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The Virtual Big Brain in clinical applications

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Over the past decade we have demonstrated that the fusion of subject-specific structural information of the human brain with mathematical dynamic models allows building biologically realistic brain network models, which have a predictive value, beyond the explanatory power of each approach independently. The network nodes hold neural population models, which are derived using mean field techniques from statistical physics expressing ensemble activity via collective variables. Our hybrid approach fuses data-driven with forward-modeling-based techniques and has been successfully applied to explain healthy brain function and clinical translation including aging, stroke and epilepsy. Here we illustrate the workflow along the example of epilepsy: we reconstruct personalized connectivity matrices of human epileptic patients using Diffusion Tensor weighted Imaging (DTI). Subsets of brain regions generating seizures in patients with refractory partial epilepsy are referred to as the epileptogenic zone (EZ). During a seizure, paroxysmal activity is not restricted to the EZ, but may recruit other healthy brain regions and propagate activity through large brain networks. The identification of the EZ is crucial for the success of neurosurgery and presents one of the historically difficult questions in clinical neuroscience. The application of latest techniques in Bayesian inference and model inversion, in particular Hamiltonian Monte Carlo, allows the estimation of the EZ, including estimates of confidence and diagnostics of performance of the inference. The example of epilepsy nicely underwrites the predictive value of personalized large-scale brain network models. The workflow of end-to-end modeling is an integral part of the European neuroinformatics platform EBRAINS and enables neuroscientists worldwide to build and estimate personalized virtual brains.

Originally trained in Theoretical Physics and Philosophy in the 1990s, Dr. Jirsa has made contributions to the understanding of how network structure constrains the emergence of functional dynamics using methods from nonlinear dynamic system theory and computational neuroscience. Dr. Jirsa has been awarded several international and national awards for his research including the Francois Erbsmann Prize in 2001, NASPSPA Early Career Distinguished Scholar Award in 2004, and Grand Prix de Recherche de Provence in 2018. He serves on various Editorial Boards and has published more than 150 scientific articles and book chapters, as well as co-edited several books including the Handbook of Brain Connectivity. Dr. Jirsa is one of the Lead Scientists in the Human Brain Project and The Virtual Brain.

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