Secondary Bifurcations in a Next Generation Neural Field Model

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Epilepsy is a dynamic complex disease involving a paroxysmal change in the activity of millions of neurons, often resulting in seizures. Tonic-clonic seizures are a particularly important class of these and have previously been theorised to arise in systems with an instability from one temporal rhythm to another via a quasi-periodic transition. We show that a recently introduced class of next generation neural field models has a sufficiently rich bifurcation structure to support such behaviour. A linear stability analysis of the space-clamped model is used to uncover the conditions for a Hopf-Hopf bifurcation whereby two incommensurate frequencies can be excited. Since the neural field model is derived from a biophysically meaningful spiking tissue model we are able to highlight the neurobiological mechanisms that can underpin tonic-clonic seizures as they relate to levels of excitability, electrical and chemical synaptic coupling, and the speed of action potential propagation. We further show how spatio-temporal patterns of activity can evolve in the fully nonlinear regime using direct numerical simulations far from a Turing bifurcation.