Shaping the brain.

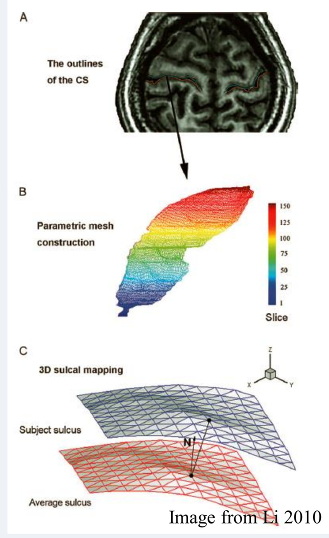
Transcranial Magnetic Stimulation to study and modulate neuroplasticity

Using lessons from elite athletes to develop therapies for brain injury patients

Dr. Damon Hoad. Mr Samuel Shribman.
Prof. John Rothwell's Lab.
Sobell Department of Motor Neuroscience and Movement Disorders.
Institute of Neurology and National Hospital for Neurology and Neurosurgery.
Queen Square. London.

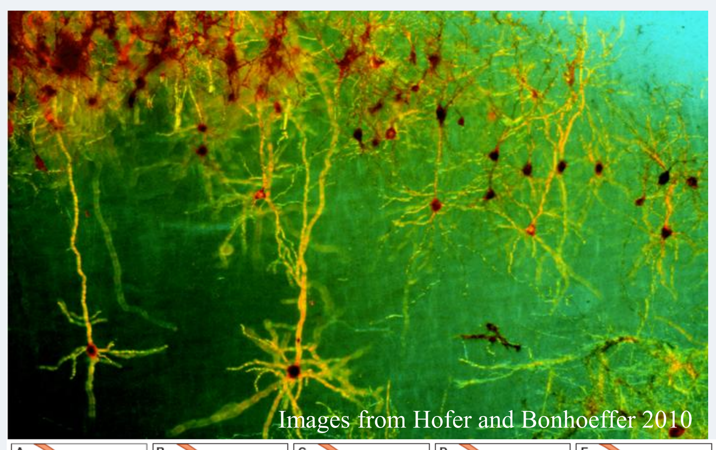
UCL

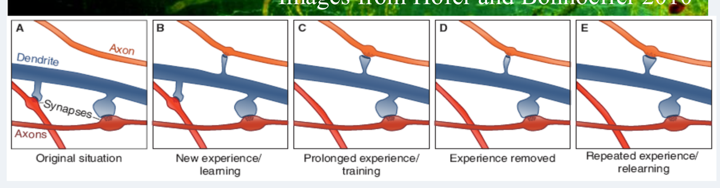
Neuroplasticity is the term used to describe the processes by which the brain may adapt to change its performance. It is the key to learning, apparent in normal development and required for the acquisition of any new skill, the formation of any new memory. At the simplest level it may be visualised as the formation of new physical connections between neurones, with new synapse formation changing the neuronal circuits which control functions. In this regard neuroplasticity may be thought of as the shaping of the brain, and that shape controls how we are, how we perform.



From Li 2010.

Visualizing the change in shape of the surface of the brain in response to training



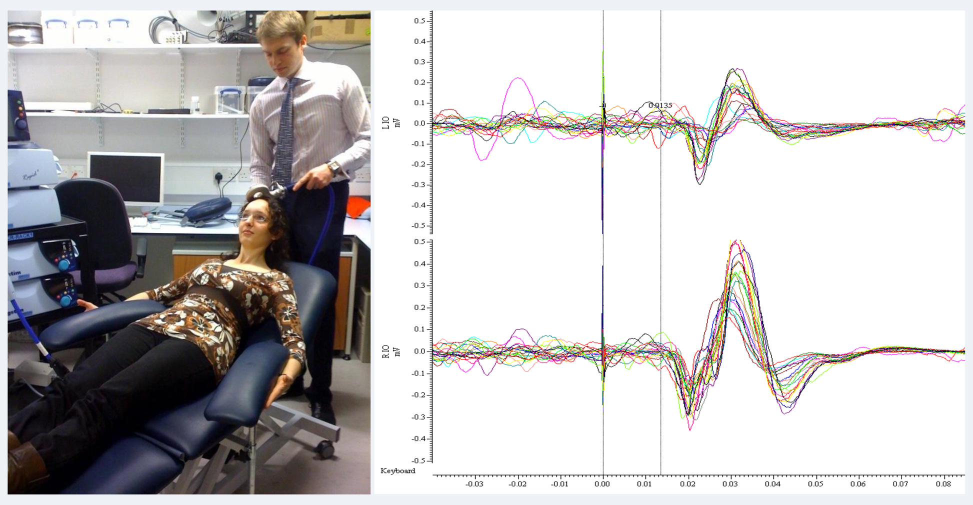


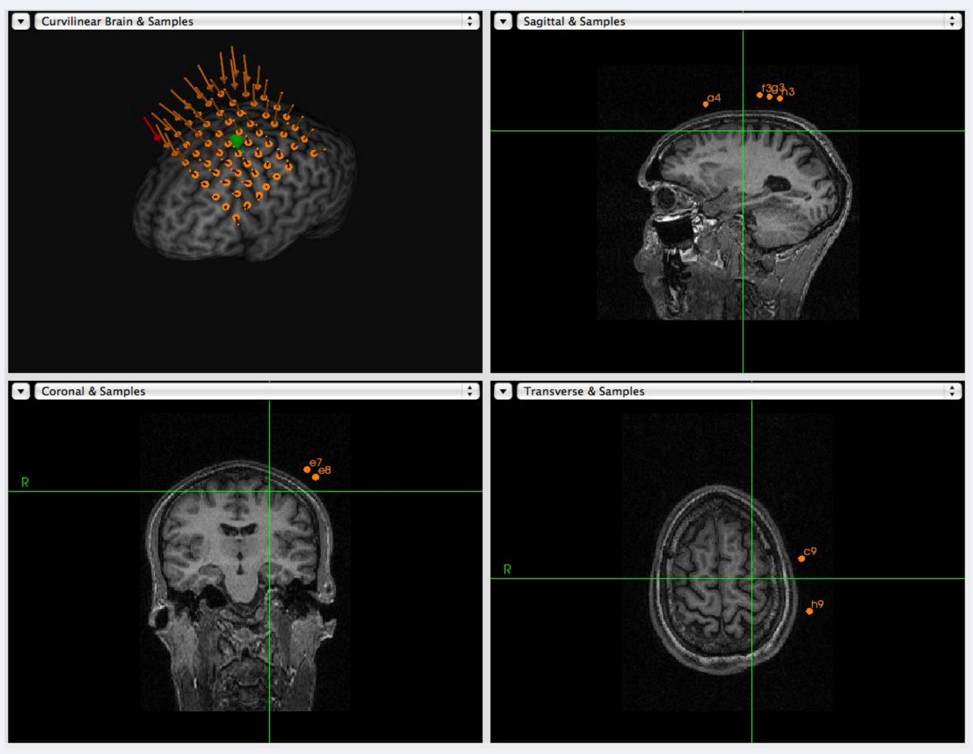
From Hofer and Bonhoeffer 2010.
New synaptic connections in response to training

The most simple idea underlying neuroplastic change is that performing a task increases activity in a neuronal circuit. The more it is used the stronger its connections become, and the more efficient the control of the function. This is what we observe in everyday life, that practice makes perfect. The neuronal translation of this is the maxim "Cells that fire together, wire together."

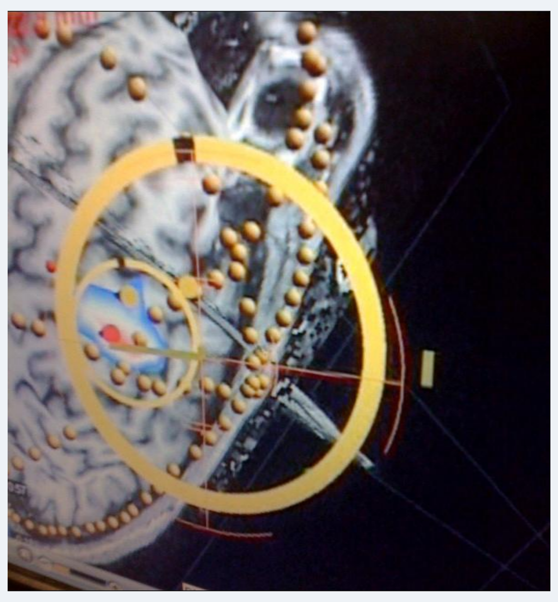
To this simple principle are added layers of complexity, additional ways in which neurones, networks and brain regions may communicate with each other to produce useful change. This provides the brain with great potential for effecting change and reserve for learning. Maximally exploiting this reserve becomes important in recovery following an injury to the brain.

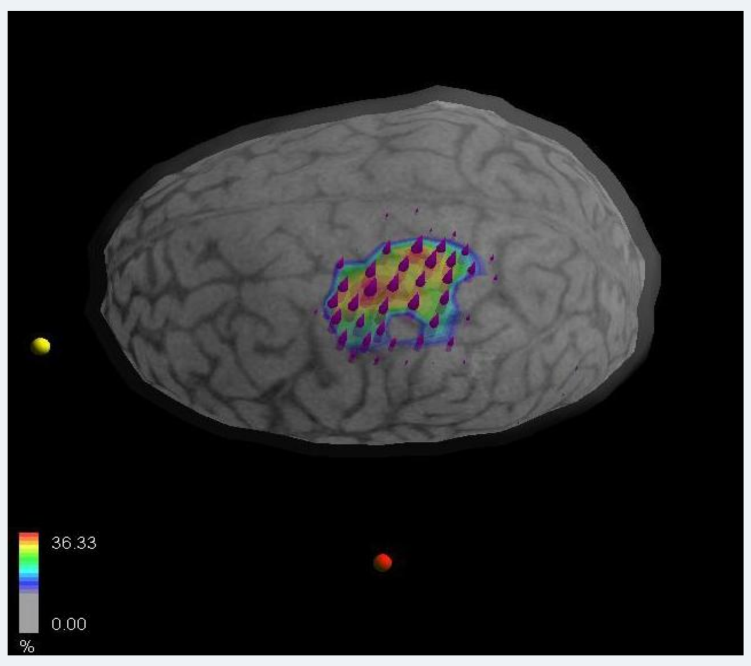
Transcranial Magnetic Stimulation is a tool for measuring the activity in neuronal pathways and deducing information about the circuitry of the cortex. We can use the tool to study how these connections change after injury such as Stroke. By studying people who are highly trained in a certain task we can determine the potential for beneficially changing these circuits. Using repetitive stimulation at different frequencies we can then alter that circuitry.





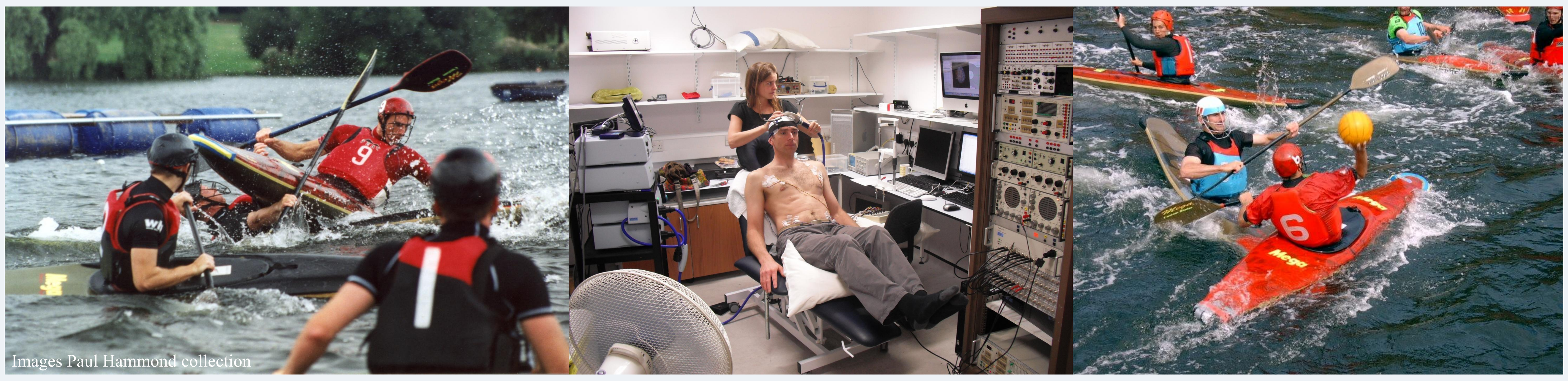
- A handheld magnetic coil is held over the scalp and delivers a strong, focussed magnetic field to the underlying cortex. This activates the population of neurones in its path.
- When applied to the part of the brain controlling movement, a response is seen in the corresponding muscle. The electrical activity of this response is recorded with surface electrodes
- Characteristics of the response such as amplitude and latency allow the nature of the circuitry of the motor pathway to be deduced.
- The subjects brain is scanned with Magnetic Resonance Imaging and a 3D reconstruction of the brain is created.
- A camera identifies landmarks on the face and scalp so that the part of the brain corresponding to a point on the surface of the scalp is shown
- By stimulating at different points on a grid an anatomical map of the region of the brain controlling a movement can be constructed



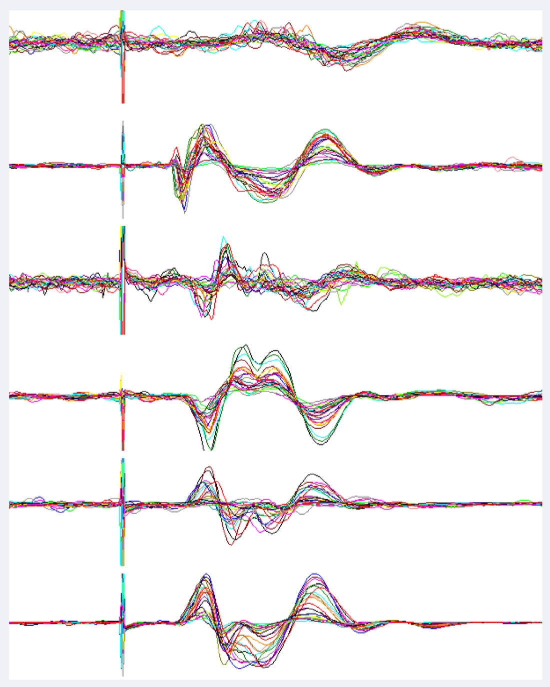


- A Neuronavigation *system guides the operator to position the magnetic coil accurately in position on the subjects head.
- A projection of the magnetic field shows the operator the precise region of the brain being targeted.
- This allows treatment protocols with repetitive stimulation to very accurately target the same spot over many sessions
- The characteristics of the response to stimulation at each position are analyzed.
- A statistical treatment calculates optimal regions for stimulation.
- The changes in response characteristics and anatomical representations tell us of the neuroplastic changes

By studying the brains of elite athletes who have perfected control of certain movements we get information about the potential for neuroplastic change through training. Using Transcranial Magnetic Stimulation to reveal the neural substrates of movement control in those who have the most highly developed and finely tuned neuronal pathways then provides us with targets for therapeutic intervention in those with brain injuries



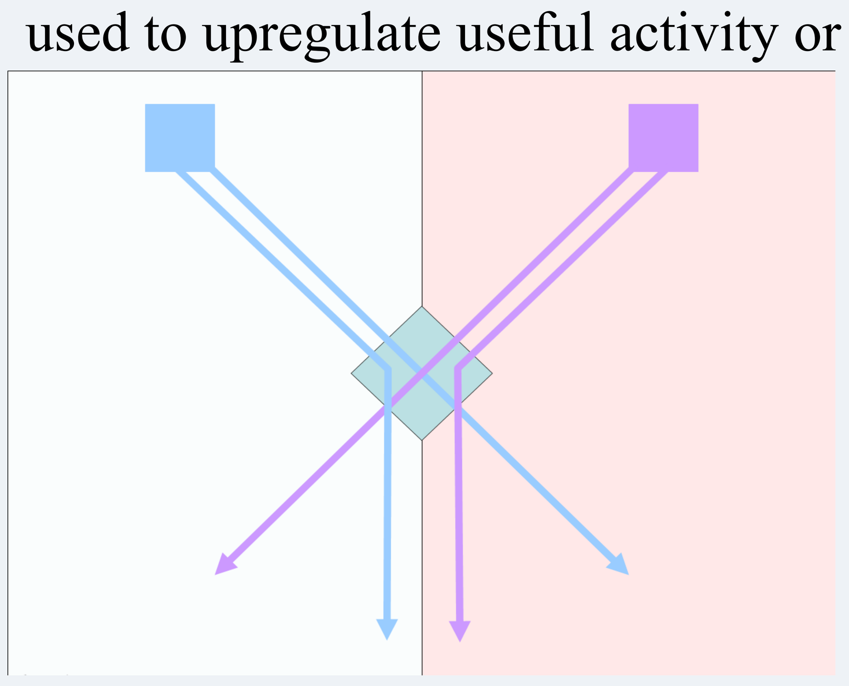
Studying world class canoe polo players with over 10,000 hours of training. They combine excellent bilateral trunk control with powerful lateralized arm and hand control

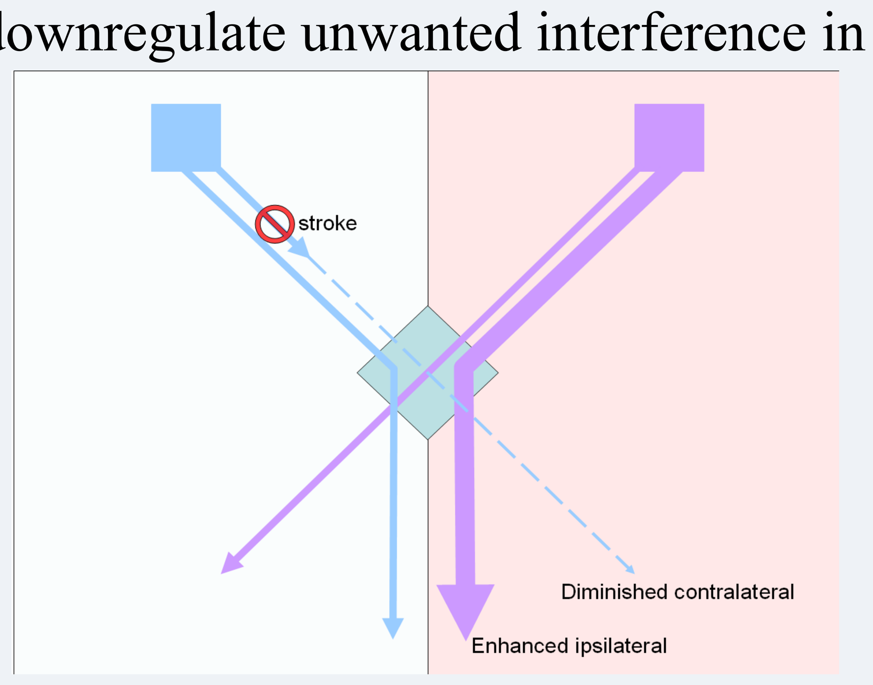


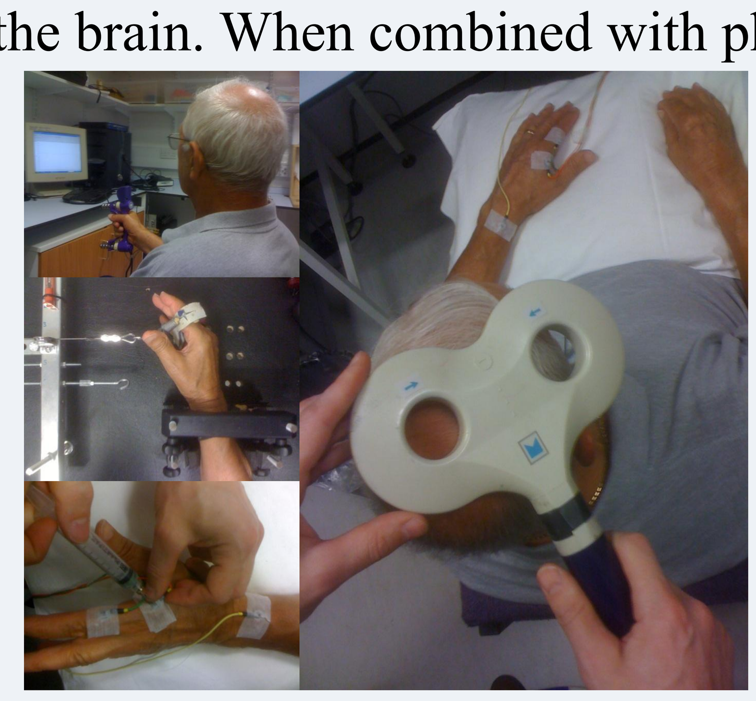
Powerful responses seen bilaterally in trunk muscles of an elite canoeist.

Pectoralis major, trapezius and external oblique respond on both sides to stimulation of a single region of the motor cortex

Transcranial Magnetic Stimulation can be used as a biomarker to monitor the neuroplastic changes following stroke. Repetitive stimulation techniques can be used to upregulate useful activity or downregulate unwanted interference in the brain. When combined with physical therapy this aids rehabilitation.







Rehabilitating a patient after stroke. Using repetitive Transcranial Magnetic Stimulation to increase activity in alternative motor pathways.

The function in the paretic hand is monitored over time

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2. Hofer and Bonhoeffer. Current Biology 2010 Feb 23;20(4):R157-9.Dendritic spines: the stuff that memories are made of? Hofer SB. Bonhoeffer T. Neuroscience, Physiology and Pharmacology, University College London