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Lateral connections synchronize population activity in a spiking neural network model of midbrain superior colliculus

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Saccades are rapid and ballistic eye-head gaze shifts between points of interest in the visual field. They are crucial for gathering high-resolution visual information. The midbrain superior colliculus (SC) generates saccadic eye-movement commands for downstream oculomotor circuits. It contains an eye-centered, gaze-motor map that relates the location of a Gaussian-shaped neural population to the intended movement vector. The gaze-motor map mediates the spatiotemporal transformation for eye-head orienting gaze shifts to peripheral targets [1]. Electrophysiological recordings have shown that SC neurons exhibit some remarkable activity properties that depend on both their anatomical position and the resulting saccade trajectory [2].

Here, we propose a biologically plausible spiking neural network model that is constrained by the observed firing patterns of real SC neurons for visually evoked saccades. The functional two-dimensional network model reproduces the spike trains of single neurons in recorded SC populations for saccades with different amplitudes and directions.

The network model consists of a 2D grid of neurons, representing the gaze-motor map. The adaptive integrate-and-fire neurons [3] portray the observed site-dependent bursting profiles of individual SC neurons through distinct intrinsic biophysical properties, whereas Mexican-hat shaped lateral connections ensure the observed synchronized population activity by a soft winner-takes-all mechanism.

We argue that our model offers a basis for neuronal algorithms of spatiotemporal transformations and bio-inspired optimal control signal generators.

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