NetClamp: a new experimental tool to manipulate neural networks

Supervisory team:
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Project description:

All of our behaviours, such as recognising friends or making a cup a tea, result from the coordinated behaviour of networks of neurons in our brain. Each behaviour is defined by a specific pattern of electrical activity in these networks. Understanding how these patterns are generated is one of the key problems in neuroscience.

In recent years, neuroscientists have made tremendous progress in determining how neurons communicate with each other. Theoreticians have used this information to construct mathematical descriptions of neural network activity, called ‘models’. Models predict how the connections in a network determine the patterns of electrical activity. In particular, they suggest that subtle changes in connection properties can have large effects on network activity. For example, activity can switch from appearing seemingly random to being highly coordinated, with changes resembling a Mexican wave in football stadiums. In some brain regions, such as those regulating breathing, coordinated rhythms are healthy. In other contexts, excessive synchrony is associated with diseases such as Parkinson’s or epilepsy.

By uncovering how neural connections shape network rhythms and synchrony, mathematical models are an essential part of the neuroscientist toolkit. However, there is currently no way to experimentally manipulate connection maps in networks of neurons to verify model predictions. This project will use a new technology to alter connection maps in real neural networks and test model predictions. This new system combines technologies that enable us to measure electrical activity in neurons using digital cameras and modulate this activity by shining light of specific colour and intensity on them. The system combines measurements and light stimulation directly with a sophisticated mathematical model of the connections between neurons, enabling full control of the biological network.

The successful candidate will use the first prototype of this system to demonstrate that it can manipulate the connection maps of small networks in culture, and so doing realise in the real biological network the activity patterns predicted by mathematical models. The use of light to control neural behaviour will also allow for functional networks to be studied in vivo once proof-of-concept has been established in vitro. In the long term, this system will enable the development of smart implants to treat brain diseases characterised by abnormal network rhythms, building on Prof Nogaret’s expertise in developing hardware neural pacemakers. These implants will detect when abnormal brain activity starts, then illuminate specific neurons to modify their connections and restore normal, healthy activity.