論文の内容の要旨

博士論文題目
Modeling Neural Dynamics of Adaptive Color Information Processing

（適応的色情報処理の神経ダイナミクスのモデル化）

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（ 本 文 ）

Chromatic environment around us keeps changing. Light intensity and spectrum change dramatically with wide range of time from ms to decades. In addition, chromatic information to acquire and tasks to deal with differ depending upon situation. In spite of such dynamic chromatic environment, the visual system acquires necessary chromatic information, and maintains a stable color perception. How can adaptive color information processing be accomplished in the brain? This study investigates some possible mechanisms which play a role for both dynamic and adaptive color information processing, through model analysis and psychophysical experiment.

First, we investigated chromatic adaptation, which induces to adjustment of sensitivity to intensity and spectrum of received light. Although it is known that chromatic adaptation occurs with various time scales, long-term chromatic adaptation has been less studied. We investigated long-term adaptation and the interaction between adaptations with different time constant, thinking several-second afterimage as short-term adaptation. In the first experiment, strengths of chromatic afterimage in L-M axis are measured under each three adaptation condition; achromatic, middle-term and long-term chromatic adaptation. We found that adaptation longer than 3 hours influenced the strength of afterimage. The afterimages of the similar color inducer to long-term adaptation color strengthened after long-term adaptation, on the other hand, the afterimages of the opponent color inducer weakened. In the second experiment, effect of background color, i.e. contrast adaptation, was also considered. The afterimage strengths of the similar color inducer did not change. Our results imply that multi-stage adaptive systems of the early visual pathway including post-receptoral process can involve in long-term adaptation, and the unique characteristics of long-term adaptation.

Next, we propose a chromatic adaptation model, based on the neural physiological knowledge of the early visual pathway. The model consists of multiple cortical and retinal adaptive mechanisms with different time constants. Through simulating the cortical process with the model, the contribution of the cortical adaptation system can be estimated. Subsequently, plausible mechanisms for chromatic adaptation with wide range of time can be analyzed. Our model reproduces dynamic changes in color appearance during and after the adaptation with a broad range of temporal scales, reported in the previous experiments. Additionally, we applied the model to various conditions of chromatic illumination and provide testable predictions on the color appearances and their dynamics in changing chromatic environments. These results suggest that neural plasticity can induce the characteristics of long-term chromatic adaptation including sustained shift of equilibrium point.

Finally, we propose the higher order color information processing model in the brain. We can perceive color using functions in visual perception, such as category and memory depending upon circumstances. Although it has been considered that higher visual areas are important sites for color perception with the functions, it is still unclear how to achieve higher order color information processing by neural network. We propose a neural population coding model for dynamic higher order color perception under top-down and bottom-up processing. The model can explain many phenomena related to higher order color information processing; the time evolutionary interactions between color category and color memory, and color discrimination as well as the task-dependent properties of neurons in IT cortex. Furthermore, we made proposals of additional analyses of Koida and Komatsu (2007) from the perspective of neural population coding on the basis of the model estimation; 1) task-dependent response of neural population, 2) temporal evolution of neural population activities, 3) functional significance of task-dependent neural population activity. The analysis results by Koida are basically consistent to our predictions. The model process can be interpreted as sub-optimal Bayesian estimation. The results suggest that perceptual biases found in task-dependent modulations of neural responses may be explained as a natural consequence of statistically optimal estimation.

We investigate adaptive color information processing in the brain to achieve dynamic color perception, through models and psychophysical experiments. We propose applicable adaptive models for dynamic color perception using physiological mechanisms which spread from the retina to higher stage in the visual pathway and which originate in the levels from single neuron to interactive neural populations. This study implies that adaptive color perception can be achieved by combinations of physiological mechanisms with each corresponding time scale and the stage in which the mechanisms work of color information processing pathway.