様式３

論　文　内　容　の　要　旨

氏　名　（　畑中　岳　）	
論文題名	Functional architecture for image statistics in early and mid-level visual cortical areas in macaque monkeys （マカカ属サル初期ならびに中次視覚野における画像統計量についての機能構築）

論文内容の要旨

Distribution patterns of functional specificities of neurons for visual image statistics determined the functional architecture of visual cortical areas. Elucidation of the architecture of a cortical area provides a critical clue to understanding how the neurons process the visual input and represent the information about the external world. Natural scenes are characterized by diverse set of image statistics, including various parameters of the luminance histogram, outputs of Gabor-like filters, and pairwise correlations between the filter output combinations of different positions, orientations, and scales (Portilla-Simoncelli statistics). Some of these statistics capture the response properties of visual neurons to the presentation of natural images and scenes. However, it remains unclear to what extent such statistics can explain neural responses to natural scenes and how neurons that are tuned to these statistics are distributed across the cortical plane. By the combination of an encoding-model approach and two-photon calcium imaging method, I addressed these issues in macaque visual areas V1 and V4. For each imaged neuron, I constructed an encoding model to mimic its responses to natural movies. By extracting Portilla-Simoncelli statistics through outputs of both filters and filter correlations, and by computing an optimally weighted sum of these outputs, the model successfully reproduced responses in a subpopulation of neurons. I evaluated the selectivities of these neurons by quantifying the contributions of each statistic to visual responses. Neurons whose responses were mainly determined by Gabor-like filter outputs (low-level statistics) were abundant at most imaging sites in V1. In V4, the relative contribution of higher-order statistics, such as cross-scale correlation, was increased. Preferred image statistics varied markedly across V4 sites, and the response similarity of two neurons at individual imaging sites gradually declined with increasing cortical distance. The results indicate that natural scene analysis progresses from V1 to V4, and neurons sharing preferred image statistics are locally clustered in V4. The combination of neural modeling methods, multi-scale and long-term imaging methods will extend the limitation of understanding the functional architecture in early and mid-level visual cortical areas in macaque monkeys.

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論文審査の結果の要旨及び担当者

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論文審査の結果の要旨

本研究では、霊長類大脳皮質視覚野におけるニューロンの応答特性と皮質内における空間配置の関係を、自然風景に含まれる画像統計量の計算アルゴリズム（PS 統計量）とニューロンの視覚応答を説明する符号化モデルを適用することによって検討した。自然動画刺激に対する視覚野ニューロンの応答を、二光子カルシウムイメージング法を用いてサルの初期視覚野（V1野）と中次視覚野（V4野）において記録した。V1野では方位・空間周波数がニューロンの視覚応答性に最も関係し、V4野では輝度分布統計量や方位・空間周波数フィルター出力間の相関など、より複雑な画像統計量の貢献が大きかった。両領野野において、似た応答選択性を持つニューロンは集まる傾向を示し、特にV4野では反応画像統計量に基づくサブ領域構造が存在することが示された。本研究は、霊長類視覚野における情報処理過程とそれを支える領域構造の理解を進めた。博士学位を授与するのに値するものと認める。