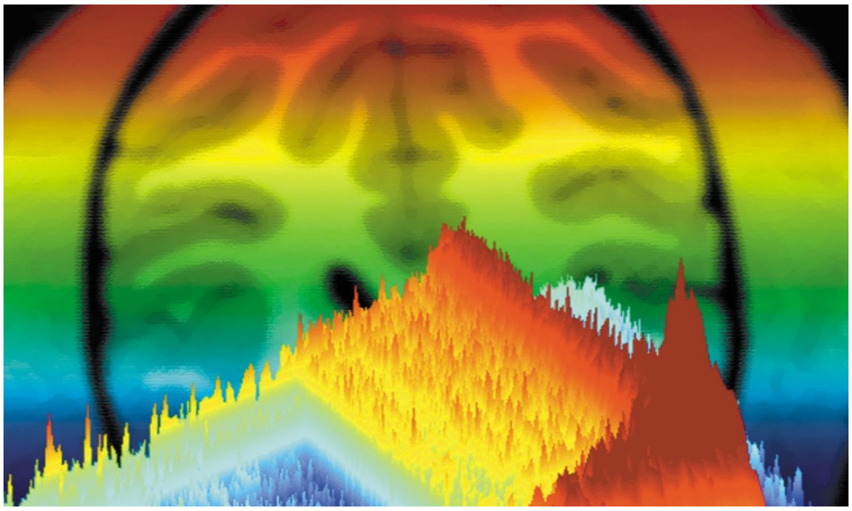
NEUROIMAGING

A bold step forward



Anatomical scan of monkey cortex together with spectrogram showing the power spectrum of the neural signal every 250 ms. Courtesy of Nikos Logothetis. Max Planck Institute.Tübingen, Germany.

Functional imaging is a fast-growing area of neuroscience, but suffers from an image problem: no-one is quite sure how the signals obtained using BOLD fMRI (blood-oxygen-level-dependent functional magnetic resonance imaging) relate to neural activity in the parts of the brain that light up during an imaging experiment. This makes it tricky to interpret the results of fMRI studies, and has led to some scepticism about its usefulness.

But Logothetis *et al.* have now made real progress in elucidating the neurophysiological basis of the BOLD fMRI signal. In a technical *tour de force*, they have managed to measure fMRI responses and neural activity simultaneously in the monkey visual cortex. Their data indicate that BOLD fMRI signals reflect the input and intracortical processing of an area of cortex, rather than its output.

BOLD fMRI is widely used for assessing activity in the brain. It actually measures haemodynamic changes in brain tissue, rather than electrical activity, but has been assumed to reflect some aspect of neural function. So, for example, when areas of visual cortex show an increased BOLD signal in response to a visual stimulus, we assume that it represents increased neural activity in those cortical areas.

Logothetis *et al.* have developed a new recording apparatus that combines specially constructed electrodes with a system that compensates for the interference caused by the strong magnetic fields used for fMRI. They measured the BOLD responses, multi-unit activity and local field potentials elicited in the visual cortex of anaesthetized monkeys by using rotating checkerboard patterns as visual stimuli. They then analysed the data to uncover the relative contributions of multi-unit activity and local field potentials to the BOLD responses.

The main finding of the study was that local field potentials correlated much more closely with BOLD responses than did multi-unit activity, indicating that BOLD activation probably reflects the activity underlying local field potentials rather than spiking output. Local field potentials are the product of inputs from other brain areas and local processing in an area of cortex. The authors comment that although output activity will often correlate with synaptic events, such as neurotransmitter release and pre- and postsynaptic currents, fMRI may reveal activation in the absence of single- or multi-unit activity if the input to a given area is mainly modulatory in function.

Logothetis *et al.* also found that neural responses have a much higher signal-to-noise ratio than fMRI signals. This may lead to underestimation of brain activation in human studies using fMRI, owing to the variability of the vascular response.

Simultaneous recordings like these, which bring together electrophysiological and imaging studies, should allow us to achieve a more complete view of brain function in both humans and animals.

Rachel Jones

References and links

ORIGINAL RESEARCH PAPER Logothetis, N. K. *et al.* Neurophysiological investigation of the basis of the fMRI signal. *Nature* **412**, 150–157 (2001)

FURTHER READING Courtney, S. M. & Ungerleider, L. G. What fMRI has taught us about human vision. *Curr. Opin. Neurobiol.* **7**, 554–561 (1997) | Kanwisher, N. & Wojciulik, E. Visual attention: insights from brain imaging. *Nature Rev. Neurosci.* **1**, 91–100 (2000)

WEB SITE Logothetis's lab