A Spiking Neural Circuit Model of Spatial Orientation Working Memory in Fruit Flies

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To navigate in a complex environment, an animal needs to keep track of its orientation. Recent studies reported that a bump of activity in the Drosophila ellipsoid body (EB) represented head-direction. However, how the activity bump maintains stability while constantly updates its representation is not completed understood. To address this issue, we constructed a biologically realistic neural circuit model based on the connectomic data. The circuit model is characterized by a symmetrical ring and an asymmetrical ring, which maintains and updates the memory, respectively. In addition, we carried out behavioral experiments based on a modified Buridan's paradigm. In the experiments, we examined how specific neurons influence orientation working memory by silencing or optogenetically activating the inhibitory ring neurons. This study confirmed the prediction of our neural circuit model on the involvement of the two rings and their distinct roles in spatial orientation memory. Furthermore, we investigated the candidate mechanisms underlying the flexible sensory-motor mapping in the circuits when the target location changed or when multiple targets were presented.

Keywords: head-direction, central complex, ring attractor, orientation memory, spiking neural model

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