Making connections

Dr Karla Miller is developing magnetic resonance imaging techniques that provide insight into the human brain. Her research focuses on the advancement of neuroscience, clinical diagnosis and treatment of diseases and disorders.

ROYAL ACADEMY OF ENGINEERING

Research area

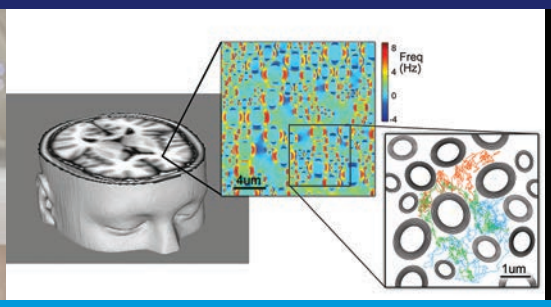
Dr Miller is a Senior Research Fellow at the Oxford Centre for Functional MRI of the Brain and a Research Lecturer in Clinical Neurology at Oxford University. A 5 year Royal Academy of Engineering Fellowship enabled her to focus on steady-state imaging techniques that offer more detailed resolution and on new ways of using ever more powerful MRI hardware to extract new information about the connection processes in the brain. Her previous research has been associated with magnetic resonance imaging (MRI) and for the past few years she has focused on diffusion imaging techniques which are used to investigate the connections between different parts of the brain. The Oxford FMRIB centre is a multidisciplinary group of engineers, scientists and physicians, and Dr Miller leads a team that is investigating new methods of data acquisition for 'functional' and 'diffusion' MRI.

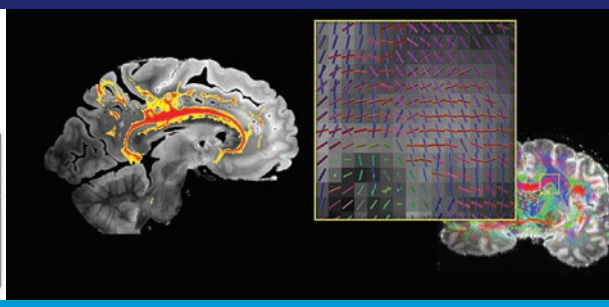
Functional MRI is used to determine which parts of the brain are active while performing a task – these areas are the brain's processing units. Diffusion MRI techniques track the movement of water molecules to reveal the underlying connections between those processing units, thereby creating a 'wiring diagram' of the brain, analogous to a wiring diagram of electricity flow.

More recent techniques developed by Dr Miller and her colleagues are used to detect changes of the brain's microstructure, which traditionally could only be studied from tissue biopsies under the microscope. In addition to improving our understanding of the healthy brain, these methods provide information on conditions that include degenerative diseases such as motor neurone disease, Parkinson's and Alzheimer's disease.

Breakthrough

Working in collaboration with colleagues at Harvard, Dr Miller was responsible for a dramatic improvement in high resolution functional MRI scanning using a precursor to the current 7-tesla MRI scanner at FMRIB: from a norm of 3mm resolution, the team achieved a resolution 570µm (micrometres), resulting in images with much better quality and higher resolution





Academy support

Dr Karla Miller was supported by a Royal Academy of Engineering/EPSRC Research Fellowship, which followed on from the interim post-doctoral research funding she was receiving at the Oxford Centre from GlaxoSmithKline.

Dr Miller considers the Royal Academy of Engineering/EPSRC Research Fellowship as 'very enabling' which allowed her to focus on her own research ideas and assemble a research team which she now leads. It was, she said, particularly suited to her as a young postgraduate with definite ideas of the research she wanted to pursue and helpful also because she was not working in a conventional university department with teaching activities that could provide an income stream. "There are not many opportunities like this that take you on at such an early career stage. It has enabled me to go on to where I am today", she said.

Other support

Dr Miller has been supported by a Wellcome Trust Fellowship. She sees the Fellowship very much as follow-on from the Royal Academy of Engineering support, allowing continuity in her research but at the same time recognising that an established researcher with a research team needs a different kind of backing.

Research impact

MRI is an established non-invasive technique for investigating internal structures of the human body. The Oxford research centre where Karla Miller is a senior researcher concentrates on the use of MRI to study the human brain.

The work has two specific benefits: it contributes to expanding knowledge in neuroscience, and it is used in clinical diagnostics. Dr Miller's research has had impact in both of these areas. Where functional MRI focuses on the activity in different parts of the brain, Dr Miller's work in diffusion imaging looks at the connections between the different areas of brain activity. "It's like trying to come up with the wiring diagram," she said. "We look to see if water can move better in one direction than in another and that tells us which way the connections are running." Neuroscience is a relatively new field that is making rapid progress: MRI is a key technology that is building understanding of how the brain works.

The other side of Dr Miller's research is that it is also helping the clinical diagnosis of a range of diseases and disorders, including life-changing events such as strokes and life-threatening conditions such as multiple sclerosis. Pharmaceutical companies also use the kind of techniques that Dr Miller is developing to monitor the effectiveness of new drugs, predict which patients are good candidates for pharmaceuticals, and to understand therapeutic mechanisms.

Future challenges

The flexibility of MRI to probe a broad range of aspects of brain function and pathology make it a constantly evolving technology. While many of the ideas that drive current research have been around for decades, Dr Miller points out that the challenges of sensitivity mean that 'great leaps forward' often require the combination of several innovations to achieve the promise of the ideas. For example, the combination of steady-state imaging techniques with the new 7-tesla high-powered MRI scanners promises images with better quality and higher resolution.

Dr Miller's focus on the connections within the brain is now becoming her main area of research. "For a long time we were concerned with mapping what parts of the brain did what," she said. "Now, the focus is shifting very much towards trying to understand the connections. It's the next stage in understanding how the brain works." The new field is termed 'connectomics' and the Oxford FMRIB Centre is collaborating in a $38 million National Institutes of Health consortium that aims to map the connections in the brain, as well as a related European Research Council project to study the development of connections in the brains of infants.

Biography/ Career Progression

1993 - 1998 Bachelor's degree in computer science, University of Illinois Urbana-Champaign

1998 - 2000 Master of Science, Department of Electrical Engineering, Stanford University

2000 - 2004 PhD, Department of Electrical Engineering, Stanford University

2004 - 2006 Post-doctoral researcher, Oxford Centre for Functional MRI of the Brain (FMRIB), University of Oxford

2006 - 2011 RAEng/EPSRC Research Fellow, FMRIB, University of Oxford

2007 - Present University Research Lecturer, Nuffield Department of Clinical Neurosciences, University of Oxford

2011 - Present Wellcome Trust Career Development Research Fellow, FMRIB, University of Oxford

"It's really rather shocking how little we know about the connections in the human brain, and there is still so much to explore."

Dr Karla Miller