Team unveils the hidden control architecture of brain networks

April 24 2019

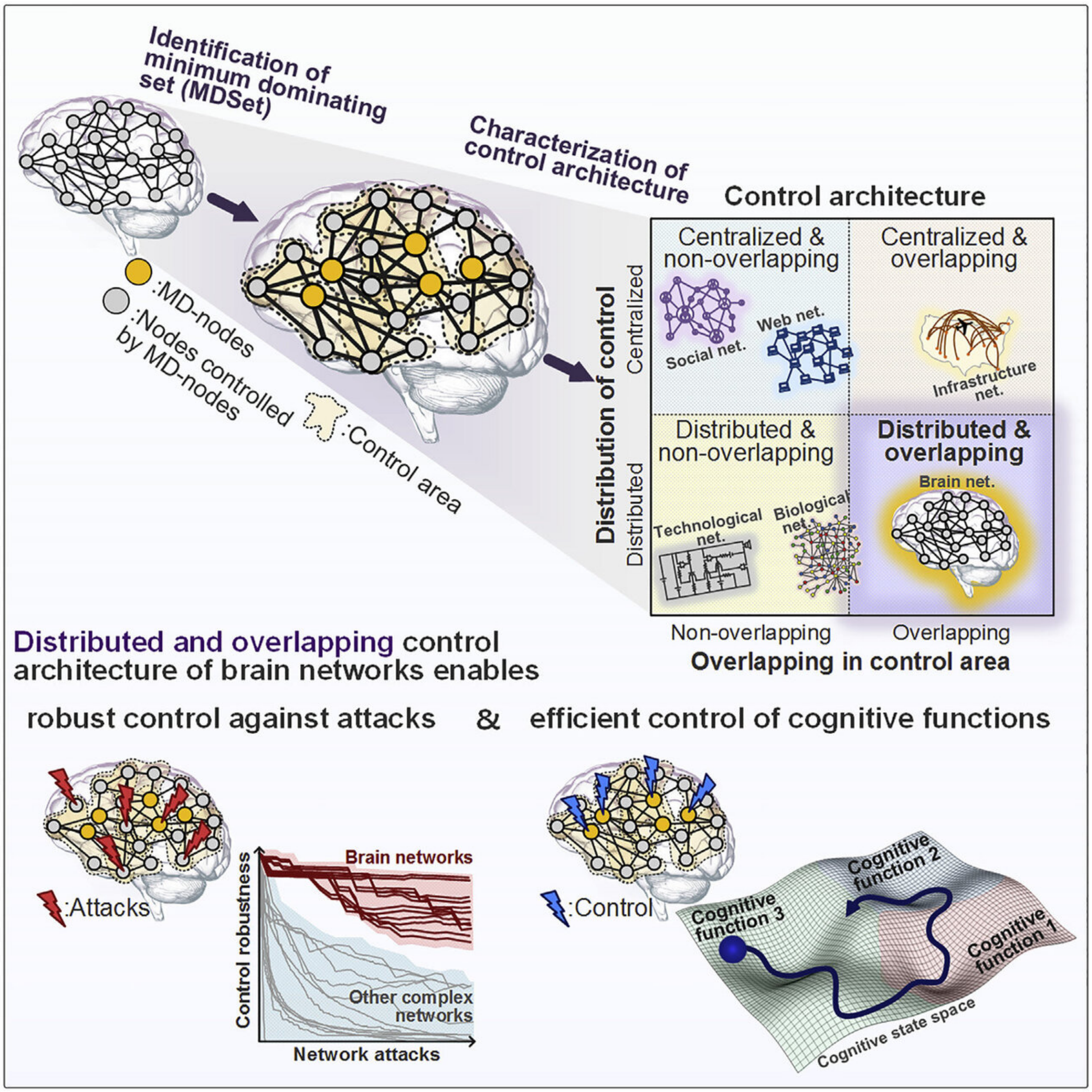

Figure 1. Schematic of identification of control architecture of brain networks. Credit: KAIST

A KAIST research team identified the intrinsic control architecture of brain networks. The control properties will contribute to providing a fundamental basis for the exogenous control of brain networks and, therefore, has broad implications in cognitive and clinical neuroscience.

Although efficiency and robustness are often regarded as having a trade-off relationship, the human brain usually exhibits both attributes when it performs complex cognitive functions. Such optimality must be rooted in a specific coordinated control of interconnected brain regions, but the understanding of the intrinsic control architecture of brain networks is lacking.

Professor Kwang-Hyun Cho from the Department of Bio and Brain Engineering and his team investigated the intrinsic control architecture of brain networks. They employed an interdisciplinary approach that spans connectomics, neuroscience, control engineering, network science, and systems biology to examine the structural brain networks of various species and compared them with the control architecture of other biological networks, as well as man-made ones, such as social, infrastructural and technological networks.

In particular, the team reconstructed the structural brain networks of 100 healthy human adults by performing brain parcellation and tractography with structural and diffusion imaging data obtained from the Human Connectome Project database of the US National Institutes of Health.

The team developed a framework for analyzing the control architecture of brain networks based on the minimum dominating set (MDSet), which refers to a minimal subset of nodes (MD-nodes) that control the remaining nodes with a one-step direct interaction. MD-nodes play a crucial role in various complex networks including biomolecular networks, but they have not been investigated in brain networks.

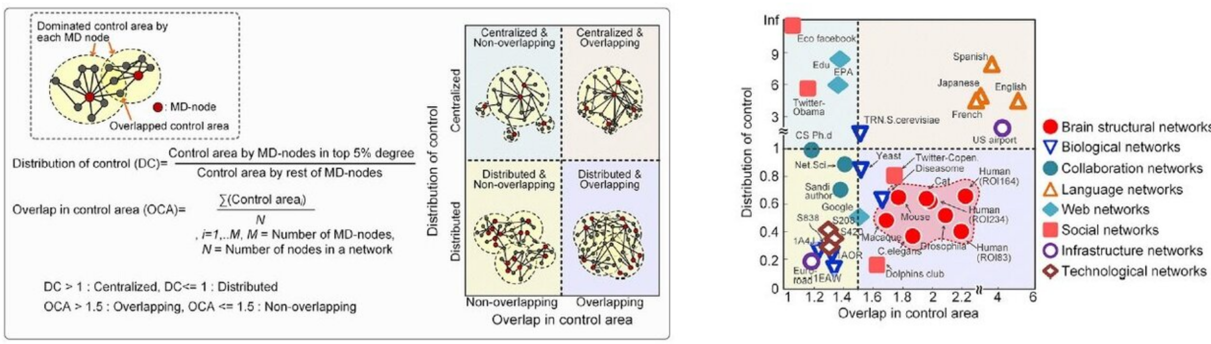

Figure 2. Identified control architectures of brain networks and other real-world complex networks. Credit: KAIST

By exploring and comparing the structural principles underlying the composition of MDSets of various complex networks, the team delineated their distinct control architectures. Interestingly, the team found that the proportion of MDSets in brain networks is remarkably small compared to those of other complex networks. This finding implies that brain networks may have been optimized for minimizing the cost required for controlling networks. Furthermore, the team found that the MDSets of brain networks are not solely determined by the degree of nodes, but rather strategically placed to form a particular control architecture.

Consequently, the team revealed the hidden control architecture of brain networks, namely, the distributed and overlapping control architecture that is distinct from other complex networks. The team found that such a particular control architecture brings about robustness against targeted attacks (i.e., preferential attacks on high-degree nodes) which might be a fundamental basis of robust brain functions against preferential damage of high-degree nodes (i.e., brain regions).

Moreover, the team found that the particular control architecture of brain networks also enables high efficiency in switching from one network state, defined by a set of node activities, to another—a capability that is crucial for traversing diverse cognitive states.

Professor Cho said, "This study is the first attempt to make a quantitative comparison between brain networks and other real-world complex networks. Understanding of intrinsic control architecture underlying brain networks may enable the development of optimal interventions for therapeutic purposes or cognitive enhancement."

This research, led by Byeongwook Lee, Uiryong Kang and Hongjun Chang, was published in *iScience* (10.1016/j.isci.2019.02.017) on March 29, 2019.

More information: Byeongwook Lee et al, The Hidden Control Architecture of Complex Brain Networks, *iScience* (2019). DOI: 10.1016/j.isci.2019.02.017

Provided by The Korea Advanced Institute of Science and Technology (KAIST)