Deep Brain Stimulation for Parkinson's Disease

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What is Parkinson's?

A brain disorder characterized by involuntary movements, including tremors, stiffness, and difficulty in maintaining balance and coordination.

Causes: Neurons is the basal ganglia (BG) die

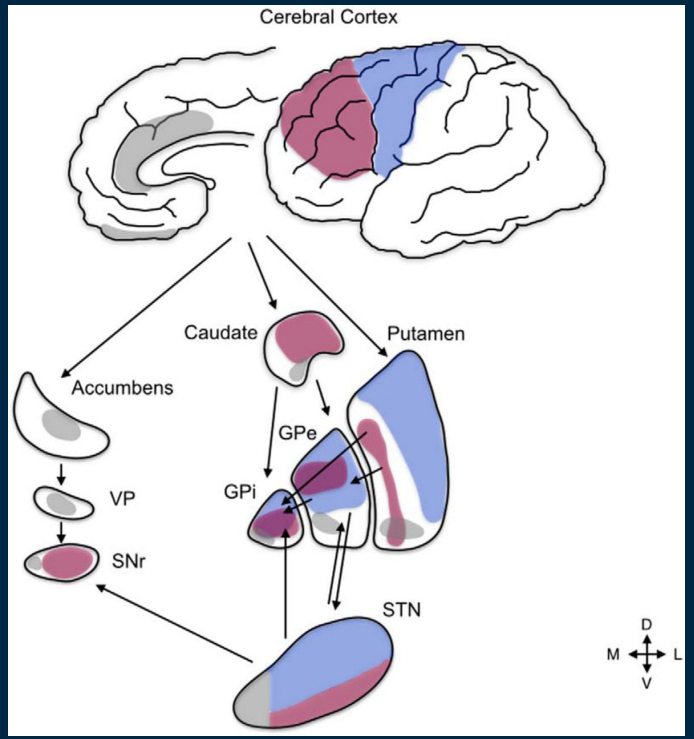
Treatments: Medicine, Surgical methods, other therapies

MAIN GOAL

DBS is a neurosurgical procedure where high-frequency pulse trains are supplied via an implanted pulse generator and injected into widely used portions of the BG network.

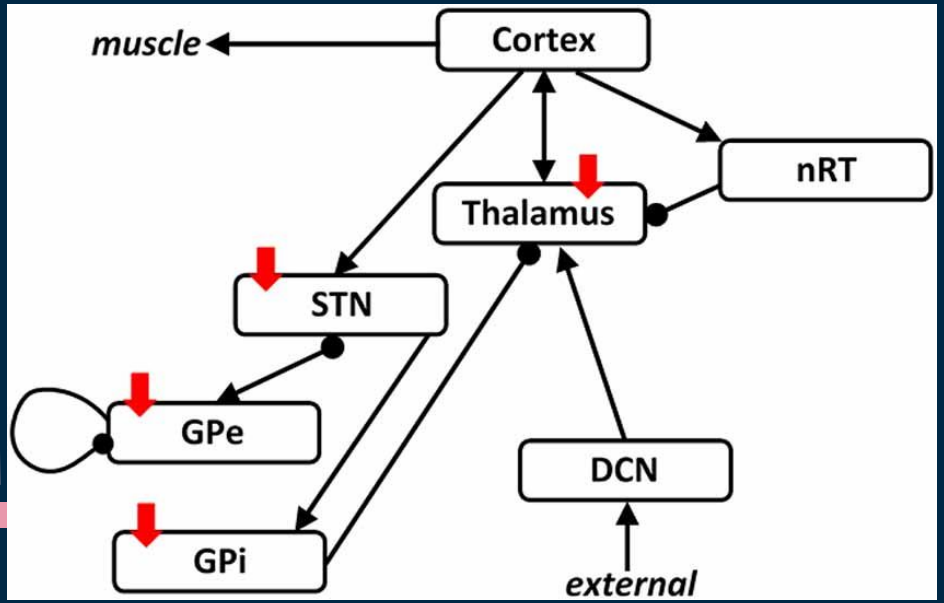
Pathways of the BG network include:

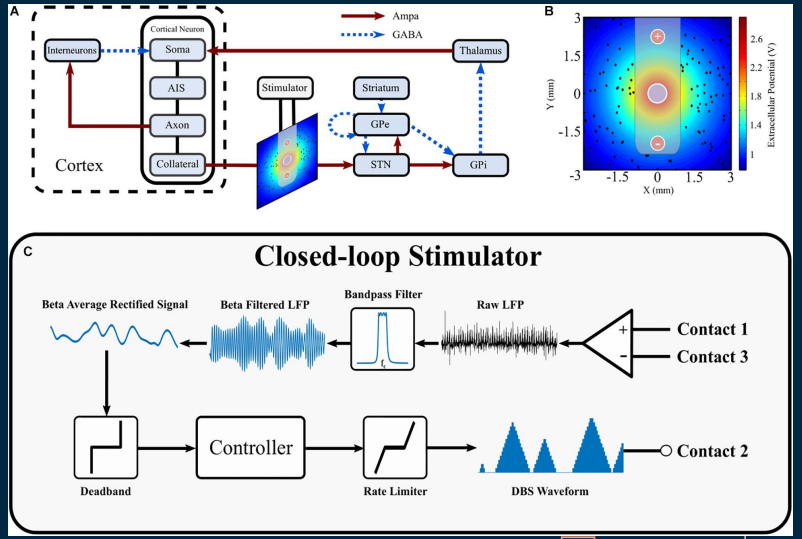
- Subthalamic Nucleus (STN)
- Globus Pallidus Pars Interna (GPi)
- Globus Pallidus Pars Externa (GPe)
- Thalamus (TH).



Parkinson's Schematic Diagram

Show closed loop model



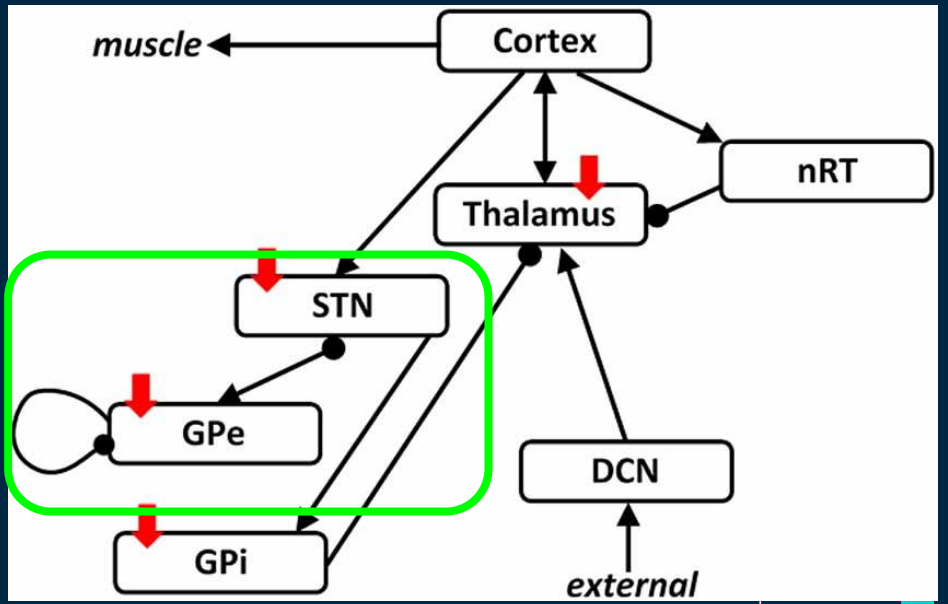


Yousif N, Bain PG, Nandi D and Borisyuk R

STN-GPe Loop

Our focus will be on the STN-GPe loop:

- Major excitatory/inhibitory pathway in the basal ganglia
- DBS at the STN is shown to suppress PD symptoms caused by **β**-band oscillations in the loop



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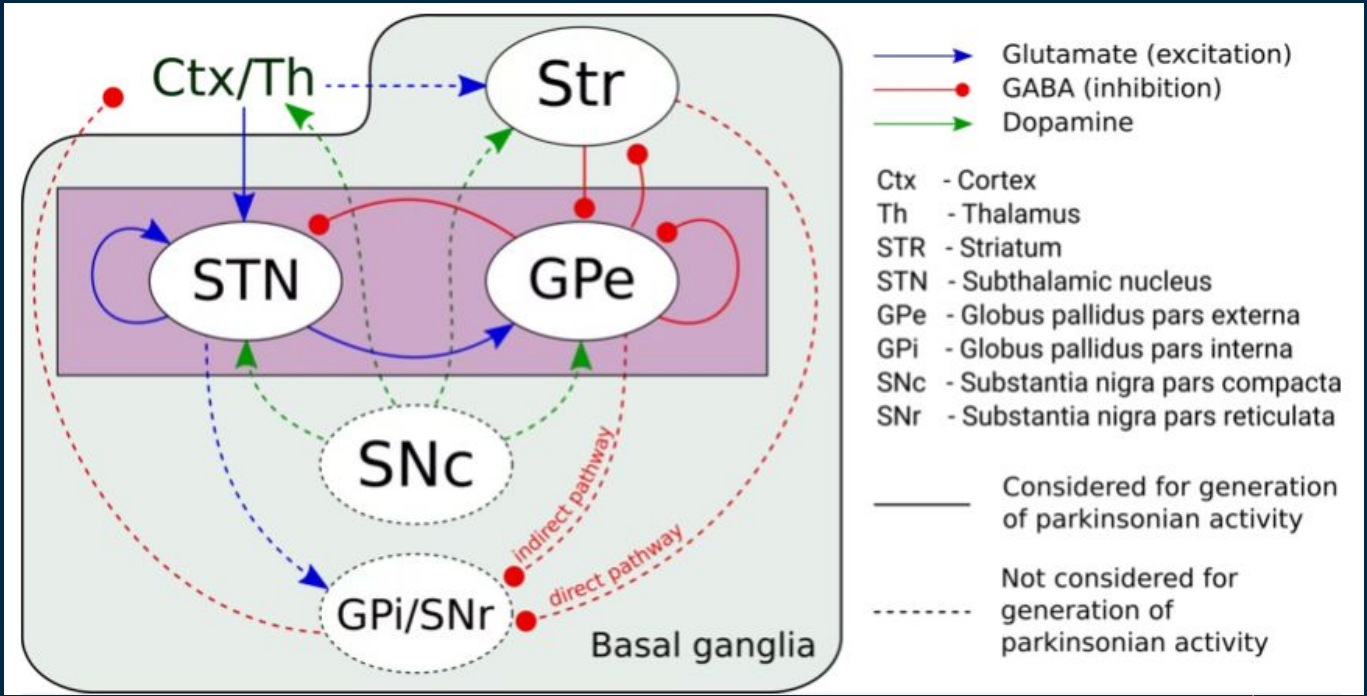
STN-GPe Loop

β-band activity:

- ~13-30 Hz
- Low frequency oscillations

The STN-GPe Loop is thought to be responsible for most parkinsonian symptoms



https://www.cbs.mpg.de/1500493/stn-gpe

Parkinson's Mathematical Representation

$$\tau_{GPe}\frac{dI_{GPe}}{dt} = -I_{GPe} + (k_i - I_{GPe}) \cdot Z_i(w_7 E_{STN} - w_8 I_{GPe}) \qquad (5)$$

$$DBS(t) = A\frac{4}{\pi}\sum_{n=1,3,5}^{1,001}\frac{1}{n}\sin(2n\pi ft), \qquad (9)$$

$$\tau_{STN}\frac{dE_{STN}}{dt} = -E_{STN} + (k_e - E_{STN}) \cdot Z_e(w_{10} E_{STN} - w_{11} I_{GPe} + DBS) \qquad (10)$$

$$Z_p(x) = \frac{1}{1+\exp(-b_p(x-\theta_p))} - \frac{1}{1+\exp(b_p\theta_p)}, \qquad (8)$$

Connection	Weigh t	Tremor Band Parameters	Healthy Band Parameters
STN to GPE	w7	5	19
GPE to GPE	w8	5	5
Cx to STN	w10	20	20
GPE to STN	w11	20	20

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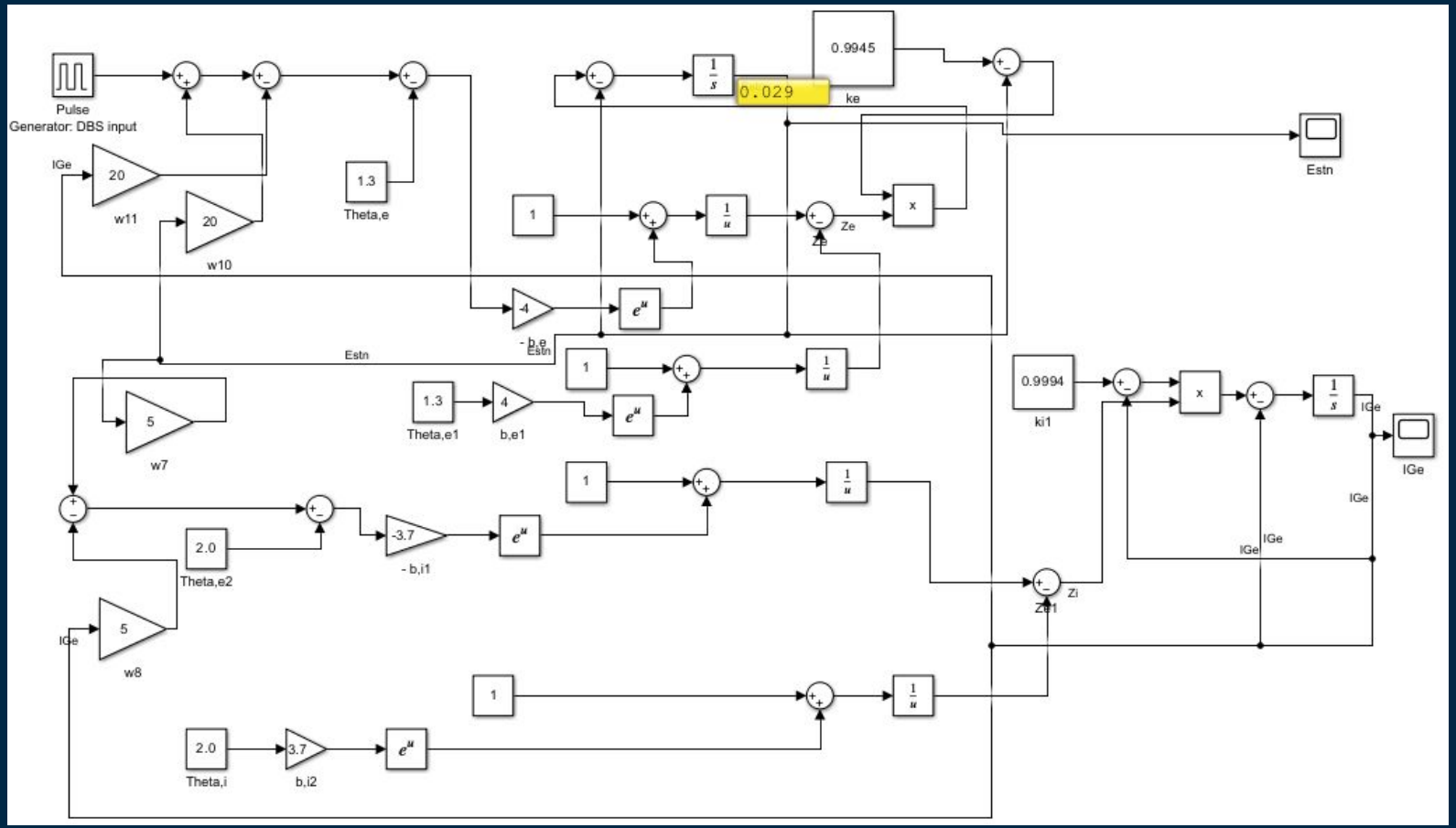
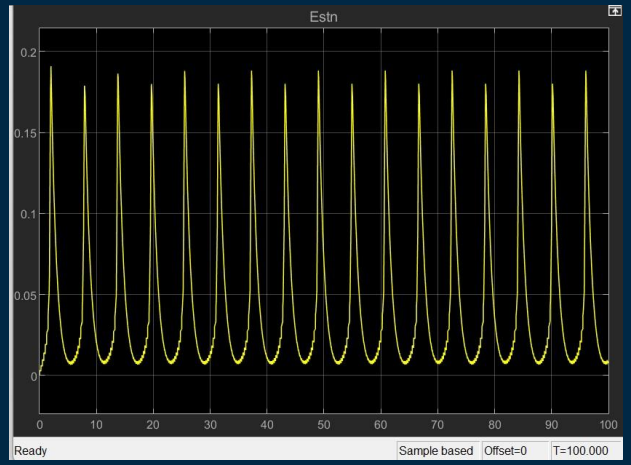
Equations and values chosen based on larger model from 2020 research paper by Yousif, Bain, Nandim and Borisyuk

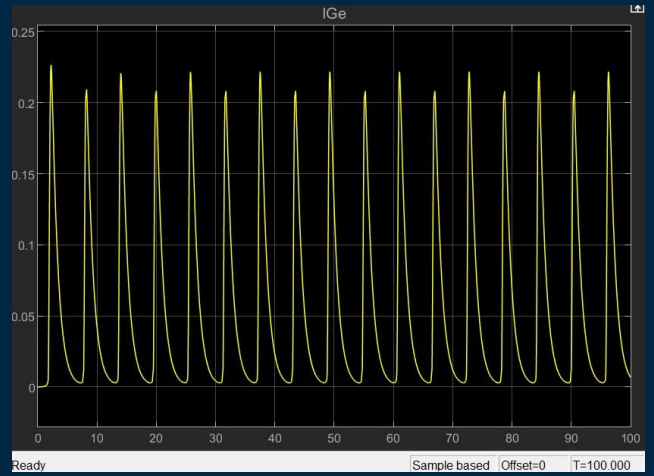
Simulink Model



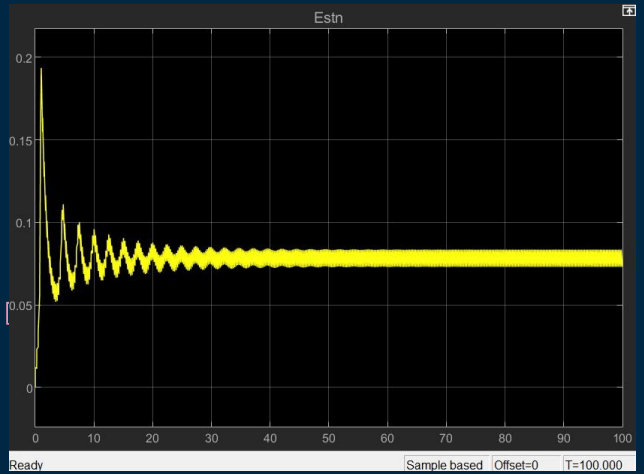
Results: Analyzing DBS amplitude change results on tremor band Frequency = 4Hz ,

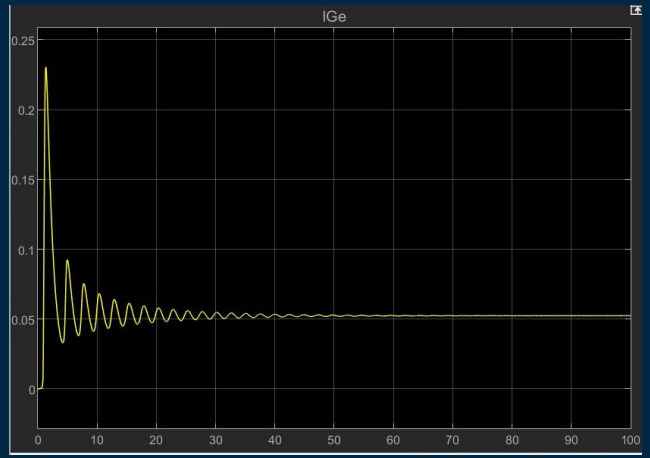
DBS amplitude = 1 :





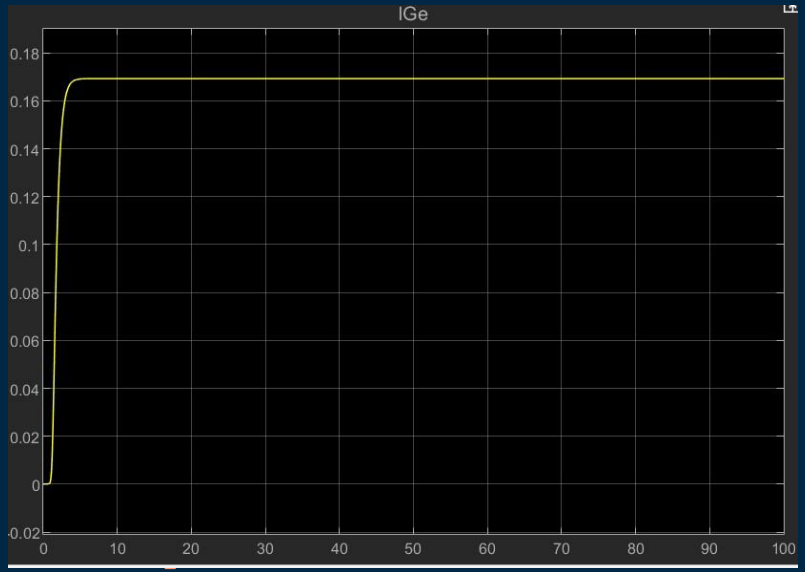
DBS amplitude = 5:



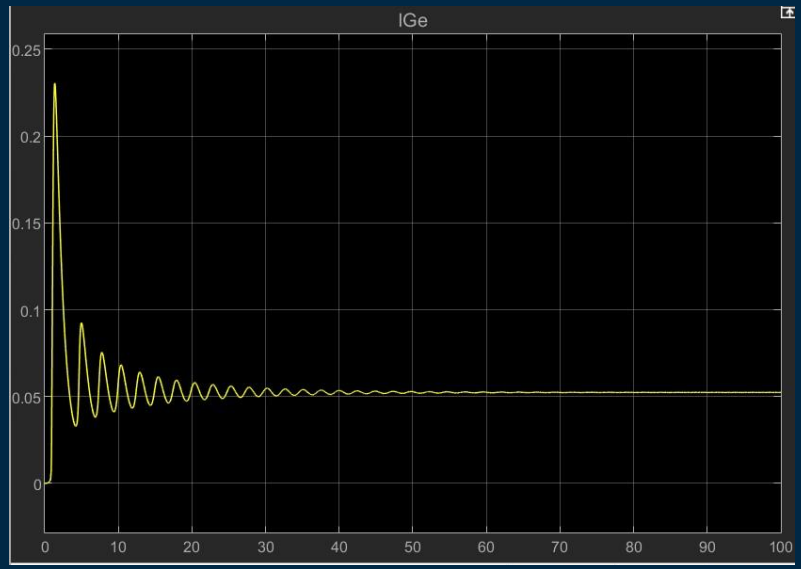


Comparing healthy to Parkinson's Patient at 10Hz, DBS amplitude = 5

Healthy Band



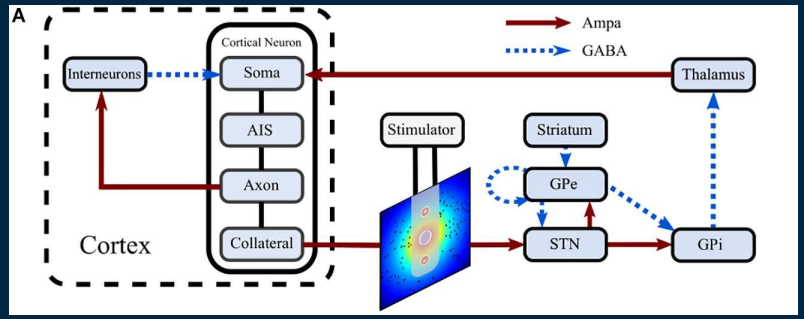
Tremor Band



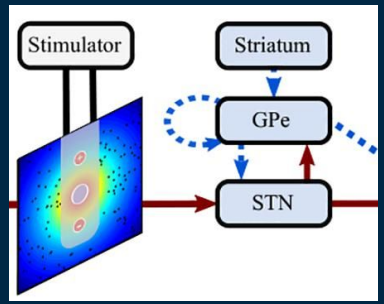
Constraints

- By focusing on the STN and GPE, and not including the cortex or thalamus, we modeled a simplified version of the closed loop system.
- In reality the system is more complex. However, our model is still useful in showing the initial response of the STN after it receives input from the DBS device

Entire System:

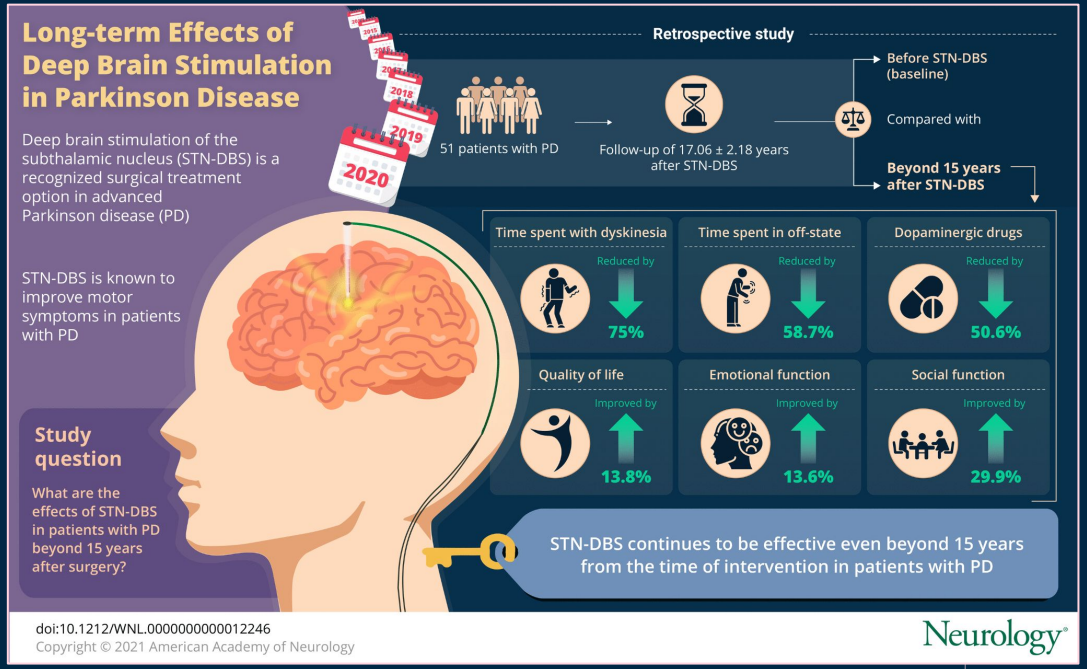


Section we focused on:



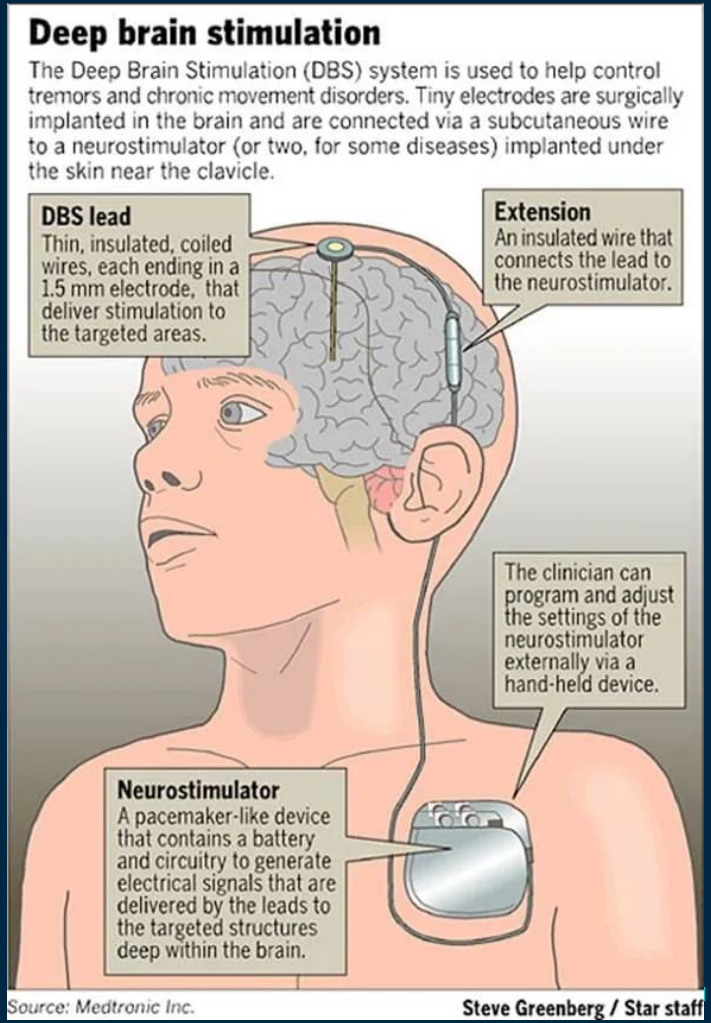
Clinical Applications

- Motor symptom improvement
- Fluctuations in medication response
- Dyskinesia management
- Reduction in medication dosages
- Improvement in quality of life
- Speech and swallowing improvement
- Cognitive function
- Long-term management



Conclusion and Future Uses

- Closed-loop systems
- Targeted simulations
- Personalized medication
- Expanded indications
- Remote monitoring and programming
- Integration with other therapies
- Improved battery technology
- Enhanced patient monitoring



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THANK YOU!