

Stimulating the brain

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Category: Researcher Prize

Sounding either like something from science fiction or something rather barbaric, deep brain stimulation (DBS), uses electricity applied directly to the human brain in order to successfully treat neurological disorders. And recent advances with computational modelling could help us to understand how it actually works.

DBS is extensively used to treat different types of movement disorders, most commonly the tremor (a repetitive uncontrollable movement of a body part) associated with Parkinson's disease. Parkinson's disease is a degenerative disease, and occurs due to the loss of a particular type of brain cells which contain a chemical called dopamine. Dopamine is extremely important in the part of the brain which controls movement (the motor system), and without it patients may develop a tremor, and may eventually become unable to initiate movement.

Such problems of the motor system are thought to occur due to abnormal electrical activity in the brain. This is because brain cells communicate with one another using essentially electrical signals. DBS is able to treat such problems by one or two electrodes being surgically implanted in specific areas of the patient's brain, and an electrical current being applied through these electrodes. This arrangement is shown in Figure 1, where we can see the electrodes implanted, and wires leading to the battery powered stimulator (a device similar to a pacemaker) which is implanted in the chest. The electricity injected during DBS can then disturb the abnormal electrical signals in the patient's brain, and ease their tremor.

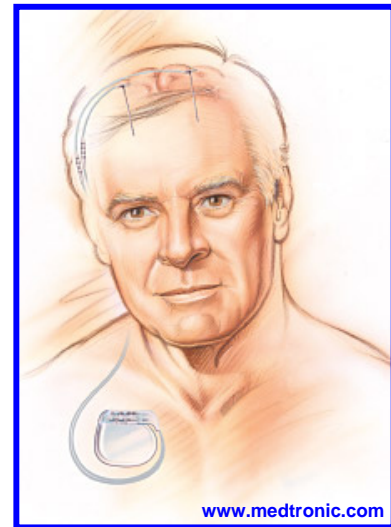


Figure 1: The electrodes are surgically implanted into the patient's brain, and a stimulator is implanted in the chest to deliver the electrical current.

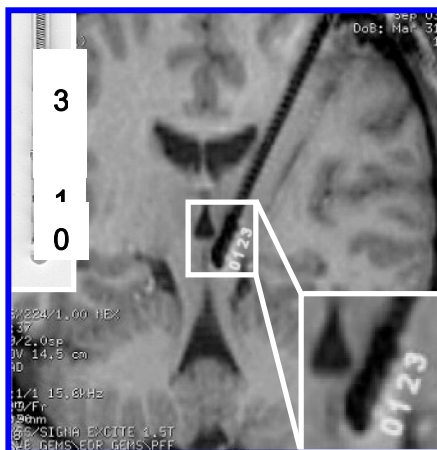


Figure 2: A scan of a patient's brain with an implanted DBS

At present, one in 500 people suffers from Parkinson's disease, and every year 10,000 people are newly diagnosed with it. Since DBS was pioneered over a decade ago there have been over 35,000 implantations worldwide, and the estimate is that as many as 80% of people who receive this treatment will experience a reduction or complete suppression of their often disabling symptoms. The decision to allow a patient to undergo this surgery depends on a number of factors, and is usually made only after trying the non-surgical option of drug treatment to replace the lost dopamine.

And yet, although DBS is widely used and successful at achieving therapeutic benefits, the precise way in which the injected electrical current affects the electrical activity of the brain is not fully understood. The difficulty is that although we can produce accurate images of where the implanted electrode is inside the brain, as shown in the MRI scan in Figure 2, there is no way that we can see or measure exactly how the current spreads in tissue, and how this current is interacting with the brain's own electrical signals.

Another way to try to understand what exactly is going on in the human brain during DBS is to use mathematics. As part of a team at Imperial College London, I am interfacing the clinical research undertaken by my colleagues, with the development of 3-dimensional computational models of the implanted electrode and the surrounding area of brain. Simple models, like the one shown in Figure 3, can be used to visualise the electric field created around the electrode. These computational models can then be used to study how the injected current interacts with the surrounding brain tissue.

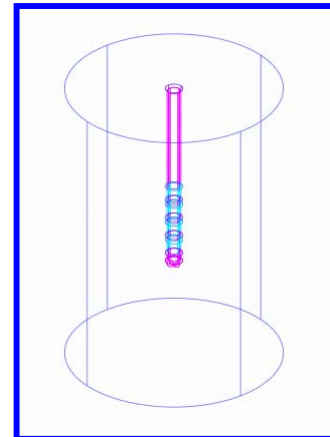


Figure 3: The 3-dimensional model, which features the DBS electrode and a cylinder

The goal is to use mathematical modelling to better understand how the current influences the brain's activity and predict how to use this procedure more effectively. Our recent results from theoretical models explains the difference in the electric fields created by two commonly used stimulation approaches, and therefore can help doctors to better target the abnormal activity that exists as a result of disease. The final challenge will be to use such computer models within routine clinical practice in order to predict the best settings for the current applied to each individual patient, as and when they require the intervention.

As the use of this procedure spreads to new ailments such as epilepsy, depression, and bipolar disorder, the number of patients who may benefit from this surgical intervention will also surely increase. But in order to understand more about how the electrical current is achieving the observed effects, theoretical research hand in hand with clinical research needs to be undertaken.

Main sources:

Benabid, A-L., et al. Deep Brain Stimulation for Parkinson's Disease. Movement Disorders, 2006

Benabid, A-L. Deep Brain Stimulation for Parkinson's Disease. Current Opinion in Neurobiology, 2003

Parkinson's Disease Society information sheet: Deep Brain Stimulation. April 2006

http://news.bbc.co.uk/1/hi/health/medical_notes/199709.stm

<http://www.medtronic.com>

http://www.tiresias.org/guidelines/parkinsons_disease.htm

Biography:

Nada Yousif graduated from Imperial College in 1998, leaving with a keen interest in the brain. She went on to study thalamocortical networks, and completed her PhD in Computational Neuroscience at the University of Plymouth. She returned to Imperial in 2005 to work on theoretical modelling of deep brain stimulation, and is currently in the first year of a 3-year post-doctoral fellowship funded by the Medical research Council.