【Grant-in-Aid for Scientific Research (S)】

Broad Section G

Title of Project： Elucidation of cognitive and learning mechanism of cerebral cortex by multiscale optogenetics

OHKI, Kenichi
(The University of Tokyo, Graduate School of Medicine, Professor)

Research Project Number：19H05642　Researcher Number：50332622

Keyword：cerebral cortex, visual cortex, imaging, optogenetics, neural circuits, information processing

【Purpose and Background of the Research】

How does the brain perform complex information processing? How does the brain alter neural circuits through learning and acquire complex functions? Our first goal is to elucidate what kind of information each neuron receives and combines it to output complex information, as an elementary process of information processing in the brain. Our second goal is to elucidate how the information input to each synapse changes, as an elementary process of learning and memory. We will further elucidate the learning rules of synaptic plasticity from the viewpoint of information, and how the learning rules relate to the changes in the function of the cell.

In order to achieve both goals, we will develop a spine level functional imaging method using optogenetics, visualize the information input to each synapse, observe the change continuously, and elucidate the elementary processes of information processing and learning and memory at synapse level. Furthermore, in combination with cell population imaging, we will elucidate how these elementary processes contribute to learning as a whole network. Finally, we will activate the cell population artificially using optogenetics, and examine whether the activity of the cell population has a causal relationship with perception and learning. As described above, in multiscale from the synapse level to the whole brain level, we will elucidate the principles of information processing and learning rules of the brain.

【Research Methods】

(1) Develop functional imaging method of spine level using optogenetics

We will develop a method to comprehensively examine what kind of information is input to thousands of synapses of each neuron.

(2) Elucidate the elementary processes of information processing in the brain

We will develop a method to systematically investigate nonlinear complex receptive fields of neurons in higher visual area using deep learning. By combining the method of item (1), we will elucidate what kind of information each neuron in higher visual cortex receives and combines it to output complex information such as the shape of an object.

(3) Elucidate elementary processes of learning in the brain and learning rules

While the animal learns a new figure over time, we will observe changes in the selectivity of neurons in the higher visual cortex, and observe changes in the information input to the individual spines of the cells over time. We will clarify the learning rules of synapse from the viewpoint of information.

(4) Elucidate changes in information representation by cell population associated with learning and memory

In (3), we will clarify how the information input to individual neurons changes with learning. Here, we will further clarify how it contributes to learning as a whole network.

(5) Develop methods of photo-suppression at the area level and photo-activation of cell populations

In order to examine the causal relationship between the activity of the cell population and perception and learning, we will develop methods of photo-suppression and photo-activation.

(6) Verify causality between cell population activity in higher visual cortex and perception and learning

Using the methods developed in (5), we will examine the causal relationship between cell population activity and perception and learning.

【Expected Research Achievements and Scientific Significance】

We will clarify what kind of information each neural cell in the higher visual area receives and combines it to output complex information, and the learning rules of synaptic plasticity from the view point of information. We expect that the elucidation of the principle of information processing and the learning rule about the information will lead to the development of a new algorithm of artificial intelligence.

【Publications Relevant to the Project】

・Ukita J, Yoshida T, Ohki K. Characterisation of nonlinear receptive fields of visual neurons by convolutional neural network. Sci Rep. 2019 Mar 7;9(1):3791.

【Term of Project】FY2019-2023
【Budget Allocation】156,200 Thousand Yen

【Homepage Address and Other Contact Information】

https://physiol1.m.u-tokyo.ac.jp/ern24596/