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Abstract

In our daily lives, every individual is inevitably faced with the need to memorize new things. Whether it is at school or university, where entire courses need to be memorized, or even when we have to remember a shopping list to do our groceries. It is easy to think that to maximize our performance when memorizing, it is necessary to work as hard as possible. However, experimental studies have contradicted this thinking and shown that punctuating learning phases with phases of rest helps to strengthen memory. This transition between learning and resting phases is directed by our brain, which moves from a state of active waking to one of quiet waking. This is reflected in changes in neuronal firing patterns. During learning (active waking state), neurons display tonic activity, whereas in the quiet waking state, they display burst activity. The role of these state switches on learning and memory consolidation is now considered to be well established, but the mechanisms underlying this phenomenon are still not well understood. Various approaches can be adopted to better understand them, including a computational approach.

It has been demonstrated that the brain stores memories in the neuronal connections, which are constantly modified through synaptic plasticity. Several models exist in the literature to model synaptic plasticity, and have proved effective when used in the active waking state. However, these models are not adapted to the changes in neuronal firing patterns that take place during state changes, and applied as they are, they do not prove the link between memory consolidation and quiet waking states. Indeed, they lead to a "homeostatic reset", which refers to the fact that no matter whether neurons have learned more or less information during active waking states, they follow the same evolution during quiet waking states. This means that all the information learned is forgotten when the quiet waking state is reached.

The aim of this thesis is to propose a structural plasticity model which, combined with traditional synaptic plasticity models, will be able to solve this homeostatic reset problem which is not consistent with memory consolidation. The structural plasticity model will then be used to transfer learning through lasting morphological changes in synapses. To achieve this goal, structural plasticity is first investigated from a biological point of view to understand the main mechanisms underlying it. Next, the various models of structural plasticity that exist in the literature are reviewed. A new structural plasticity rule is then proposed and tested in different experiments. In addition, an analysis of the model parameters is provided. The results were convincing, and the rule was able to take advantage of homeostatic reset to consolidate memory. The effectiveness of the model is then tested in a simple task. The results showed that combining the structural plasticity rule with a traditional plasticity rule in the presence of switches from tonic to burst activity improved the signal-to-noise ratio (SNR) across several tonic/burst cycles. Finally, the effectiveness of our model is illustrated in a simple pattern recognition learning task and the results showed that neurons learned better in the presence of structural plasticity. To conclude, future prospects aiming to further explore the rule of structural plasticity developed in this thesis are proposed.