Brain Cells as Biocomputers

Kagan et al., In vitro neurons learn and exhibit sentience when embodied in a simulated game-world, *Neuron* (2022). https://doi.org/10.1016/j.neuron.2022.09.001

CORTICAL LABS

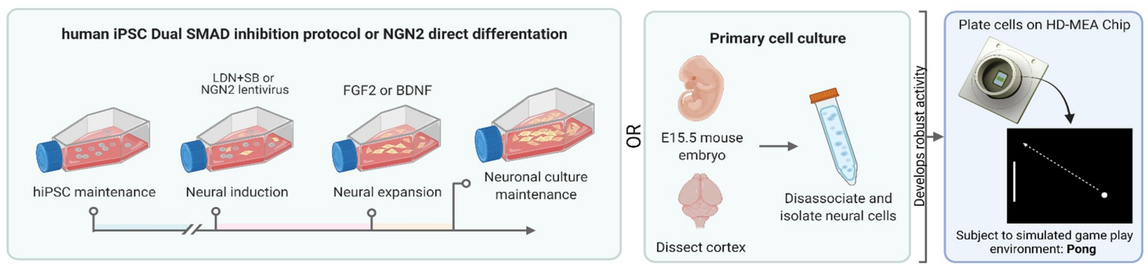
Background & Setup

Biological neurons display an innate learning ability.

Harnessing this ability offers a new paradigm of intelligent.

Brain cells have learn rapidly, use minimal power, and are flexible and responsive to changes in environments.

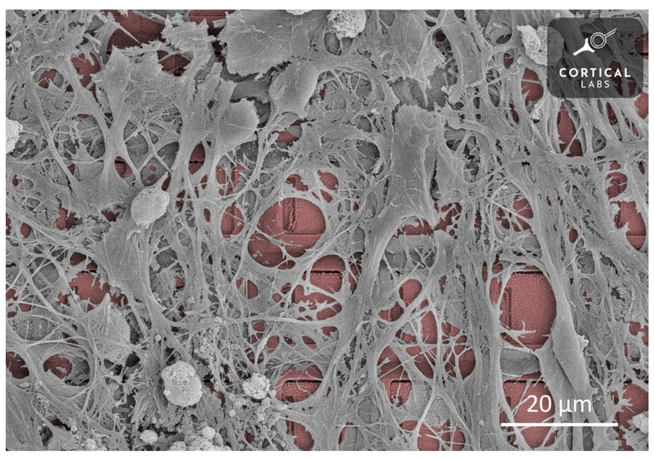
We attempted to teach biological neurons in a dish to learn the task of playing a simplified game of Pong.



Living Biological Brain Cells

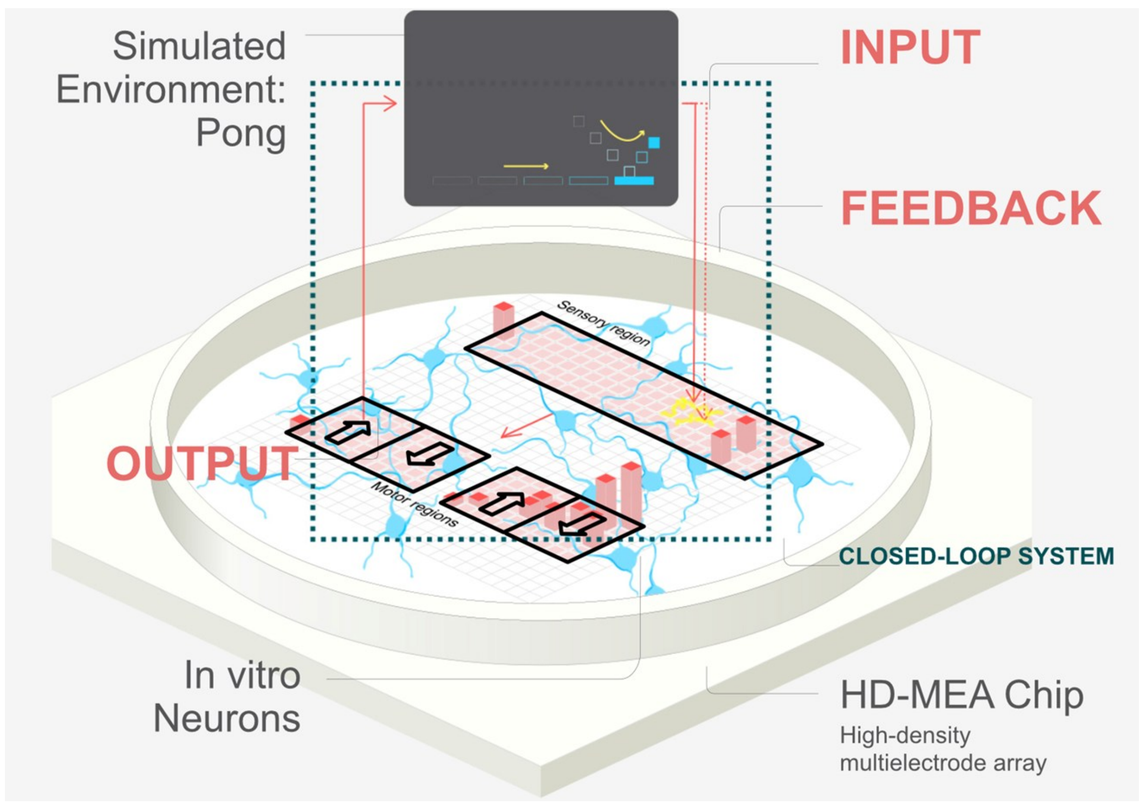
Neurons are grown from either embryonic mouse brain or differentiated from human stem cells.

These survive on multielectrode arrays for 6+ months.

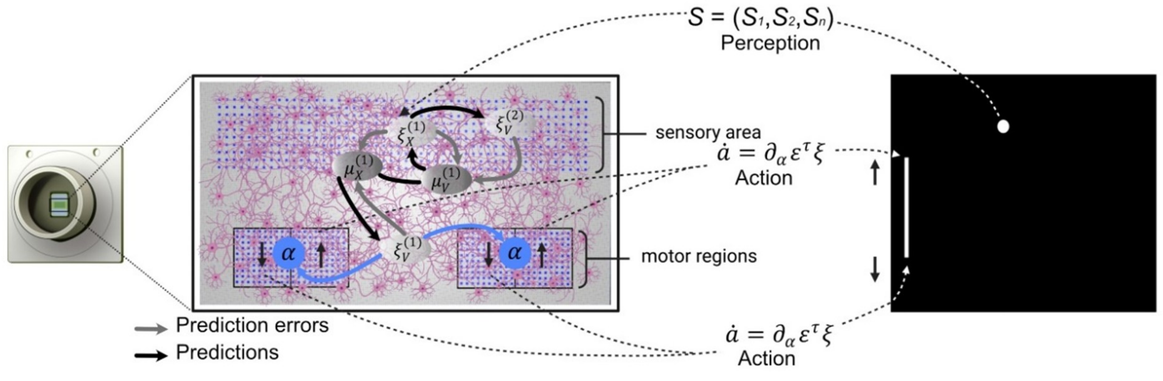


Real-Time Embodied Environments

We provided structured information (stimulation) to represent ball position in a real-time closed loop environment.



Feedback is provided by altering the information entropy of the incoming signals, where higher entropy is a disincentive.



Following the Free Energy Principle, neural systems should organise activity to make the environment more predictable.

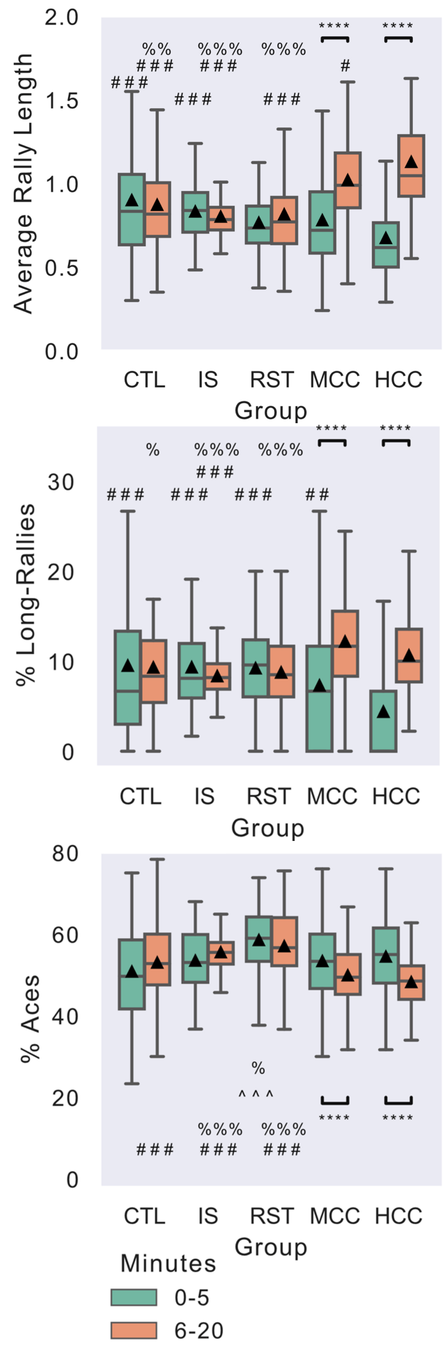
Gameplay Analysis

Pong gameplay over time was assessed to determine whether learning was occurring by determining whether neurons activity changed to control a paddle to hit a ball in a simulated gameplay environment of *Pong*.

Tested against multiple controls.

- CTL = media only
- IS = in-silico computational model with random noise
- RST = rest session with recording activity to move paddle, but no stimulus
- MCC = mouse cortical cells with stimulus and recording
- HCC = human cortical cells (from iPSCs) with stimulus and recording

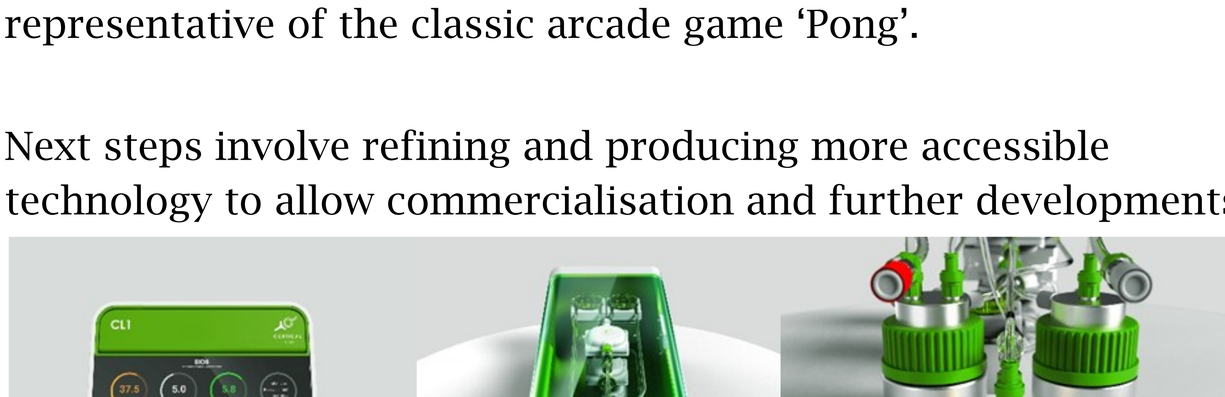
MCC and HCC groups showed statistically significant improvements over time, but not control groups. This was replicated over multiple metrics across all analyses.



Activity Changes Mirror Learning

Average cross sensory-motor correlation significantly less in rest compared to gameplay for both motor regions.

% exclusive activity per second across motor regions increased significantly during gameplay vs rest, with decreased correlation matching the observed increase in gameplay performance.



Synthetic Biological Intelligence

DishBrain exhibits natural intelligence by harnessing the inherent adaptive computation of neurons – what we termed Synthetic Biological Intelligence (SBI).

Through electrophysiological stimulation and recording via a HD-MEA, neurons were embedded in a simulated world, representative of the classic arcade game 'Pong'.

Next steps involve refining and producing more accessible technology to allow commercialisation and further developments.