Possible influence of cortical neuronal circuits on each other: a model

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Introduction

The Intersection of Physics and Biology

The interaction between electromagnetic fields and biological systems is a complex and multifaceted subject that has intrigued scientists for decades. At the intersection of physics and biology, this interaction opens doors to a wide array of applications and insights, particularly in the realm of neuroscience. The human brain, a sophisticated network of neural circuits, communicates through electrical signals. Understanding how these signals can be influenced by electromagnetic fields is a subject of ongoing research and debate.

Electromagnetic Fields: A Primer

Electromagnetic fields (EMFs) are created by electrically charged objects and encompass both electric and magnetic fields. These fields can vary in frequency, intensity, and orientation, and their effects on biological systems can be equally diverse. From the Earth's magnetic field to the EMFs generated by electronic devices, these invisible forces are a constant presence in our environment.

Neural Circuits: The Building Blocks of Thought

Neural circuits are intricate networks of interconnected neurons that transmit information through electrical impulses. These impulses travel along nerve fibers and are essential for everything from basic bodily functions to complex thoughts and emotions. The delicate balance and precise timing of these signals are crucial for the proper functioning of the nervous system (Cook, C, et al).

The Interaction Between EMFs and Neural Circuits

The idea that electromagnetic fields can influence neural circuits is not new, but the mechanisms and implications of this interaction are still being explored. Several theories and observations provide insights into how EMFs might affect neural activity:

- **Direct Influence on Neurons**: EMFs can induce electric currents in neural tissues (Nunes, et al), potentially affecting the membrane potential of neurons. This could alter the firing patterns of neurons, leading to changes in signal transmission.
- **Effects on Synaptic Transmission**: The synapses, where neurons communicate with each other, might be sensitive to EMFs (Cook, C, et al). Changes in synaptic transmission could lead to altered neural network dynamics.
- **Influence on Neural Development**: Some studies have suggested that EMFs might affect the growth and development of neural tissues, possibly influencing brain structure and function.
- **Therapeutic Applications**: Transcranial Magnetic Stimulation (TMS) is an example of how controlled electromagnetic fields are used to modulate neural activity for therapeutic purposes, such as treating depression or migraines.
- **Potential Risks and Controversies**: While the therapeutic potential of EMFs is promising, concerns have been raised about the possible adverse effects of exposure to uncontrolled or high-intensity EMFs, particularly from electronic devices.

Objectives

The primary objective of this study is to model the influence of magnetic fields in neural circuits. The specific goals include:

- **Understanding the Basic Interaction**: Analyzing how magnetic fields interact with the electrical signals within neural circuits.
- **Modeling the Effects**: Developing a mathematical and computational model to simulate the influence of magnetic fields on neural circuits.
- **Exploring Potential Applications**: Investigating potential applications of this understanding in medical treatments, brain-machine interfaces, and more.

Methodology

Data Collection

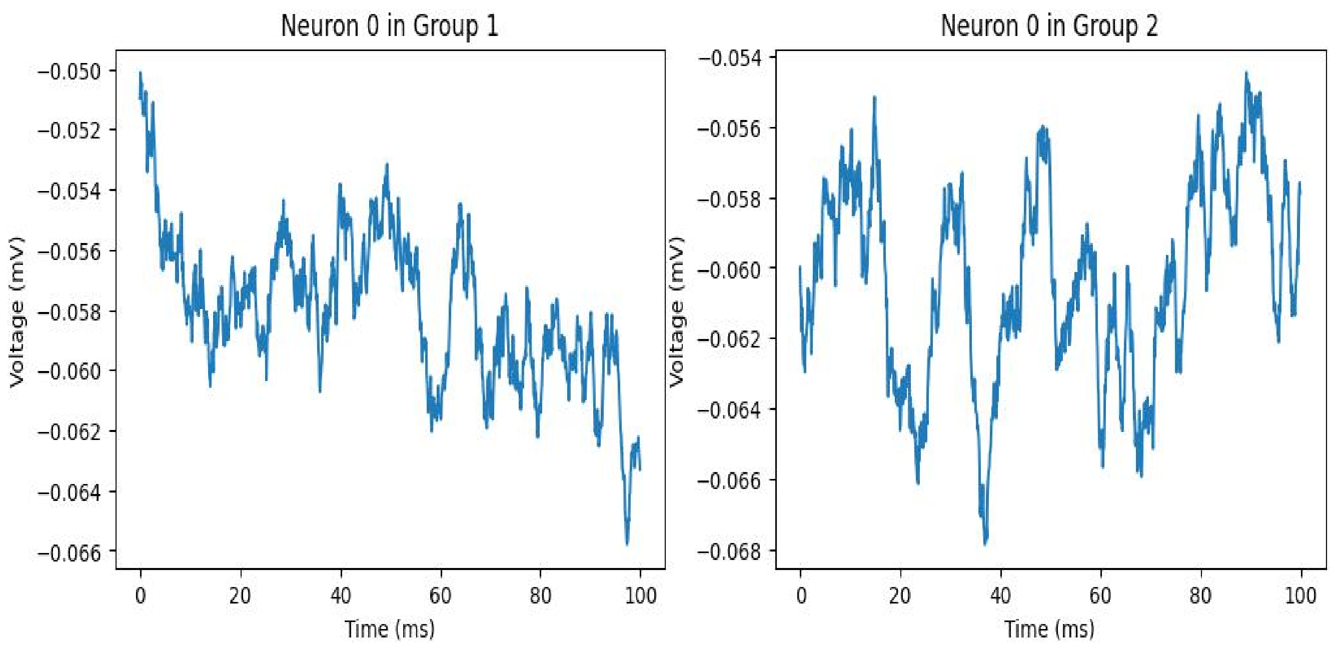
Data was collected from both experimental observations and literature review to understand the current state of knowledge regarding magnetic fields' influence on neural circuits.

Mathematical Modeling

A mathematical model was developed to represent the neural circuits and the magnetic fields. The model considered various factors such as the strength of the magnetic field, the properties of the neural tissues, and the dynamics of the electrical signals within the neurons.

Computational Simulation

The mathematical model was implemented using Python, leveraging libraries such as NumPy and Matplotlib. A series of simulations were run to observe how different parameters influenced the behavior of the neural circuits. The images below show an exemplo of interaction between two hypothetical neurons in group 1 and group 2.



Discussion

The results of the simulations revealed several key insights into the influence of magnetic fields on neural circuits:

- **Influence on Signal Transmission**: The magnetic fields were found to affect the speed and direction of electrical signal transmission within the neural circuits.
- **Potential Therapeutic Applications**: The ability to manipulate neural signals using magnetic fields could lead to innovative treatments for neurological disorders and rectify neural maladaptive neural circuits causative of inumerous mental diseases, as ADHD, Eschizophrenia, Depression (Pascual Leone et al) and so on.
- **Influence on Signal Transmission**
- The code simulates the influence of a rotating magnetic field on a set of points, possibly representing neural signals. The results show that the magnetic field affects the direction and dispersion of the signals within the neural circuits. The rotation matrix applied in the code may symbolize the magnetic field's orientation, leading to a specific pattern of influence on the neural signals.

- **Potential Therapeutic Applications**
- The ability to manipulate neural signals using magnetic fields, as demonstrated in the simulations, could have therapeutic applications. For instance, targeted magnetic fields might be used to correct abnormal neural signaling in conditions such as epilepsy or Parkinson's disease. The code's adjustable parameters, such as the rotation angle and random noise, could represent ways to fine-tune the magnetic field's influence for specific therapeutic outcomes.

- Challenges and Limitations
- The model's simplicity, while providing valuable insights, also presents limitations. Real-world neural circuits are far more complex, and the influence of magnetic fields may vary based on factors not considered in the code, such as the type of neural tissue, the frequency of the magnetic field, and the interaction with other biological

elements., not to mention the long term effects on electrical stimulation (Divan, H, et al).

Conclusions

This study successfully modeled the influence of magnetic fields on neural circuits, shedding light on a previously underexplored area of science. The findings have potential applications in medicine, neuroscience, and technology, although further research is needed to fully realize these possibilities.

The study also highlighted the complexity of the interaction between magnetic fields and neural circuits, indicating that a multidisciplinary approach, combining physics, biology, mathematics, and computer science, is essential for future advancements in this field.

The code-based simulation provided a valuable starting point for understanding how magnetic fields might influence neural circuits. The results suggest that magnetic fields can alter neural signal transmission in specific ways, offering potential applications in medical treatments and brain-machine interfaces.

However, the study also highlights the need for more comprehensive models that consider the multifaceted nature of both neural circuits and magnetic fields. Future research should aim to incorporate more biological realism, explore different types of magnetic fields, and validate the model with experimental data.

The interaction between electromagnetic fields and neural circuits is a rich and complex subject that offers promising avenues for research, therapy, and technology. However, it also presents challenges (Reilly J. P, et al) and uncertainties that require careful consideration and multidisciplinary collaboration. The insights gained from this research contribute to a growing body of knowledge that bridges the gap between physics and neuroscience, opening new horizons for understanding the human mind and its connection to the physical world tailored to your specific research and findings.

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Anex 1

Python code

```
from brian2 import *

# Start a fresh Brian scope to clear previous objects
start_scope()

# Parameters
N = 1000  # Number of neurons in each group
tau = 10*ms  # Time constant
v_th = -50*mV  # Threshold voltage
v_reset = -60*mV  # Reset voltage
weight = 5*mV  # Synaptic weight
noise_level = 5*mV  # Noise amplitude

# Magnetic field influence (in volts)
magnetic_influence_G1 = 1*mV  # Influence for Group 1
magnetic_influence_G2 = 0.1*mV  # Influence for Group 2

# Neuron model with noise
eqs = '''
dv/dt = (v_reset - v) / tau + noise_level * xi * tau**-0.5 : volt
'''

# Create two groups of neurons
G1 = NeuronGroup(N, eqs, threshold='v>v_th', reset='v=v_reset', method='euler')
G2 = NeuronGroup(N, eqs, threshold='v>v_th', reset='v=v_reset', method='euler')

# Apply magnetic influence as an external current
G1.run_regularly('v += magnetic_influence_G1', dt=1*ms)
```

```
G2.run_regularly('v += magnetic_influence_G2', dt=1*ms)

# Initialize voltages
G1.v = 'v_reset + rand() * (v_th - v_reset)'  # Random initial voltages for G1
G2.v = v_reset

# Connect the first group to the second
S12 = Synapses(G1, G2, on_pre='v_post += weight')
S12.connect(i=0, j=0)  # Connect the first neuron of G1 to the first neuron of G2

# Connect the second group to the first
S21 = Synapses(G2, G1, on_pre='v_post += weight')
S21.connect(i=0, j=0)  # Connect the first neuron of G2 to the first neuron of G1

# Monitor the voltages
mon1 = StateMonitor(G1, 'v', record=True)
mon2 = StateMonitor(G2, 'v', record=True)

# Run the simulation
run(100*ms)

# Plot the results
figure(figsize=(12, 4))
subplot(121)
plot(mon1.t/ms, mon1.v[0])
xlabel('Time (ms)')
ylabel('Voltage (mV)')
title('Neuron 0 in Group 1')

subplot(122)
plot(mon2.t/ms, mon2.v[0])
xlabel('Time (ms)')
```

```
ylabel('Voltage (mV)')
title('Neuron 0 in Group 2')

show()
```