Report on the cortical microcircuits

Introduction

Cortical microcircuits are small repeating units of neuronal networks in the brain. They have intricate recurrent structures that are similar throughout the different brain areas(Costa et al,2018). They can be optimized to solve complex contextual problems and computational tasks.

Types of neurons

1.Excitatory Neurons:

It comprises almost 80% of the brain's space. It lets the positive ions in and increase the likelihood that target proton will fire an action potential

2.Inhibitory Neurons

It comprises 20% of the brain's space. It lets the negative ions in and decreases the likelihood that the target proton will fire an action potential.

Connectivity Patterns

1. Laminar Structure

Cortical circuits in the brain have laminar structure consisting of six major layers each having its different roles and operations.(Costa et al,2018)

1. High Recurrence

Another remarkable fact is the high degree of recurrence even at the local level which creates a complicated network of neurons within the circuits.

They have a very detailed and tight balance of excitation and inhibition.

1. Balance of Excitatory and Inhibitory signals.

In biological networks, the gates, i.e. inhibitory neurons, act (to a first approximation) subtractively — excitatory and inhibitory (EI) currents cancel each other linearly at the level of the postsynaptic membrane potential (Costa et al,2018)

1. Subtractive neural integration

When a presynaptic cell fires, the neurotransmitter is released by its synaptic terminals. The neurotransmitter is subsequently bound by postsynaptic receptors where it prompts a structural change of an ion channel to allow the flow of electrically charged ions into or out of the postsynaptic cell. Depending on the receptor type, the ion flux will either increase (depolarise) or decrease (hyperpolarize) the postsynaptic membrane potential. If sufficiently depolarising “excitatory” input is provided, the postsynaptic potential will reach a threshold and fire a stereotyped action potential.This can be modelled as RC circuit.

Computational Function

This intricate network of cortical circuits biological implementation of LSTM is run to better understand the cortical architecture and dynamics. So cortical networks are modelled as Sub-LSTMs which are inspired by the LSTM framework with slight modifications.

LSTMs are basically gated Recurrent Neural Networks that are crafted to successfully perform the tasks like language modelling,speech recognition etc. The ongoing presentation of stimuli makes it difficult to learn to separate meaningful data from background noise. LSTMs closely resemble cortical networks with the only difference In LSTMs gates control the memory cell as a multiplicative factor but in biological networks, the gates, i.e. inhibitory neurons, act subtractively.

Further such subtractive inhibitory mechanisms must be well balanced to act as a gate to the input in the closed state. The central element in the LSTMs and similar RNNs is the memory cell. The biological resemblance are the pyramidal cells in layer 5. There is a relatively high level of recurrence and non-random connectivity between pyramidal cells in layer5(Costa et al,2018). Sensory areas exhibit shorter than higher brain areas particularly prefrontal cortexThe gates that protect a given memory in LSTMs can be mapped onto lateral inhibitory inputs in cortical circuits.Similar to LSTMs, the input gate is implemented by inhibitory neurons in layer-2/3 . Such lateral inhibition is consistent with the canonical view of microcircuits.