The Leverhulme Trust

Awards in Focus

Multi-modal functional neuroimaging: a window on the human mind

The human brain represents the last great frontier to unlock the secrets of the human body. Scientifically it is by far the most studied organ and yet we still know relatively little about it. In recent years however neuroscience has been revolutionised by the introduction of 'functional neuroimaging' a collective term for a number of techniques that allow us to 'see' the brain at work. The most popular technique for functional neuroimaging is functional magnetic resonance imaging (fMRI). fMRI exploits the magnetic properties of oxygenated and deoxygenated blood, using them as naturally occurring contrast agents to detect changes in blood flow brought about by changes in brain activity. The brain itself is divided into functionally specific regions; e.g. those responsible for vision, movement etc. When these regions become 'active' there is an increased need for oxygen; this prompts an increase in blood flow and induces a response detectable using fMRI. fMRI can map active brain regions with high precision and this process has generated a hitherto unprecedented understanding of brain function. Unfortunately fMRI has a major drawback; it cannot be used to measure directly the electrical signals that mediate brain function. Rather it is limited to the blood flow response; an indirect consequence of electrical activity. Further, blood takes around 8 seconds to arrive whereas brain activity occurs on a much faster timescale. This means that whilst fMRI can locate where brain activity occurs, it cannot be used to determine when it occurs.

In contrast, Magnetoencephalography (MEG) is a relatively new technique that has gained popularity in recent years. MEG measures the tiny magnetic fields that are induced outside the head by current flow through electrical brain cells. Using modern computing and complex mathematics, it is then possible to use these magnetic fields to reconstruct images of current flow in the brain. The spatial precision of MEG is not as high as fMRI, however the temporal precision is far better. Most importantly, MEG allows us to bypass blood flow and assess directly the brains electrical activity. Our research is aimed towards combining fMRI and MEG to yield a new generation of 'multi-modal' neuroimaging with high spatial and temporal precision.

Our work has facilitated measurements of electrical brain activity with extremely high precision (e.g. Fig.2 A/B). Further we have been able to show that these measurements are equivalent to electrical signals measured invasively using electrodes placed on or beneath the brain surface. MEG is completely safe and thus offers a non-invasive alternative to electrode work in humans and animals. In our most recent work, we have used the multi-modal approach to measure how spatially separate brain regions communicate. Communication (or connectivity) between brain areas is key to the way in which the brain performs tasks.

Furthermore, abnormal connectivity is thought to be responsible for diseases such as schizophrenia. The question of how to measure connectivity is therefore of great scientific and clinical significance. In the past, scientists have measured connectivity using fMRI but measurements are confounded by the indirect response. In recent months we have shown that MEG represents an alternative, complementary way to measure connectivity. Furthermore, it yields a far richer signal which enables not only identification of connections, but a means to probe the precise electrical processes that mediate those connections. This opens up the exciting possibility of a new understanding of healthy brain function and, more importantly, facilitates a means to probe brain dysfunction in disease. We hope that these techniques will yield novel biomarkers of disease progression and treatment efficacy.

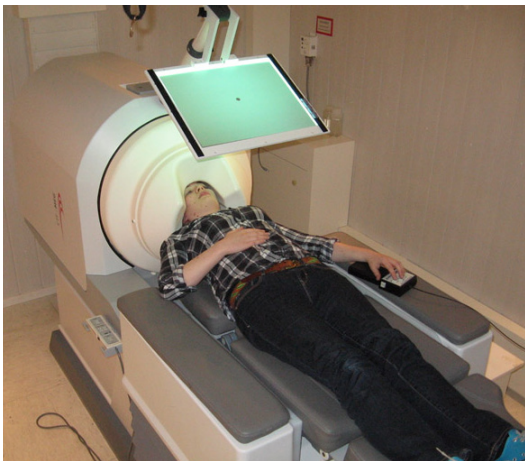

Figure 1: A volunteer in the MEG scanner housed in the Sir Peter Mansfield Magnetic Resonance Centre, University of Nottingham.

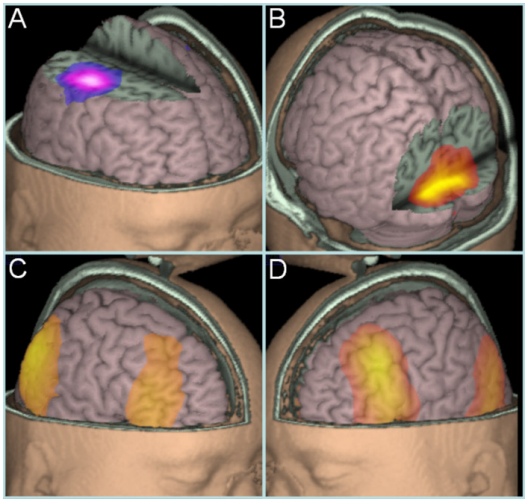

Figure 2: Brain activity identified using MEG A) The brain area controlling left index finger movement; B) processing visual input; C/D) Communication between frontal and parietal regions in the right(C) and left (D) 'attention networks'. This communication is key to cognitive function.

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Matt was awarded an Early Career Fellowship grant in 2010.