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様式３

論　文　内　容　の　要　旨

〔　題　　　名　〕

Visual information processing and integration mechanism of cat early visual pathway
（ネコ初期視覚経路における視覚情報処理及び統合メカニズム）

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In the early visual system of mammals, visual information is received by the retina and then relayed to the primary visual cortex (V1) via the lateral geniculate nucleus (LGN). Through these stages, receptive field (RF) properties, such as orientation-, spatial frequency-, and temporal frequency-tunings, are successively elaborated, which expands the sensitivity for various visual features in neurons of the early visual system (Hubel and Wiesel, 1959, 1962; Enroth-Cugell and Robson, 1966; Campbell et al., 1969; Movshon et al., 1978; Derrington and Fuchs, 1979; Frishman et al., 1987).

In the LGN of cats and monkeys, it had been commonly believed that neurons exhibit only weak or no orientation selectivity, and their RFs are almost circular (Hubel and Wiesel, 1959, 1962, 1977). However, more recent studies have reported that LGN neurons exhibit moderate orientation sensitivity in cat (Soodak et al., 1987; Shou and Leventhal, 1989; Smith et al., 1990), mouse (Scholl et al., 2013; Zhao et al., 2013; Niell, 2013), and marmoset (Cheong et al., 2013) due to an elliptical RF structure (Soodak et al., 1987; Ahmed and Hammond, 1991). Meanwhile, it has been suggested that the non-linear response modulation from outside the classical RF (CRF) was sensitive to the stimulus orientation (Sillito et al., 1993; Sun et al., 2004; Naito et al., 2007), suggesting an elliptical CRF alone does not explain orientation selectivity. In other words, there is a possibility that even when the CRF is completely circular, LGN neurons exhibit significant orientation selectivity due to a simultaneous stimulation of CRF and outside the CRF which induces orientation-sensitive surround suppression.

Therefore, I directly described the spatiotemporal RF structure of cat LGN neurons using a reverse correlation method with dynamic noise stimuli. I found that a certain population of LGN neurons exhibits a significantly elongated RF structure and that the long axis of the RF structure of individual neurons corresponds to their preferred orientation. Additionally, the measured orientation tuning was significantly sharper than that predicted from the RF structure. My results suggest that orientation-tuned non-linear operations between linear products from the RF and spiking response contribute to orientation tuning in the LGN and that this is due to suppressive modulation elicited by a stimulation of outside the RF (Suematsu et al., 2012).

However, there were still questions: how the elliptical RF structure of LGN neurons was generated, and how the orientation selectivity of LGN neurons contributed to that of V1 neurons. Then, I investigated the mechanisms generating the RF structure of cat LGN neurons, conducting simultaneous recordings of retinal ganglion cells (RGCs) and monosynaptically connected LGN neurons, and found that RGCs and LGN neurons exhibited similarly elliptical spatial RF structures, and that an RGC projection of the same response sign was the primary contributor to the generation of the RF center of the LGN neuron, while an RGC projection of the opposite response sign was responsible for enhancing the antagonistic surround. In addition, the temporal RF structure of an RGC was tightly correlated with its target LGN neuron. These results suggest that the elongated RF of LGN neurons is mainly inherited from that of the primary-projecting RGC and that convergent inputs from multiple RGCs improve the stimulus feature sensitivity of LGN neurons, presumably contributing to efficient processing in the visual cortex (Suematsu et al., 2013).

様式 7

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

申請者は、動物が物を見る際に脳内のニューロンにおいてどのような反応が起こり、その視覚情報がどのように伝わり処理されるのかを探る研究を、ネコの初期視覚系をモデル系として用いて行った。眼に入ってくる視覚情報は網膜において電気信号に変換され、網膜神経節細胞から外側膝状体ニューロンへと運ばる。申請者は、麻酔非動化ネコの外側膝状体ニューロンの活動を細胞外記録法により計測し、個々のニューロンの受容野（ニューロンの見ている領域）と方位（例：物体の輪郭線の傾き具合）に対しての選択性を定量的に解析した。その結果、外側膝状体ニューロンの方位選択性は楕円形受容野構造と応答修飾により形成されることを明らかとした。

更に、申請者は、麻酔非動化ネコの網膜神経節細胞及び外側膝状体ニューロンの同時記録を行い、機能的結合の同定されたペア間での受容野の比較を行った。その結果、網膜から外側膝状体へと投射が行われる際、最適方位は維持され、空間周波数（例：線分の細さ）や時間周波数（例：光の点滅頻度）に対しての選択性が変化し得るような、収束する結合関係が存在することを明らかとした。

申請者の研究は、１）外側膝状体の神経細胞において見られる方位（例：物体の輪郭線の傾き具合）に対しての選択性を定量評価し、そこに係わる神経基盤を明らかとした点、２）網膜神経節細胞から外側膝状体の神経細胞への投射様式を詳細に検討し、網膜から外側膝状体へ信号が伝わる際に視覚情報への選択性がより強まる投射様式となっていることを明らかとした点、この二点において意義及び新規性がある。

これら研究成果は既に二本の原著論文として出版されており、学位の授与に値すると考えられる。