Differences in spatial dynamics: effects of adaptation versus h-currents in a Wilson-Cowan field

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Abstract:
During non-REM sleep, the brain shows repetitive patterns of slow oscillations (SOs, <1 Hz) between periods of active and silent neuronal activity. These activity patterns are assumed to play a crucial role in memory consolidation. Intracranial recordings during sleep measure the activity on a high spatial and temporal resolution and allow identifications of propagation direction and velocity of traveling waves of SOs. The formation of these rhythms has been an ongoing subject of investigation for in-silico studies that utilize neural mass and field models to identify candidate mechanisms in support of empirical research. A working hypothesis is that SOs are driven by an adaptive process, whereas hyperpolarizing spike-frequency adaptation as well as hyperpolarization-activated currents have been discussed as potential mechanisms. We aim to deepen the knowledge about both candidate mechanisms and quantify how they affect the dynamical landscape of an adaptive Wilson-Cowan neural field model where we equip the excitatory population with either one of the two feedback currents. We show that the adaptive Wilson-Cowan neural field model is suitable to simulate traveling waves of SOs on the macroscale, and for local regions of the cortex. It allows semi-analytically solving for components that dominate spatial features, such as the minimum wavenumber that occurs in Turing-unstable states in which spatiotemporal patterns can emerge. In a state space exploration, we find regimes of Hopf and Turing instability. The temporal dynamics of emerging traveling waves are qualitatively and quantitatively similarly affected by both mechanisms. Temporally oscillatory activity patterns increase in dominant temporal frequency when the feedback strength for either mechanism is increased while slowing down the time scales of the mechanisms decreases the dominant temporal frequency.
On the other hand, the spatial dynamics are not similarly affected. For specific regimes in which Turing instability occurs, we show that differences in spatial dynamics are more pronounced. We see the difference in effect explicitly in Turing-unstable states that don't occur

without a spatial domain. Among other differences, h-currents generally promote destabilization of high-activity homogeneous steady states through an emerging Turing bifurcation while adaptation facilitates Turing instability in low-activity states.

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