

Introduction

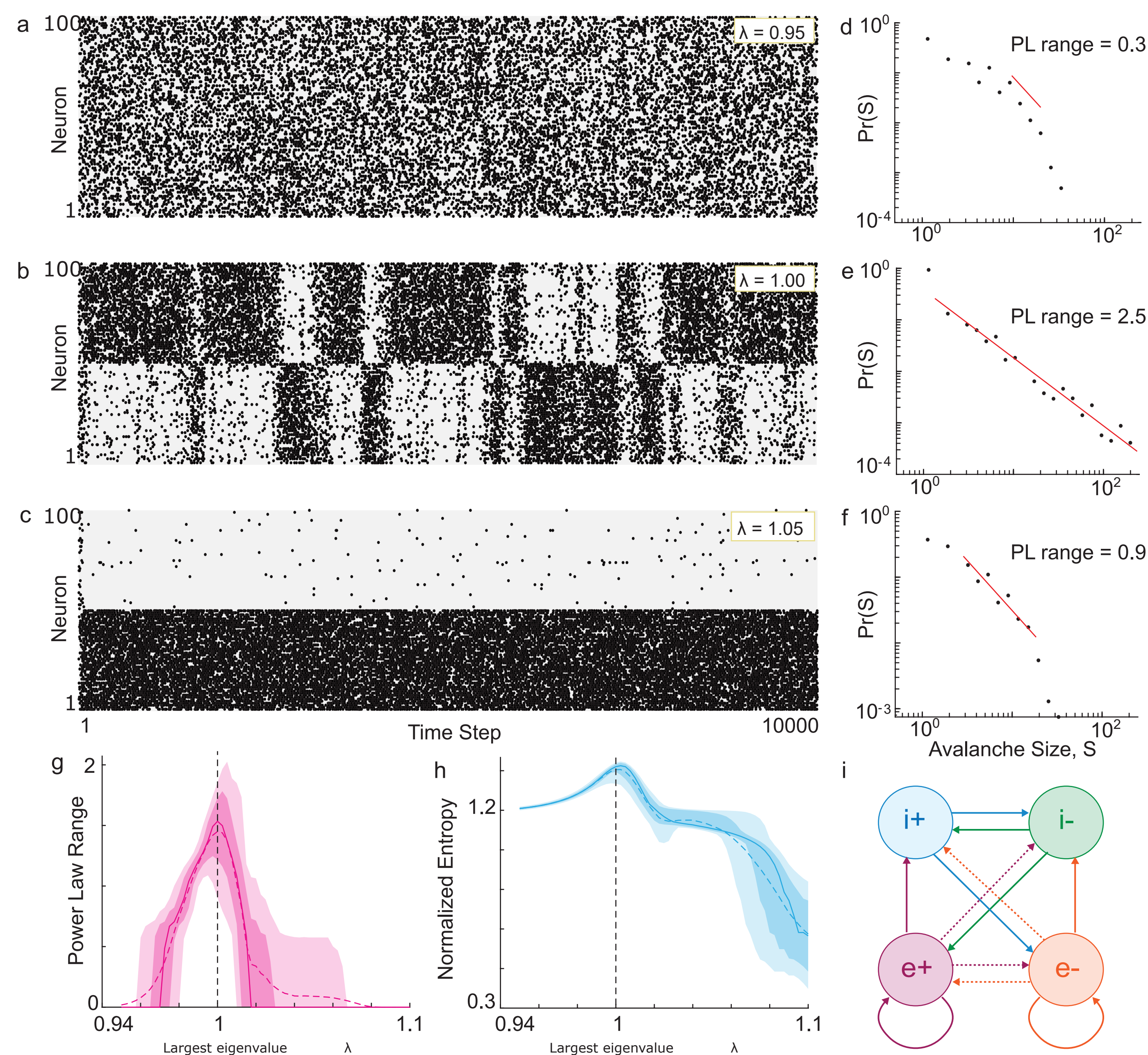
Working memory is thought to require neural activity that persists during the period the information is held in mind. However, if activity persists indefinitely, this would hinder flexible switching between different functions. It seems a balance between persistence and switching is needed.

Does being near a critical point optimize persistent neural activity?
Does being near a critical point optimize the switching of what is held in memory?
Does the medial prefrontal cortex (mPFC) operate near a critical point?

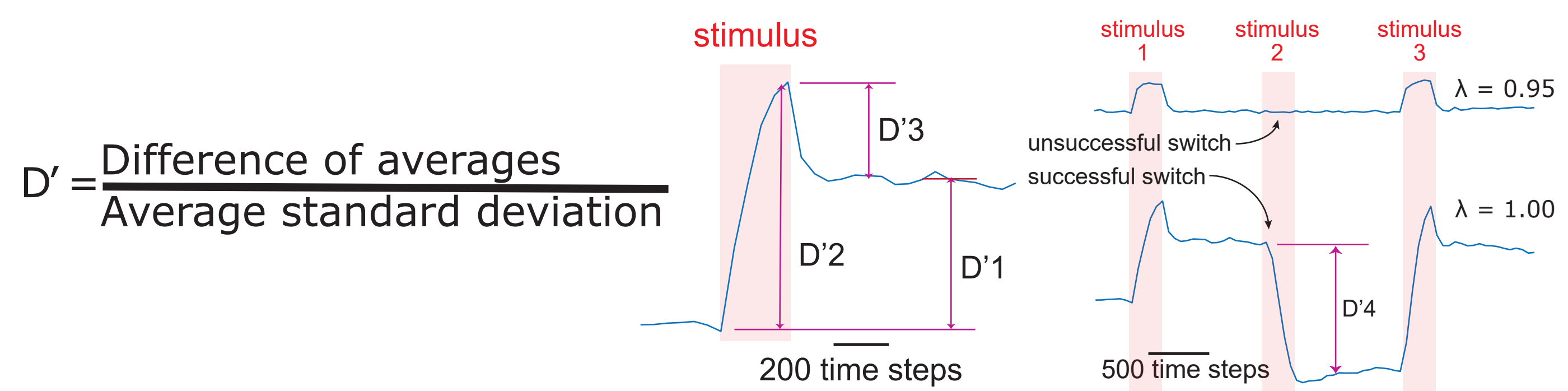
Winnerless Competition Model

A new form of criticality was discovered in the visual cortex which is a balance between a noncompetitive phase and a winner-take-all phase¹.

This form of criticality relies on the existence of crossing inhibition in the neural network which is a feature of models that have been used to study working memory for years



Persistence and Flexibility Measurements

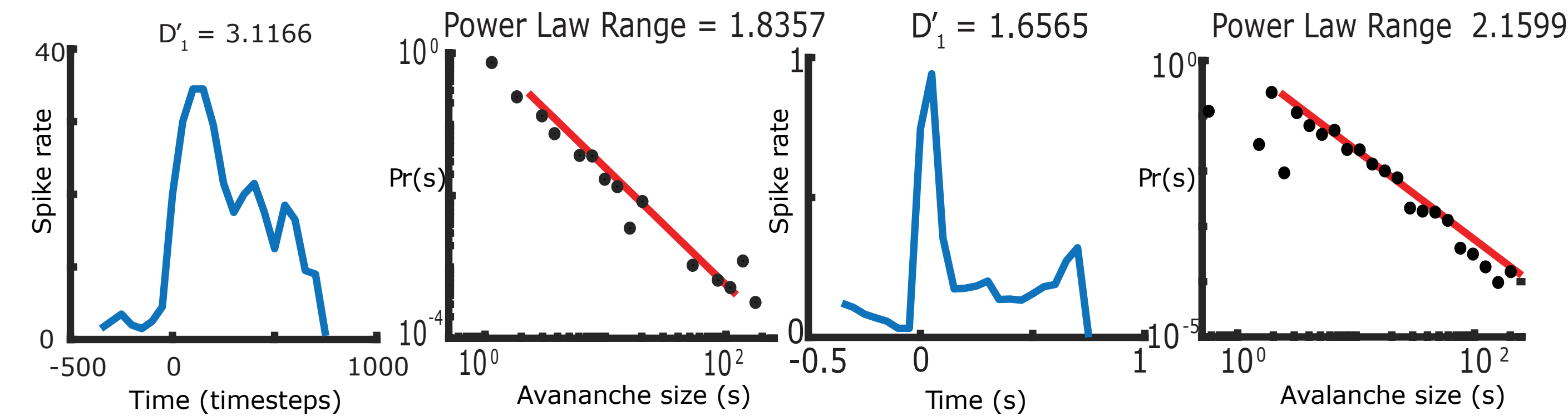


D' is the measure used to analyze how the network responds to a stimulus.

The figure on the left shows how $D'1$ - $D'3$ were measured using a PSTH of the network activity with $D'1$ being the primary measure of persistence

The figure on the right shows how $D'4$ was measured which is the primary measure of how flexible the network is to switching what is being held in memory

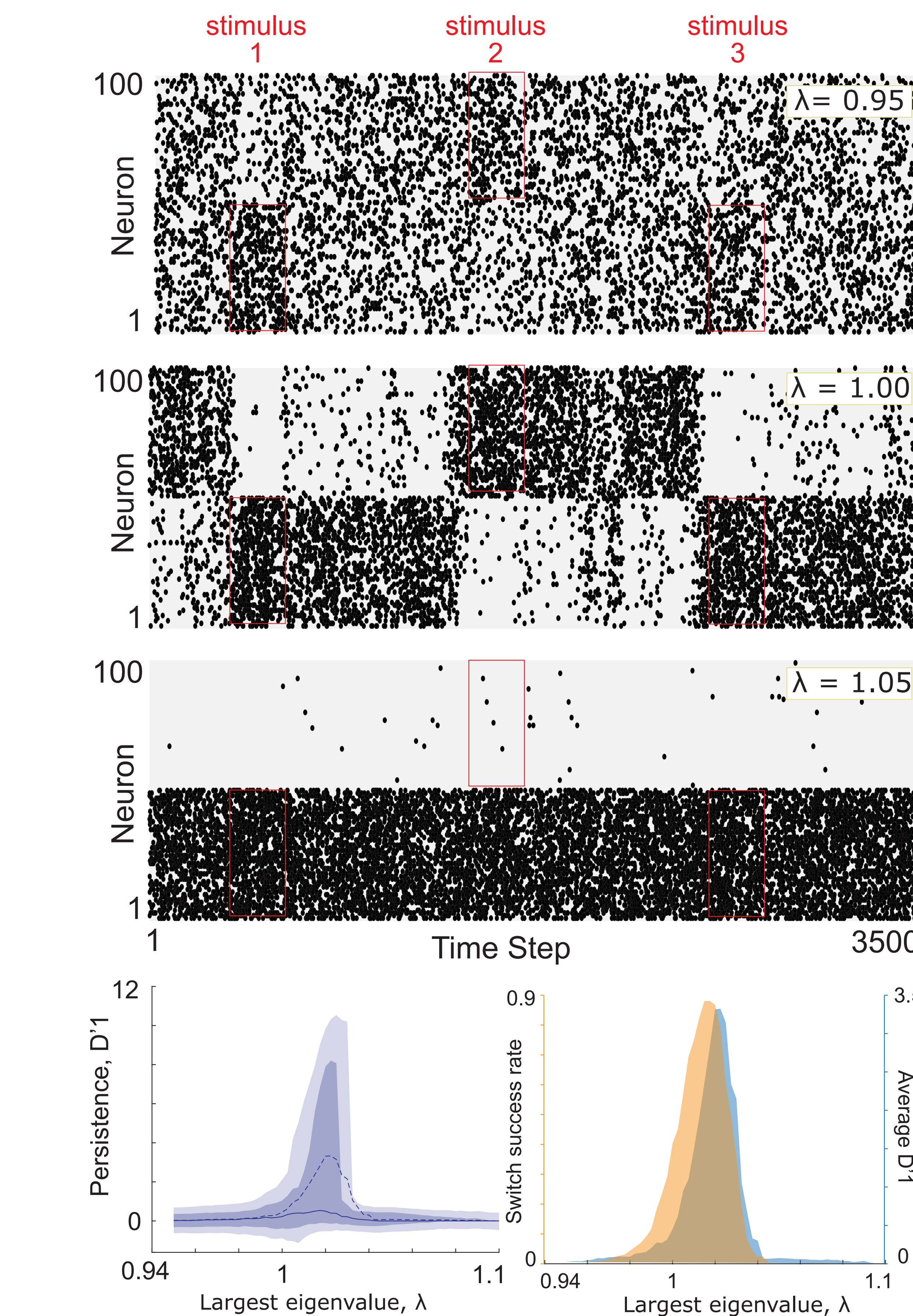
Criticality Measurements



The figure on the left shows the avalanche distribution and PSTH of a single neuron from the model and the figure on the right is a single neuron from the experimental data

These figures show that single neurons that show good persistence can also show power law trends in the avalanche distributions

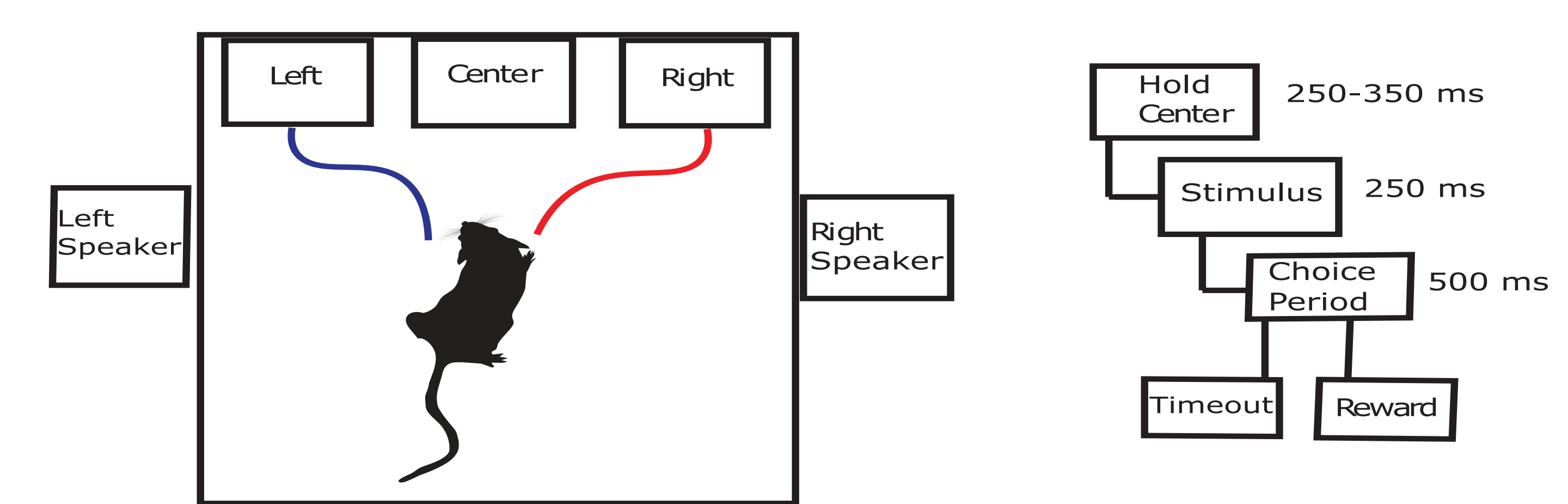
Model Results



The figure on the left shows that when operating slightly above the critical point the neural network can maximize persistence.

The figure on the right shows that flexibility is also optimized by operating near the critical point.

Experimental Setup

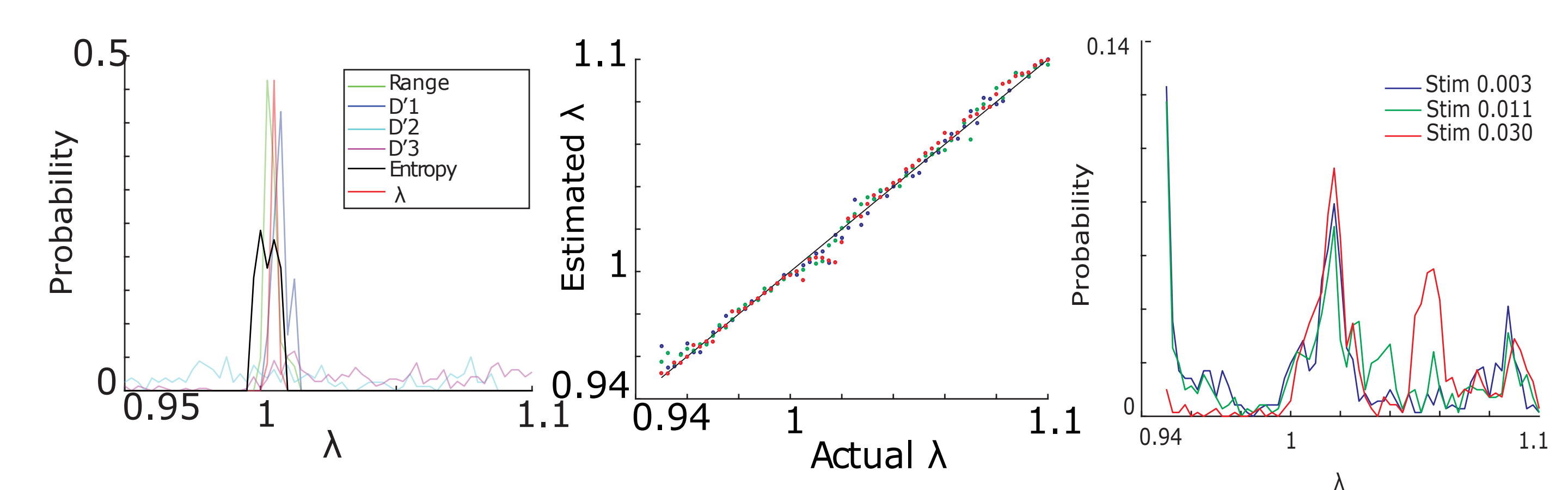


On the left is a diagram of the setup of the working memory experiment performed by Rodgers et al²

On the right is the timeline for each trial of the working memory experiment

Multiple different stimuli were presented to the rat and based on the stimulus the rat had to make a specific choice

Maximum Likelihood Estimate of Largest Eigenvalue



For a given observation of $D'1$, $D'2$, $D'3$, entropy, and power law range, what does the model predict for the largest eigenvalue. The figure to the left shows the method of estimating the most likely largest eigenvalue.

The figure in the middle shows the estimated eigenvalues vs the actual eigenvalues for the neurons for the model showing that the method is accurate.

The figure on the right shows the probability distributions for the estimated λ values from the experimental neurons in the mPFC.

Conclusions

With winnerless competition criticality it is possible to get power law trends in the avalanche distributions of single neurons.

By operating slightly above the critical point neural networks can maximize persistence.

By operating slightly above the critical point neural networks can optimize the ability to switch what information is being held in memory.

With winnerless competition criticality neural networks are able to optimize both persistent activity and flexibility at the same time by operating near the critical point.

The medial prefrontal cortex has a subset of neurons that behave as our model predicts near criticality, potentially balancing persistence and flexibility.

References

[1] Jones, S. A., Barfield, J. H., & Shew, W. L. (n.d.). Scale-free behavioral dynamics directly linked with scale-free cortical dynamics. <https://doi.org/10.1101/2021.05.12.443799>

[2] Rodgers, C. C., & DeWeese, M. R. (2014). Neural correlates of task switching in prefrontal cortex and primary auditory cortex in a novel stimulus selection task for rodents. *Neuron*, 82(5), 1157-1170. <https://doi.org/10.1016/j.neuron.2014.04.031>