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Control of oscillation periods and phase durations in half-center central pattern generators: a comparative mechanistic analysis.

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Summary: Central pattern generators (CPGs) consisting of interacting groups of neurons drive a variety of repetitive, rhythmic behaviors in invertebrates and vertebrates, such as arise in locomotion, respiration, mastication, scratching, and so on. These CPGs are able to generate rhythmic activity in the absence of afferent feedback or rhythmic inputs. However, functionally relevant CPGs must adaptively respond to changing demands, manifested as changes in oscillation period or in relative phase durations in response to variations in non-patterned inputs or drives. Although many half-center CPG models, composed of symmetric units linked by reciprocal inhibition yet varying in their intrinsic cellular properties, have been proposed, the precise oscillatory mechanisms operating in most biological CPGs remain unknown. Using numerical simulations and phase-plane analysis, we comparatively investigated how the intrinsic cellular features incorporated in different CPG models, such as subthreshold activation based on a slowly inactivating persistent sodium current, adaptation based on slowly activating calcium-dependent potassium current, or post-inhibitory rebound excitation, can contribute to the control of oscillation period and phase durations in response to changes in excitatory external drive to one or both half-centers. Our analysis shows that both the sensitivity of oscillation period to alterations of excitatory drive and the degree to which the duration of each phase can be separately controlled depend strongly on the intrinsic cellular mechanisms involved in rhythm generation and phase transitions. In particular, the CPG formed from units incorporating a slowly inactivating persistent sodium current shows the greatest range of oscillation periods and the greatest degree of independence in phase duration control by asymmetric inputs. These results are explained based on geometric analysis of the phase plane structures corresponding to the dynamics for each CPG type, which in particular helps pinpoint the roles of escape and release from synaptic inhibition in the effects we find.

Keywords: central pattern generators; half-center oscillations; persistent sodium current; postinhibitory rebound; adaptation; geometric singular perturbation analysis

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