

# Synaptic Plasticity and Spatial Patterning in the Next-Generation Neural Field Model

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### Abstract:

Synaptic plasticity, the mechanism underlying learning and memory, enables neural networks to dynamically rewire in response to activity, optimising their structure for efficient information processing. This adaptivity reshapes synaptic landscapes, influencing the emergence and organisation of spatial patterns in neural activity.

Neural field models are powerful tools for understanding how spatially organised patterns, such as bumps and waves of activity, develop and evolve in brain networks. However, traditional models often assume a high degree of neural synchrony, limiting their ability to capture changes in population-level synchrony. In our previous work, we incorporated adaptive coupling into a network of theta-neurons and derived a mean-field approximation for the system [1]. Inspired by the next-generation neural field model of Byrne, Avitabile, and Coombes (2019) [2], this study extends our model to include spatial dynamics, allowing us to explore biophysically realistic plasticity in a spatial framework.

We demonstrate that incorporating spatial interactions and adaptive plasticity leads to a rich repertoire of spatiotemporal dynamics, including Turing and Turing-Hopf bifurcations (Figure 1). Numerical simulations reveal the emergence of complex patterns such as localised bumps and travelling waves, which may encode information relevant to cognitive functions like working memory and attention.

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We investigate how adaptive connectivity governs the formation and stability of these patterns. This work advances our understanding of the interplay between plasticity, connectivity, and pattern formation, providing a more comprehensive framework for modelling neural selforganisation and its role in cognitive function.

## References:

[1] Fennelly, Niamh & Neff, Alannah & Lambiotte, Renaud & Keane, Andrew & Byrne, Áine. (2024). Mean-field approximation for networks with synchrony-driven adaptive coupling. 10.48550/arXiv.2407.21393.

[2] Byrne, Aine & Avitabile, Daniele & Coombes, Stephen. (2019). Next-generation neural field model: The evolution of synchrony within patterns and waves. Physical Review E. 99. 10.1103/PhysRevE.99.012313.

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