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Research Article

Study on network and computational model of brain memory function

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Abstract: In order to discover the function of brain memory, the network is one of the ways to display the memory function. With network, the memory can be demonstrated by node or edge with structural analysis and functional discovery combing with imaging data. The results implied that the memory structure is a network and is also a network in functional analysis. Among them, neural network is a useful tool to study the function of memory. Except that, computational model is another way to display memory structure and function.

Keywords: Brain memory functional networks; Neural network; Complex network; Imaging; Computational model.

INTRODUCTION

Early on, as a kind of cognitive function, psychologists wanted to know many secrets of memory. How memories are formed, what is the process, how memories are stored and forgotten, and how to describe memory. When the memory formed, how does the brain handle memory data efficiently, when and how the forgetting comes, and how to remember the forgetting. Meanwhile, all the questions in the brain structure are the same puzzles. With times going on and the blending of disciplines, functions of memory are becoming clear gradually, especially the anatomy, neuroscience and radiation technologies. Although under the development of brain science and life science, the evolution mechanism, the overall structure and individual work forms are still under the water.

In this paper, we focus on the contribution of network to memory of human brain. Although the technology and method are more than network, it provides a novel view to recognize the function of memory. Network is a kind of structure in graph theory; after the definition of node and edge, the network forms to a logic data structure or model. By the structure we can analyze the inner relation and characters.

METHODS

From the network view, a tool is neural network which includes biological neural network and artificial neural network. Biological neural network generally refers to the biological brain neurons, cells, contacts and other components of the network, and it is the production of biological consciousness and helps biological thinking and action. Artificial neural network is a mathematical model of information processing that is similar to the structure of synaptic connections in the brain. With neural network, memory got many achievements such as association.

Another tool is complex network, which is based on graph theory and control dynamics. With complex networks, memory can be treated by a complex network with nodes and edges of different meanings.

Computational model is also a tool to simulate memory. A successful example is the three level processing model of memory information. The structure of memory consists of three parts from the sensory memory to short storage and long storage, and information flow also can be directly from the sensory memory to the long storage; long term storage of information can be extracted to deal with the current information in the short term storage

RESULTS AND DISCUSSION

Memory can be expressed to a network from the structural and functional way, especially in the neural-network perspective, with the help of physiology, psychology, anatomy, etc. [1–9]. Meanwhile, at different levels many reference models and algorithms were proposed from psychological to neural, much about memory functions, such as free recall,

recognition, learning and dynamics [10–14]. As a function of the brain, many of memory networks were studied as functional networks, even if in the region of artificial intelligence and neural network. Several associative neural memory models were discussed from the perspective of neuron and cortical layers. Mitterauer [15] proposed a new model of the reticular formation of the brainstem, the model referred to the neuronal and glial cell systems. Hasselmo and Wyble [16] simulated the effects of pharmaceuticals on human memory functions, and discussed the free recall and recognition in the memory network model. Talebi et al. [17] also investigated the changes in brain memory retrieval with pharmaceuticals and EEG data. Lv et al. [18] investigated the memory-network synchronization by the input signals and network topological characters. Romani et al. [19] reported a phenomenological model to simulate the memory information retrieval; they proposed that association was the key in information searching, and forgetting was affected by the retrieval process. Moreover, the retrieval process was deterministic, and encoding was random. Therefore, modular and submodular hierarchical structures could not be realized. Of course, some models aimed at specific brain cortical regions with physiological and anatomical substrates [16], or a specific memory catalog with cognitive tasks [20. Liang et al. [21] introduced a memory network model aimed at working memory, and developed the bistable neuron model for the recurrent structure of the brain's neocortex. Jaramillo et al. [22] reviewed the taste memory model for studying memory formation. Overall, in the neural network fields, revolving around the specific neural mechanisms or character functions of memory, many hierarchical and/or modular models were investigated extensively [6–11,23].

Recently, with the developments of information science, neuroinformatics, and complexity science, the studies on memory have been rapidly translated to model memory functional network based on complex network. Various brain memory functional networks were developed [15,24–29]. Among the studies, a remarkable branch is the quantitative analysis of memory based on the graph theory; in this method, the memory is modeled as a network of anatomical substrates and functional connections. Stanley et al. [30] modeled the working memory of modular organization with graph theory measures, complex network analyses and neuroimaging data. Burianova et al. [31] demonstrated a common brain memory functional networks model; they used different tasks and different memory types to model the memory retrieval. He et al. [32] found that the memory networks of Schizophrenia patients had been altered; the working memory did not perform the same as small-world network. Xu and Luo [12] reported a dynamic memory model with small-world network and simulated its adaptivity, then discussed the network dynamics affected by multiples delays. Overall, in the new fields, memory was investigated more extensively based on complex networks and graph theory, meanwhile combing with anatomical and functional imaging.

In the past several decades, despite extensive researches from the networks, a consensus has yet to be reached in the neuron level about the memory retrieval. Conceptually, the memory network ought to be interrelated, not only the anatomical neural organization, but also the phenomena of memory functions [6,11,15,16,33,34], such as Hebbian and anti-Hebbian phenomena, memory storage, training, controlling, forgetting, retrieving, association, manipulation, and maintenance of cognitive task or information processes [7,15, 33,34]. For memory function, several brain regions participate in the process, such as the prefrontal and medial temporal cortices, hippocampus, and amygdala [10,17,31]. Of course, many neurons take part in the memory process. for example, Zhu [35] also proposed a similar conception, namely, memorymeta, and explained that the memorymeta was a physical unit; the unit stored information and worked as a component of nerve cell.

CONCLUSION

Most of the models in the past were innovative; they can guide behavioral experiments, and understand the behavioral data, mechanism and phenomenon, even the clinical impairments and disorders [20,36,37]. However, despite these studies on brain memory functional networks, to date, few studies have attempted to construct network models with anatomical abstraction and functional characters discarding the specific experimental surroundings. Earlier studies focused on the designs of the experiment and the results of behavioral treatments in accordance with the experimental data, not the definitions of the node, edge, and mechanism of the memory network, which are more extensively applied to brain memory functional networks. From the results of them, we can conclude that network is the effective way to study the brain memory memory.

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