Imperial College London

Literature review and thesis proposal
MRes. Neurotechonlogy

Investigating plasticity in Cortico-Basal Ganglia-Thalamus models for improving stimulation-based treatments

Aaron Panaitescu
(*CID:* 02054726)

Supervisor:
Hayriye Cagnan

Word Count: ????

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Contents

1 Introduction / Abstract?

Stylistically, I would prefere to do an abstract here and breakdown the concepts in the following section

2 Background and literature review

start this off nicely with a diagram of the research gap

2.1 Parkinson's Disease

Outline

** 1. Loss of SNc dopaminergic neurons.**

** 2. indirect GPe → STN pathway ↑, hyperdirect Cortex → STN pathway ↓. (dimmer switch model [Helmich et al., 2012], [West et al., 2022])**

** **add diagram** **

** 3. Hypersynchrony in the Basal Ganglia.**

2.2 DBS: theory and practice

DBS as the state of the art in treatment

Limitations of DBS (invasiveness, side effects, it needs to be on permenently, why 130Hz? when tremors are $\sim$ 20Hz)

citations needed

$\Rightarrow$ plenty of things to be improved

2.3 Stimulating at the right time?

important [Cagnan et al., 2017] [Beudel et al., 2018] [West et al., 2022]

2.4 Plasticity to recover network states

mention [Lebedev and Nicolelis, 2017] [Cramer et al., 2011]

2.5 Neuron-level vs. Mean-field models

briefly, in general and expand in the context of plasticity

cover [Jansen and Rit, 1995] ([Hodgkin et al., 1952] does this really need to be cited?)

important [Duchet et al., 2023] [Shupe and Fetz, 2021] [Schwab et al., 2020]

2.6 **Other ways of improving stimulation-based treatments**

stimulation parameter optimizations, closing the loop (e.g. aDBS [Beudel et al., 2018]) *Maybe this can be folded into the stimulating at the right time part since they are pretty closely related*

3 Project Plan

3.1 Aims

1. Model neuroplasticity in a Parkinsonian CGBT network
2. Investigate the viabillity of harnessing plasticity to remove the system from the pathological state and analyze the dynamics that follow

   here i care about things like for how long and how does the network change. To what degree can we induce changes etc.

   should look into viable timescales for simulation
3. Try to link potential results to potential stimulation protocols?

3.2 Methodolgy

How indeed? HH/IF Pakrkinsoni model + plasticity rules, trying different stimulation-based protocols (link with experimental data?)

3.3 Timeline

Gant chart thingy

References

[Beudel et al., 2018] Beudel, M., Cagnan, H., and Little, S. (2018). Adaptive brain stimulation for movement disorders. *Current Concepts in Movement Disorder Management*, 33:230–242.

[Cagnan et al., 2017] Cagnan, H., Pedrosa, D., Little, S., Pogosyan, A., Cheeran, B., Aziz, T., Green, A., Fitzgerald, J., Foltynie, T., Limousin, P., et al. (2017). Stimulating at the right time: phase-specific deep brain stimulation. *Brain*, 140(1):132–145.

[Cramer et al., 2011] Cramer, S. C., Sur, M., Dobkin, B. H., O'Brien, C., Sanger, T. D., Trojanowski, J. Q., Rumsey, J. M., Hicks, R., Cameron, J., Chen, D., et al. (2011). Harnessing neuroplasticity for clinical applications. *Brain*, 134(6):1591–1609.

[Duchet et al., 2023] Duchet, B., Bick, C., and Byrne, Ã. (2023). Mean-field approximations with adaptive coupling for networks with spike-timing-dependent plasticity. *Neural Computation*, 35(9):1481–1528.

[Helmich et al., 2012] Helmich, R. C., Hallett, M., Deuschl, G., Toni, I., and Bloem, B. R. (2012). Cerebral causes and consequences of parkinsonian resting tremor: a tale of two circuits? *Brain*, 135(11):3206–3226.

[Hodgkin et al., 1952] Hodgkin, A. L., Huxley, A. F., and Katz, B. (1952). Measurement of current-voltage relations in the membrane of the giant axon of loligo. *The Journal of physiology*, 116(4):424.

[Jansen and Rit, 1995] Jansen, B. H. and Rit, V. G. (1995). Electroencephalogram and visual evoked potential generation in a mathematical model of coupled cortical columns. *Biological cybernetics*, 73(4):357–366.

[Lebedev and Nicolelis, 2017] Lebedev, M. A. and Nicolelis, M. A. (2017). Brain-machine interfaces: from basic science to neuroprostheses and neurorehabilitation. *Physiological reviews*, 97(2):767–837.

[Schwab et al., 2020] Schwab, B. C., König, P., and Engel, A. K. (2020). Spike-timing-dependent plasticity can account for aftereffects of dual-site transcranial alternating current stimulation. *bioRxiv*.

[Shupe and Fetz, 2021] Shupe, L. and Fetz, E. (2021). An integrate-and-fire spiking neural network model simulating artificially induced cortical plasticity. *Eneuro*, 8(2).

[West et al., 2022] West, T. O., Magill, P. J., Sharott, A., Litvak, V., Farmer, S. F., and Cagnan, H. (2022). Stimulating at the right time to recover network states in a model of the cortico-basal ganglia-thalamic circuit. *PLOS Computational Biology*, 18(3):1–32.

Appendices

A First appendix

B Second appendix