

EEG, fMRI and Their Combination in the Study of Epilepsy

Electroencephalography (EEG) and Functional Magnetic Resonance Imaging (fMRI) are two important techniques for the study of the human brain, healthy or diseased. For example, EEG is of primary importance in the clinical evaluation of patients with epilepsy, by allowing the visualisation of very brief (order of ms) electrophysiological abnormalities during seizures and between seizures, such as interictal spikes (focal epileptic spikes).¹ EEG can therefore provide specific markers of epilepsy containing some localising information in relation to an underlying brain abnormality responsible for the epilepsy. EEG is also capable of recording patterns linked to specific external (visual, sensorial, etc) stimuli, in the form of evoked responses. Salient features of the scalp EEG, such as spikes or rhythms, reflect increased synchronisation of cortical activity at various spatial scales, ranging from sub-lobar to the entire brain. Simulations and experimental data have shown that such EEG features must involve a patch of cortex with an area of at least 10cm². Crucially, scalp EEG is most sensitive to superficial cortical activity with limited or no sensitivity to events taking place deeper in the brain such as on the medial aspect of the temporal lobe, which are only detectable via propagation to more superficial cortex.

Some localising information on the generators of EEG features can be derived qualitatively from visual inspection of the recordings by experienced observers, mainly based on consideration of the feature's amplitude in relation to the various channels particularly for discharges such as focal epileptic spikes. In patients with drug-resistant epilepsy who may benefit from surgery EEG recordings combined with careful examination of

the clinical manifestations observed during seizures (such as recorded on video-EEG telemetry) are capable of providing very useful information, but at the lobar level. Focal spikes being much more common than seizures, a great effort has been made to use these for localisation purposes. Although in general spikes may originate from outside the epileptic focus itself (their generator is called the irritative zone), in many cases there is considerable overlap. In theory, spike generator localisation can be improved on using computational EEG source reconstruction methods based on assumptions on the form of the EEG generators.² The simplest and commonest assumption is that EEG generators can be represented as electrical dipoles, consisting of combined positive and negative sources. Although widely used in research this type of localisation has had limited impact on clinical practice in large part due to uncertainties in the modelling assumptions.

Functional MRI

Therefore, EEG-based localisation remains limited in accuracy and clinical utility. On the other hand functional MRI, in the form of activation maps derived from series of scans, is a powerful tool for visualising changes linked to epochs of specific brain activity contrasted to a control state.³ Two great advantages of fMRI are its more or less equal sensitivity irrespective of location in the brain and sampling down to a few mm. Although fMRI-based localisation does not suffer from the same type of uncertainties as EEG-based localisation as highlighted above, it is limited by other factors such as poor temporal resolution (of the order of seconds) and is subject to numerous artefacts (particularly at high field strengths such as 3T and above). Perhaps more impor-



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Born in the city of Québec in Canada, Louis Lemieux obtained a PhD in Physics at the Université de Montréal in 1990. He joined the Institute of Neurology (which became part of University College London in 1997) at Queen Square, London, the same year to work in the Epilepsy Research Group (Drs David Fish and Simon Shorvon) on multi-modal imaging applied to Epilepsy. In 1995 the Group established an MRI Unit entirely dedicated to research in Epilepsy located on the site of the National Society for Epilepsy in Chalfont St Peter, Buckinghamshire. Professor Lemieux's interests focus on the application of functional MRI to the study of paroxysmal activity and longitudinal quantitative MR imaging.

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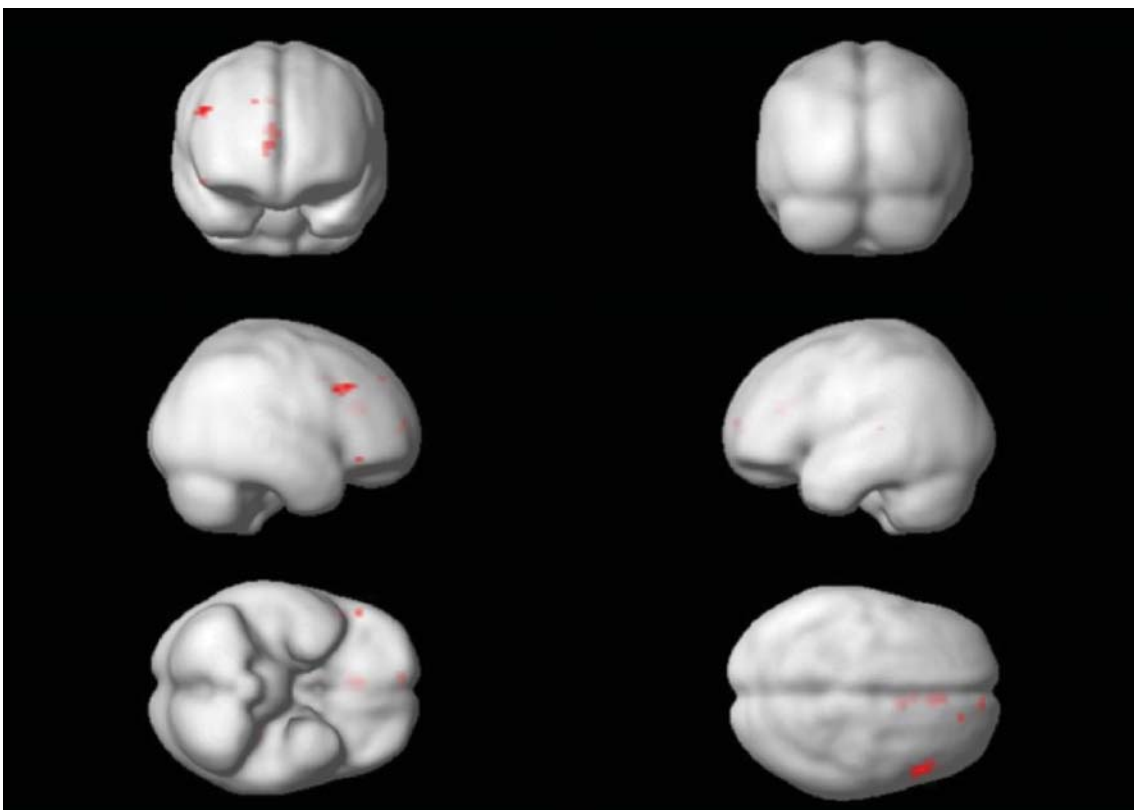


Figure: Spike-related activation pattern (BOLD increase, in red) derived from combined EEG-fMRI experiment, associated with frequent focal spikes originating in the right frontal lobe in a patient with drug-resistant epilepsy. There are clusters in the mesial and lateral aspect of the frontal lobe.

