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Large-scale network modelling of interactions between prefrontal cortex and dorsal raphe nucleus using SpiNNaker

Alok Joshi¹, Oliver Rhodes¹, Andrew Rowley¹, Alan Barry Stokes¹, Michael Hopkins¹, Trevor Sharp², Wong-Lin KongFatt³ and Steve Furber¹

¹ **School of Computer Science, University of Manchester, Manchester, United Kingdom**

² **Department of Pharmacology, University of Oxford, Oxford, United Kingdom**

³ **Intelligent Systems Research Centre, University of Ulster, Derry-Londonderry, United Kingdom**

The prefrontal cortex (PFC) has been shown to play a key role in high-level cognitive functions such as attention, memory, decision-making, and mood regulation. Afferents from the dorsal raphe nucleus (DRN) and the existence of serotonin (5-HT) receptors (e.g. 5-HT1A, 5-HT2A and 5-HT3A) in the PFC suggest that serotonin signalling is important for the modulation of these functions. Reciprocally, PFC neurons are also connected to neurons in the DRN. The emergent dynamics and interactions within the PFC-DRN circuitry are as yet unclear. Additionally, the PFC also modulates the thalamus area which in turn is connected to the DRN. A further level of complexity arises due to the existence of glutamatergic and various interneuron populations and their complex interactions. This complexity is present right across the PFC micro-columnar organization. Thus, it becomes exceedingly difficult to understand how serotonin modulates the neuronal activity of the PFC. Realistic neurocomputational models may help to illuminate the functions of such large-scale and complex neural circuits. However, they are computationally intensive to simulate. In this study, real-time simulation of coupled large-scale populations of point-based neurons of the PFC, thalamus and DRN is performed on SpiNNaker (Spiking Neural Network architecture), a brain-inspired highly parallel hardware platform. The major aims of our study are to use the high-performance SpiNNaker platform to: (i) explore connections among the microcolumns and between the PFC and DRN, assuming microcolumns are connected in a chain and (ii) assess the effects of different 5-HT receptors on PFC neuronal activities. This work will lay the foundation for an understanding of the complex dorsal raphe- cortical network, and also provide the basis for future work to investigate dysfunction associated with these brain areas and their links to neuropsychiatric disorders.