Doctoral Dissertation summary

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Neuronal basis for object recognition and its functions

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Content

1.1 Summary of doctoral dissertation

Object recognition is one of the fundamental brain functions. The visual system rapidly and effortlessly recognizes a large number of diverse objects in cluttered, natural scenes, which is usually a difficult task for computer vision. In the present study, neuronal basis for object recognition and its functions have been investigated with the use of behavioral and electrophysiological methods. To understand the underlying neuronal mechanism on object recognition, Japanese monkeys were trained to have different prior experiences on trained objects through three types of object discrimination tasks before electrophysiological recording. The behavioral change as well as the electrophysiological change in inferotemporal cell activity were systematically investigated. This thesis summarizes the results. The thesis consists of five chapters. The research background, behavioral results, electrophysiological results at the level of single cells and at the level of cell population are summarized in different chapters.

1.2 Summary of doctoral dissertation chapters

1.2.1 Preface

This chapter summarizes the results of previous studies on the representation of visual information in the IT cortex in monkeys. The brain is the center of the nervous system of humans and non-human primates. It integrates inside or outside information and then exerts control. In neuroscience, the operations of individual neurons in visual cortices have been studied in considerable detail, for example, the action potentials can be detected extracellularly through placing a micro-electrode to a neuron *in vivo,* and however, the neuronal mechanism underlying visual functions remains a mystery. Inferotemporal (IT) cortex in monkeys locates at the last stage of the ventral cortical pathway, which, as temporal association cortex, has been demonstrated to be critical for object recognition and discrimination. To understand the overall visual functions of the brain, it is important to figure out the underlying neuronal mechanism in this area.

1.2.2 Chapter 2 ~ Chapter 4

Chapter 2 "Single neuron response in PIT and AIT to 3D object images with long-term visual experience" describes the results in single-cell electrophysiological activity. The representation of three-dimensional object was investigated through investigation of single cell stimulus selectivity. Furthermore, we also investigated the changes in the responses of single neurons after long-term object discrimination experiences. Cytoarchitectonically, IT

can be divided into the anterior part of the inferotemporal cortex (AIT) and the posterior part of the inferotemporal cortex (PIT). I also examined the difference in the properties of stimulus selectivity between AIT and PIT, with a focus on response tuning across changes in object viewing angle. As a result, the response of PIT cells did not show tolerance to the change in viewing angle. In contrast, AIT cells demonstrated response tolerance of 60° - 90° in viewing angle. As AIT receives mainly the neuronal projection from PIT, this result provides a possible explanation on the formation of cell stimulus selectivity in AIT.

In Chapter 3 "Population coding in PIT and AIT" I investigated the stimulus selectivity and its dynamical changes based on the cell population activity. To understand the underlying neuronal mechanism for view-invariant object recognition, not only the activity in single-cell level, it is important to know the behavior of cell population activity. To evaluate the distance between neuronal representations of two stimulus images, Pearson's correlation coefficient (r) representing the similarity of responses in the cell population was introduced. A population vector was generated from the responses of all cells to each stimulus, and a Pearson correlation coefficient (r) was calculated between the vector pairs. 1-r is defined as the distance between stimulus images. Smaller distance denotes more similar neuronal representations of two stimulus images. In AIT, the distance between different viewing angle images of the same object was significantly smaller than the distance between different objects in the same viewing angle difference. In AIT, the responses in cell population showed the activity tolerance in the range of viewing angle up to 90°. On the other hand, the tolerance of response was in the range of up to 30° in PIT.

Chapter 4 "Dynamics of stimulus selectivity in inferotemporal neurons" discusses the dynamics of stimulus selectivity. I proposed a method identifying the optimal stimulus image in a stimulus set with a temporal resolution which can be as high as several ten milliseconds. As an application demonstrating the power of the method, the response time period was divided into the 100 - 280 ms as the early phase and 280 – 660 ms as late phase. I found that IT neurons could be divided into four types depending on the stimulus selectivity in the early and late phases: cells selective to the same viewing angle image of the same object, cells selective to different viewing angle images of the same objects, cells selective to the same viewing angle images but different objects, and those selective to different viewing angle images of different objects. Finally, I demonstrated the possibility by using the proposed method to trace the stimulus selectivity change in the temporal resolution of 20 ms.

1.2.3 Conclusion

I made final conclusion of this study in Chapter 5 “Conclusion”. After the prior experience of object discrimination across viewing angles, AIT cell response tolerance was confirmed over the arrange of 30° - 60° in viewing angle at the single-cell level, and response tolerance of up to 90° was observed at the cell population level. In contrast, in PIT, cells did not show any significant viewing angle response tolerance at the single-cell level, a viewing angle tolerance in the viewing angle range of about 30° was observed at the cell population level. In addition, the change in IT cell stimulus selectivity of single cells displayed various patterns in the time course during their responses, which implies the necessity for further analysis of such patterns.