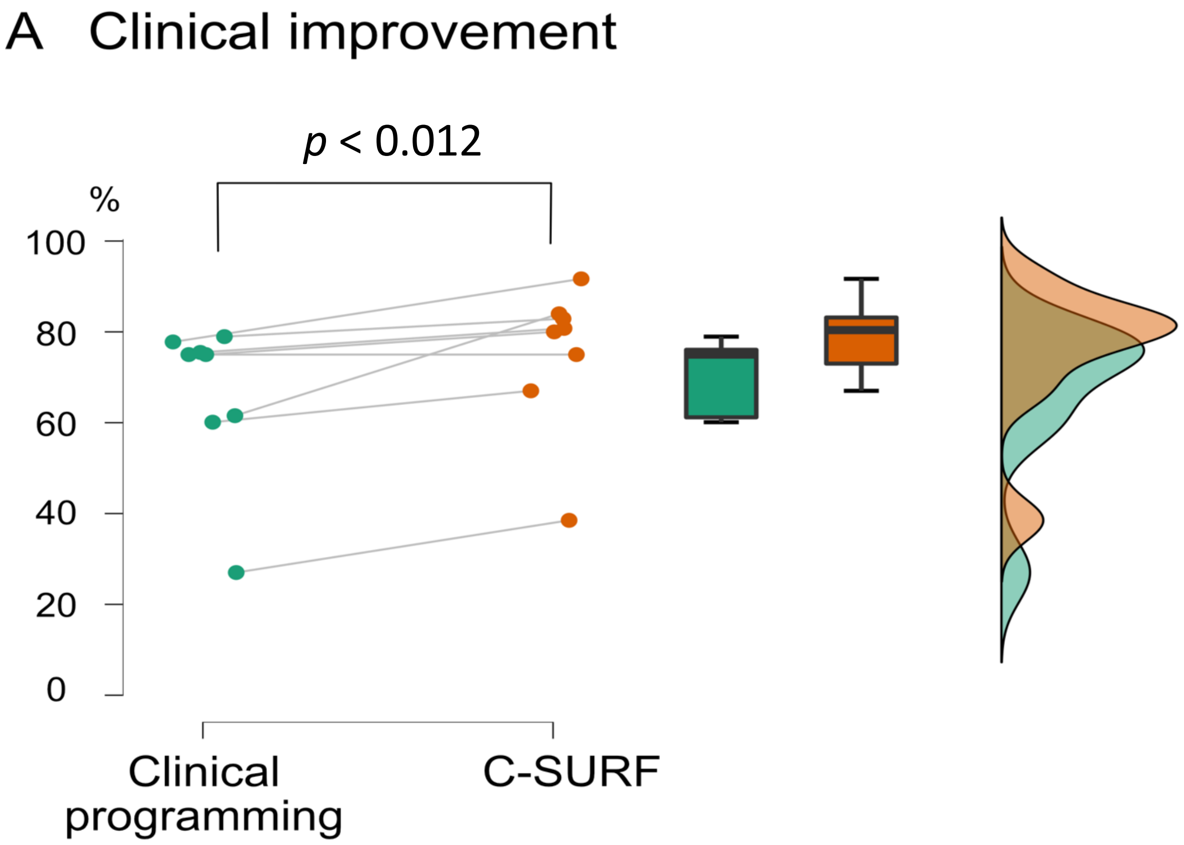
# Akute Wirkung/Nebenwirkungen

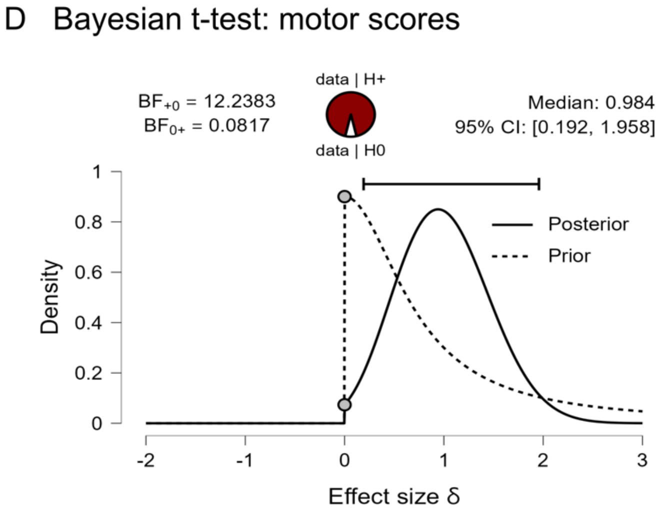



F. Lange , C. Soares, J. Roothans , R. Raimundo, H. Eldebakey , B. Weigl, C. Daniels, T. Musacchio, J. Volkmann, M. Rosas, M. M. Reich .(2023)
„C-Surf: Artificial intelligent DBS programming results of a prospective feasibility study “, Brain Stimulation

# 2-weeks Outcome Dystonia






F. Lange , C. Soares, J. Roothans , R. Raimundo, H. Eldebakey , B. Weigl, C. Daniels, T. Musacchio, J. Volkmann, M. Rosas, MM. Reich . (2023) „**C-Surf: Artificial intelligent DBS programming results of a prospective feasibility study**“, **Brain Stimulation**

# 1991

1991 THE LANCET

## Long-term suppression of tremor by chronic stimulation of the ventral intermediate thalamic nucleus

ALIM L. BENABID PIERRE POLLAK CLAIRE GERVASON
DOMINIQUE HOFFMANN DONG M. GAO MARC HOMMEL
JEAN E. PERRET JACQUES DE ROUGEMONT

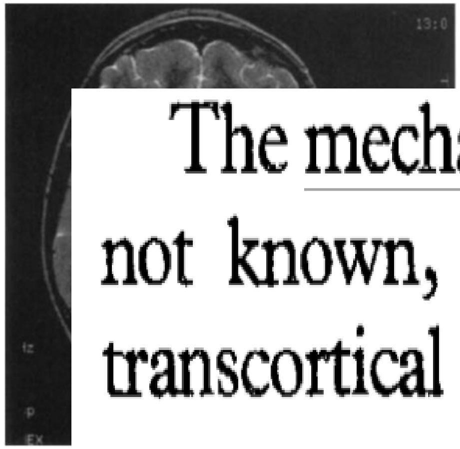
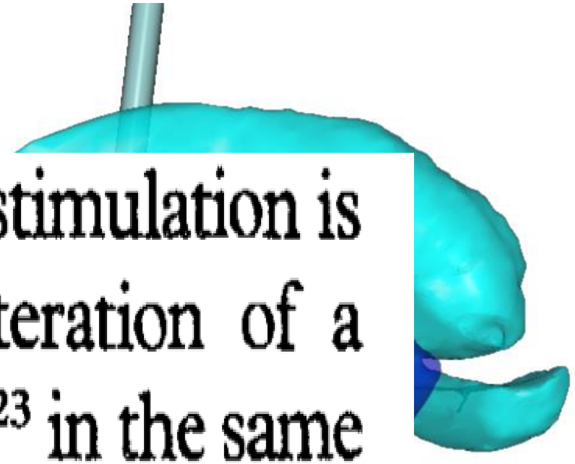
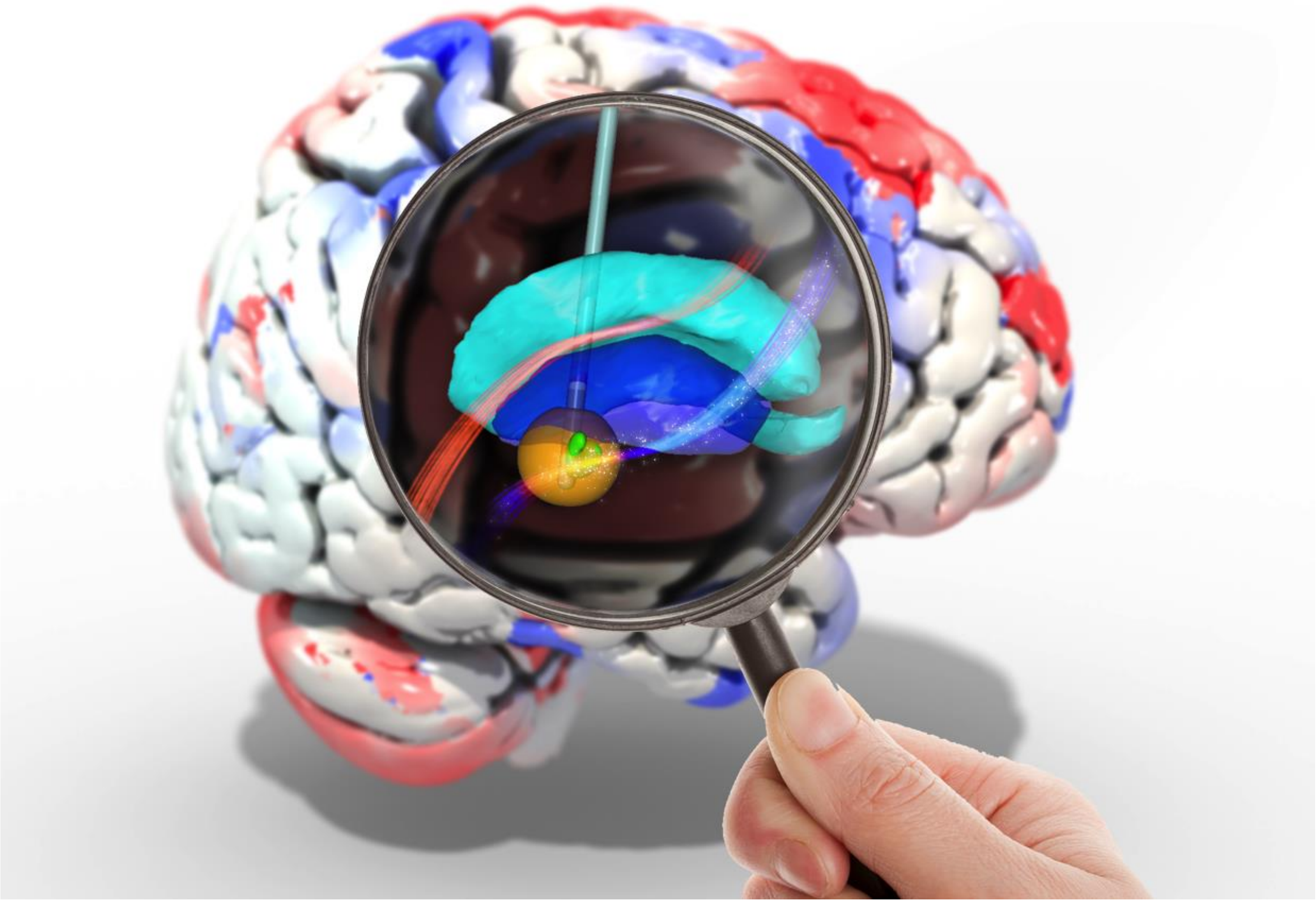


FIG. 1. S

The mechanism of action of electrical Vim stimulation is not known, but it cou[redacted]ue to the alteration of a transcortical reflex loop passing through Vim,[23] in the same manner as a thalamotomy. Instead of the removal by



# today



# Stimulation or neuromodulation ?

nature REVIEWS NEUROLOGY

Review Article | Published: 28 July 2017

## Insights into the mechanisms of deep brain stimulation

Keyoumars Ashkan, Priya Rogers, Hagai Bergman & Ismail Ughratdar

*Nature Reviews Neurology* **13**, 548–554 (2017) | Download Citation

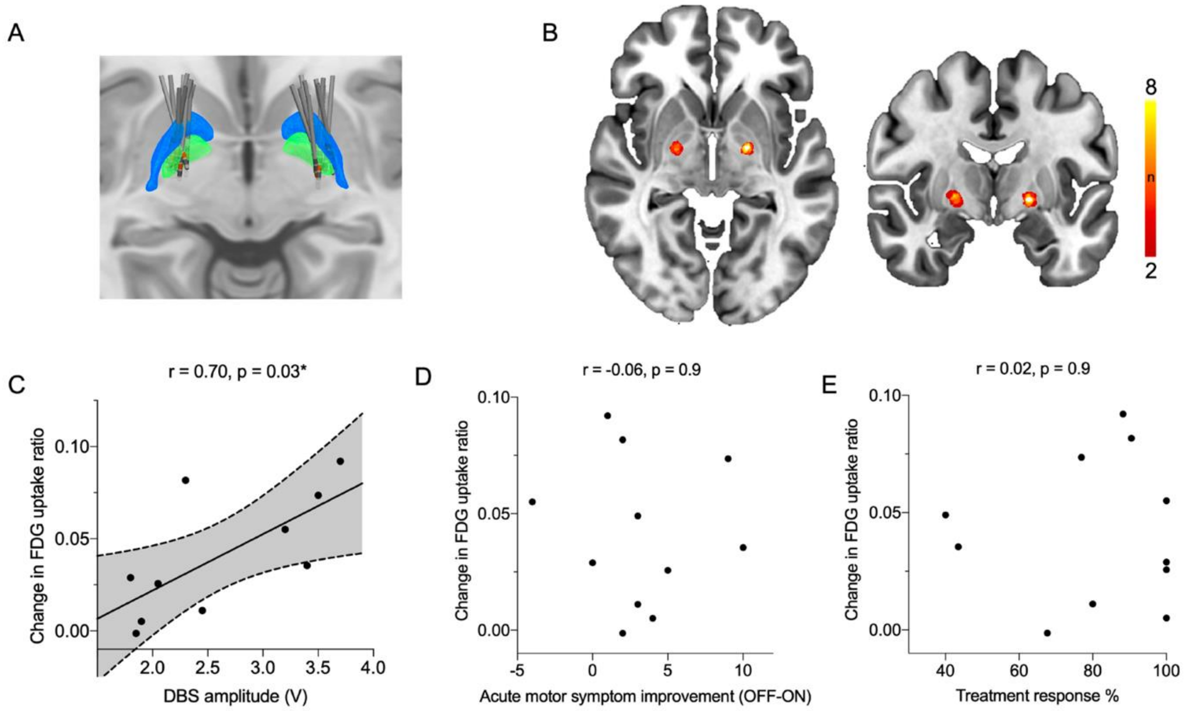
'deep brain stimulation' warrants modification. A potentially more accurate term is 'deep brain neuromodulation', as the mode of action spans an array of therapeutic effects over a variable period of time, and is not just limited to 'stimulation' of the basal ganglia brain centres.

Movement disorders

Original research

# GPi-DBS-induced brain metabolic activation in cervical dystonia

Emma A Honkanen,[1,2,3,4] Jaana Rönkä,[1,5] Eero Pekkonen,[6] Juho Aaltonen,[2] Maija Koivu,[6] Olli Eskola,[4] Hazem Eldebakey,[7] Jens Volkmann,[7] Valtteri Kaasinen,[1,5] Martin M Reich,[7] Juho Joutsa[1,2,4]



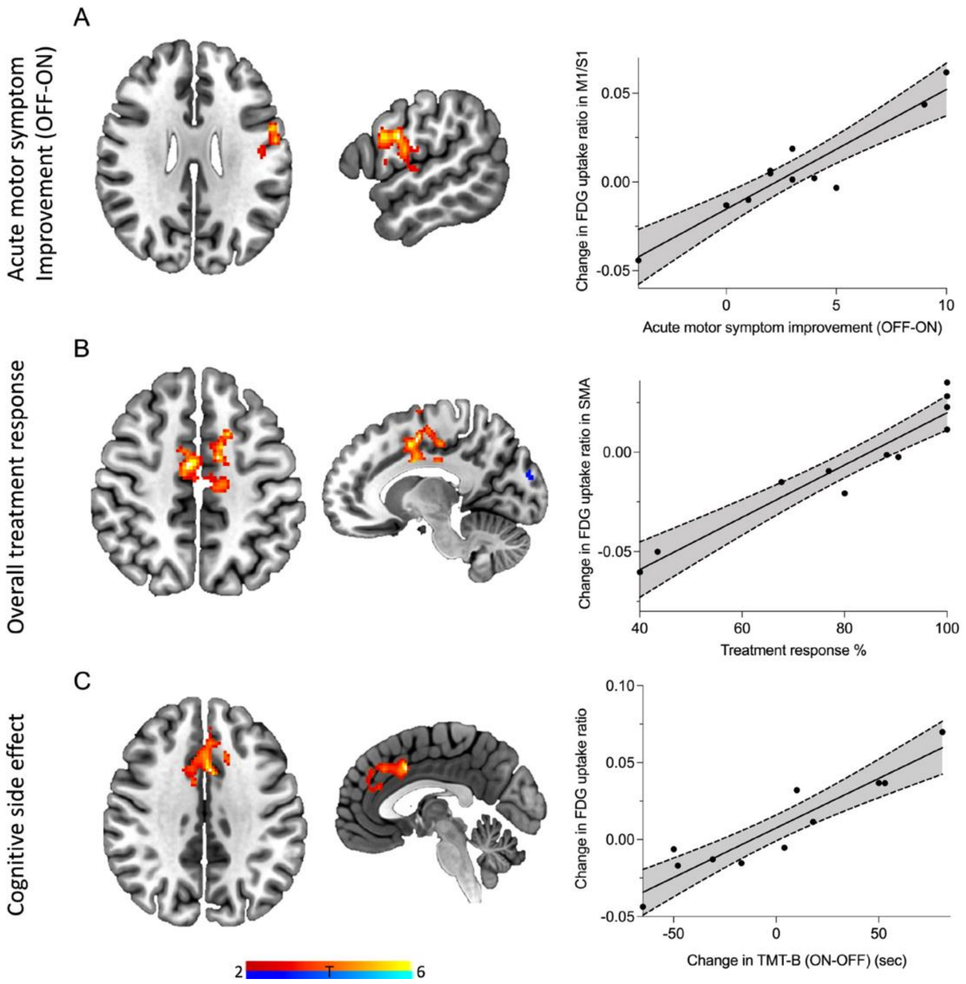

Honkanen EA, *et al. J Neurol Neurosurg Psychiatry* 2023;**0**:1–9. doi:10.1136/jnnp-2023-331668

Movement disorders

Original research

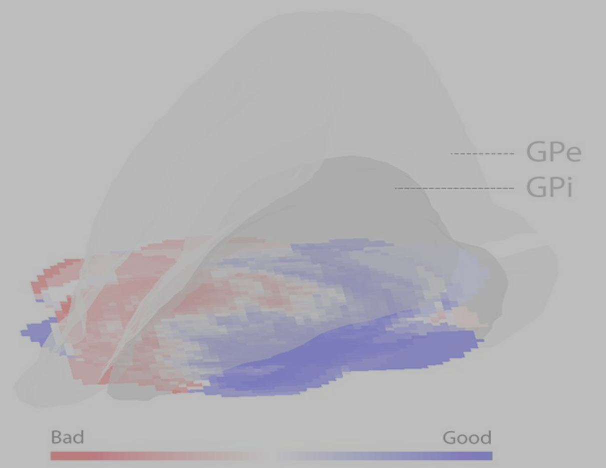
# GPi-DBS-induced brain metabolic activation in cervical dystonia

Emma A Honkanen [1,2,3,4] Jaana Rönkä,[1,5] Eero Pekkonen,[6] Juho Aaltonen,[2] Maija Koivu,[6] Olli Eskola,[4] Hazem Eldebakey,[7] Jens Volkmann,[7] Valtteri Kaasinen,[1,5] Martin M Reich,[7] Juho Joutsa [1,2,4]

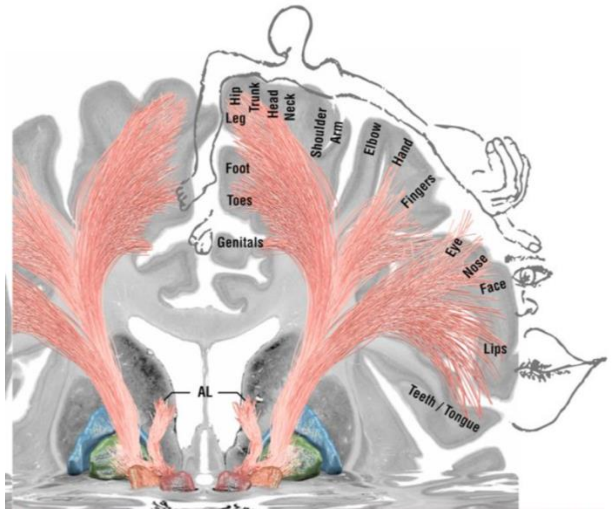



Honkanen EA, *et al. J Neurol Neurosurg Psychiatry* 2023;**0**:1–9. doi:10.1136/jnnp-2023-331668

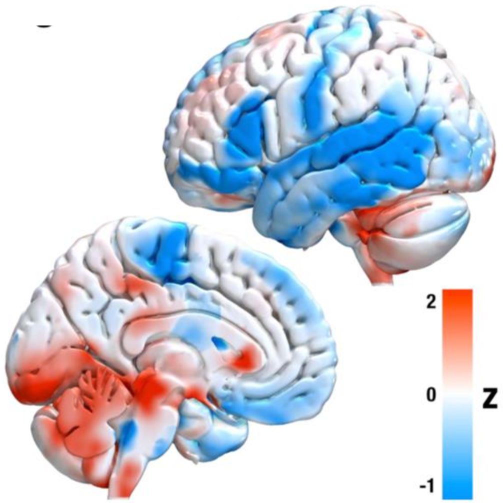
# Network modelling with normative connectomes




Local Heatmaps

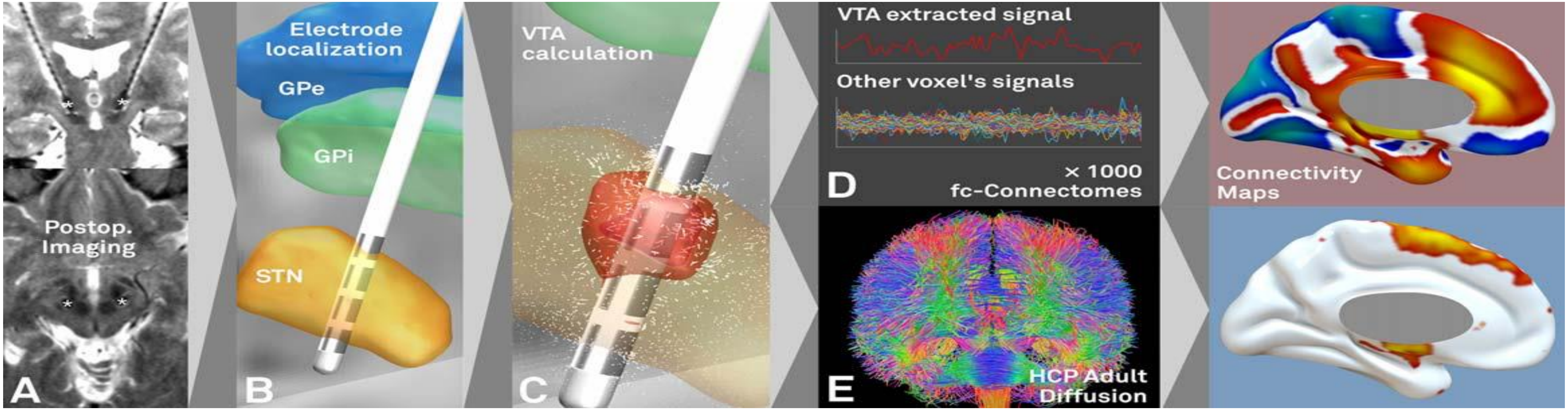



structural connectivity



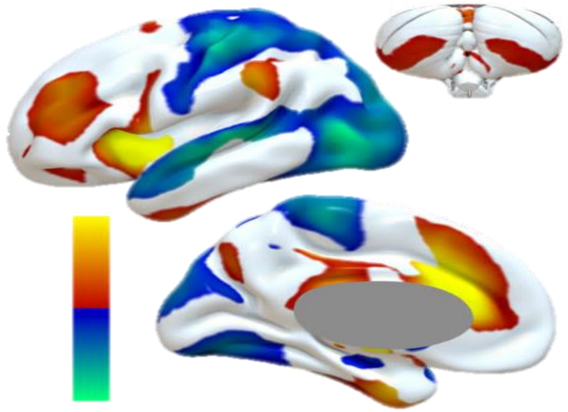

functional connectivity

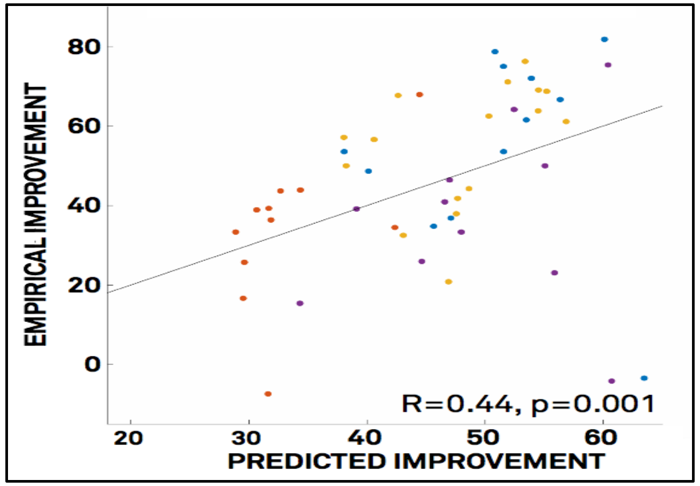
# Seed-based connectivity



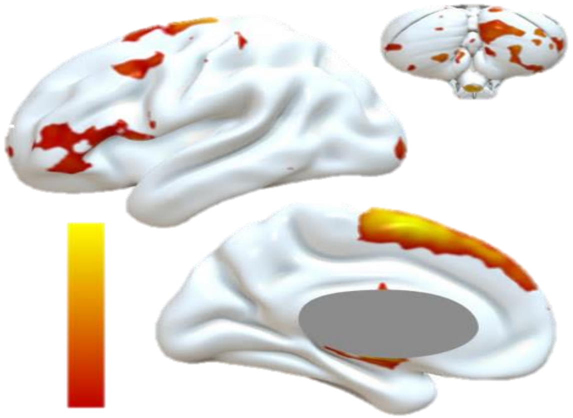
Clinical Response Map

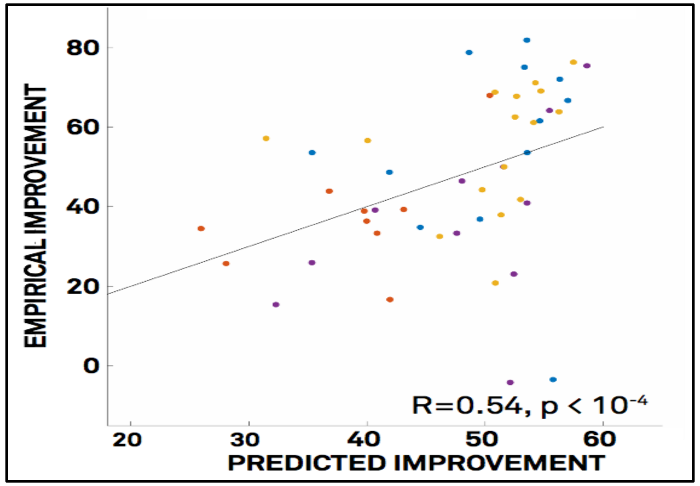
Functional Connectivity






Structural Connectivity

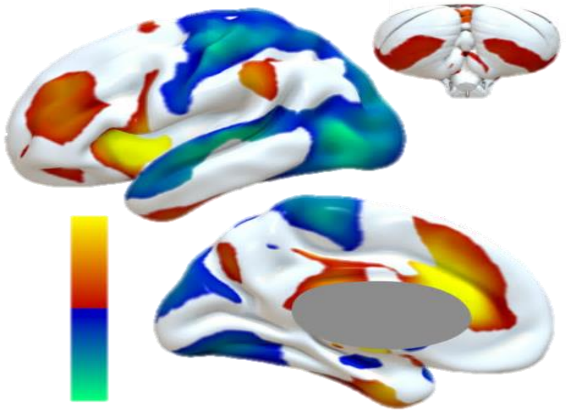


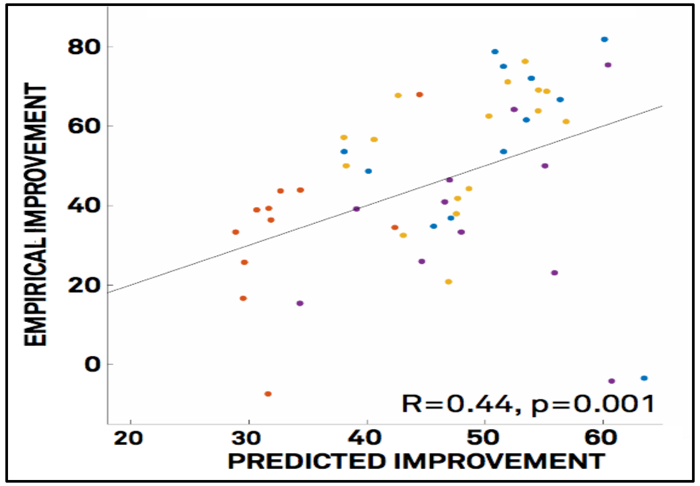


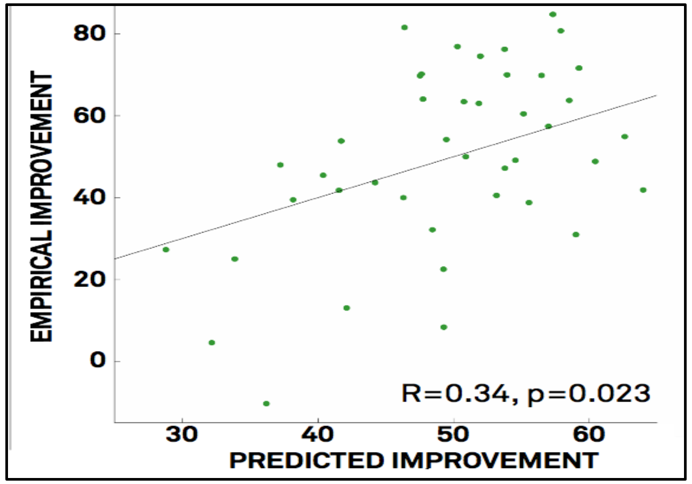
Clinical Response Map

Independent Cohort

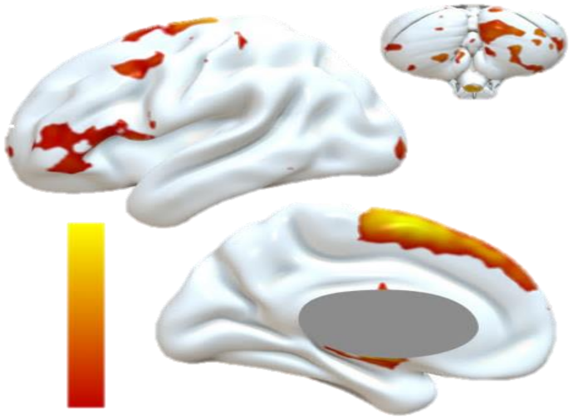
Functional Connectivity

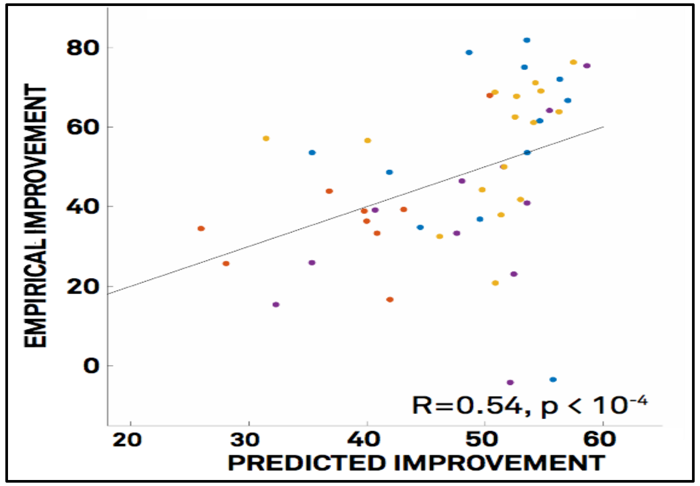


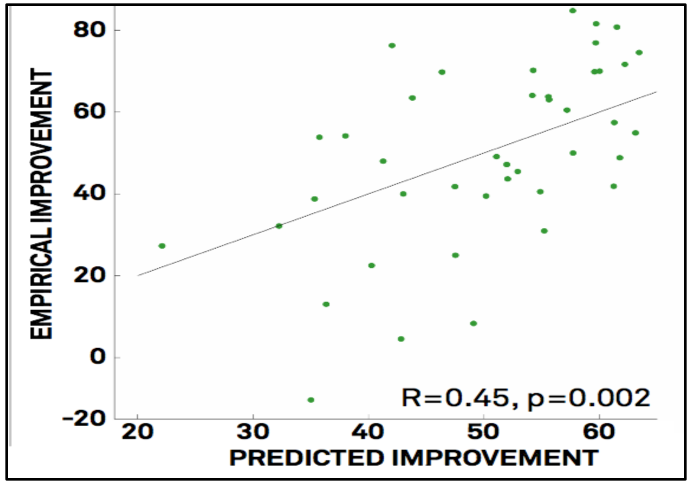


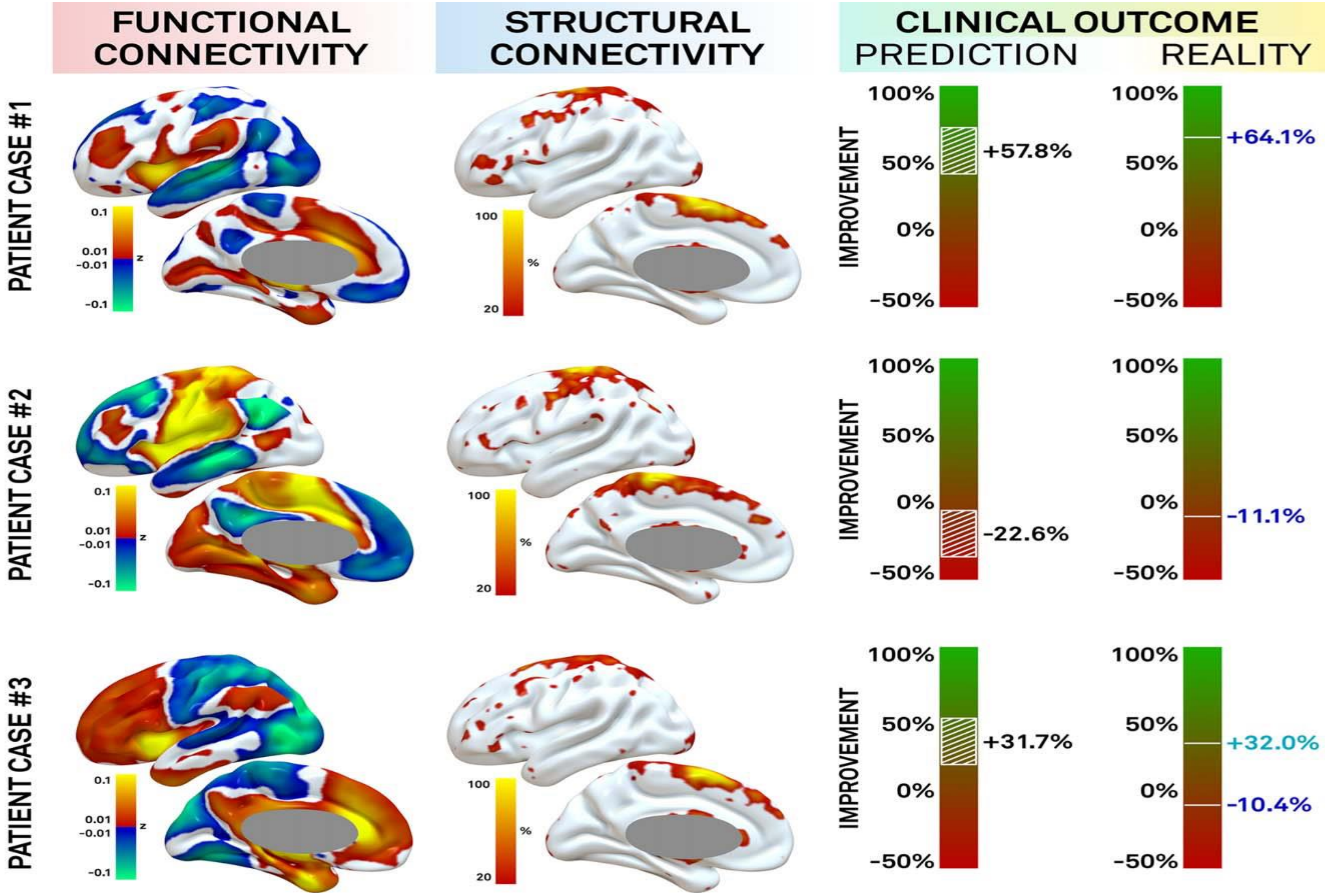




Structural Connectivity



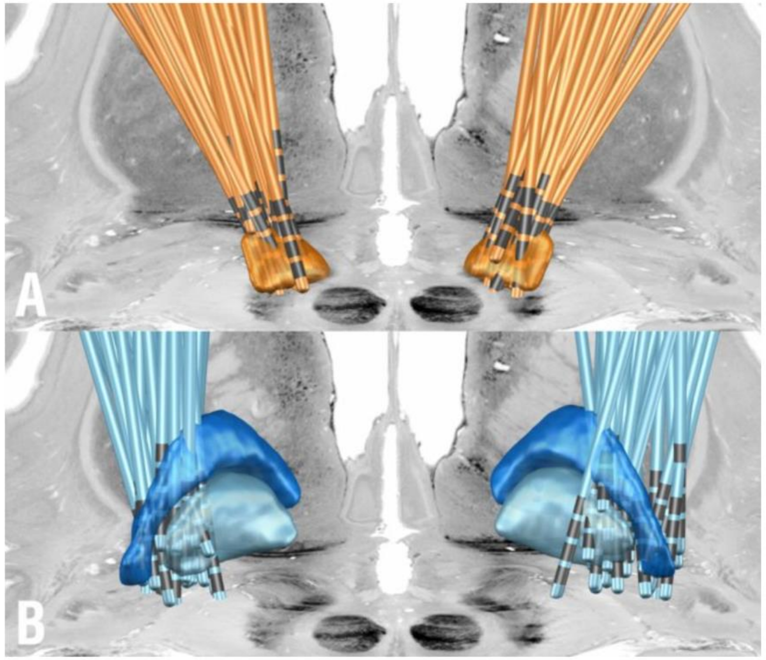


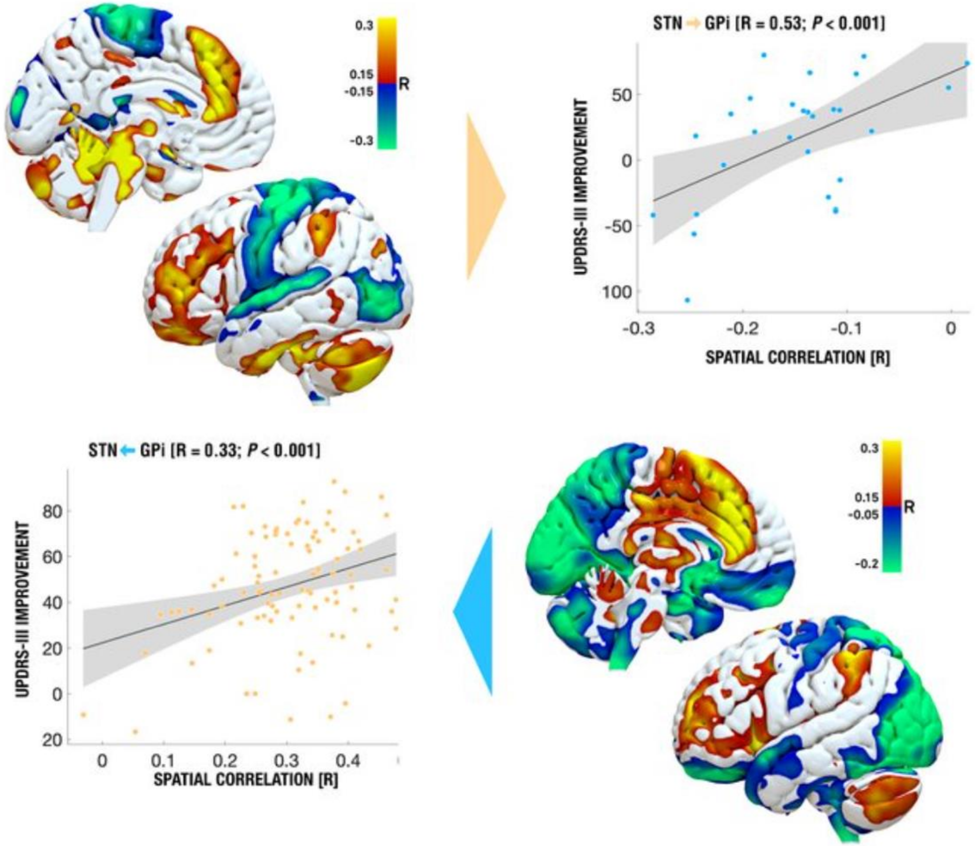






Horn, Reich et. al 2017 Annals of Neurology

# Neuronal network of parkinsonism improvement



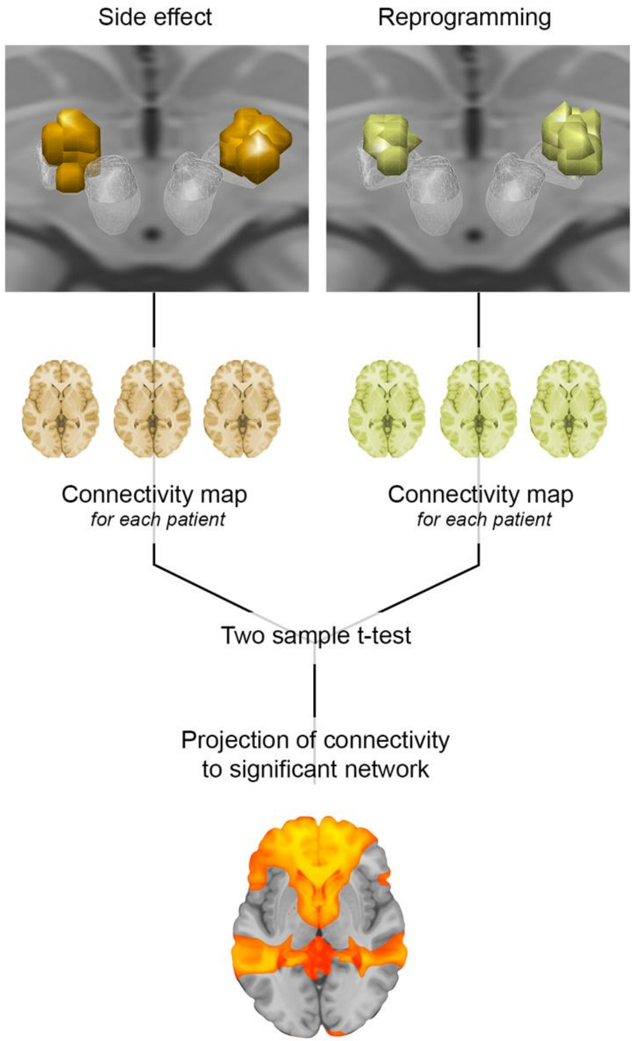

Leon Sobesky, L. Goede, ..., M. Reich, J. Volkmann, Rob M.A. de Bie, A. Kühn, A. Horn (2021) **„Subthalamic and pallidal deep brain stimulation – are we modulating the same network?.** , Brain

# Neuronal network of side effects ?

## - Small cohorts -

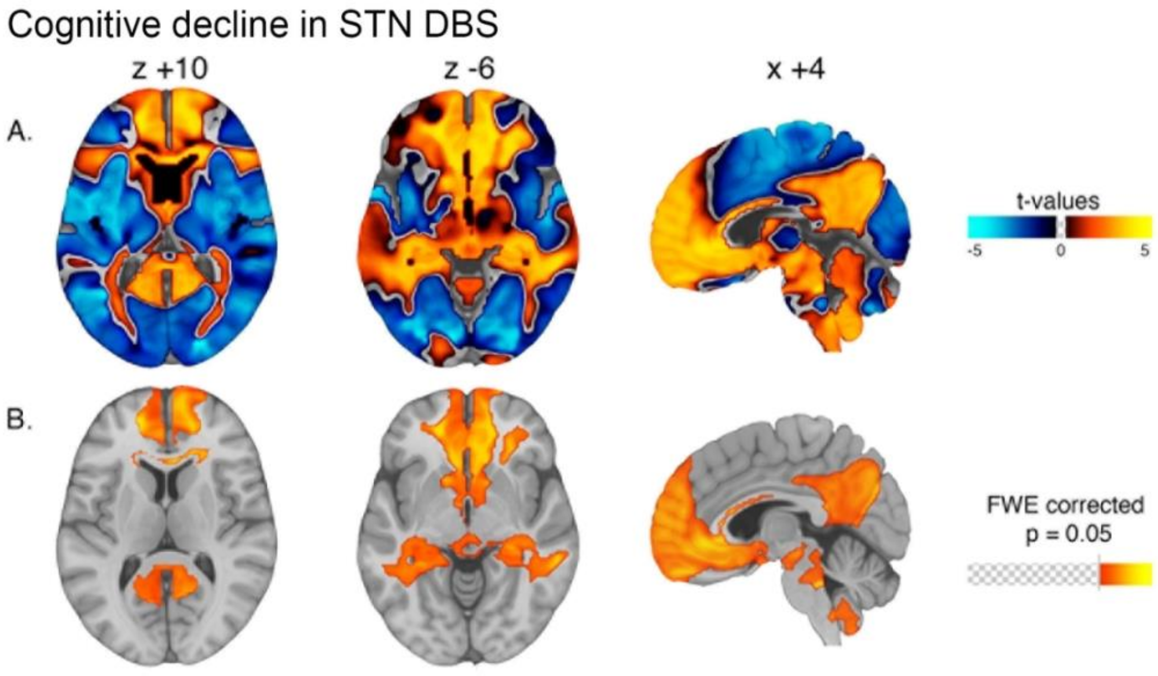
Reich, M. M., J. Hsu, M. Ferguson, F. Schaper, J. Joutsa, J. Roothans, R. C. Nickl, A. Frankemolle-Gilbert, J. Alberts, J. Volkmann and M. D. Fox (2022). "A brain network for deep brain stimulation induced cognitive decline in Parkinson's disease." Brain,

# Neuronal networks in small cohorts




Reich, M. M., J. Hsu, M. Ferguson, F. Schaper, J. Joutsa, J. Roothans, R. C. Nickl, A. Frankemolle-Gilbert, J. Alberts, J. Volkmann and M. D. Fox (2022). "A brain network for deep brain stimulation induced cognitive decline in Parkinson's disease." Brain,

# Neuronal network of cognitive (decline)




ACCEPTED MANUSCRIPT

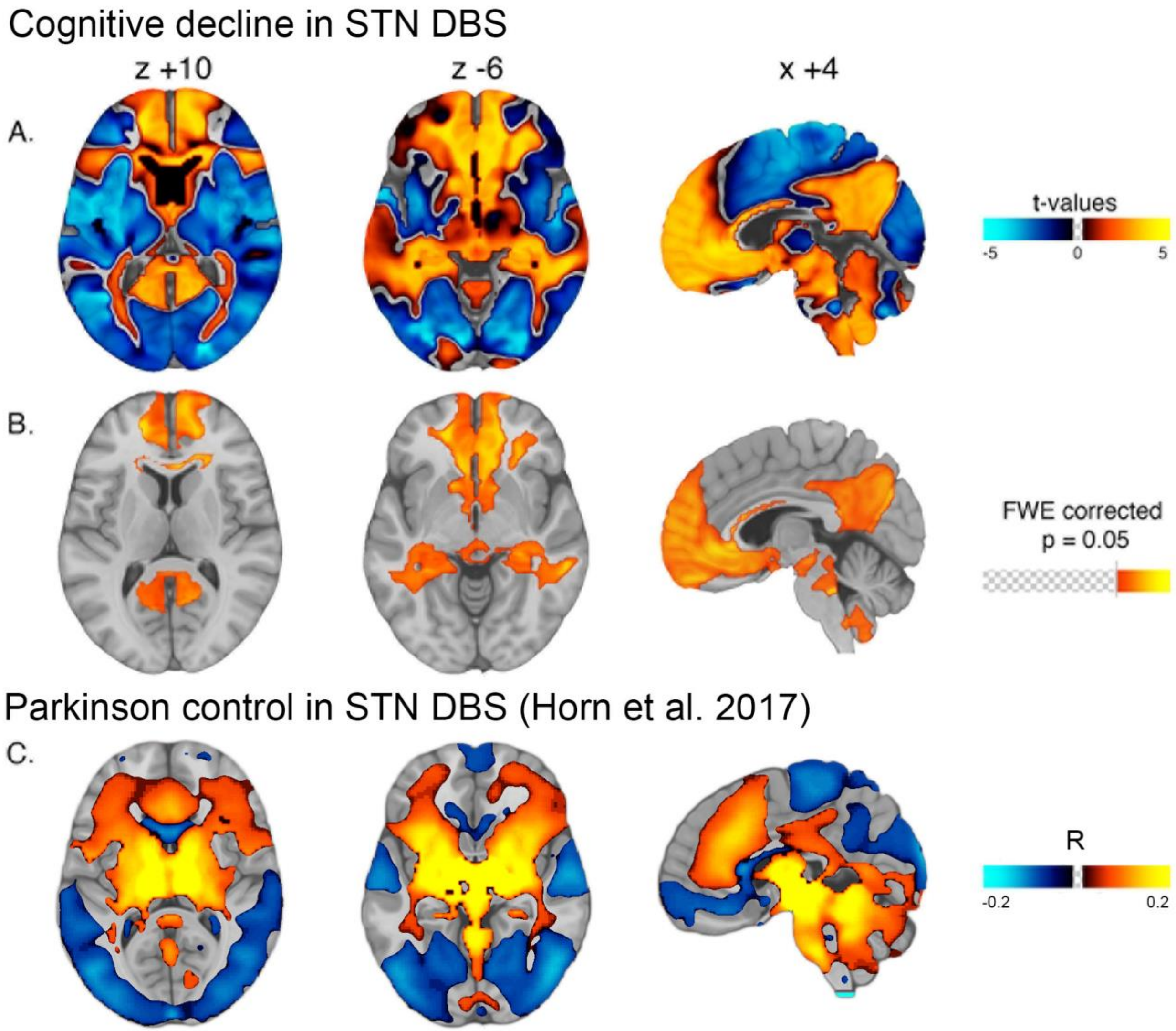
## A brain network for deep brain stimulation induced cognitive decline in Parkinson's disease

Martin M. Reich, Joey Hsu, Michael Ferguson, Frederic L. W. V. J. Schaper, Juho Joutsa, Jonas Roothans, Robert C. Nickl, Anneke Frankemolle-Gilbert, Jay Alberts, Jens Volkmann, Michael D. Fox

*Brain*, awac012, https://doi.org/10.1093/brain/awac012
**Published:** 17 January 2022 **Article history** ▾

Reich, M. M., J. Hsu, M. Ferguson, F. Schaper, J. Joutsa, J. Roothans, R. C. Nickl, A. Frankemolle-Gilbert, J. Alberts, J. Volkmann and M. D. Fox (2022). "A brain network for deep brain stimulation induced cognitive decline in Parkinson's disease." Brain,

# Network non-similarity




r = 0.29 p = 0.52

Reich, M. M., J. Hsu, M. Ferguson, F. Schaper, J. Joutsa, J. Roothans, R. C. Nickl, A. Frankemolle-Gilbert, J. Alberts, J. Volkmann and M. D. Fox (2022). "A brain network for deep brain stimulation induced cognitive decline in Parkinson's disease." Brain,

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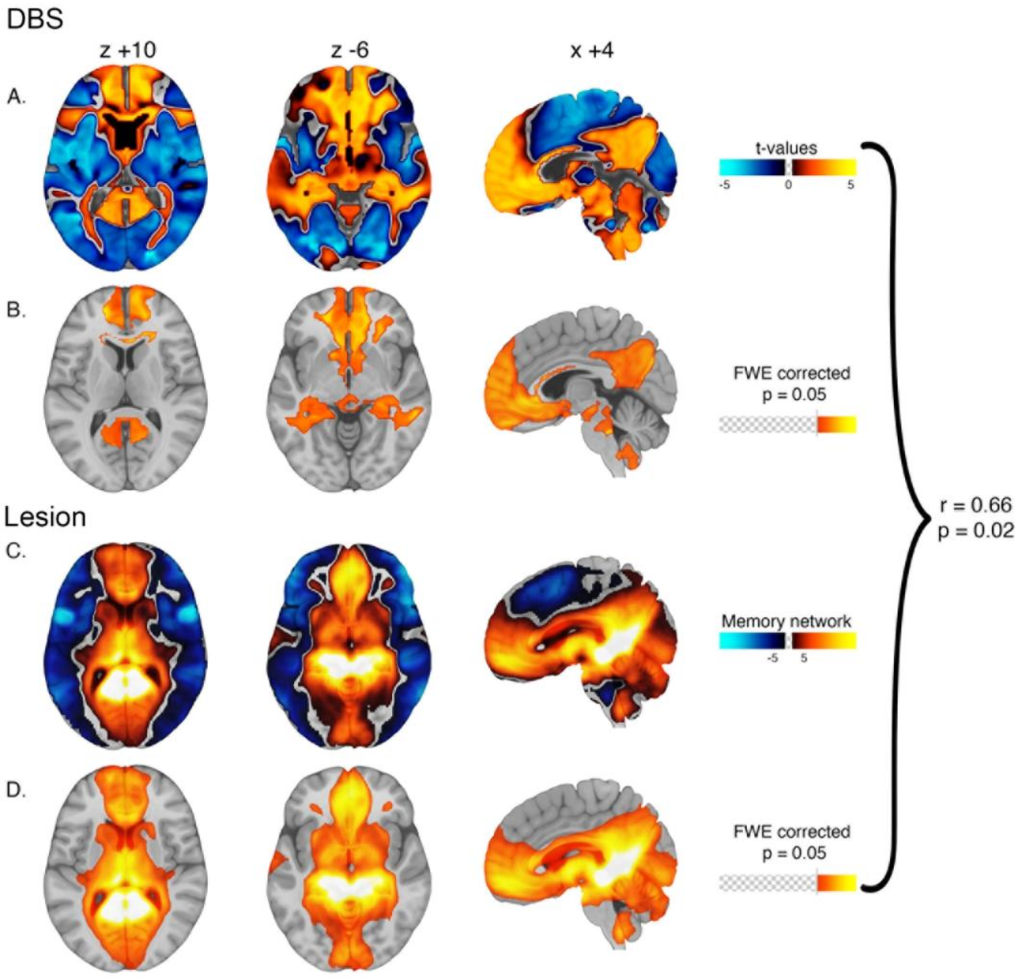



ACCEPTED MANUSCRIPT

**A brain network for deep brain stimulation induced cognitive decline in Parkinson's disease**

Martin M. Reich, Joey Hsu, Michael Ferguson, Frederic L. W. V. J. Schaper, Juho Joutsa, Jonas Roothans, Robert C. Nickl, Anneke Frankemolle-Gilbert, Jay Alberts, Jens Volkmann, Michael D. Fox

*Brain*, awac012, https://doi.org/10.1093/brain/awac012

**Published:** 17 January 2022 **Article history ▾**

nature COMMUNICATIONS

ARTICLE

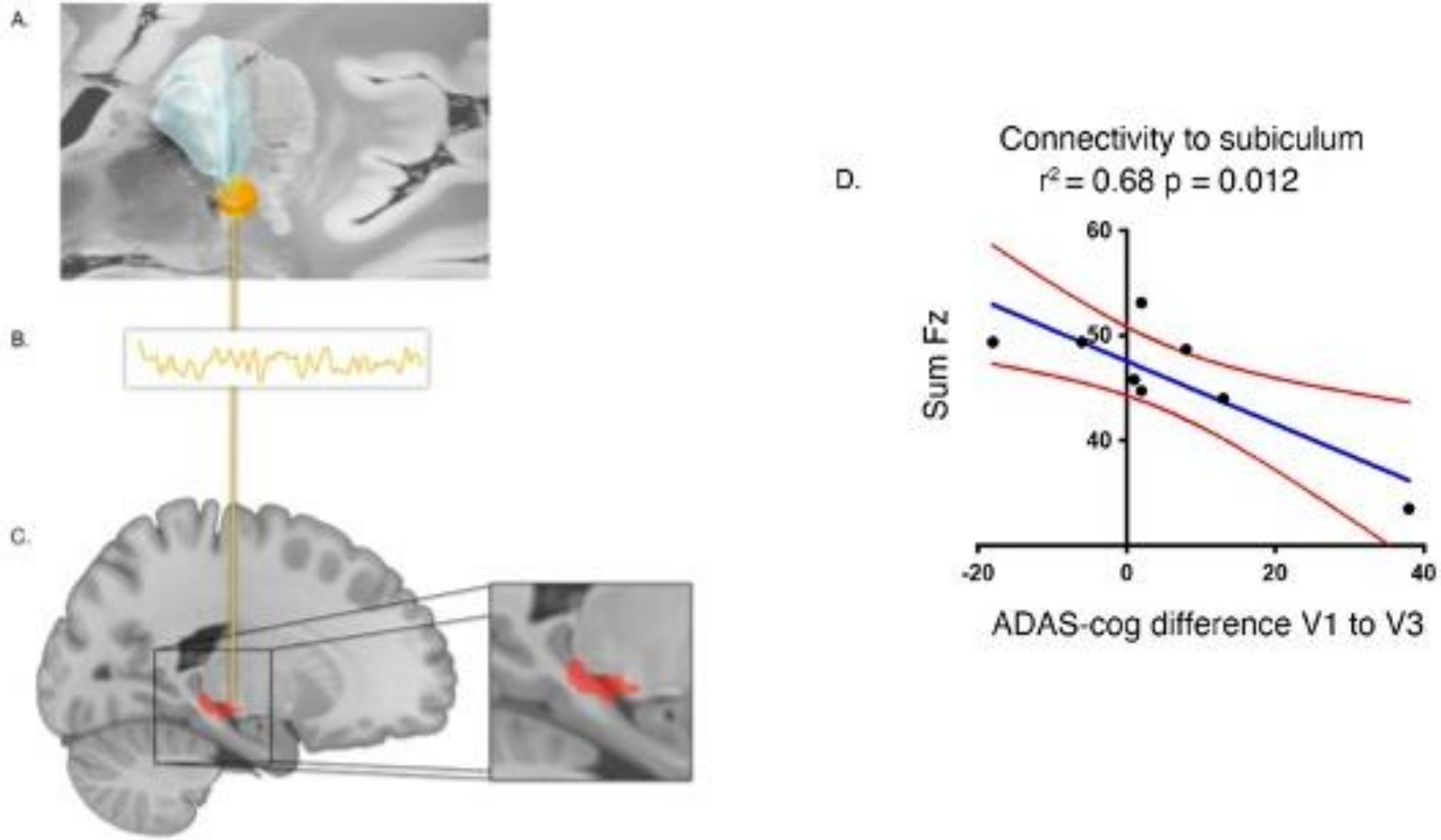
https://doi.org/10.1038/s41467-019-11353-z OPEN

A human memory circuit derived from brain lesions causing amnesia

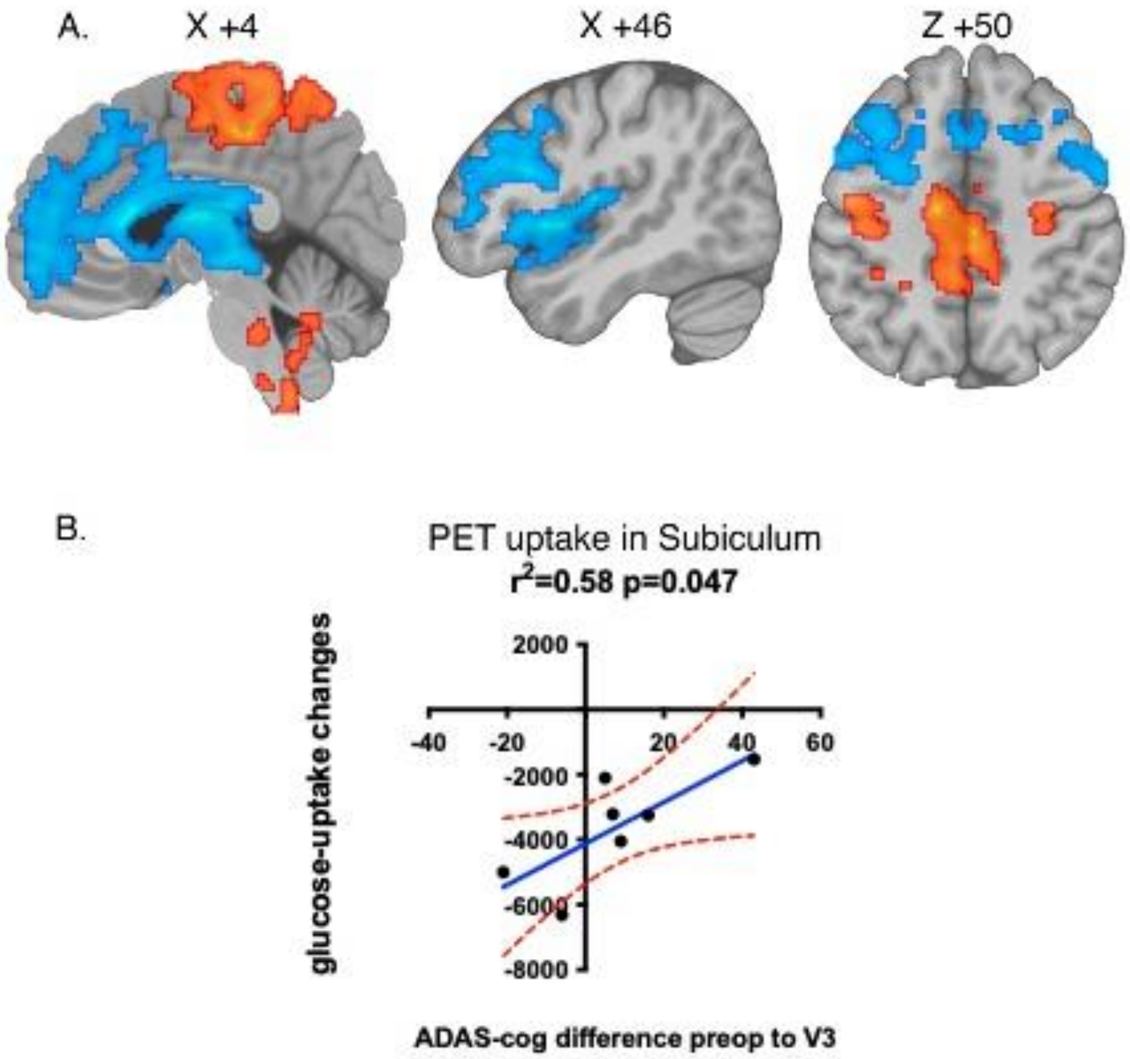
Michael A. Ferguson[1,2], Chun Lim[1,2,11], Danielle Cooke[1,2], R. Ryan Darby[3], Ona Wu[4], Natalia S. Rost[5], Maurizio Corbetta[6,7,8], Jordan Grafman[9,10] & Michael D. Fox[1,2,4,11]

Reich, M. M., J. Hsu, M. Ferguson, F. Schaper, J. Joutsa, J. Roothans, R. C. Nickl, A. Frankemolle-Gilbert, J. Alberts, J. Volkmann and M. D. Fox (2022). "A brain network for deep brain stimulation induced cognitive decline in Parkinson's disease." Brain,

# NBM-Connectivity to memory circuit



# Metabolic brain changes under chronic combined NBM and STN-DBS



# Low and high Frequency Stimulation in PET

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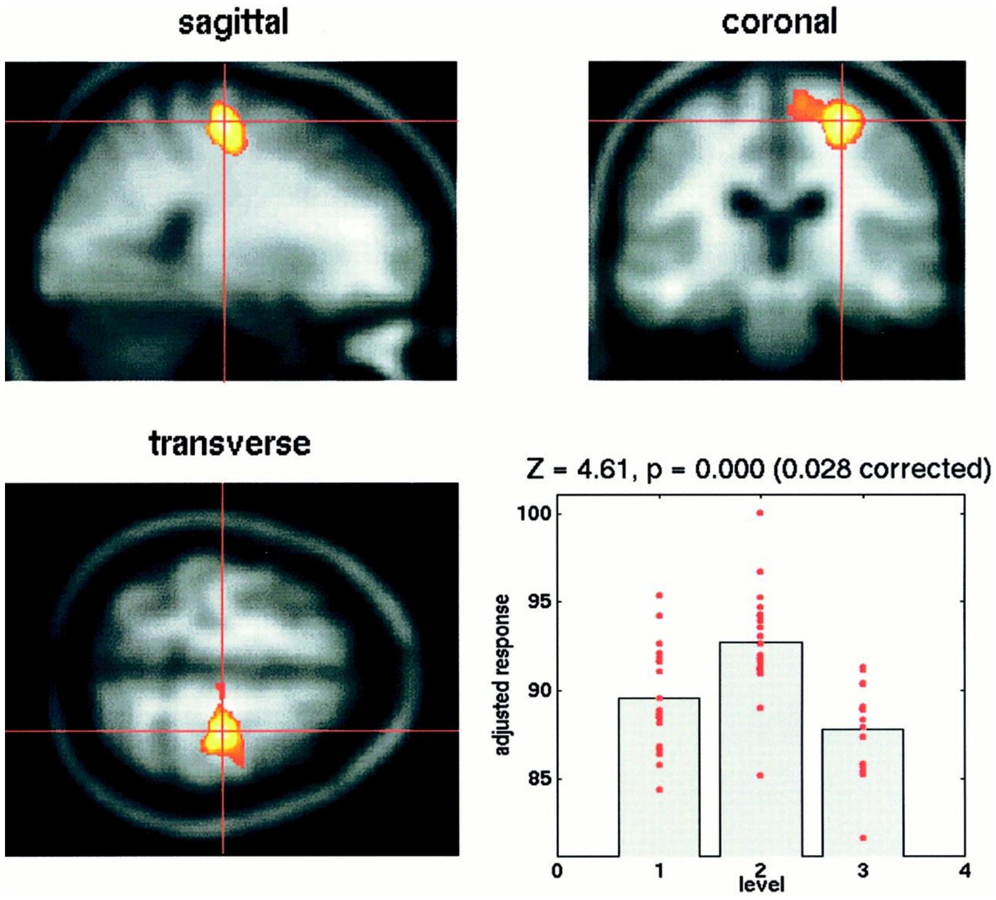
May 22, 2001; 56 (10) ARTICLES

**Thalamic stimulation for essential tremor activates motor and deactivates vestibular cortex**

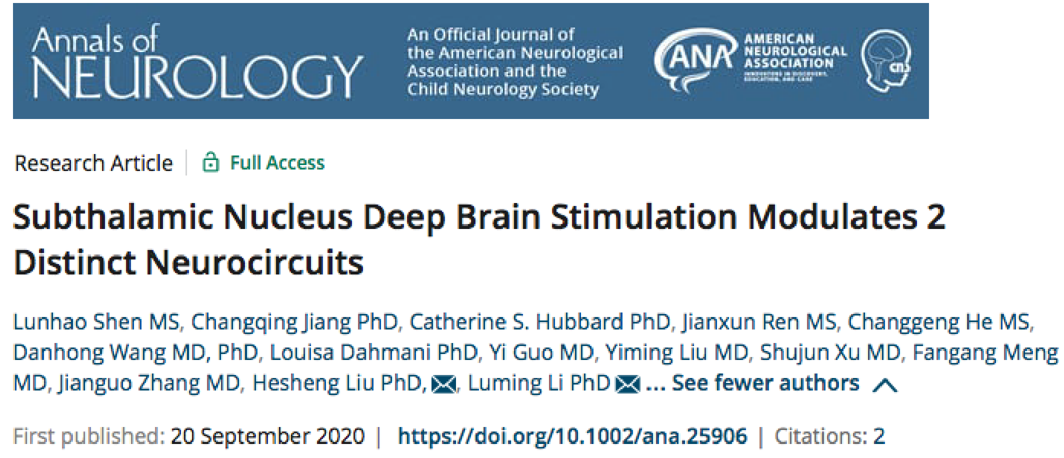
A. O. Ceballos-Baumann, H. Boecker, W. Fogel, F. Alesch, P. Bartenstein, B. Conrad, N. Diederich, I. von Falkenhayn, J. R. Moringlane, M. Schwaiger, V. M. Tronnier

First published May 22, 2001, DOI: https://doi.org/10.1212/WNL.56.10.1347




No DBS 160 Hz 50 Hz

# Different high Frequency Stimulation in fMRI



Annals of NEUROLOGY
An Official Journal of the American Neurological Association and the Child Neurology Society
AMERICAN NEUROLOGICAL ASSOCIATION

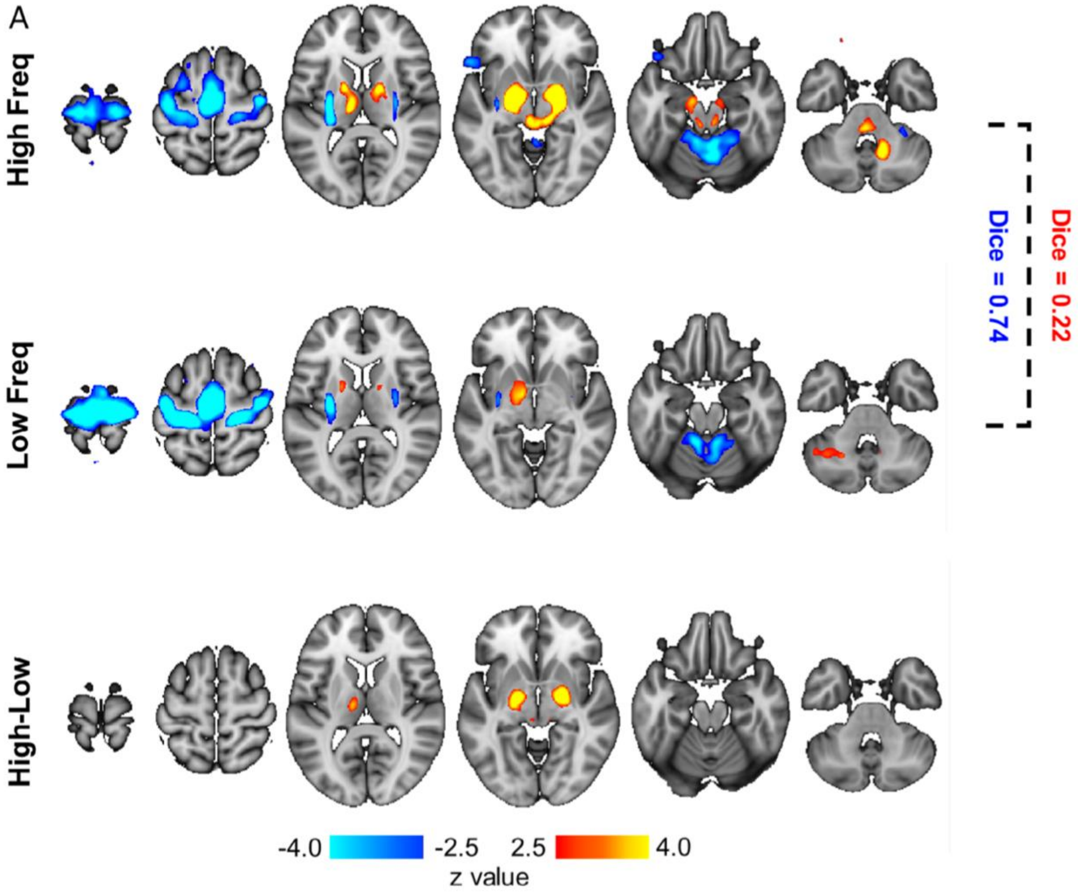

Research Article | Full Access

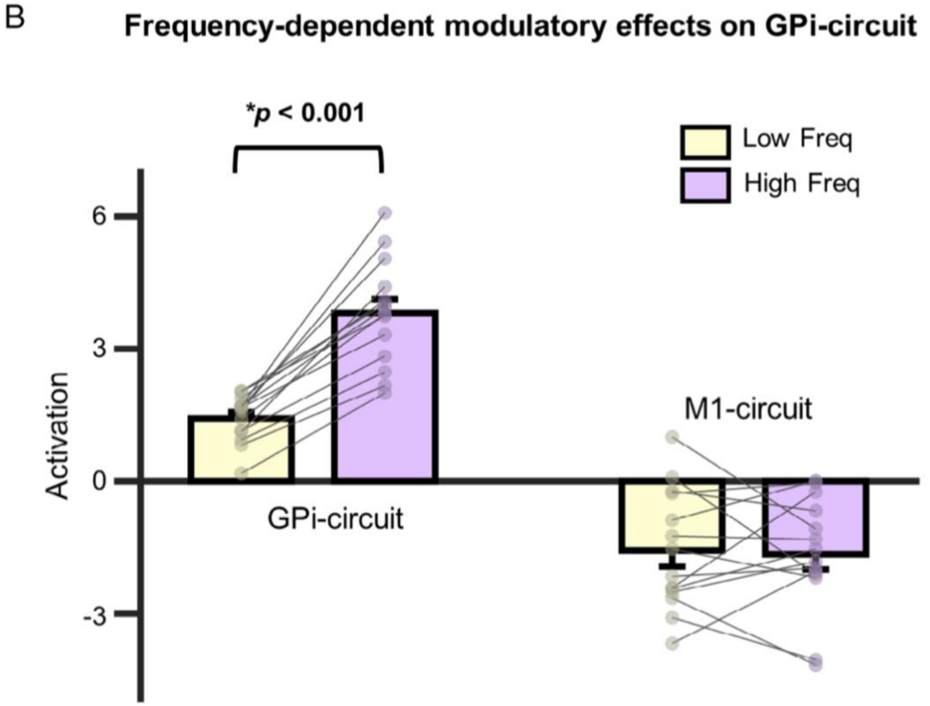
**Subthalamic Nucleus Deep Brain Stimulation Modulates 2 Distinct Neurocircuits**


Lunhao Shen MS, Changqing Jiang PhD, Catherine S. Hubbard PhD, Jianxun Ren MS, Changgeng He MS, Danhong Wang MD, PhD, Louisa Dahmani PhD, Yi Guo MD, Yiming Liu MD, Shujun Xu MD, Fangang Meng MD, Jianguo Zhang MD, Hesheng Liu PhD, Luming Li PhD ... See fewer authors

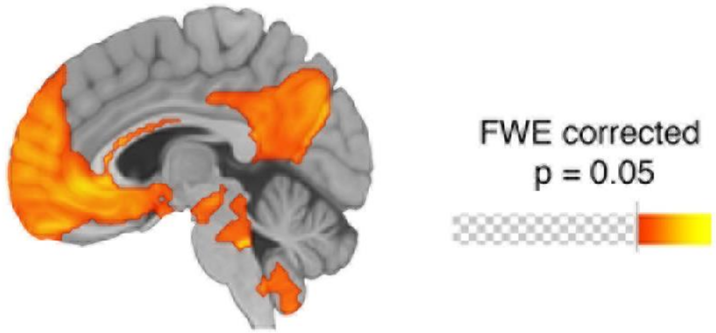


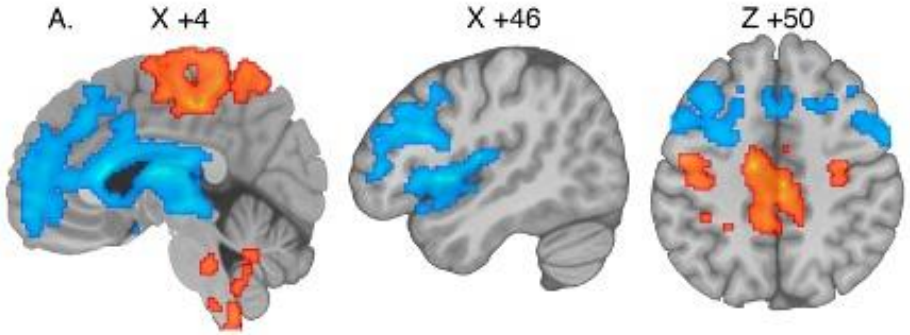
First published: 20 September 2020 | https://doi.org/10.1002/ana.25906 | Citations: 2

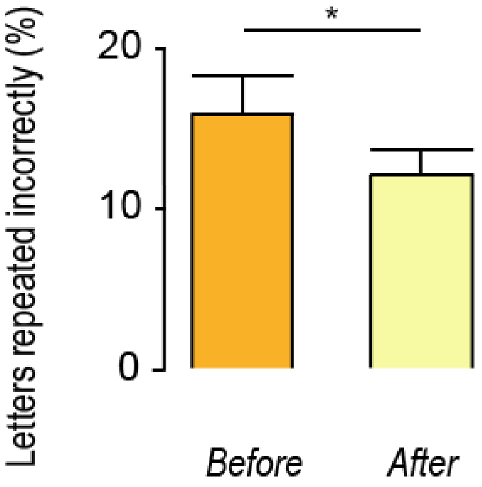



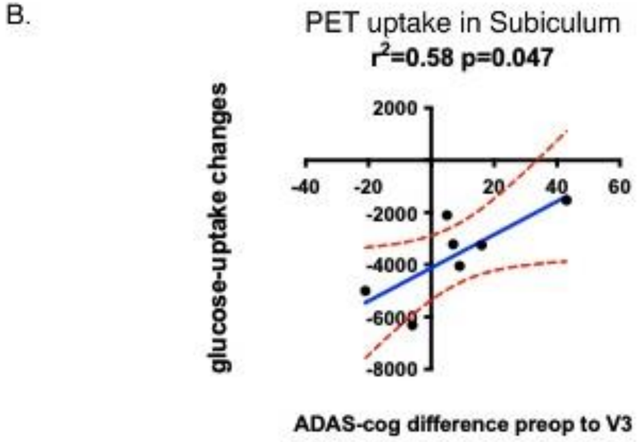



# 130 Hz (STN) vs. 20 Hz (NBM)



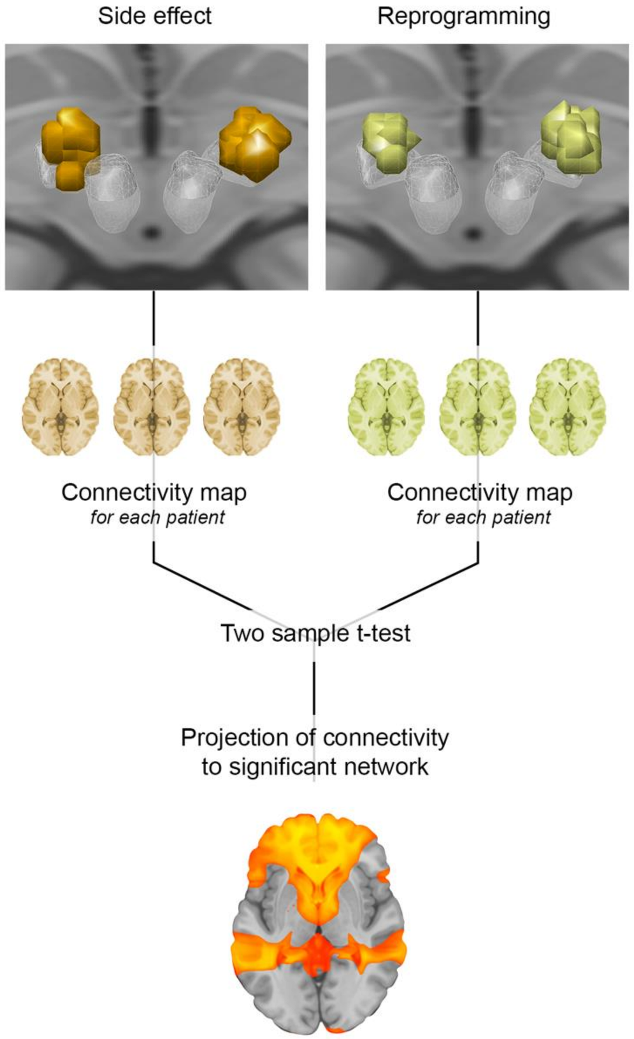



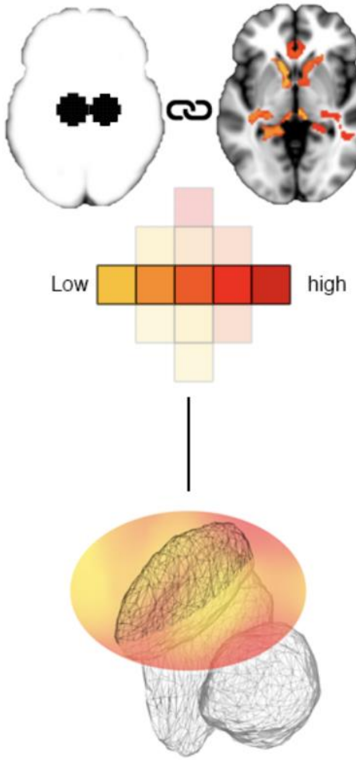





Reich, M. M., J. Hsu, M. Ferguson, F. Schaper, J. Joutsa, J. Roothans, R. C. Nickl, A. Frankemolle-Gilbert, J. Alberts, J. Volkmann and M. D. Fox (2022).
"A brain network for deep brain stimulation induced cognitive decline in Parkinson's disease." Brain,

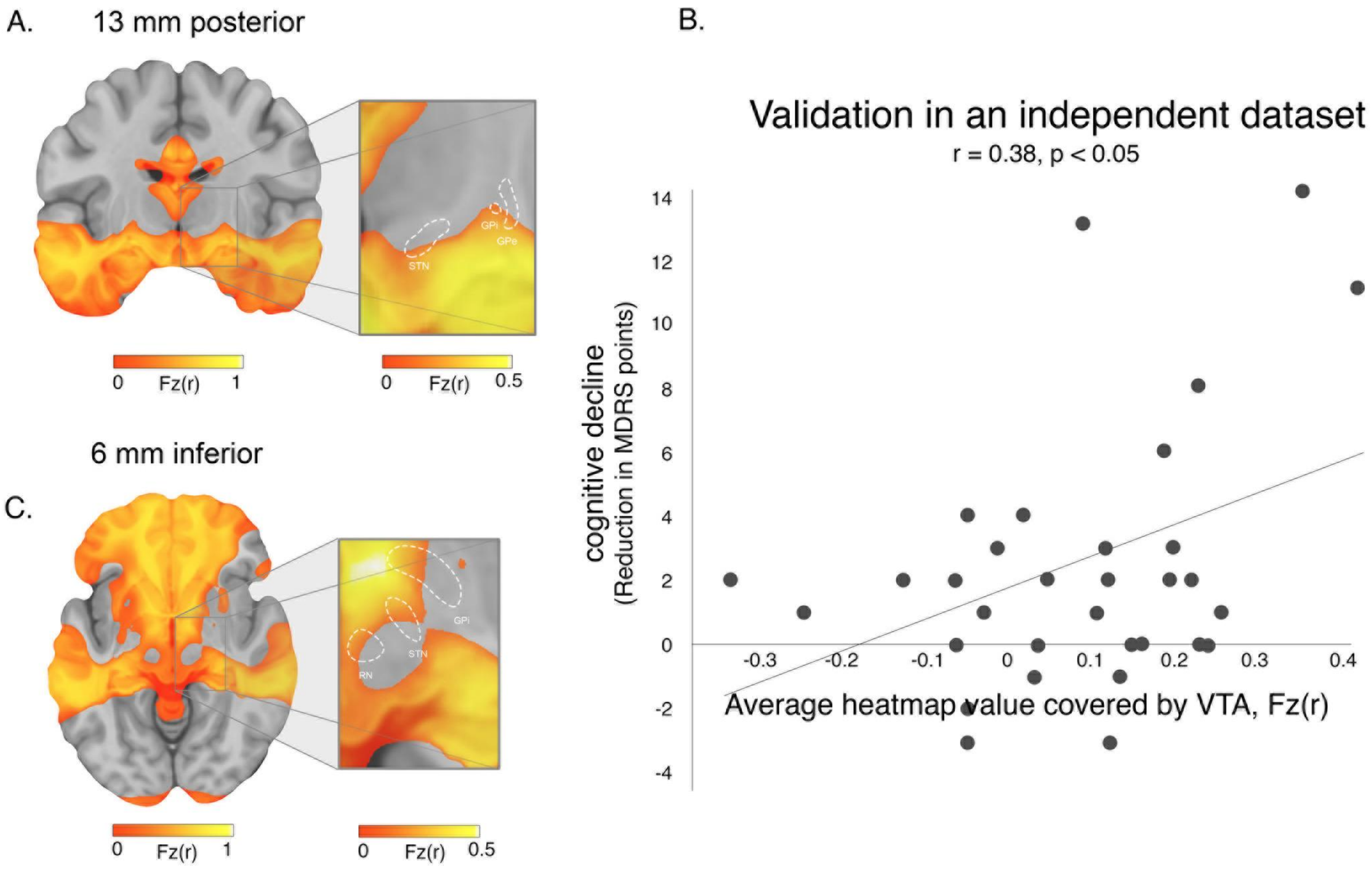
# To network and back to local



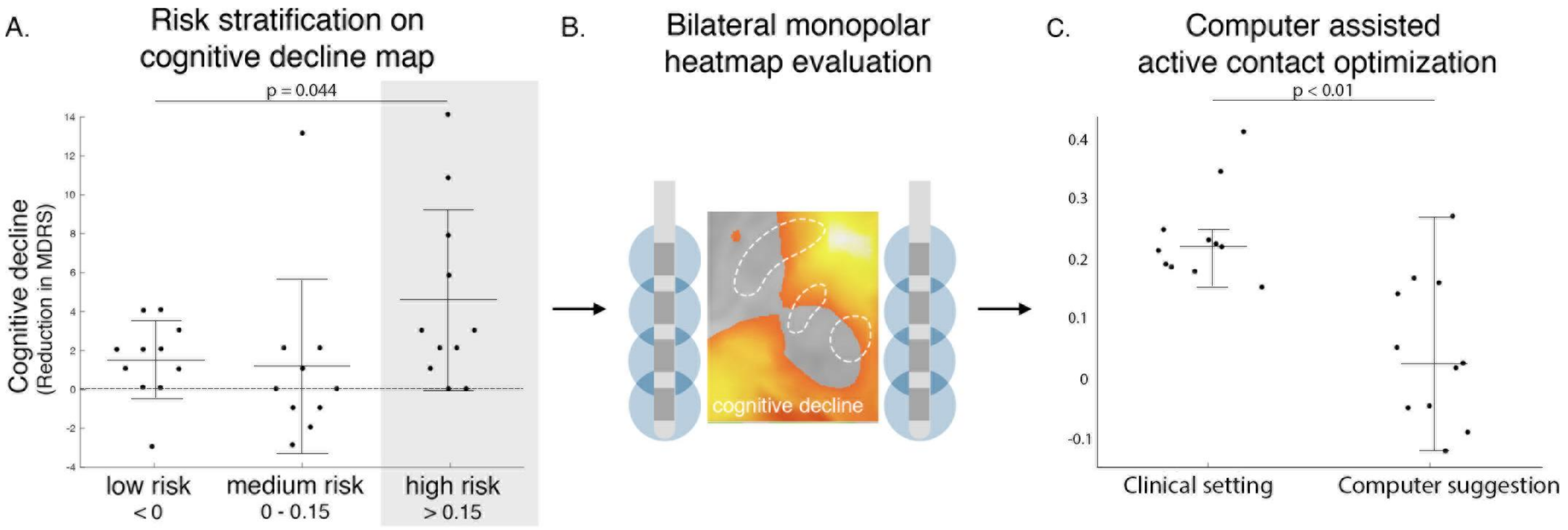

Reich, M. M., J. Hsu, M. Ferguson, F. Schaper, J. Joutsa, J. Roothans, R. C. Nickl, A. Frankemolle-Gilbert, J. Alberts, J. Volkmann and M. D. Fox (2022). "A brain network for deep brain stimulation induced cognitive decline in Parkinson's disease." Brain,

# Local heatmap validation




Reich, M. M., J. Hsu, M. Ferguson, F. Schaper, J. Joutsa, J. Roothans, R. C. Nickl, A. Frankemolle-Gilbert, J. Alberts, J. Volkmann and M. D. Fox (2022). "A brain network for deep brain stimulation induced cognitive decline in Parkinson's disease." Brain,

# Translational approach to patient care

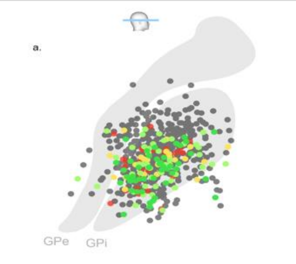


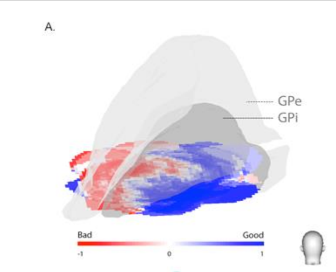


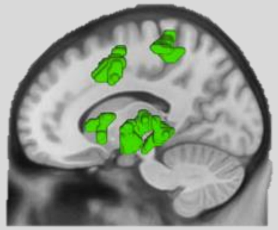
Reich, M. M., J. Hsu, M. Ferguson, F. Schaper, J. Joutsa, J. Roothans, R. C. Nickl, A. Frankemolle-Gilbert, J. Alberts, J. Volkmann and M. D. Fox (2022). "A brain network for deep brain stimulation induced cognitive decline in Parkinson's disease." Brain,

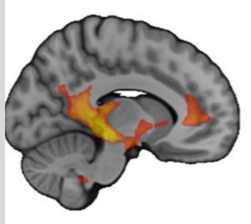
# Computational modelling in neuromodulation

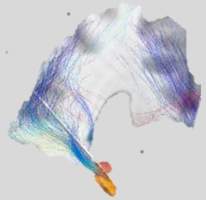
***Methods***

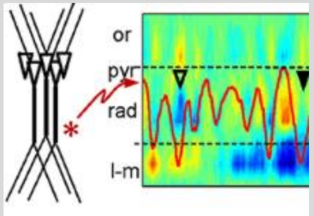


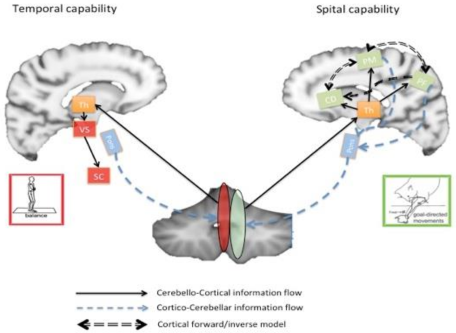





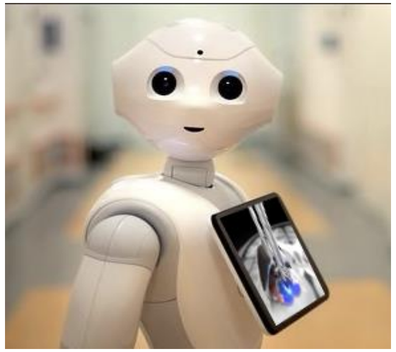





**Aim**

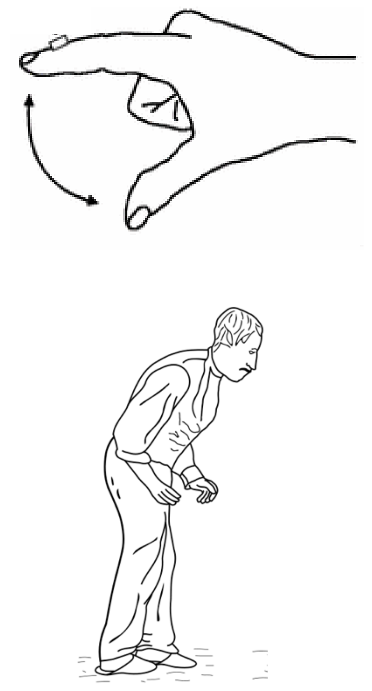


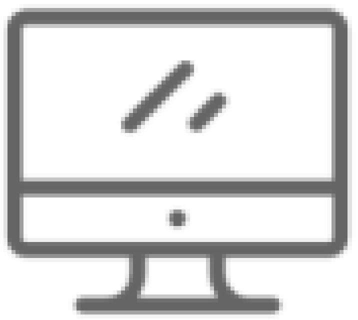

?

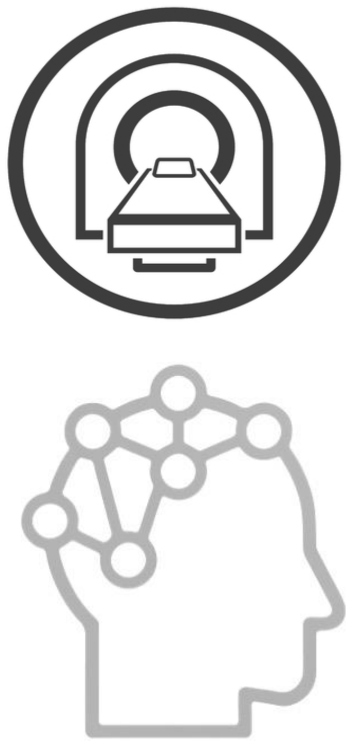


# Matlab Toolbox ARENA

# DBS programming of > 12.000 options







nature COMMUNICATIONS

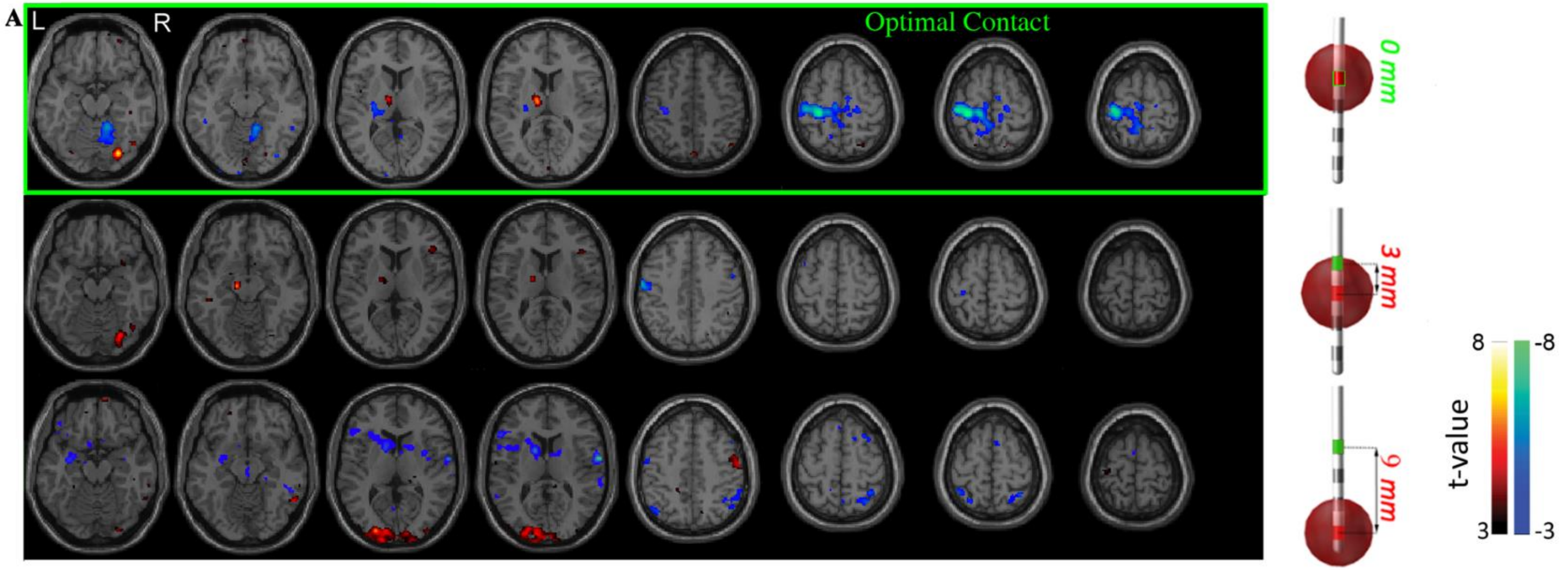
ARTICLE

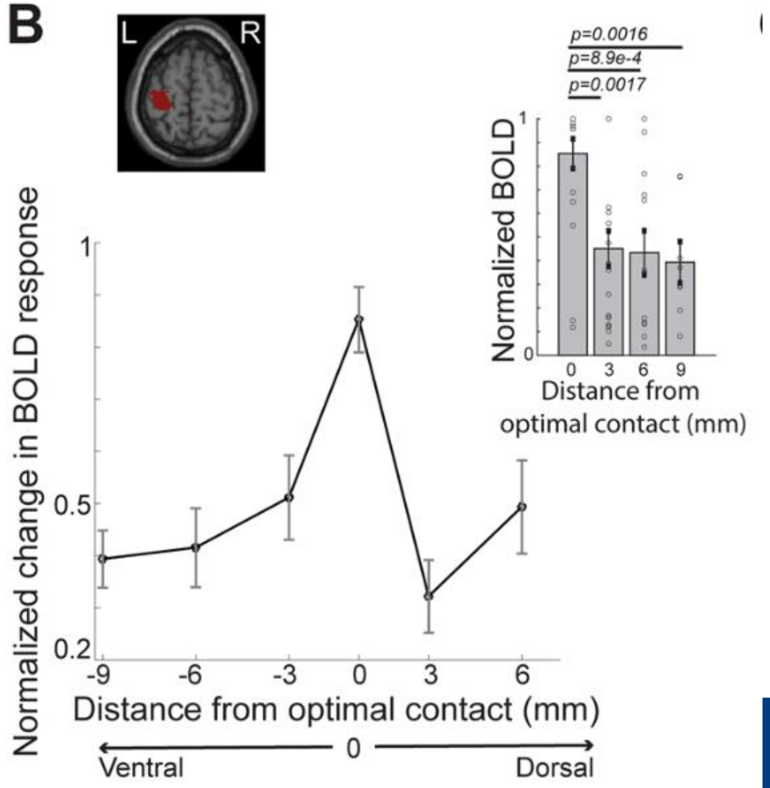
Check for updates

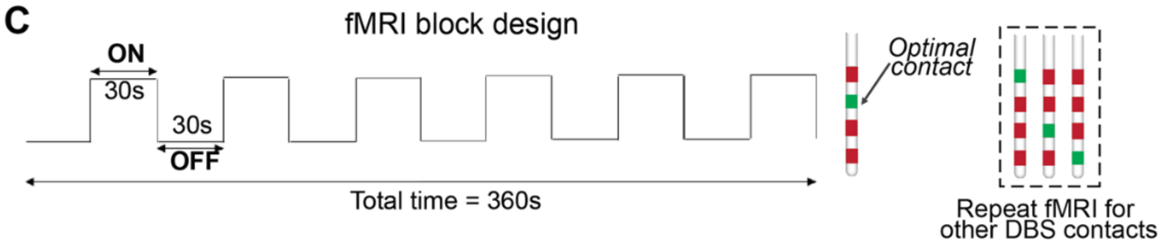
https://doi.org/10.1038/s41467-021-23311-9 OPEN

# Predicting optimal deep brain stimulation parameters for Parkinson's disease using functional MRI and machine learning

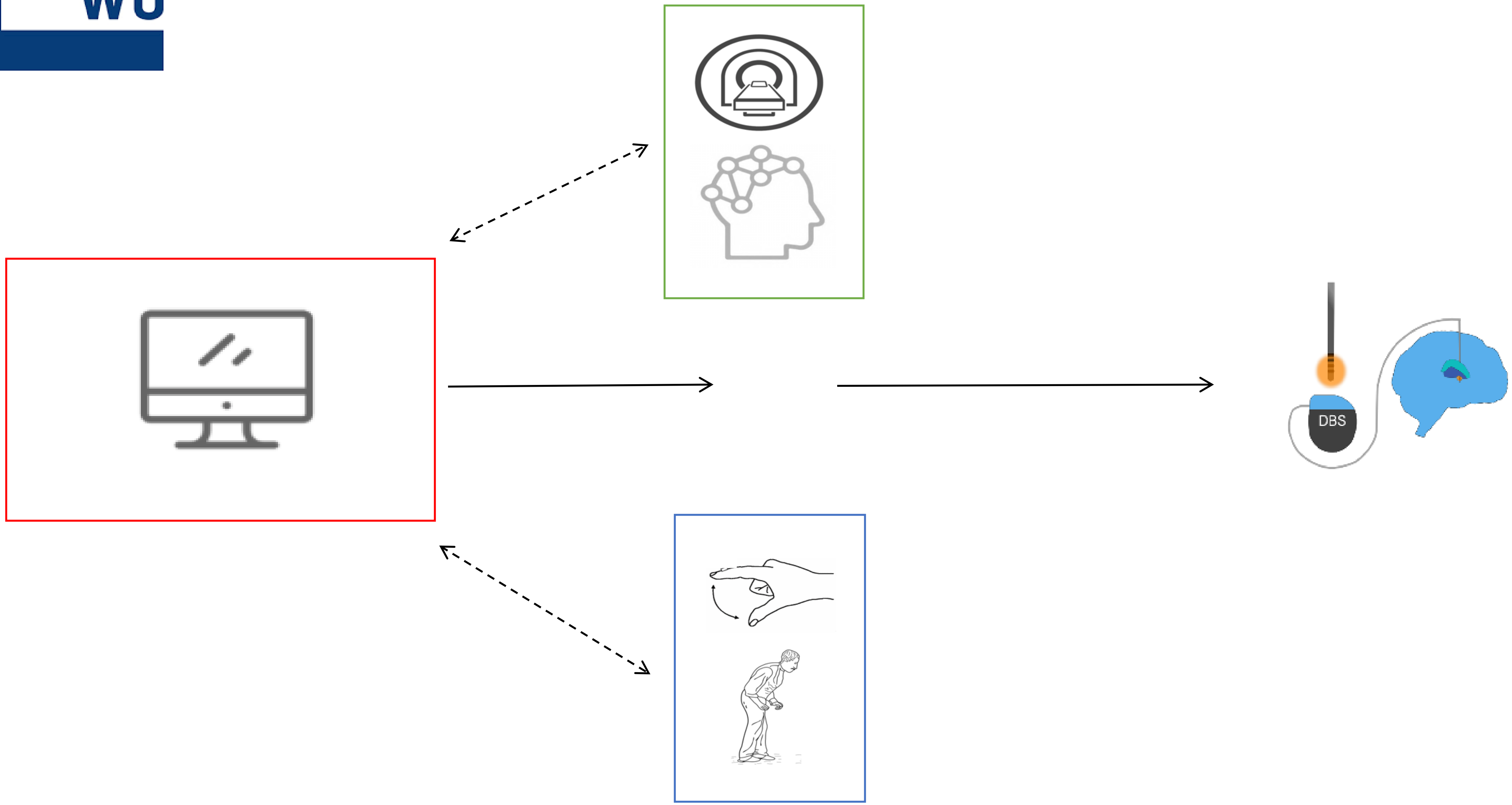
Alexandre Boutet[1,2,8], Radhika Madhavan[3,8], Gavin J. B. Elias[2], Suresh E. Joel[4], Robert Gramer[2], Manish Ranjan[2], Vijayashankar Paramanandam[5], David Xu[2], Jurgen Germann[2], Aaron Loh[2], Suneil K. Kalia[2], Mojgan Hodaie[2], Bryan Li[1], Sreeram Prasad[5], Ailish Coblentz[1], Renato P. Munhoz[5], Jeffrey Ashe[3], Walter Kucharczyk[1], Alfonso Fasano[5,6,7] & Andres M. Lozano[2,6,7]✉

# Future type of DBS programming




Cohort (> 1000)

Individual (< 20)

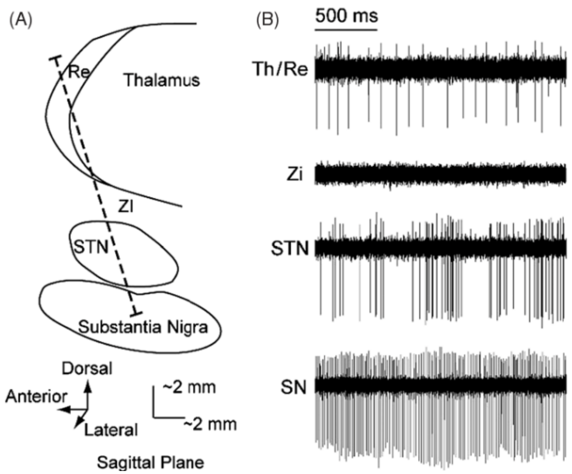
programming / adapting (< 5)

# Oscillatory activity and closed-loop DBS

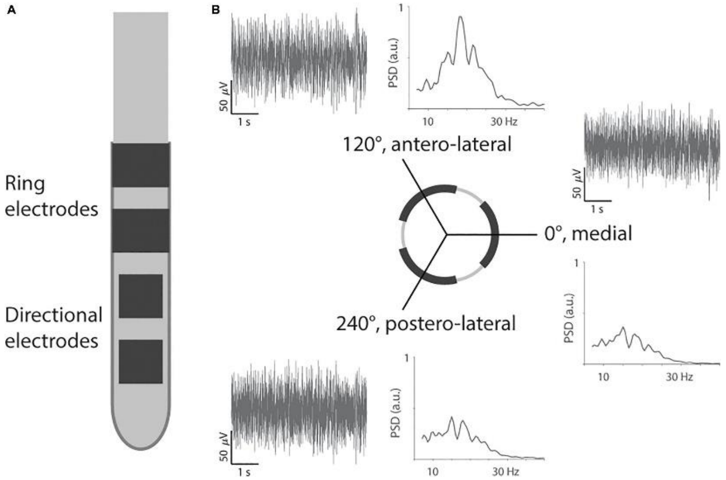
# Why electrophysiology?

- Time resolution
- Overground walking

- Recording at the site of stimulation
- Chronic recording (at home)




Microelectrode recordings
Single-unit activity

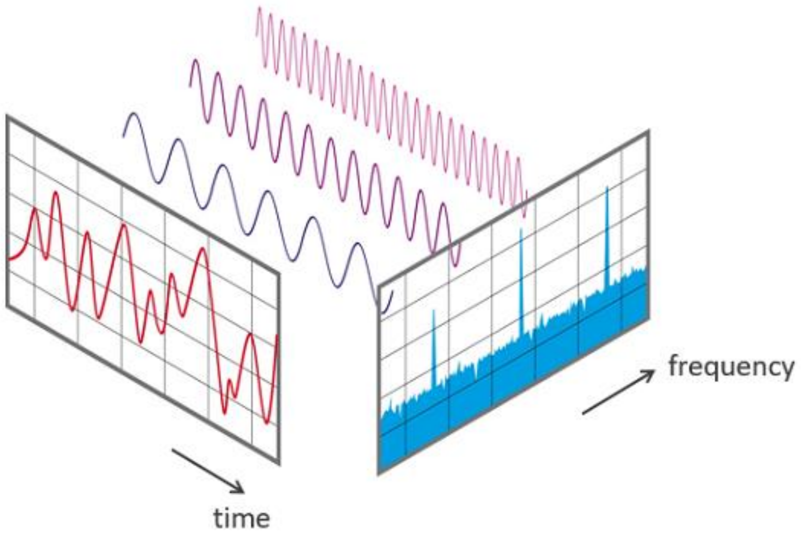



Chronically implanted electrodes
Local field potentials

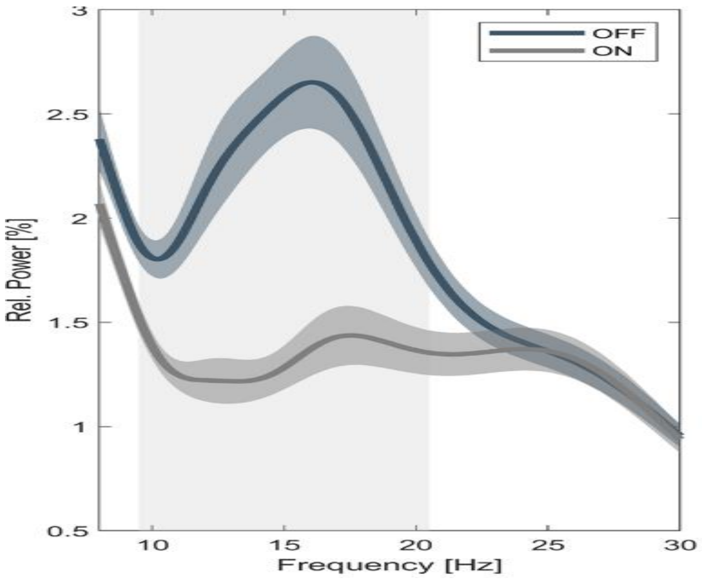

Wong et al. Neural engineering 2009
Nguyen et al. Front Hum Neurosci 2020

# What are we looking for?

- Input signal (biomarkers)
- They must remain pathological over time (Brain-computer interface)!
- Example: exaggerated β frequency band oscillations

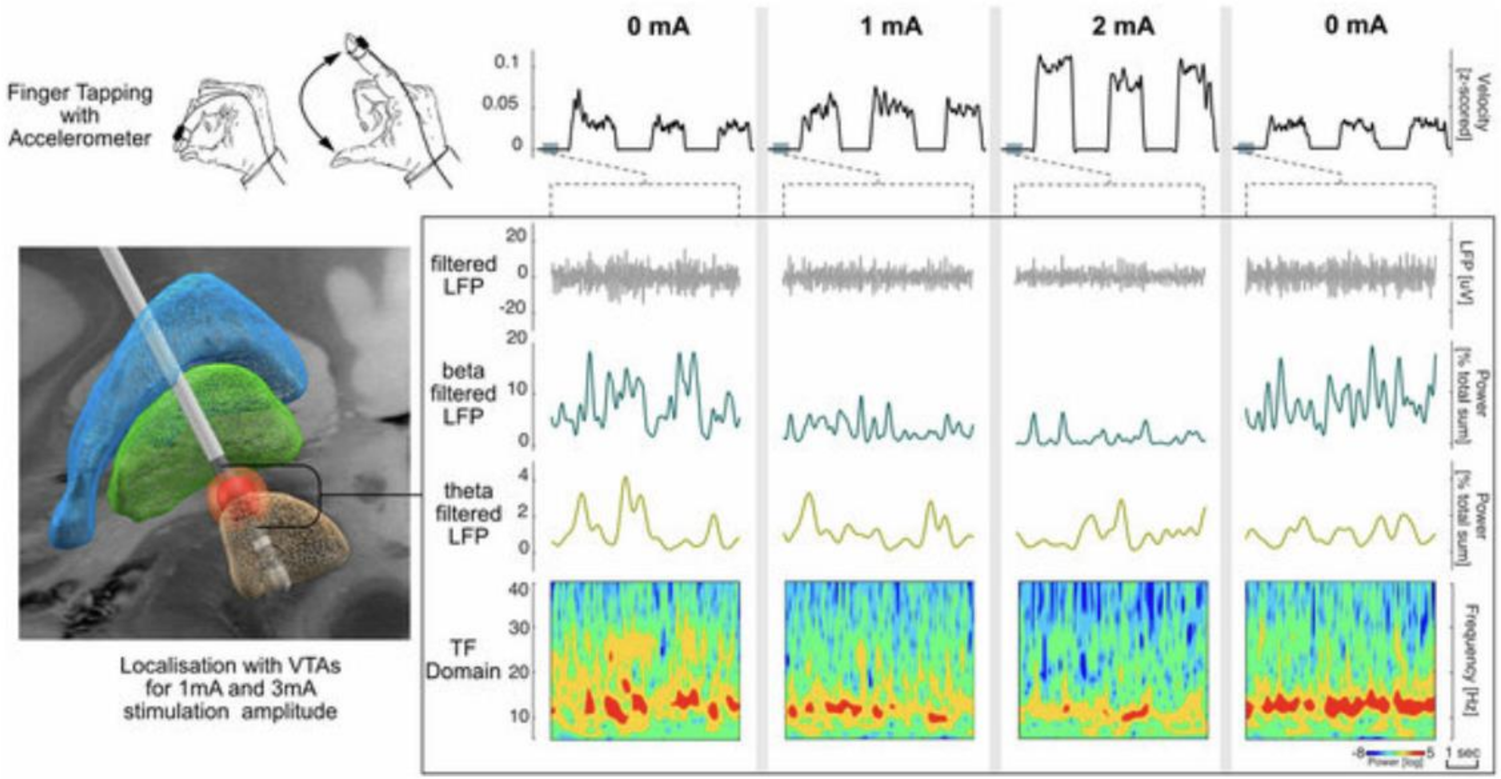



Fast Fourier Transformation

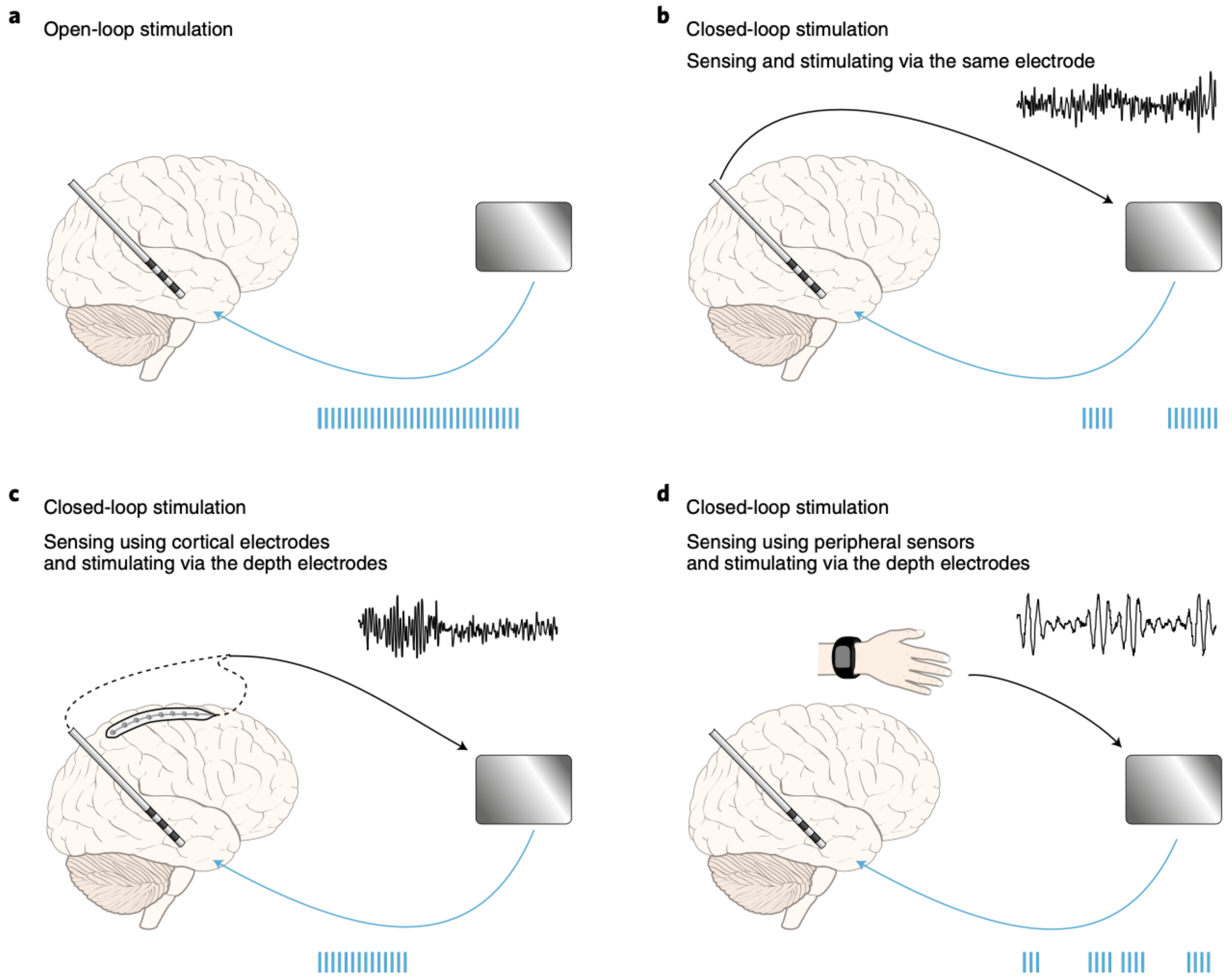



Power spectrum density

# Tuning DBS on LFP Signals

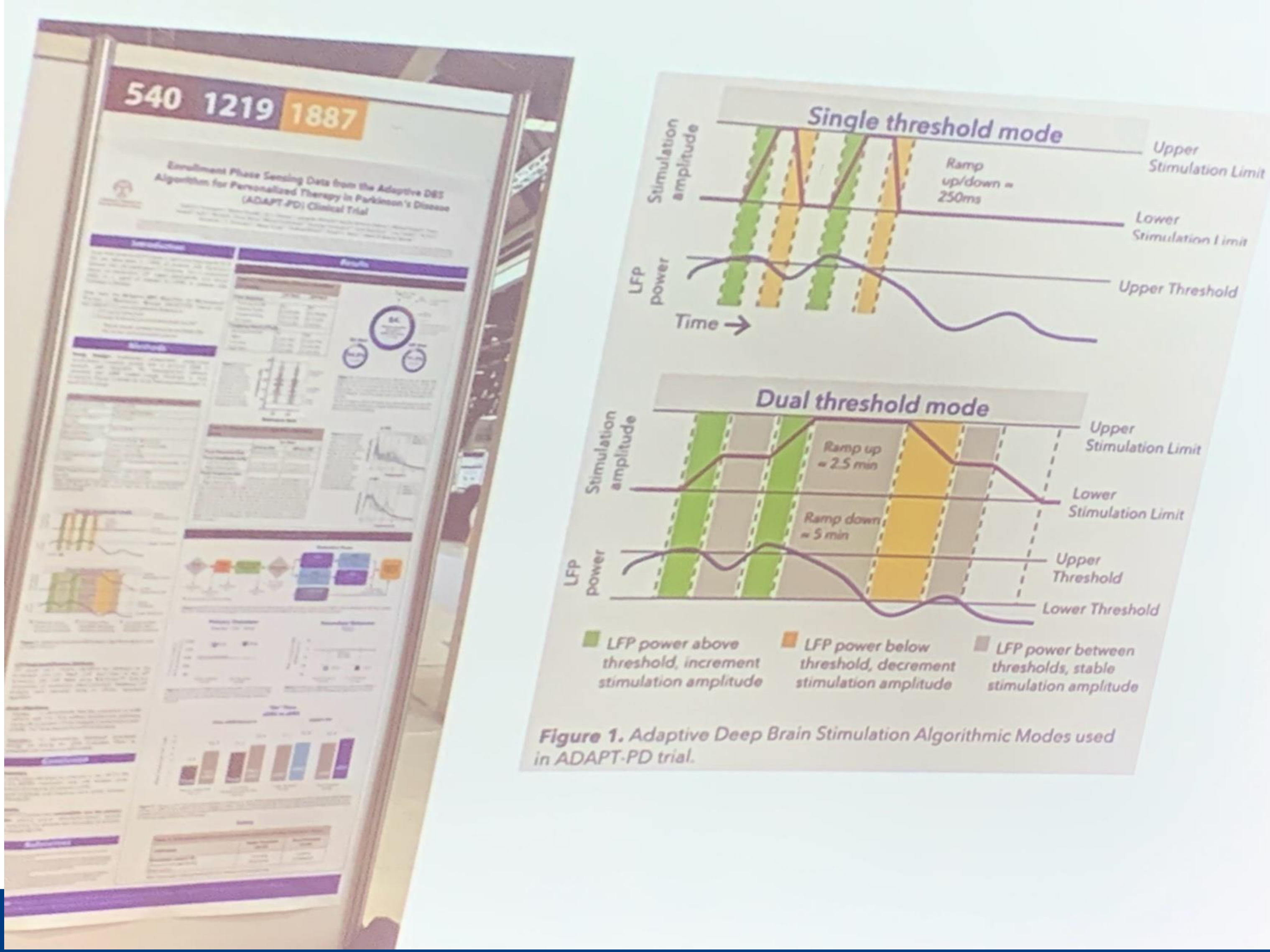


# Closed-loop / Adaptive DBS




Cagnan et al. NaTurE BIoTECHNology | VOL 37 | SEPTEMBER 2019 | 1024–1033

# ADAPT-PD trial (same Electrode)



# Phase-specific deep brain stimulation

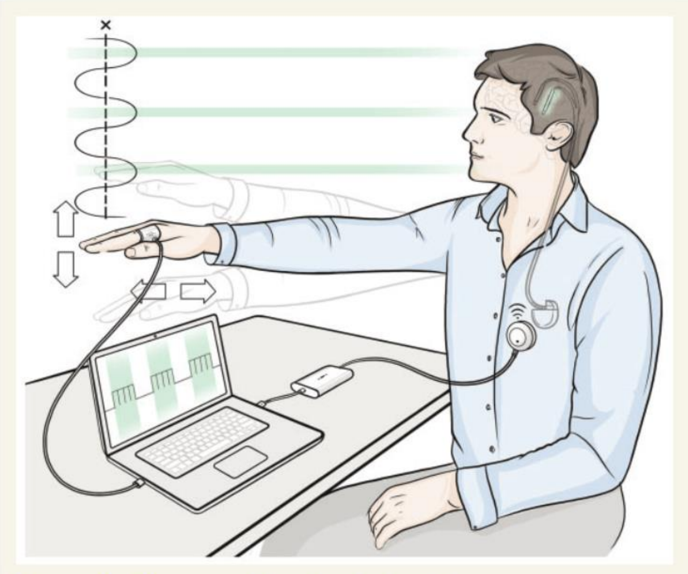
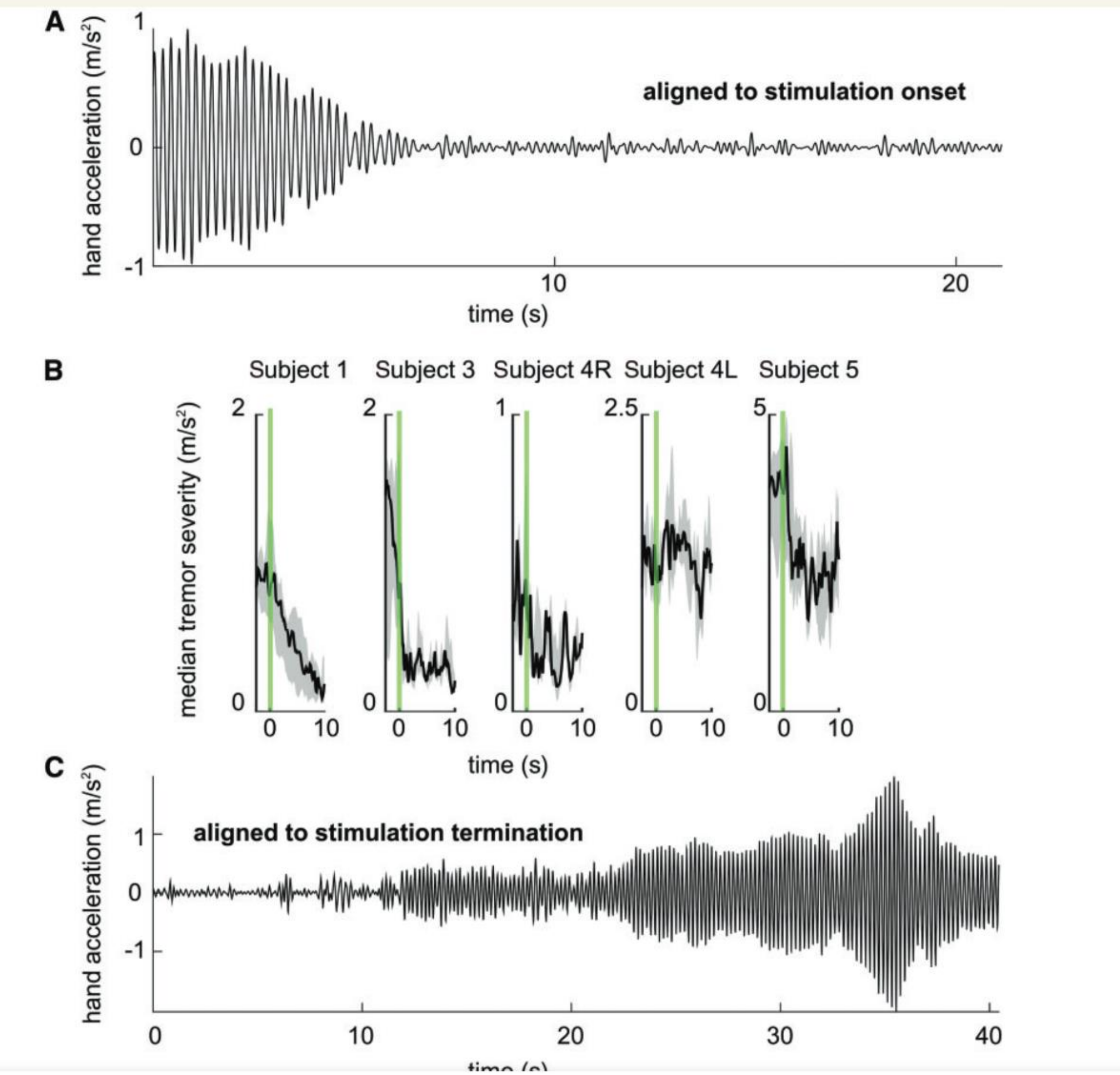
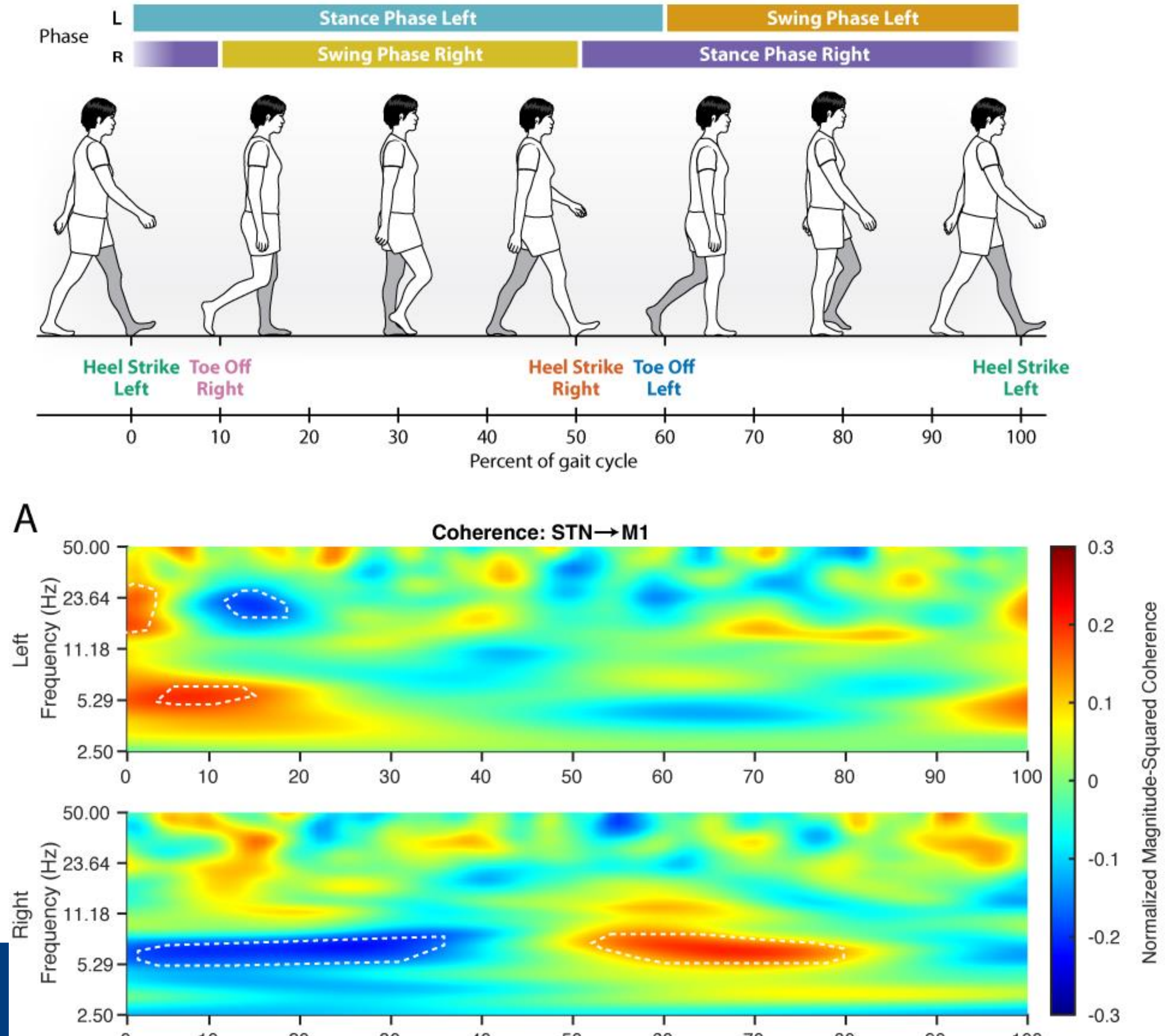


**Figure 1 Phase-specific stimulation.** The neurostimulator is



# Two electrode recordings (STN + M1)

- More information about movement states



# Overview

**General aspects:**

Indications

Procedure

Programming

Contact / Amplitude

Pulse width

**Computational and Imaging methodes:**

Sweetspots

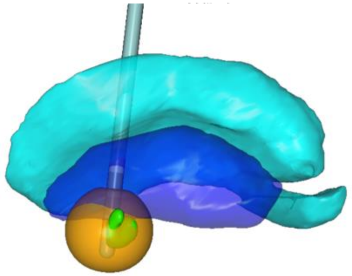
Probabilistic mapping

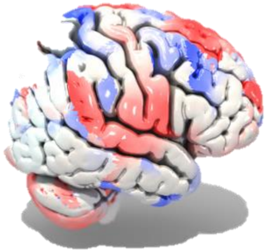
Connectomics

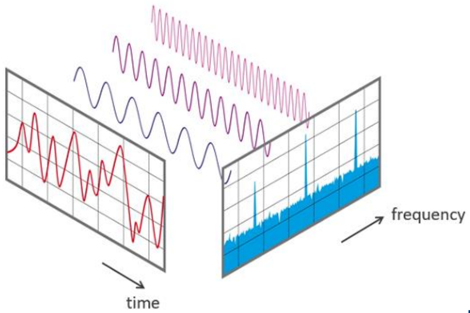
**Oscillatory activity and closed-loop DBS:**

LFPs

adaptive Concepts







# Junior Research Group Reich

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dpg Deutsche Gesellschaft für Parkinson und Bewegungsstörungen

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