

THE EMOTIONAL BRAIN

Background

Professor Ray Dolan, currently at the Institute of Neurology, University College London (UCL), trained as a psychiatrist and started his research career in psychiatric research; but he soon realised that his ability to make progress in the field was being held back by the limited understanding of the functional architecture of normal cognitive function such as emotion, learning, memory and decision-making. He therefore set about a systematic study of human emotion, beginning with fear, in particular fear elicited by facial expression, and its interaction with cognition. Since then he has used state-of-the-art brain imaging techniques to explore various aspects of how our emotions influence high-level cognitive function, including decision-making, at the levels of both behaviour and neurobiology.

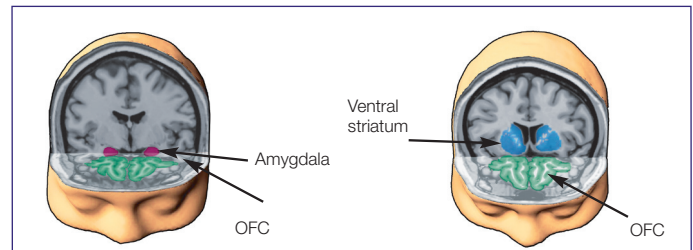
Professor Dolan has also been a driving force in securing funds for and leading the development of a major centre for cognitive research at UCL. The Wellcome Trust Centre for Neuroimaging, of which Dolan is currently the Director, has grown over the last ten years to accommodate the latest technology in neuroimaging and has attracted top researchers to become a world-leading centre of expertise and resources in neuroscience.

Advance

Professor Dolan published the first demonstration that activation of the amygdala is involved in the processing of fear in humans. He then went on to show that fear in response to visual stimuli is encoded by an increase in the connectivity between early visual regions and the amygdala. He has also demonstrated that the amygdala is a centre for the processing of all categories of emotions. He went on to provide the first direct link between a specific computational process and its instantiation in the human brain during emotional learning.

Professor Dolan's more recent work involves a cross-disciplinary approach to complex questions in higher order mental functions in humans. A good example of this approach is research on reward-seeking behaviour, published by Dolan and co-workers in *Nature* in 2006. In this study he looked at the biology underlying how humans use past experiences of success and failure to improve their decision-making – a process known as instrumental learning. This is influenced by the dopaminergic system in the striatum, and so Professor Dolan and colleagues tested whether manipulating levels of dopamine in the brain would affect the rate at which people learn optimal behaviours. The researchers found that subjects treated with L-DOPA, which boosts dopamine levels in the brain, were more likely to choose actions associated with the highest reward than subjects treated with haloperidol, which decreases dopamine levels by blocking the dopamine receptor. Using a combination of behavioural, pharmacological, computational and functional MRI techniques, the study was the first to show that dopamine-related drugs can modulate the apparent value of rewards as represented in the striatum.

At the same time as leading a productive research team, he has continued to pursue his practice as a psychiatrist. He has also made major contributions to the neurosciences by leading the development of major research resources for the cognitive sciences at UCL.



Interconnected regions of the brain affect our decision-making. The **amygdala** (red) is involved in processing and remembering emotions, while the **orbitofrontal cortex** (green) is thought to integrate rational and emotional inputs. The **striatum** (blue) receives dopamine from the midbrain, and influences how we learn from the good or bad outcomes of decisions.

Images by Benedetto De Martino, a PhD student in Professor Dolan's laboratory who was awarded a Sir Henry Wellcome Postdoctoral Fellowship in 2007.

How it's making a difference

Professor Dolan's findings on the neurobiological bases of emotion and cognition are applicable to decision-making deficits seen in many neurological and psychiatric disorders. For example, sufferers of Parkinson's disease are often prescribed dopamine replacement therapy, but this can cause side effects that include compulsive behaviours such as over eating, hypersexuality and compulsive gambling – the value of the end results (whether food, sex or winning) being over inflated. Similarly people with damage to their orbital prefrontal cortex – a locus for emotions – display severely altered emotional behaviour.

This is only one example of high-profile research by Professor Dolan's group. Over his career, he has published over 300 peer-reviewed studies in the cognitive neurosciences and is one of the most highly cited scientists in the field of neuroscience and behaviour. In 2006 he was awarded the Minerva Foundation Golden Brain Award, the Kenneth Craik Prize and in 2007 he won the Max Planck Research Award. He has collaborated with experts in diverse fields including computational neuroscience and behavioural economics in order to develop a theoretical framework for understanding the interactions between cognition and emotion in determining behaviour. These collaborations also include work with the Epilepsy Group at the National Hospital to test specific theoretical models in patients with focal lesions, research with John Driver on attention, and studies with the Gatsby Computational Neuroscience Unit.

The Functional Imaging Laboratory was founded in 1994 and has received major grants for infrastructural support from the Wellcome Trust in 1999 and 2004. This funding has allowed the centre to evolve from predominantly PET-based studies to a multidisciplinary centre accommodating the latest neuroimaging technologies – functional magnetic resonance imaging, magneto-encephalography and electroencephalography.

Following a Wellcome Trust Strategic Award in 2006, the laboratories have become the Wellcome Trust Centre for Neuroimaging at UCL under the directorship of Ray Dolan. This is a major neuroimaging resource for clinicians and scientists studying higher cognitive function, and accommodates the laboratories of many key researchers in the field of cognitive neuroscience.

The Centre is also home to the Statistical Parametric Mapping (SPM) resource, a tool for the analysis and collation of functional imaging data from multiple sources such as MRI, MEG and SPECT. SPM is a key part of the theoretical neuroscience infrastructure, expertise biomathematics and data analysis being developed at the Centre for Neuroimaging.

Next steps

Psychiatric disorders are the commonest disorders and the most expensive to manage in the developed world. Professor Dolan started his research career in the study of psychiatric complaints and subsequently worked for 20 years on the laying the foundations of cognitive neuroscience. He is now in a position to apply his characterisation of the neurobiology of emotion and cognition as a theoretical basis for the development of protocols that can unravel the neurobiological basis of common psychiatric disorders in a manner that can lead to therapeutic strategies. Recent work by Professor Dolan's group on memory has been adopted by clinical groups as a pre-operative clinical predictor of post-operative memory deficits in patients with intractable temporal lobe epilepsy.

In his current research programme, he is extending his understanding of the encoding of emotion to ask questions about how the brain uses emotional information to influence decision-making. Professor Dolan is drawing on diverse fields such as behavioural ecology, machine learning and microeconomics in order to explore this issue in the context of behavioural optimisation. He is deploying his Max Planck Award to study neuromodulatory control of psychological functions including emotion and decision-making.

References

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O'Doherty J, Dayan P, Friston KJ, Critchley H and Dolan RJ. (2003) Temporal difference models account for neural responses in human ventral striatum and orbitofrontal cortex during Pavlovian appetitive learning. *Neuron*: 38, 329–337.

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Daw ND, O'Doherty JP, Dayan P, Seymour B and Dolan RJ. (2006) Cortical substrates for exploratory decisions in humans. *Nature* 2006 Jun 15;441(7095):876–9.

De Martino B, Kumaran D, Seymour B and Dolan RJ. (2006) Frames, biases and rational decision-making in the human brain. *Science* 2006 Aug 4;313(5787):684–7.

Table of achievements

Inputs

- Wellcome Trust Programme Grant (1993, 1999, 2000, 2006)
- Howard Hughes Medical Institute (2001)
- Wellcome Trust Project Grant (2002)
- Wellcome Trust SRIF grant for magneto encephalography facility at the Institute of Neurology (2004)
- Human Sciences Frontier Programme Grant (2004)
- Wellcome Trust Strategic Award: Imaging Neuroscience (2006)

Key activities/outputs

- Key findings in the cognitive neurosciences on cognition, emotion and their interaction
- Over 300 peer-reviewed papers, many in top journals
- Kinross Professor of Neuropsychiatry, UCL (2000)
- Co-organiser of Nobel Symposium on emotion (2005)
- Advised author Ian McEwan on neuroscience and psychiatry for several of his novels
- Section editor of the *Journal of Neuroscience*; on the editorial board of many journals, e.g. Archives of General Psychiatry

Outcomes

- Director of the Wellcome Trust Centre for Neuroimaging (2006)
- Among the top 10 most cited scientists in field of Neuroscience and Behaviour (2005)
- Awarded the Alexander Von Humboldt Research Award International Research Award for Outstanding Scholars (2004) in recognition of his work on emotion
- Kenneth Craik Research Award (2006)
- Minerva Foundation Golden Brain Award (2006)
- Max Planck Research Award (2007)

Timeline of Professor Ray Dolan

