The Spatially-Embedded Brain

Henry Kennedy
INSERM, France

Using brain-wide retrograde tracing experiments in macaque, we are generating a consistent database of between area connections with projection densities, and distances (Markov et al., 2014). The network is neither a sparse small-world graph nor scale-free (Markov et al., 2013). Local connectivity accounts for 80% of labeled neurons (Markov et al., 2011), meaning that cortex is heavily involved in local function. Importantly link weights, are highly characteristic across animals, follow a heavy-tailed lognormal distribution over 6 orders of magnitude, and decay exponentially with distance.

The statistical properties of the cortex will give insight into the nature of the processing mode of the cortex (Markov and Kennedy, 2013). We have made a weighted network analysis that reveals a trade off between local and global efficiencies. An important finding is that a distance rule (EDR) predicts the binary features, the global and local communication efficiencies, clustered topography and the wire-minimization of the cortical graph (Ercsey-Ravasz et al., 2013, Song et al., 2014). These findings underline the importance of weight-based hierarchical layering in cortical architecture and hierarchical processing (Bastos et al., 2015, Michalareas et al., 2016). We have therefore evaluated the shapes and dimensions of cortical areas, which place different parts of the same area in different neighborhoods, with respect to EDR predictions of connectivity. We have shown that in the visual cortex central representations are preferentially linked to the ventral stream and peripheral representations to the dorsal stream.

Altogether, analysis of quantitative measures of connectivity suggest evolutionary optimization of areal shape, location and cortical folding and point to the need to consider the brain in space when considering the statistics of the inter-areal cortical network.

I will briefly mention on-going work on the mouse connectome that shows that the EDR model applies equally well across different species and different brain sizes suggesting general principals of organization (Horvat et al., 2016). Interestingly however the core-periphery structure, indicative of a global work space cognitive architecture, includes primary areas in mouse and uniquely higher order areas in macaque. This comparative connectomic approach could lead interesting predictions on the human brain currently not available with present day imaging techniques (Donahue et al., 2016).