ABSTRACT

The hippocampus is a brain structure essentially involved in episodic memory, spatial navigation and other complex cognitive functions. The distinct network architecture of hippocampal CA3 allows to combine converging sensory inputs in creation of complex neural representations. The hippocampus further interacts with the entorhinal cortex to organize knowledge into relational representations, also known as ‘cognitive maps’.

In rodents, the hippocampal pyramidal neurons behave as place cells, where a neuron is active whenever the subject occupies specific location in the environment. The collective activity of the place cells represents a neural map that is reinstated during repeated exploration of the same space. The place cell maps are thus recognized as neural substrate of spatial memory.

In this work, we aimed at better understanding of hippocampal CA3 network dynamics during period of reinstatement of the appropriate place cell representation. We thus analysed CA3 place cell activity recorded during ‘teleportation’ experiment, where the rats are exposed to abrupt changes in spatial context identity. As shown previously, the network state transitions involve short competitive period, where network state quickly switches between the representations of the previous and the present environment.

We show that the network state transitions are accompanied by marked increase in total place cell activity. The network hyperexcitability displayed a peak shortly after the cue switch and averaged activity levels returned to baseline within several seconds. Further analysis revealed increased place activity during network states with decoded map for the new environment.

Next, we evaluated quality of place cell spatial code shortly after the change of environment identity. We detected increase in decoded position error associated with representation of the present context. Notably, place cell ensembles coding for the previous context continued to provide robust positional information, as the respective decoded position error values were comparable to the control conditions.

Furthermore, we detected a considerable mixing of the alternative place cell maps during the network state transition period. The coactivity of concurrent representations occurred during individual theta cycles as well as within short time intervals (<10 ms). The coactivation at such short timescale is relevant for organization of activity into functional cell assemblies and might facilitate synaptic plasticity. This might induce associations between originally segregated network states.

Additionally, we assessed hippocampal network oscillatory activity associated with spatial map recollection. We observed increase in theta and gamma rhythmicity following switch of context identity. We suggest that strong theta oscillations mediate effective network inhibition, allowing the relevant input to promptly update the network state. The enhanced gamma oscillations might support formation of cell assemblies and coordinate flow of information within the hippocampal formation.