Measuring the Electrophysiological Effects of Space-Related Altered Gravity on Primary Neurons

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Background and Motivation

In this study, we investigate how changes in mechanical force fields related to altered gravity in space may affect the electrophysiological behavior of embryonic rat cortical neurons (eRCNs). We use different scales of magnetic field gradients to mimic transitions into and out of space-related altered gravity. Understanding how neurons adapt to altered gravity is critical, as spaceflight has been linked to neurological changes [1], still the mechanisms driving these effects remain unclear. The problem lies in the limited knowledge of how gravitational shifts influence neuroplasticity, which is essential for cognitive and behavioral function

Experimental Design

We cultured eRCNs on microelectrode arrays and exposed them to two permanent magnetic fields (high, low), with and without nano particles, to mimic gravity shifts. This allowed us to record neural activity and explore how gravity-related forces may affect brain function.

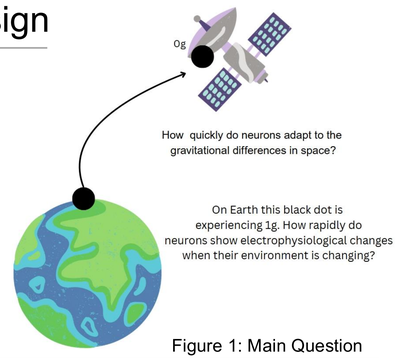

Figure 1: Main Question

1. Dissociated embryonic rat cortical neurons (eRCNs) cultured on 60-electrode MEAs
2. After 12 days in vitro, half of the cultures were treated with iron oxide nanoparticles (10 µg/mL). The groups without nanoparticles served as control groups to assess mechanical force.
3. Magnetic force fields generated using 1.27 cm × 1.27 cm neodymium magnets
4. Two-phase exposure: cultures experienced either high (0.563 T) or low (0.036 T) magnetic fields, then switched
5. Spontaneous neuronal activity recorded using the MEA2100 system
6. Spike rate and amplitude analyzed to assess effects of magnetic field transitions

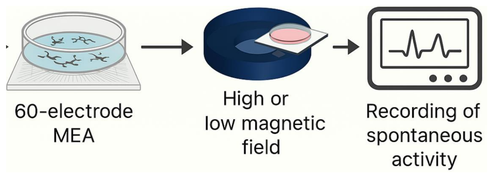

Figure 2: Experimental Design

Signal Recording and Processing Method

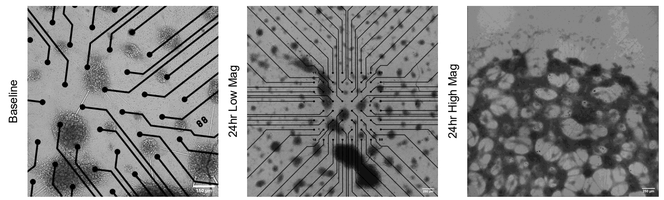

Figure 3: Brightfield microscopy images taken on the respective days the graphs from our results were made. Here you can see each electrode and how the neurons were situated on them. This can affect signal output and spike detected.

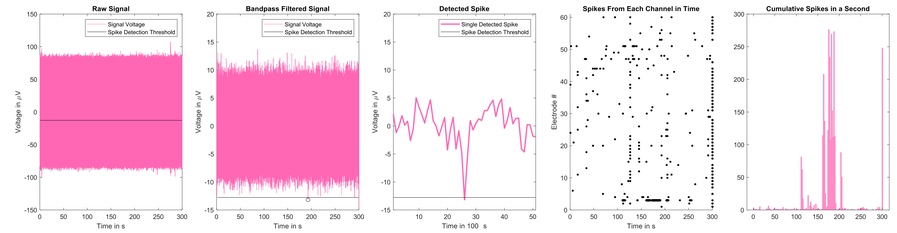

Figure 4: a. A graph of the raw unprocessed signal recorded from the Multichannel recording station. b. Graph of the signal filtered using MATLAB®. We used bandpass filters to keep the frequencies between 300 Hz and 400 Hz. c. Time-continues signal form indicating a singular spike detected from the graph shown under b. d. Raster plot shows detected spikes from all 63 micro electrode channels. e. Histogram plot shows accumulated spike count per second interval.

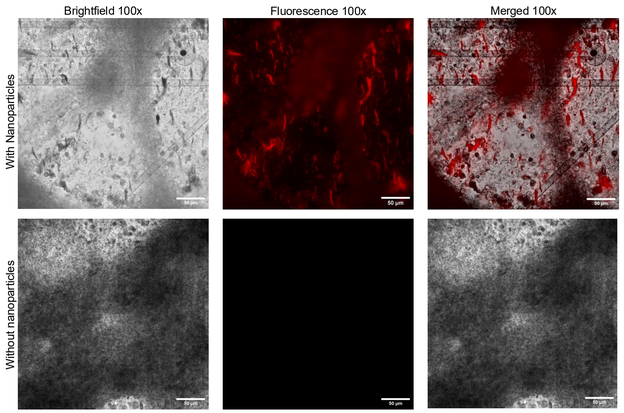

Figure 5: To assess nanoparticle uptake, we took fluorescent images and compared them to the corresponding brightfield microscopy images. We then repeated the process with the dishes that received no nanoparticles. Each red fluorescence shown is a cluster of nanoparticles. We added nanoparticles to increase the magnetic force effects on the neurons.

Spike Detection Results

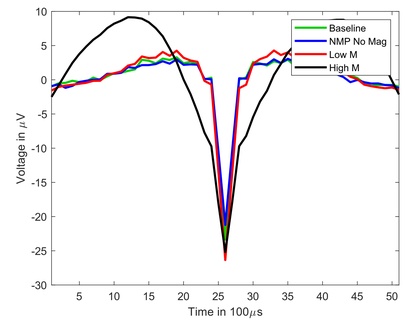

Figure 7: Average spike waveforms across four conditions, highlighting changes in spike shape with varying magnetic environments. The High Magnetic Field condition shows the greatest deviation, with broader, larger spikes—suggesting stronger fields may alter electrophysiological properties, possibly via ion channel or network changes.

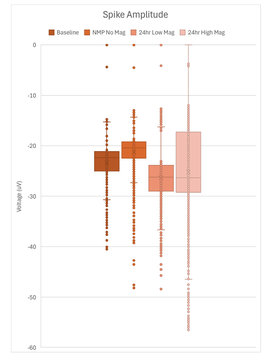

Figure 8 : Spike amplitude distributions across conditions, with boxplots and overlaid data points. The 24 h High Mag group displays greater variability and more negative amplitudes than other groups.

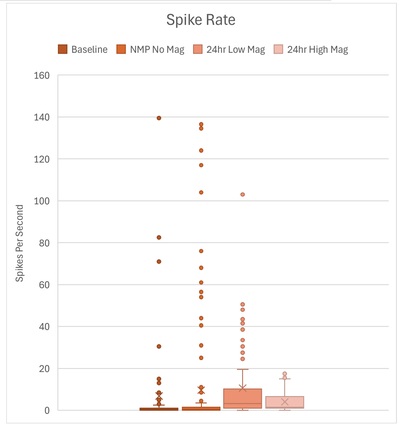

Figure 9 : Neuronal spike rates across conditions using box plots with overlaid data points. Spike rates were low in the Baseline and NMP No Mag groups, but increased—especially in the 24hr Low Mag group—suggesting low-intensity magnetic field exposure may enhance neural excitability.

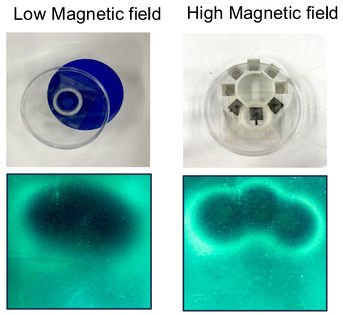

Figure 6 : Magnetic field each condition experienced. The darker areas show where the magnetic field is the strongest, while the lighter areas show a decreasing magnetic field. For the purposes of our experiment; Earth's gravity is characterized as the high magnetic field condition and outer space conditions are characterized by the lower magnetic field condition. The MEA was placed right on top and in the center of these magnetic fields.

Summary of Results

- Spike amplitudes remained consistent across all conditions, but began to show greater variability and increased negativity in the 24hr Low Mag, with the largest and most variable amplitudes in the 24hr High Mag condition (Fig. 4)
- Spike waveforms in the 24hr High Mag condition displayed a significantly different shape, with both a larger peak-to-peak amplitude and a broader duration.
- Baseline, NMP No Mag, and 24hr No Mag groups showed similar neural activity patterns; indicating that neither time nor NMPs alone significantly alter spike characteristics.

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References

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