Week 5 answers

1 Video 1

Design an experiment in which you can pharmacologically block a protein involved in LTP and use behavioural assays that would support the role of LTP in learning.

Many experiments would work. For instance, the Morris water maze. But also a T-maze where the animal has to remember the location of food (or perhaps the relationship between the location of food and some other stimulus. You would measure performance on the behavioural task with/without the blocker, and you'd expect worse performance with the blocker.

How would you assess the performance of animals?

This depends on the type of behavioural experiment. For instance, for the Morris water maze, the performance measure is how long the animal spends in the quadrant containing the platform.

Describe the difficulties with interpreting the results of such an experiment, why it is hard to conclude from it that LTP is sufficient for learning.

"Sufficiency" would imply that LTP alone is sufficient for learning. But "sufficiency" is a bit of a strange concept in biology. LTP itself, and learning in general requires alot of other ongoing biological processes, if only to maintain cells. Additionally, biological systems are very complex, when you try to block one protein, that might have effects on lots of other processes (either because the protein is involved in lots of different things, or because the drug itself has off-target effects).

If you had the opportunity to do in electrophysiological recordings, how would you do them to give further support to your previous results (assuming they were positive)?

You'd use a protocol for stimulating long-term potentiation (e.g. STPD: patch two cells, stimulate pre-then-post and high frequency). When unblocked, this should result in a stronger connection. When blocked, nothing happens.

2 Video 2

Discuss the limitations of path integration as a navigational strategy

Small errors in the estimate of velocity build up over time to give increasingly larger errors in position estimate.

3 Video 3

Define pattern completion and separation: what do they do?

To know how to act in any given situation, we need to know what past situations are similar/different. Pattern separation is the separation of superficially similar situations. While pattern completion is noting similarities between superficially different situations.

How would we obtain total pattern completion (all inputs lead to completely overlapping output), and total pattern separation (all inputs lead to completely non-overlapping output). Is it possible or desirable to implement complete separation?

Total pattern completion would map all inputs to the same output, indicating that all situations are exactly the same. Total pattern separation would map each situation to a unique and non-overlapping output, indicating that all situations are completely different. Neither is desirable: we need to carefully discriminate *which* past experiences are similar to the current situation, saying they're all the same vs they're all different is not helpful.

4 Video 4

In the Hopfield network, consider the effect on the energy of setting a single neural activation, x_α, to $+1$ or -1 while freezing all the other neural activations. Thus, show that asynchronous evolution always reduces the energy.

The energy is defined as,

$$E = -\tfrac{1}{2} \sum_{ij} x_i W_{ij} x_j \tag{1}$$

separate this into terms depending on x_α and not depending on x_α,

$$E = -\tfrac{1}{2} \sum_{i \neq \alpha, j \neq \alpha} x_i W_{ij} x_j - \tfrac{1}{2} \sum_{j \neq \alpha} x_\alpha W_{\alpha j} x_j - \tfrac{1}{2} \sum_{i \neq \alpha} x_i W_{i\alpha} x_\alpha + \tfrac{1}{2} x_\alpha W_{\alpha\alpha} x_\alpha \tag{2}$$

The final positive term emerges because we have double counted $x_\alpha W_{\alpha\alpha} x_\alpha$ it in middle two terms. As we are only changing x_α, the first term is constant,

$$E = \text{const} - \tfrac{1}{2} \sum_{j \neq \alpha} x_\alpha W_{\alpha j} x_j - \tfrac{1}{2} \sum_{i \neq \alpha} x_i W_{i\alpha} x_\alpha + \tfrac{1}{2} x_\alpha W_{\alpha\alpha} x_\alpha \tag{3}$$

And as W_{ij} is symmetric, and index-labels in the sum are arbitrary,

$$E = \text{const} - x_\alpha \sum_{j \neq \alpha} W_{\alpha j} x_j + \tfrac{1}{2} x_\alpha W_{\alpha\alpha} x_\alpha \tag{4}$$

And as $x_\alpha = \pm 1$, the final term always takes the same value (because $x_\alpha^2 = 1$),

$$E = \text{const} - x_\alpha \sum_{j \neq \alpha} W_{\alpha j} x_j \tag{5}$$

How do we minimize this energy? If $0 < \sum_{j \neq \alpha} W_{\alpha j} x_j$, then we should set $x_\alpha = 1$ (so that we overall subtract off this term), and if $0 < \sum_{j \neq \alpha} W_{\alpha j} x_j$, we should set $x_\alpha = -1$. Formally,

$$x_\alpha = \begin{cases} 1 & \text{if } 0 < \sum_{j \neq \alpha} W_{\alpha j} x_j \\ -1 & \text{otherwise} \end{cases} \tag{6}$$