Planning invasive and non-invasive brain network disorder treatments using computational models

Marcus Kaiser
Professor of Neuroinformatics,
School of Computing / Institute of Neuroscience, Newcastle University, UK

Our work on connectomics over the last 15 years has shown a small-world, modular, and hub architecture of brain networks [1,2]. Small-world features enable the brain to rapidly integrate and bind information while the modular architecture, present at different hierarchical levels, allows separate processing of various kinds of information (e.g. visual or auditory) while preventing wide-scale spreading of activation [3]. Hub nodes play critical roles in information processing and are involved in many brain diseases [4].

After discussing the organisation of brain networks, I will show how connectivity in combination with machine learning and computer simulations can identify the progression towards dementia before the onset of symptoms informing interventions that can delay disease progression [5]. For epilepsy patients, connectome-based simulations can also be used to predict the outcome of surgical interventions as well as alternative target regions [6]. While these models rely on the network between brain regions, we also developed models of tissue within a brain region (http://www.vertexsimulator.org). Such models can observe the effects of invasive [7] or non-invasive electrical brain stimulation.

I will finally outline how these models could, in the future, inform invasive interventions, such as optogentic stimulation in epilepsy patients (http://www.cando.ac.uk) or non-invasive interventions using electrical, magnetic or focused ultrasound stimulation.

[1] Martin, Kaiser, Andras, Young. Is the Brain a Scale-free Network? SfN Abstract, 2001.
[2] Sporns, Chialvo, Kaiser, Hilgetag. Trends in Cognitive Science, 2004.
[3] Kaiser et al. New Journal of Physics, 2007.
[4] Kaiser et al. European Journal of Neuroscience, 2007.
[5] Peraza et al. Alzheimer's & Dementia: Diagnosis, Assessment & Disease Monitoring, 2019.
[6] Sinha et al. Brain, 2017.
[7] Thompson et al. Wellcome Open Research, 2019.

Biography: Marcus Kaiser studied biology and computer science at the Ruhr-University Bochum and the Distance University Hagen and obtained his PhD from Jacobs University Bremen in 2005. He is initiator and co-director of the Wellcome Trust PhD programme in Systems Neuroscience. He is leader of Neuroinformatics UK (http://www.neuroinformatics.org.uk), Chair of the British Neuroscience Association SIG Neuroinformatics, and leader of Neuroinformatics research at Newcastle University (http://neuroinformatics.ncl.ac.uk/). He is author of the first major review (Trends in Cognitive Sciences, 2004; cited 1,800+ times) as well as of more than 90 other publications in the field of brain connectivity (connectomics). Since 2016, he is Fellow of the Royal Society of Biology. Research interests are understanding the link between structure and function by modelling brain development, neural dynamics, and therapeutic interventions (see http://www.dynamic-connectome.org/).