Optimising brain stimulation treatment for depression using computational simulations and machine learning.

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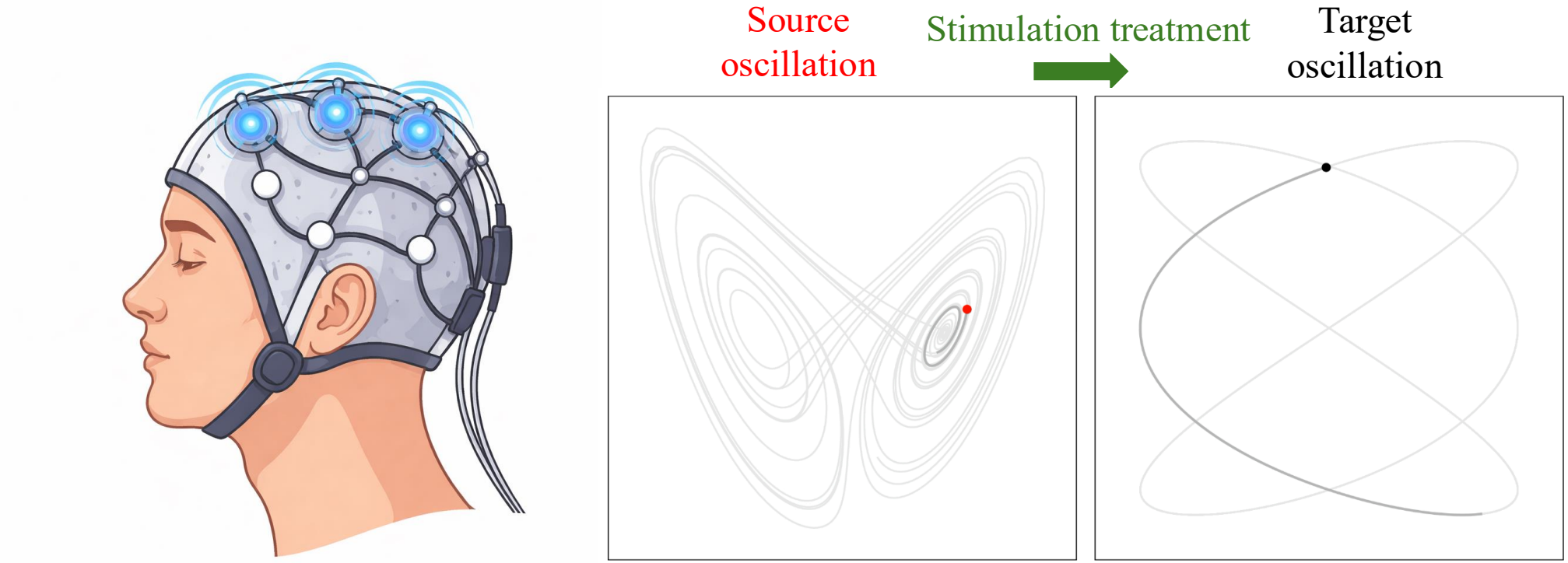
Acknowledgement of Country

Background: Closed-loop brain stimulation



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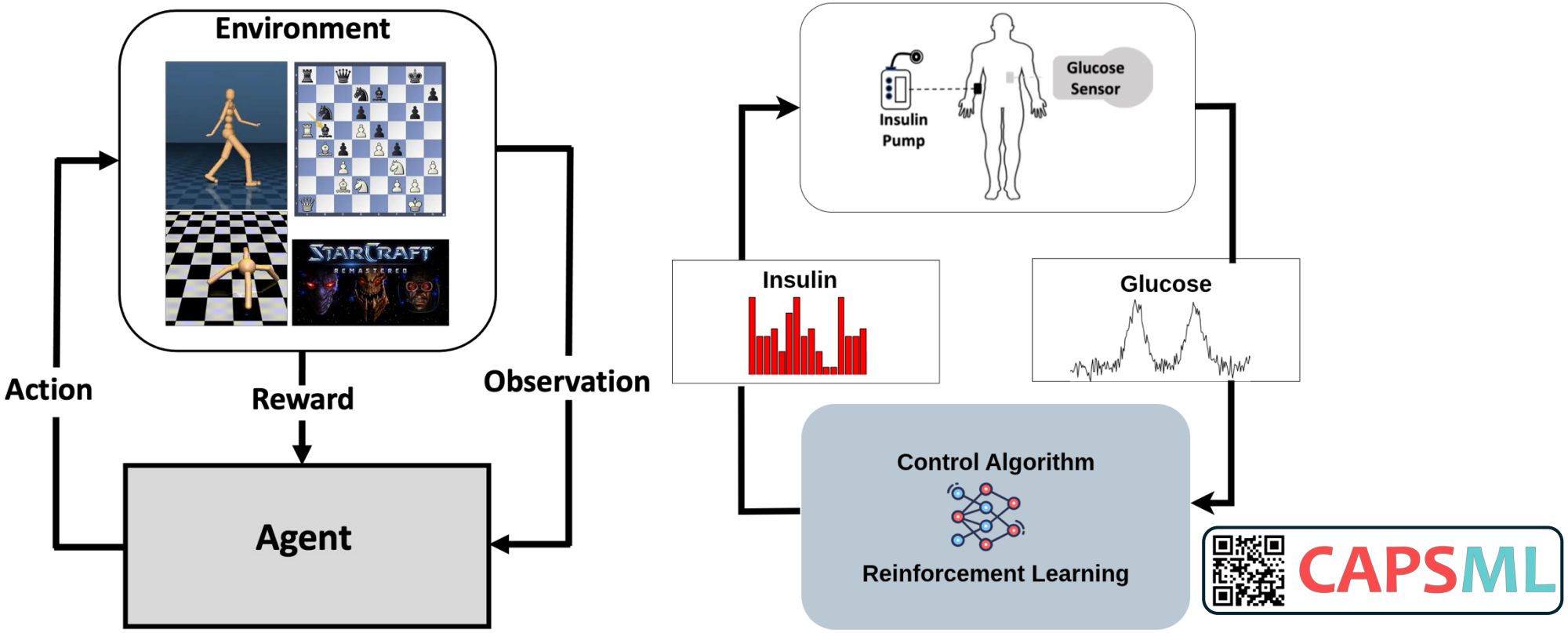
Differences in neural oscillations have been observed in people experiencing psychiatric and neurological conditions, and brain stimulation treatment is explored to support and regulate these patterns.

In closed-loop brain stimulation, an electric current or magnetic field stimulates brain activity and dynamically adjusts stimulation using real-time EEG feedback.

Background: Reinforcement learning (RL) and closed-loop clinical treatment



The “Law of Effect” in psychology introduced learning by trial and error,
which described the effect of reinforcing events based on the tendency to select actions.

Simulating closed-loop transcranial brain stimulation for reinforcement learning-based treatment discovery.

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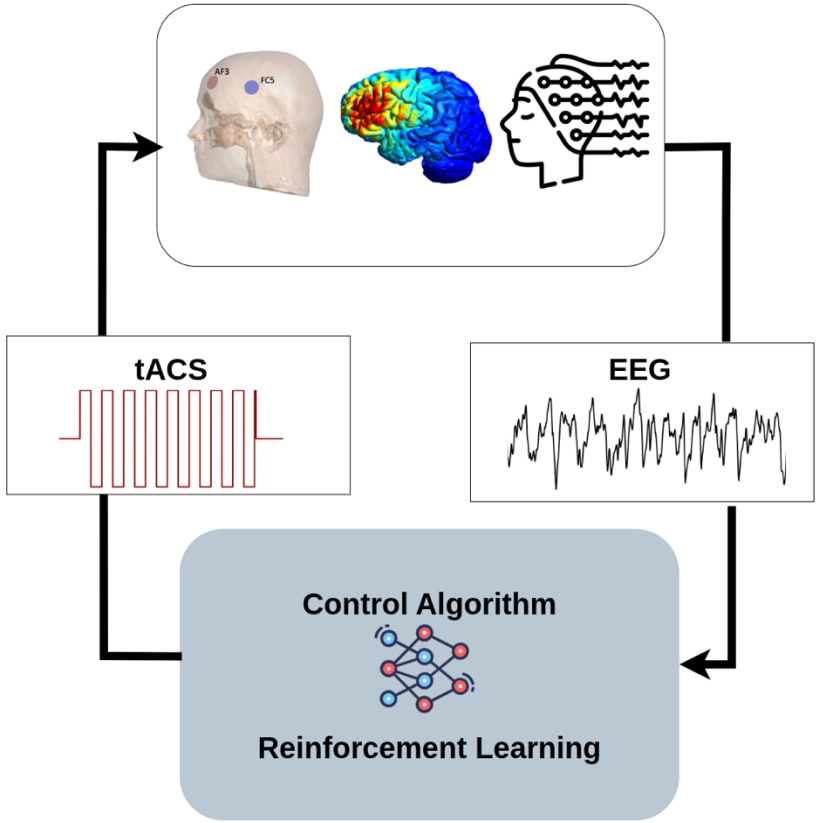
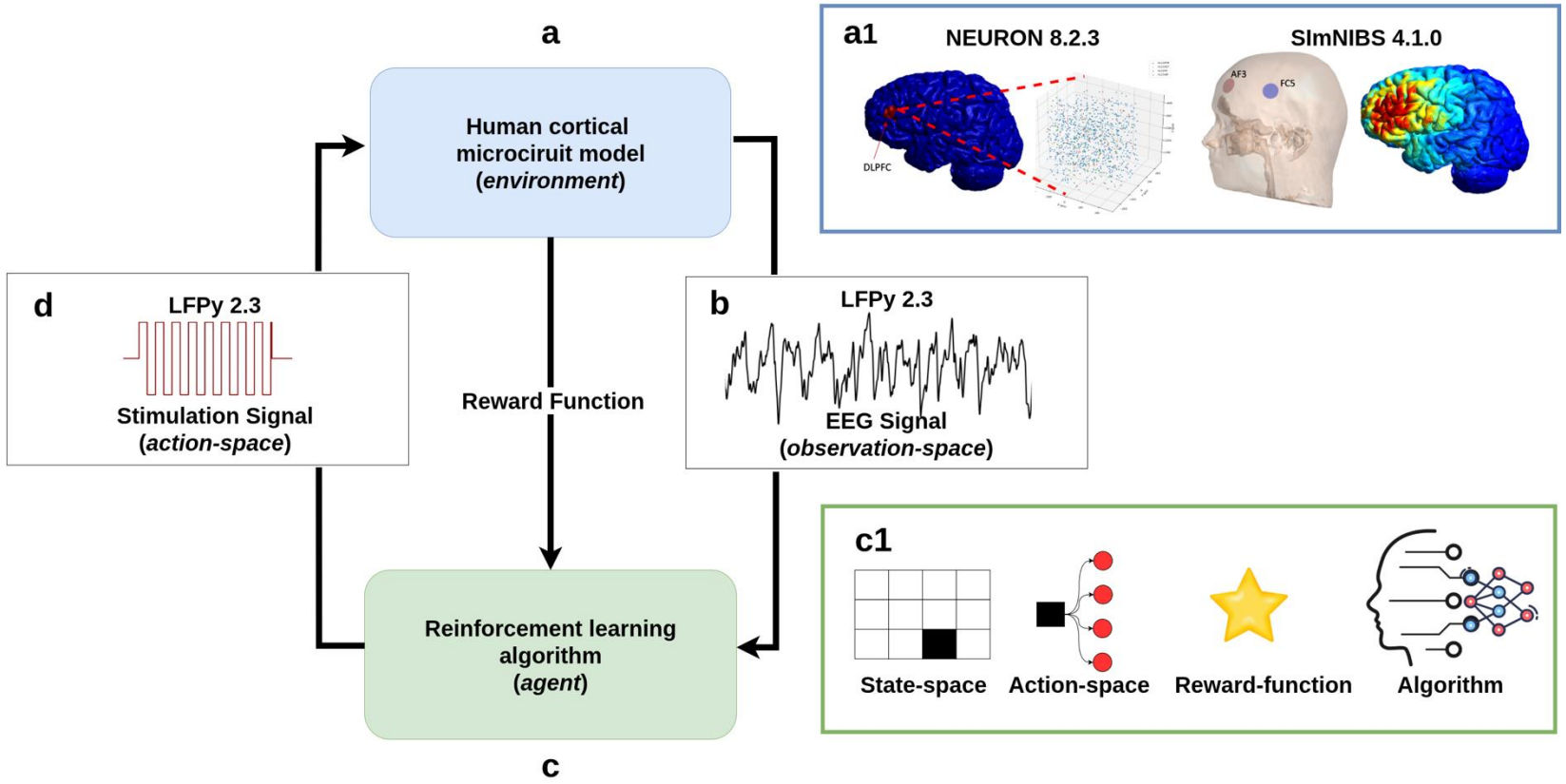
Why do we need computational models & simulations?



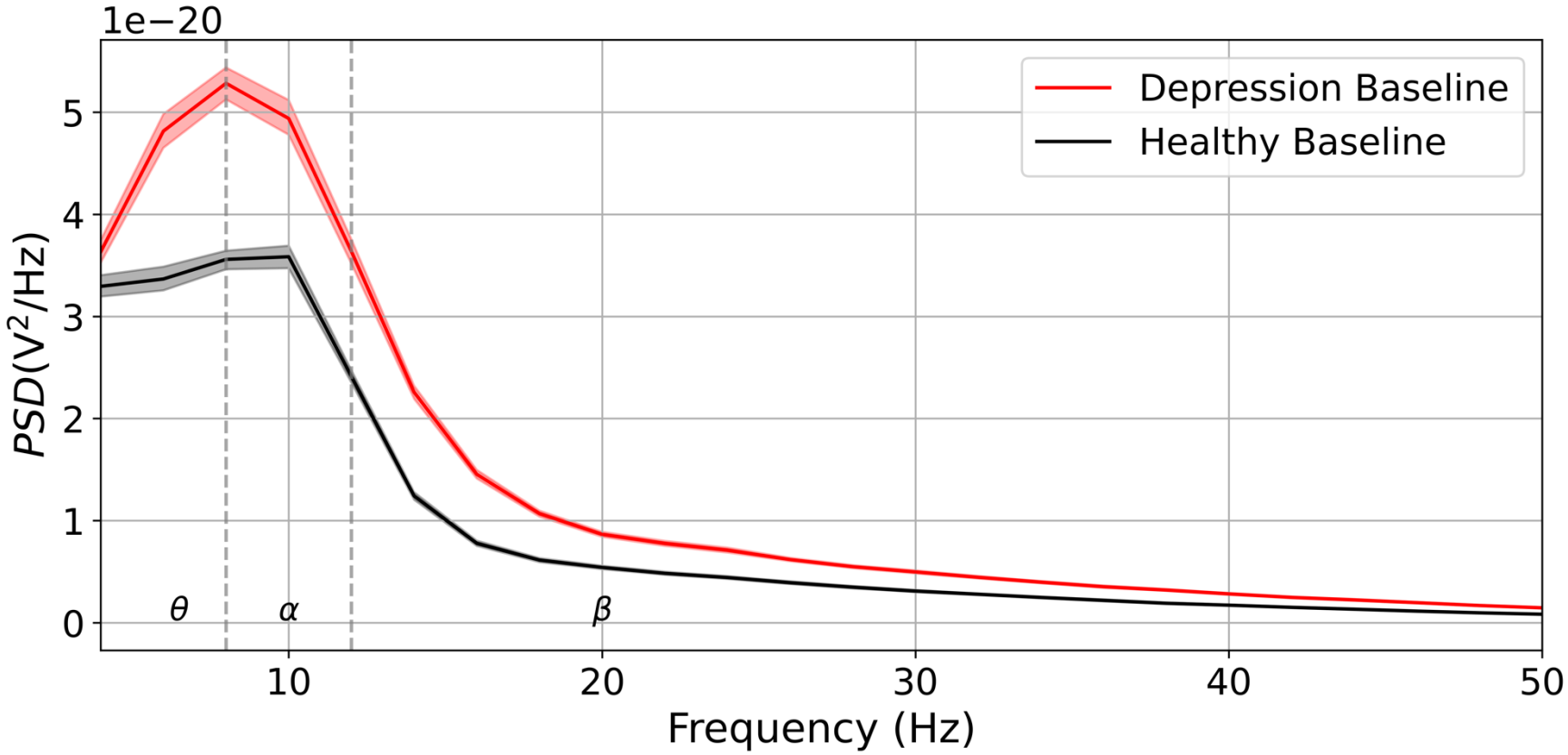
The human brain is a complex dynamical system, and computational neuroscience has been vital in advancing our understanding of brain function.

Why apply reinforcement learning (RL)?



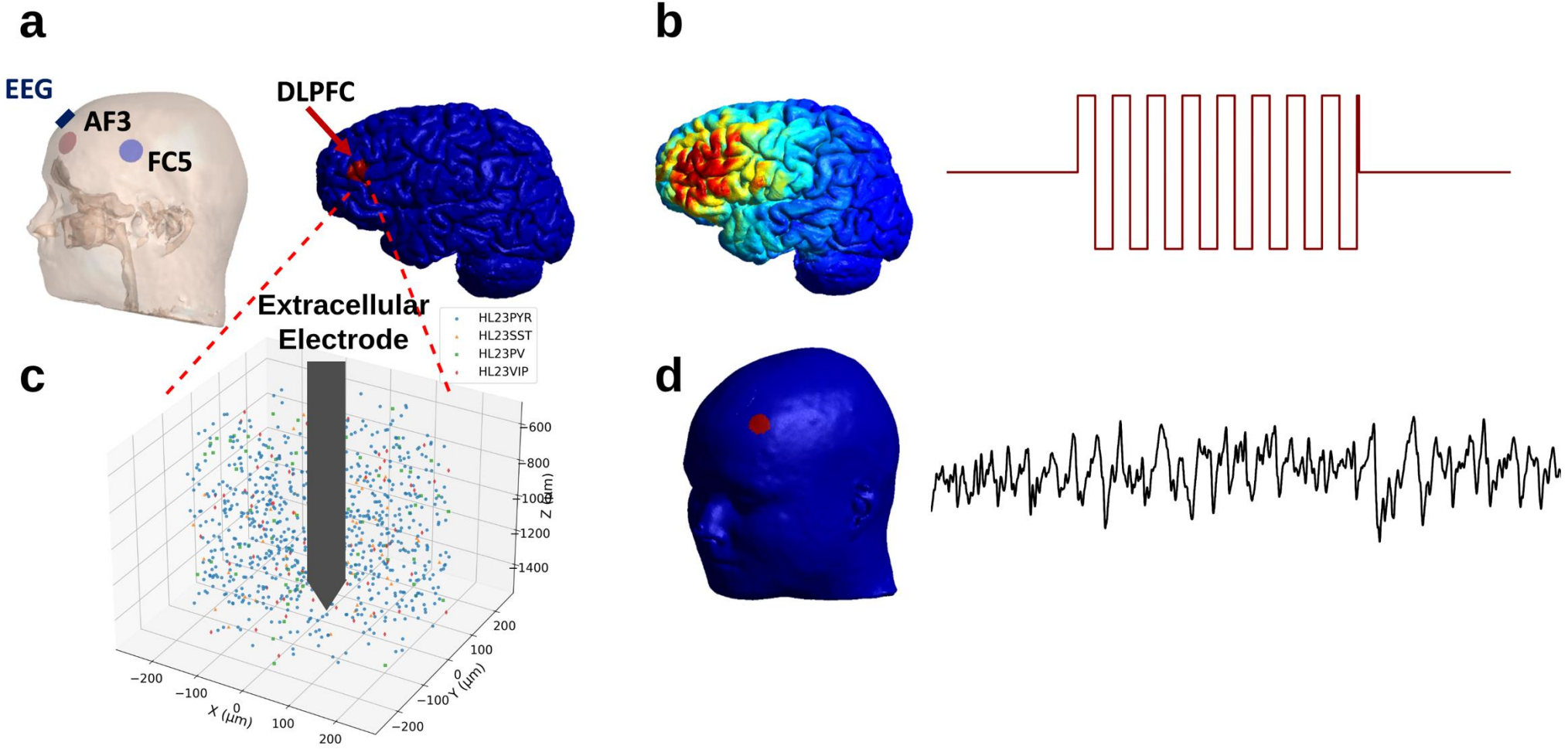
Open-loop brain stimulation strategies face many challenges: personalising neuromodulation, multi-parameter optimisation process (amplitude, phase, frequency).

Case study: Transcranial alternating current stimulation (tACS) for depression



Systematic reviews of EEG literature, examining neural activity patterns in depression, identify that elevated power in theta, alpha, and beta frequencies is the main and consistently reported finding.

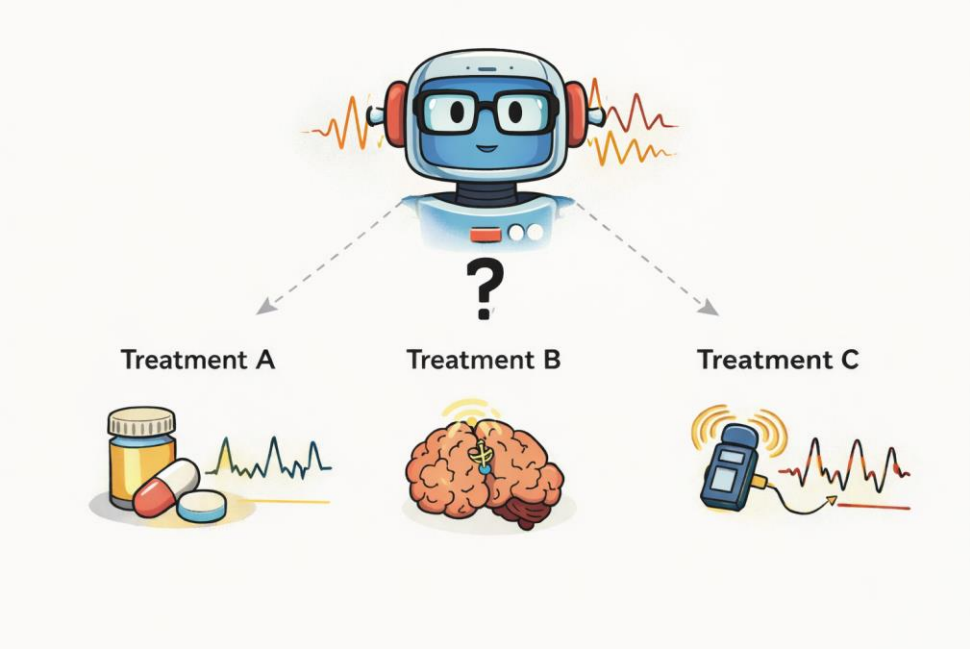
Methods



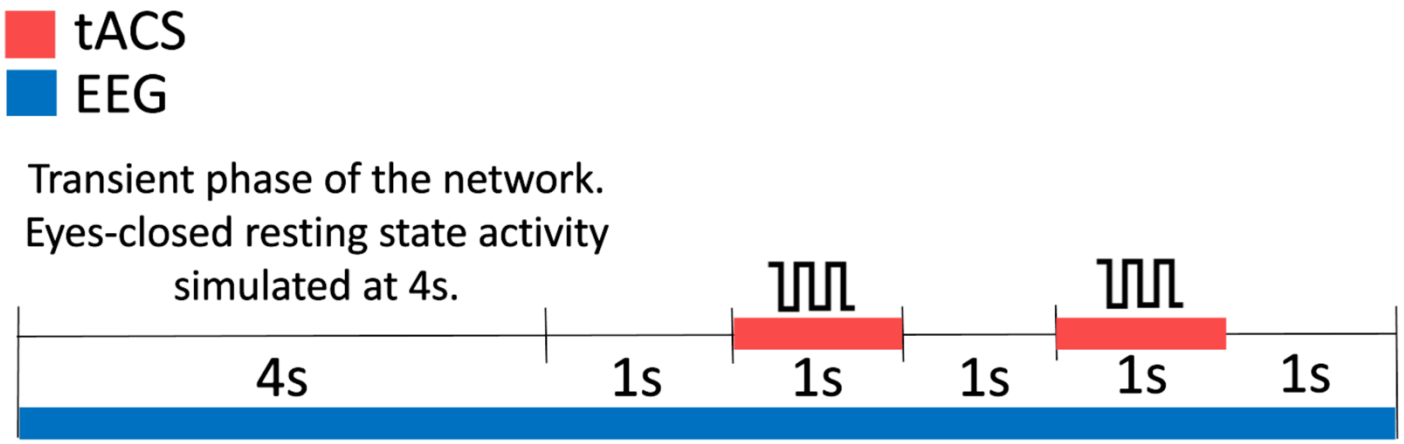
We simulated a depression microcircuit (1,000 neurons) in the left-DLPFC region, applied tACS stimulation electrodes (AF3, FC5), and recorded EEG.

Methods: We presented the RL algorithm with several treatment options and asked which was best for modulating depression-related oscillations.

Multi-arm stochastic bandit algorithm.

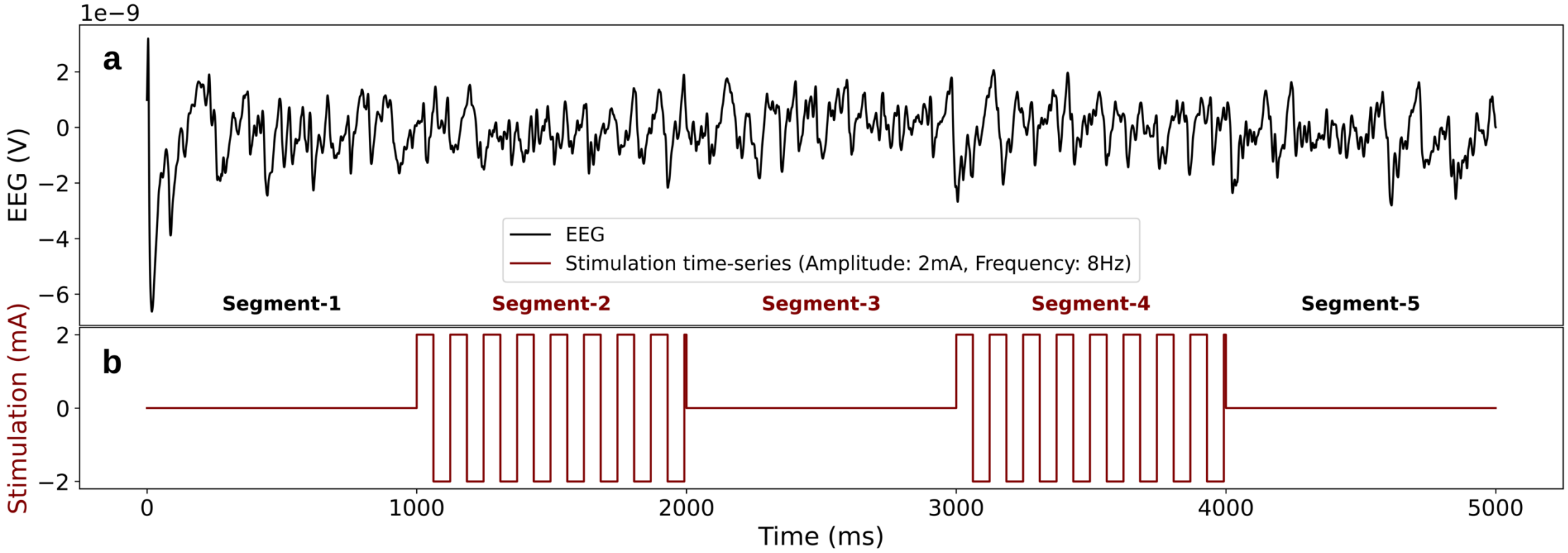


[Image credits DALL·E]



Stimulation protocol used in the study.

Results

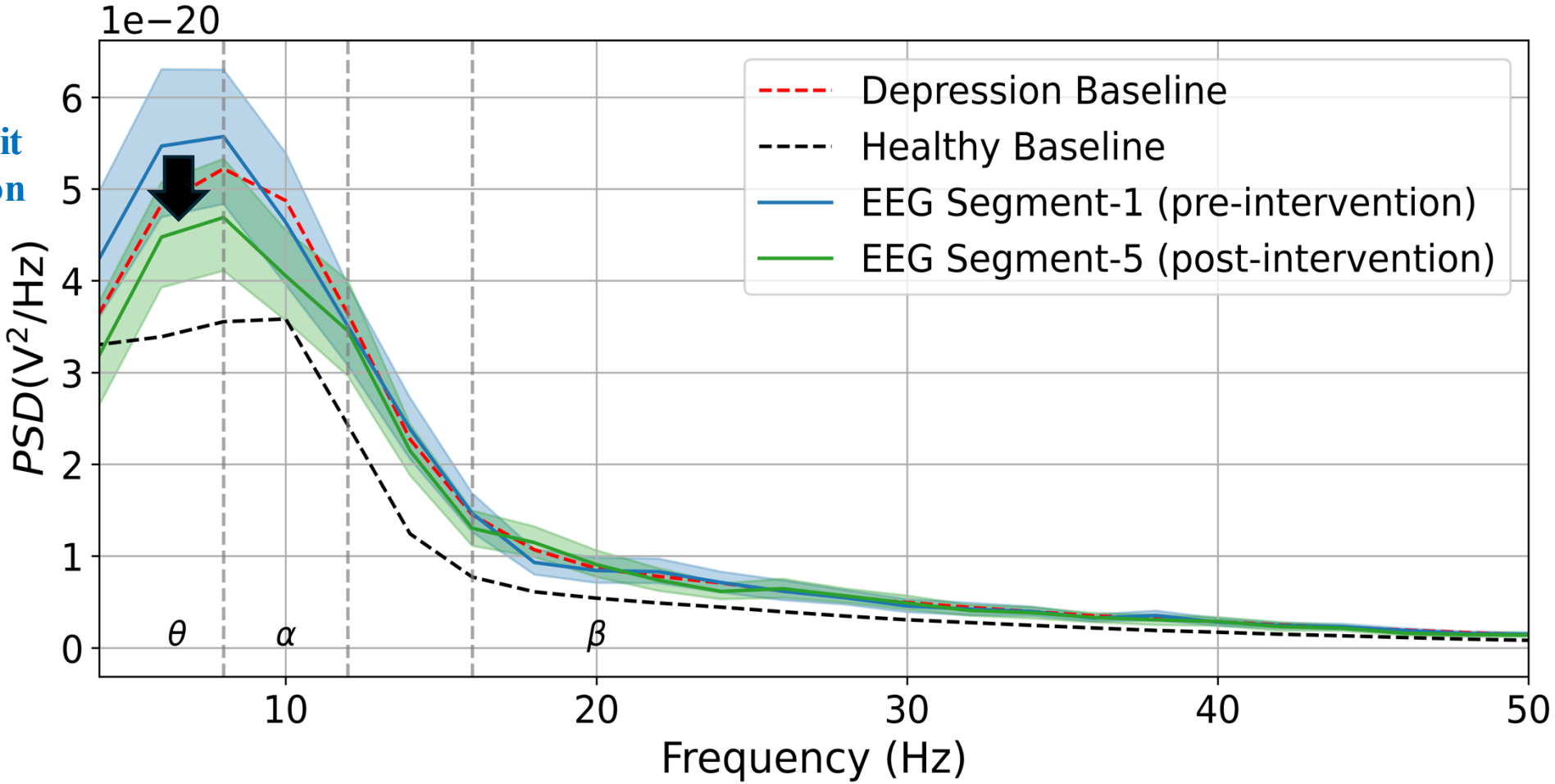


The algorithm selected a set of treatment parameters (2 mA, 8Hz) to achieve the goal of modulating power in target frequency bands.

Results

Depression circuit before stimulation

After tACS stimulation



Demonstrated finding a tACS strategy to modulate neural dynamics representative of depression towards healthy. A statistically significant decrease in theta band power was observed.

Conclusion and future directions

- We engineered an open-source framework for simulation and RL-based brain stimulation, which can address neurological diseases beyond depression.
- We demonstrated promising initial results using RL-based algorithms for treatment selection to successfully modulate neural dynamics representative of depression towards healthy states.
- The current study is limited to primary effects during stimulation and uses only a very simple algorithm, which paves the way for more advanced analysis.