



# Foresight Cognitive Systems Project

## Advanced Neuroscience Technologies

**Research on neural systems has entered a new phase with the development of techniques that allow scientists to make real-time measurements from the brain and other parts of the nervous system. With magnetic resonance imaging and optical microscopy, aided by genes from jelly fish, researchers can draw increasingly detailed maps of the brain's activation as people, and other animals, carry out various cognitive tasks. The same techniques may also help in clinical work on some mental conditions.**

### Imaging the human brain

Early research into what happens where in the brain relied heavily on studies of people who had suffered accidental brain damage. This may or may not have provided representative insights into what happens in the normal brain. Recent progress in our ability to make accurate scientific measurements is beginning to change the way in which neuroscientists work.

This progress owes much to developments in the physical sciences, in such areas as magnetic resonance imaging, optical microscopy and laser technology. These advances allow researchers to make invasive and non-invasive measurements. Instead of having to work with tissue taken from post mortems, we really can begin to study the brains of humans, and other animals, as they perform normal tasks.

### Magnetic pointers

The technique of functional magnetic resonance imaging (fMRI) now allow us to scan the brains of normal people doing ordinary things. Advances in fMRI, a technology developed originally for medical use, have improved the resolution and time sensitivity of brain imaging.

State of the art fMRI allows us to image the brain in a second or so. The brain processes involved work over timescales of 4 to 8 seconds, so a session lasting half an hour can deliver many images of the brain.

Researchers can now observe brain activity while subjects perform tests that experimental psychologists have developed over the years in their work. This gives research into brain imaging access to a considerable body of knowledge on concepts and techniques in cognitive neuroscience.

A more recent development is the ability to use magnetic stimulation of the brain, creating temporary and reversible disruptions to its normal patterns. Using these techniques, known as transcranial magnetic stimulation, researchers can investigate how disruptions in one part of the brain influence behaviour, including what happens in different but connected parts of the brain. This approach is useful for looking across different senses, such as where vision and touch work together.

One challenge for research is to understand the relationships between the different measurements, and to combine the results from fMRI and other ways of imaging the brain such as electroencephalography.

As well as advancing research into how the brain works, new imaging techniques can help in medicine, in clinical work on brain damage and in such conditions as Alzheimer's disease, schizophrenia, depression and so on.

## Neuron recording

Much as brain imaging has revolutionised the neurosciences, it measures metabolism rather than direct cell firing and thus provides only an indirect record of what goes on in the brain. From the perspective of those working on the brain at the level of single neurons, it is a coarse tool. If we want a more detailed understanding of how the brain works, we need to know how neurons signal between one another. Advances in instrumentation techniques now mean that we can monitor as many as 100 neurons at a time. The best research laboratories increasingly undertake ensemble recording of this kind. Recent advances in information theory also allow us to begin to understand how the brain processes signals.

Research at the neuron level is important because it addresses such issues as the timing of the signals in the brain, and how much information is contained in the 'spikes' of brain activity.

## New light on brain cells

The brain is alive, yet you might not realise this from looking at textbook pictures of stained neurons. Just as non-invasive brain imaging opened up a new world to cognitive neuroscientists 10 years ago, optical imaging could be about to usher in a new revolution.

Much of what we know about how the brain works has come from studying neural circuits in different parts of the brain. These measurements combine electrophysiological techniques to record the activities of individual neurons coupled with anatomical methods for tracing connections.

Until recently, the anatomical part of this work was limited to working with dead tissue. This is all changing, thanks partly to the discovery of genes from jellyfish and other marine organisms that produce fluorescent proteins inside living cells. Putting these genes into living animals through bioengineering techniques means that their nervous systems can make these fluorescent proteins. So the nervous system gives off light and we can actually see what is happening in live neuronal circuits.

These optical imaging techniques let us follow individual molecules inside nerve cells. With them, we might be able to discover where and when in the brain molecular events related to learning and memory take place.

These new ways of observing the nervous system have already had an immense impact on research into the molecular and cellular mechanisms of brain function. Equally promising is their potential for investigating conditions such as mental retardation or schizophrenia. These may be related to disturbances of the anatomy and signalling mechanisms of nerve cells, but we are only just beginning to understand how.

Recent imaging studies show that we can follow changes in the brains of live mice over several days. In future, we may be able to watch these changes in the brains of animals as they go about their normal lives. We really can begin to think about observing circuits in the brain in the same detail as we can now study electronic circuits.

## Further details

This Research Brief draws on the Research Review "Advanced Neuroscience Techniques," written by Bashir Ahmed, Jon Driver, Karl Friston, Andrew Matus, Richard Morris and Edmund Rolls for the Foresight Cognitive Systems Project. This paper, other Research Briefs, Research Reviews and details of the project, are available on the Foresight web site at: <http://www.foresight.gov.uk/cognitive.html>