Brain model pins down motor decisions

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Talking or reading. Texting a message or listening. The dilemma of choosing between various tasks is not an invention of the modern information age. Humans and all vertebrates have to prioritise their actions. But to understand the neurobiology of how these decisions are made is a challenging scientific problem. Now, the EU-funded projectSelect-and-Act, completed in 2012, has provided further insight into such problem.

"We wanted to understand the mechanisms by which the decisions are made and a given type of movement is released", says project coordinator Sten Grillner, director of the Nobel Institute for Neurophysiology at the Karolinska Institute in Stockholm, Sweden. The project developed a computational model of a part of the brain responsible for motor decision-making. This was guided by brain experiments during animal behaviour. The model was capable of reproducing realistic tasks. And it may have application further afield, namely in robotics and medicine.

The striatum is part of the basal ganglia, a group of ancient structures located deep in the brain. It receives a wide range of sensory, motor, cognitive, affective and motivational input. To better understand how this part of the brain filters information and selects an appropriate action "we addressed the problem from different perspectives," Grillner tells youris.com. Experiments dealt with single neurons in local microcircuits of various animals as they performed movements. This included lampreys, rats and monkeys.

They found some interesting results. "The output neurons of the basal ganglia keep their target motor centres under inhibition at rest. They release the movements by removing this inhibition," explains Grillner, "Thus, when you decide to do something you remove that inhibition from the group of nerve cells that control the specific behaviour of interest." But, he adds: "it is rather difficult to intuitively understand these complex networks, where many different components change from millisecond to millisecond".

The scientists therefore also applied computational modelling approaches. Specifically, the project developed detailed models of the cortex and basal ganglia and their connectivity as well as an abstract model of these structures. "We modelled a number of actions, for example, left-right movements and positive and negative rewards", says

Anders Lansner, sub-project leader and professor at the department of Computational Biology at the Royal Institute of Technology in Stockholm, Sweden. "We also measured how fast the machine learned," he tells youris.com. According to Lansner, this model could even quantitatively replicate published data on simple monkey movements. "We now have an abstraction of a biological system that performs realistic tasks," he adds.

Interestingly, the model may have uses in robotics. "Robots have the same problem as a living creature. They must be able to deal with information and to do the appropriate thing," Grillner tells youris.com. Indeed, "we want to use the abstract model for robotics," Lansner says. The scientists are also preparing proposals dealing with disease models. However, to be able to describe a disease using computational modelling "you have to go down to more details of synaptic models," he adds. "The long term goal is to build an artificial brain," he says, "but this is not yet on the level of the human brain in any sense."

One expert appreciates the project's approach. "These are important steps", comments Christian Beste, professor of cognitive neurophysiology at the Technical University Dresden, in Germany. He considers computational modelling as applied in the project as a "useful tool" to study diseases associated with the basal ganglia. These include Parkinson's disease or attention deficit hyperactive disorder. For example, researchers can try to reproduce the physiological patterns of different diseases and identify the underlying mechanisms.

Another expert appreciates the challenge of the project. "This is a very ambitious project", comments neurobiologist Peter Redgrave, who recently retired from his post as professor for systems neuroscience at the University of Sheffield, UK. He particularly welcomes that the project's approach to include analyses of what is going on in the brain at different levels of description. For example, including individual neurons, microcircuits and behaving animals. "It allows us to understand how processes at lower levels manifest themselves in the levels above," Redgrave tells youris.com.

Redgrave welcomes the use of so-called biologically constrained models by the project consortium. "Computational modelling is the only way of testing whether the biological circuitry that is too complicated to understand by thinking does what it is supposed to do", he says. In his view, contemporary neuroscience has difficulty in generating hypotheses that identify the processes that must be performed to achieve a particular outcome. "Models are hypothesis generators", he says. "If there is a known circuit but its function is unknown, you can manipulate the system purposefully and compare the results to biology", he adds. "Moreover, modelling the decision processes in the brain has applications for artificial intelligence and the behavioural control of multifunctional artificial agents," Redgrave concludes.

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