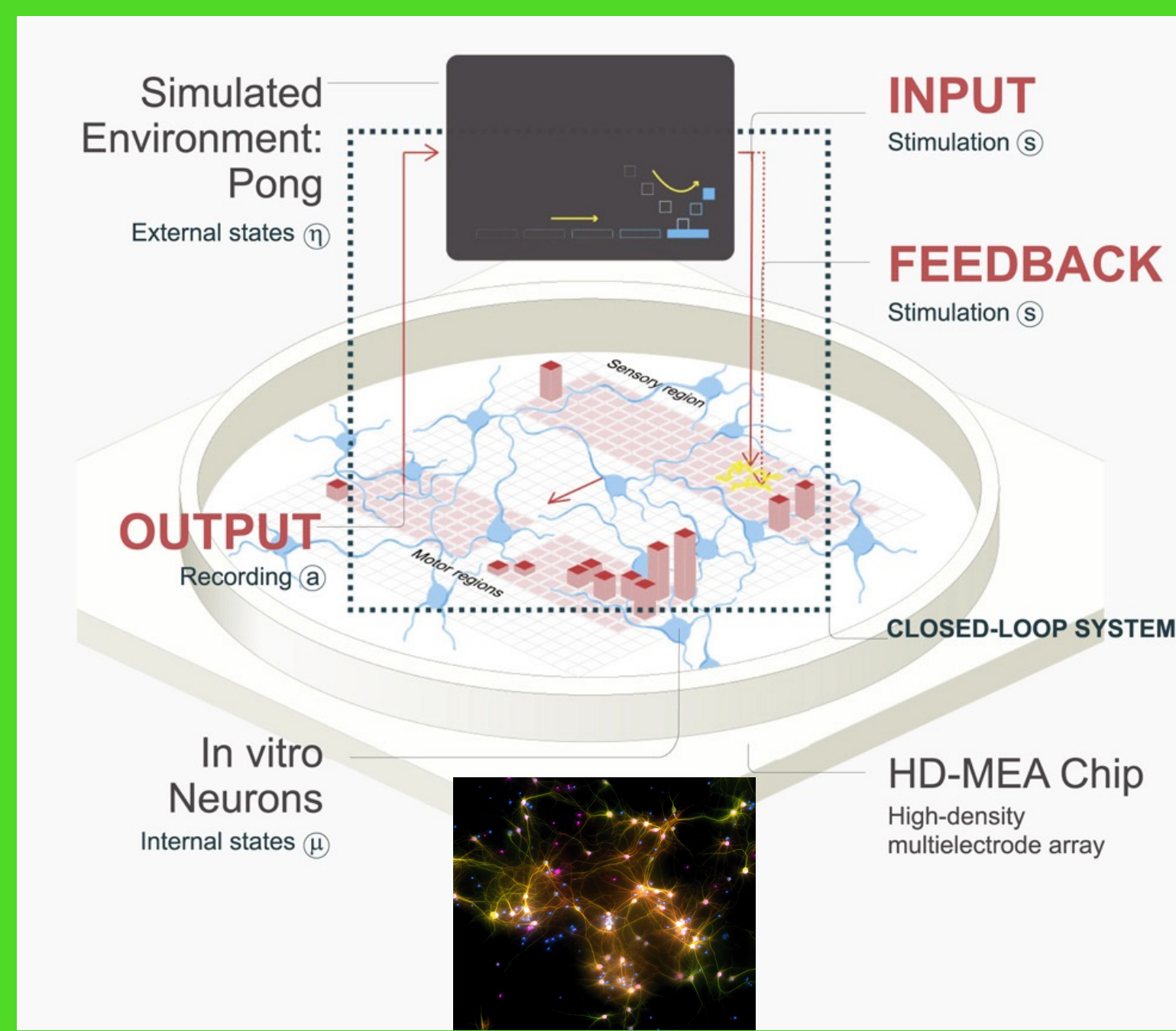


Examining Neural Dynamics within Embodied Environments

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- Simple in vitro networks of cortical cells obtained were shown to modify their electrophysiological activity in a manner consistent with learning and shown to have significant improvement in a simplified game of 'Pong'.

- To enable a learning protocol, electrophysiological information was recorded in real-time, applied to the simulated game-world, then provided back to the neurons through stimulation.

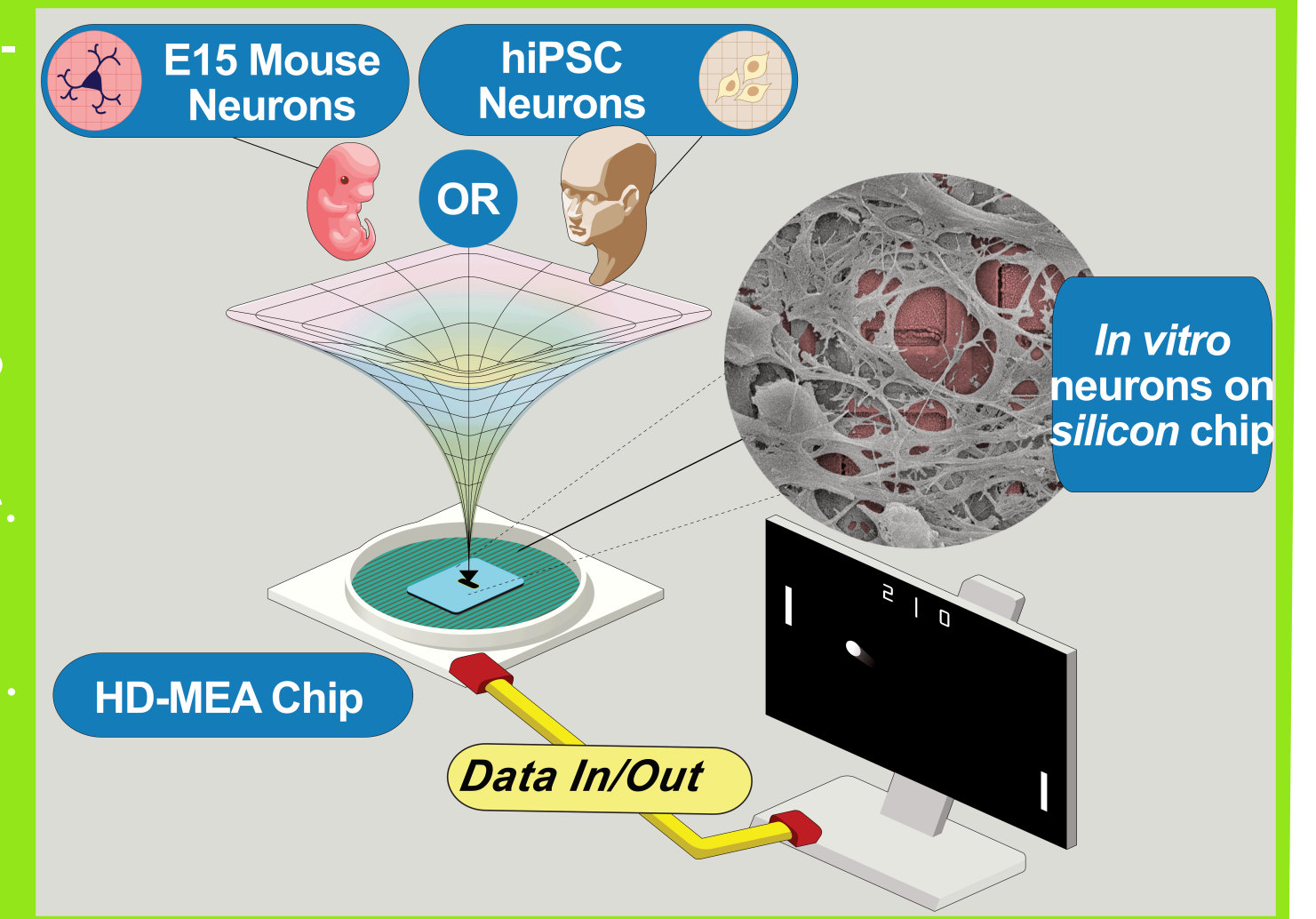
- The creation of a real-time closed-loop environment was proposed to 'embody' these neurons within this simulated game-world as it created a statistical barrier between internal and external information sources.

- Cortical neurons were plated on high density multielectrode arrays (HD-MEA).

- 75mv stimulations were applied in a rate- (4Hz - 40Hz) and place-coded (8 sites) manner to show ball position relative to paddle.

- Feedback was provided in the system as per protocol.

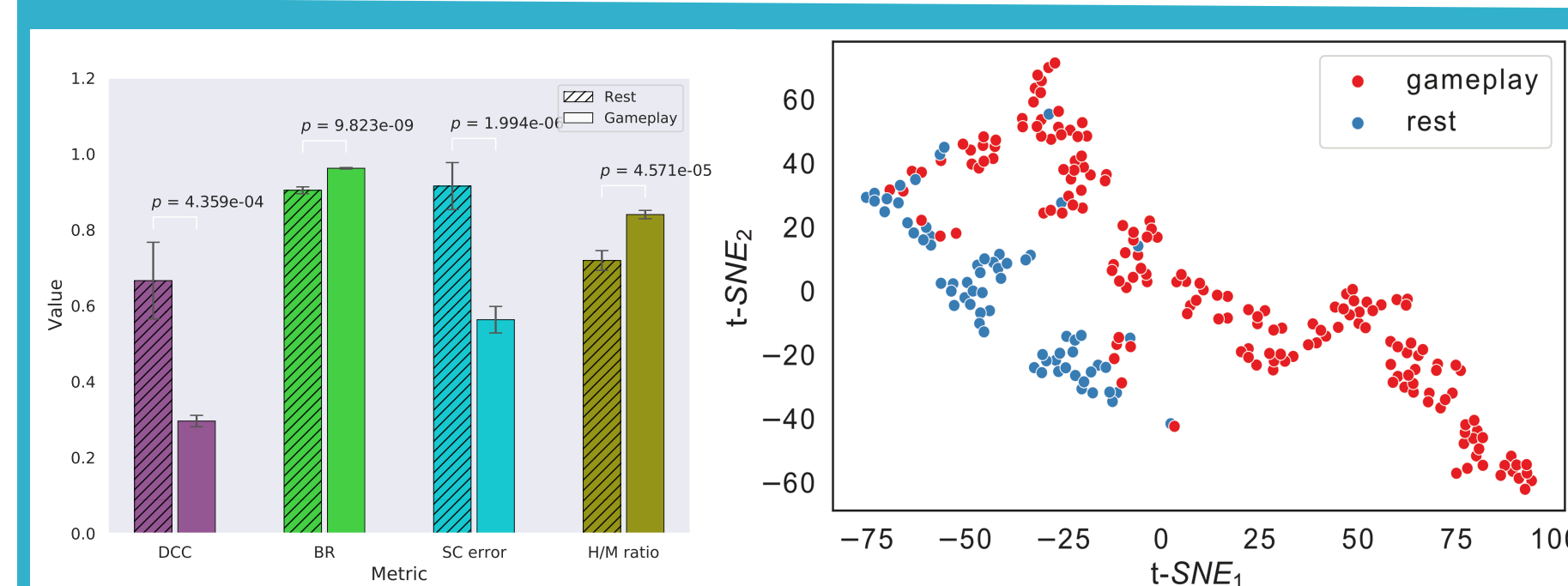
- Paddle movement was dictated by the relative number of action potentials detected across counterbalanced 'motor regions'.



- We aimed to investigate how networks of in vitro neurons altered electrophysiological activity when embodied in a structured information landscape.

- Here we showcase examples from:

- Mean informational entropy
- Low dimensional representations
- Functional connectivity
- Criticality metrics

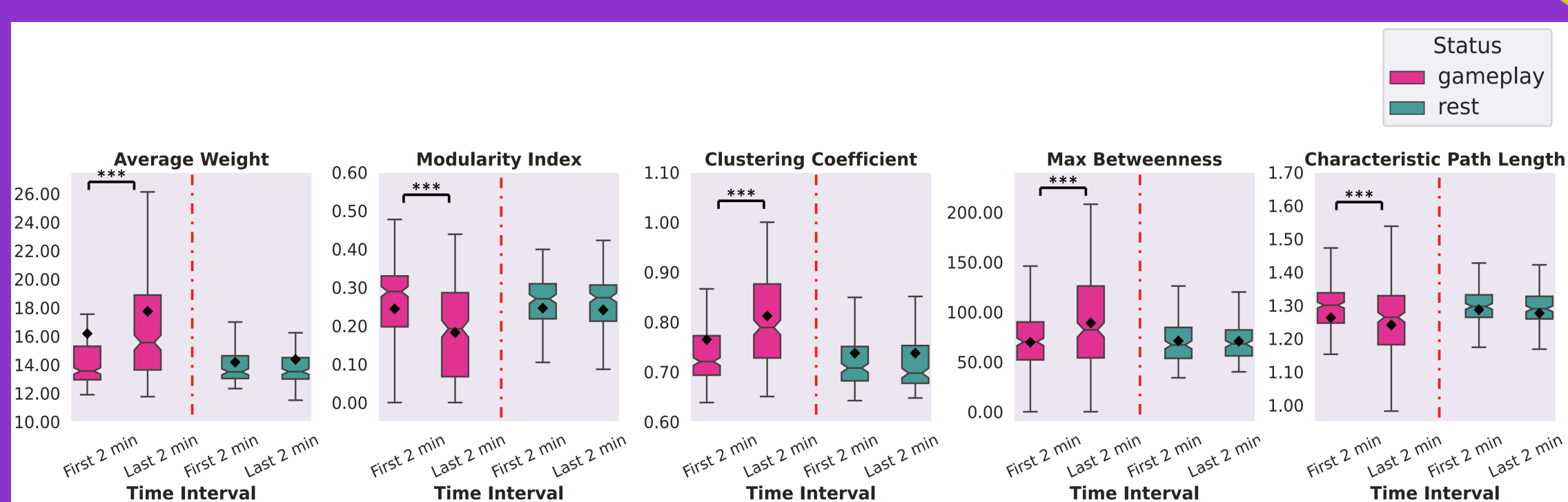


- All three metrics of neural criticality, deviations of criticality coefficient (DCC), branching ratio (BR), and shape collapse (SC) error, are closer to criticality when neural cells are embodied in gameplay².

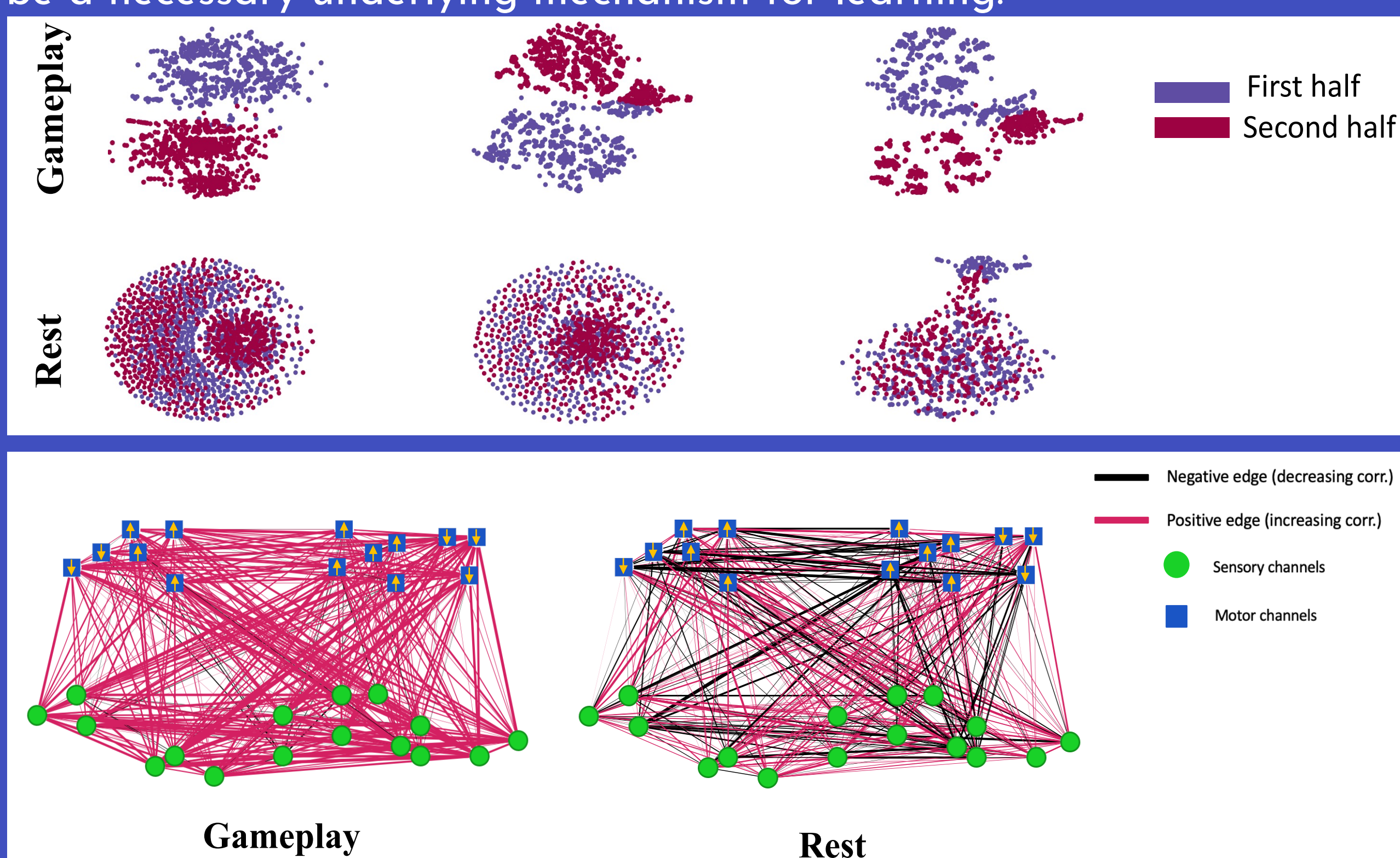
- Difference is significant enough that activity state (Gameplay vs Rest) can be predicted with 92.4% accuracy via only activity metrics.

- Network summary statistics between the first and last 2 minutes of recordings.

- Network metrics show statistically significant differences during Gameplay but not Rest.

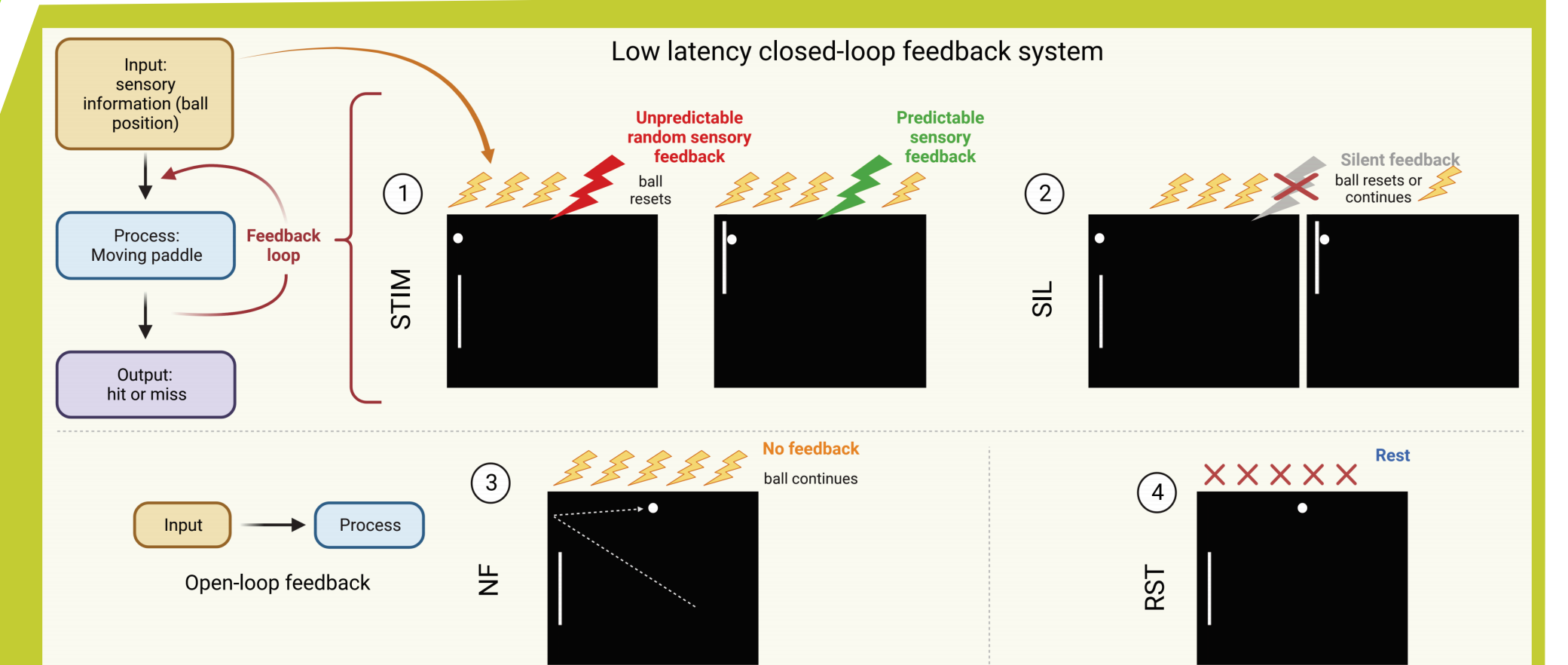


- Significant network plasticity occurs in these cultures that can be a necessary underlying mechanism for learning.



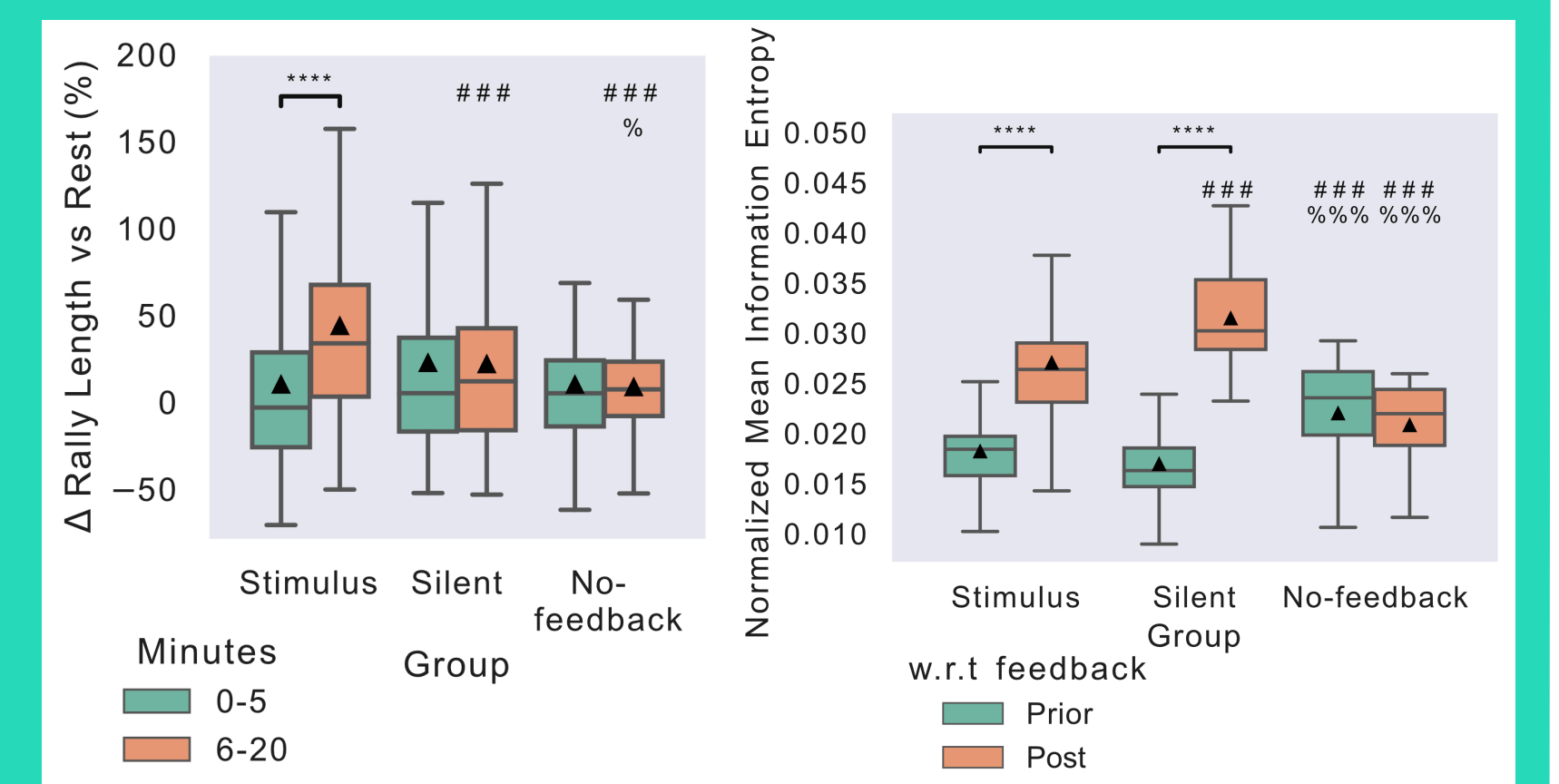
Low-dimensional representation of sample Gameplay and Rest sessions using t-SNE. Colour labels represent the first and second half of the recordings.

Average networks over all Gameplay and Rest sessions. Edge weights represent changes in functional connectivity for the last 2 minutes to the first 2 minutes



- Feedback was either predictable or unpredictable stimulation(1), a removal of all stimulation (2), or no-feedback (3). Rest involves no stimulation (4).

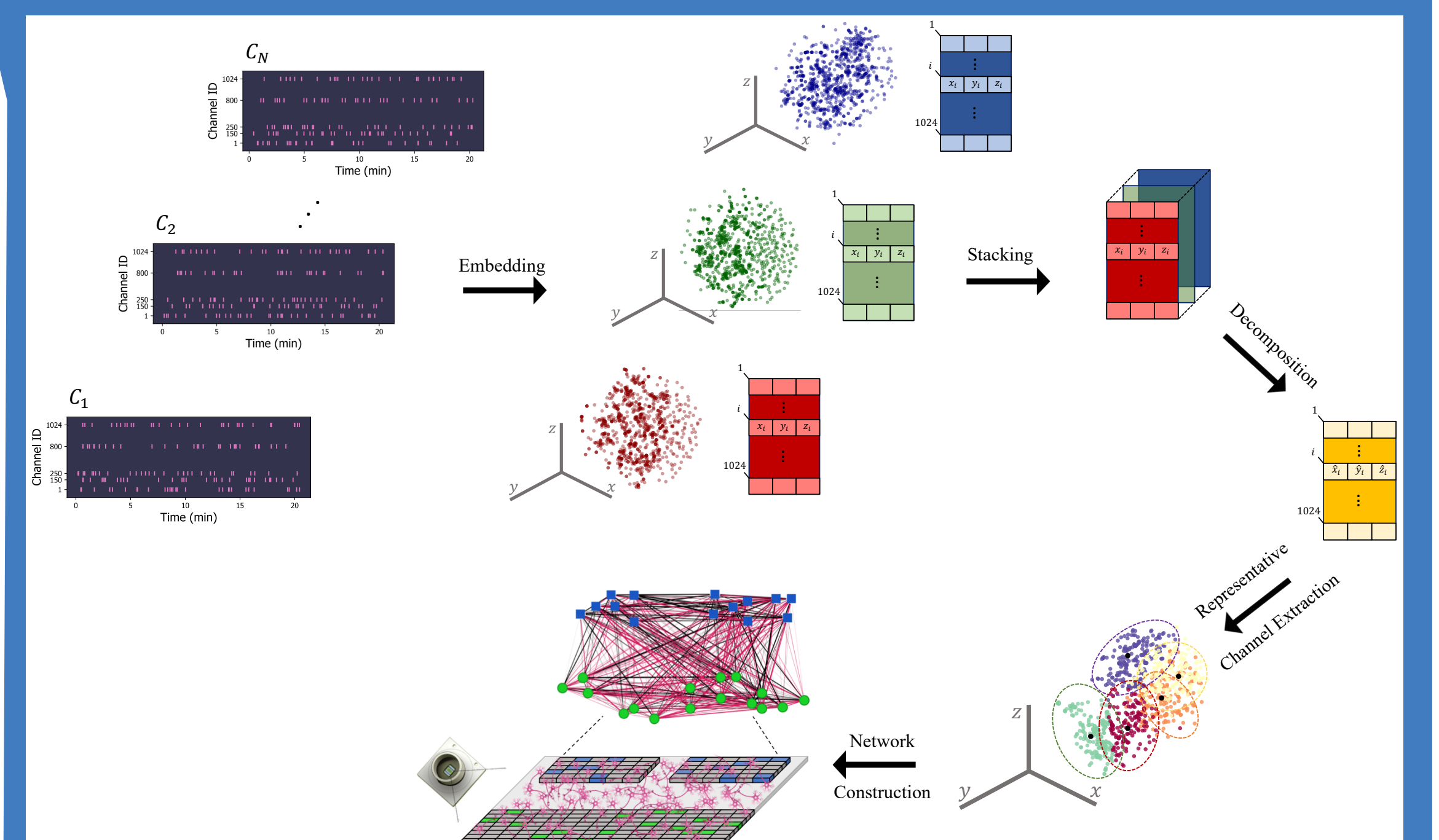
- While all types of feedback increased the information entropy in the system, only high entropy (unpredictable) stimulation resulted in significant learning over time.



Significance bars show within-group differences denoted with *. Symbols show between-group differences at the given timepoint: # = vs Stimulus; % = vs Silent. The number of symbols denotes the p-value cut off, where 1 = p < 0.05, 2 = p < 0.01, 3 = p < 0.001 and 4 = p < 0.0001.

- Complex network dynamics of live in-vitro neuronal systems during Rest and STIM Gameplay was characterised.

- Spiking activity of recorded neurons was embedded in a lower-dimensional space to find a subset of representative channels to explore patterns of macroscopic neuronal network dynamics³.



Spiking time series data is transformed into a 3D space using t-SNE, then combined into a tensor and decomposed with Tucker. The K-medoids algorithm identifies representative channels, forming nodes, with edge weights based on pairwise Pearson correlation values.

References

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