Parkinson's – a mathematical description

In search for answers to how the brains of Parkinson patients function there are not many tools available. One of them proves to be mathematics. Another is rodent experiments, which play an important and necessary role in the process of finding new treatments for the disease. Research indicate that, in rodents, it is possible to distinguish between different states of health and disease by using mathematical analysis. This can be done by analysing the brain signals of the animal, and this without knowing what state the animal is in at that time. It seems possible to use mathematics to describe different states of health and disease, opening up new possibilities on the road to finding new treatments. But, how does this actually work?

Parkinson's disease is the second most common degenerative disease. It damages the brain with consequences such as impaired movements, tremors at rest, dementia and, finally, 10 to 20 years later, death. The knowledge of exactly how the area of the brain affected by Parkinson's works is unfortunately still limited. Better knowledge could lead to the development of new treatments, hopefully with less side effects than those currently used.

The brain is the part of our body that controls our thoughts, feelings and actions. It interprets, helping us to make sense of the world, and controls actions such as breathing, talking and moving (to mention very few). Our actions, including movements, are controlled by the use of nerve cells, called *neurons*, connected to each other in a complicated network. The neurons use this network to communicate with each other by sending and receiving electrical signals: *action potentials*.

At Neuronano Research Center (NRC), Lund University, a group of scientists has found a way to perform the very challenging task of recording the signals from a lot of these tiny neurons. The brain signals recorded are from rats and, specifically, from neurons in an area of their brain that controls movements. The reason that this area has been chosen is that it is strongly affected by diseases that impair our movements, such as Parkinson's disease.

The rats used in the experiments at NRC have received drug injections infecting half of their brains with Parkinson's disease. In this way, the healthy half of the brain can be used as a reference when analysing what happens in the other, diseased half. During the experiments, action potentials from neurons in both the healthy and diseased part of the brain are recorded and saved, resulting in a very large dataset. The amount of action potentials, as well as the pattern that they are fired in affects the message being sent. Let us look at a simple example:

A sequence of action potentials, sent from a neuron, can be represented by ones and zeros. A one is an action potential and a zero means that nothing happened at that time:

$$1 \quad 1 \quad 0 \quad 1 \quad 1 \quad 0 \quad 1 \quad 1 \quad 0 \quad 1 \quad 1 \quad 0$$

$$0 \quad 1 \quad 1 \quad 0 \quad 0 \quad 0 \quad 1 \quad 0 \quad 1 \quad 0 \quad 0 \quad 1$$

The first sequence consists of two ones followed by a zero whereas the second does not follow any obvious pattern. Also, the first one has more action potentials (eight) than the other has (five). These properties, among many others, can easily be expressed mathematically. It has been found that the sequences of action potentials change when the behaviour changes: The meaning of a certain sequence from a certain neuron is not yet known, but maybe it will be in the future! But, the fact that sequences change when the behaviour of the animal changes is a strong motivation to continue the search: Answers to how our brains function and new treatments for diseases can be uncovered by means of mathematics.