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博士の専攻分野の名称	博士（工学）
学位記番号	第 24984 号
学位授与年月日	平成23年12月31日
学位授与の要件	学位規則第4条第1項該当 生命機能研究科生命機能専攻
学位論文名	The role of macaque area V4 in fine stereoscopic depth perception （細かい奥行き知覚におけるサル視覚皮質V4野の役割）
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論文内容の要旨

Primates are capable of discriminating depth with remarkable precision using binocular disparity. Neurons in area V4 are thought to play a role in fine stereoscopic depth perception because V4 neurons are selective for relative disparity, which is the crucial visual cue for discrimination of fine disparity. However, there has been no direct comparison of responses of V4 neurons and fine disparity discrimination. In this thesis, I investigated the relationship between neuronal responses in V4 and perceptual decisions about fine disparity.

I conducted a series of experiments in monkeys discriminating whether the center disk of a dynamic random-dot stereogram was in front of or behind its surrounding annulus. I first behaviorally tested the reference frame of the disparity representation used for performing this task. After learning the task with a set of surround disparities, the subject generalized its responses to untrained surround disparities. The results suggest that the decisions were generated from a neural representation of disparity in a relative frame of reference. I then recorded single-unit responses from V4 while the monkeys were performing the task. I quantified the sensitivity of V4 neurons in relation to psychophysical performance of the subjects. I found that neuronal thresholds were higher than the behavioral thresholds on average. The most sensitive neurons reached thresholds as low as the behavioral thresholds, indicating that V4 contains the disparity signals that are sufficiently reliable to support psychophysical performance. I then examined trial-to-trial covariation between responses of V4 neurons and fine disparity judgments. For subthreshold disparities, the monkeys made frequent errors. The variable decisions were predictable from the fluctuation in the neuronal responses. The predictions were based on a decision model in which each V4 neuron transmits the evidence for the disparity it prefers. I finally altered the disparity representation artificially by means of microstimulation to V4. The decisions were systematically biased when microstimulation boosted the V4 responses. The bias was toward the direction predicted from the decision model, establishing a causal link between V4 responses and fine disparity discrimination.

Taken together, I conclude that disparity signals carried by V4 neurons underlie precise

discrimination of fine stereoscopic depth. No other areas have been found to contribute to fine disparity discrimination in a bottom-up manner. V4 may play a unique role in stereopsis among a number of visual cortical areas representing stereoscopic depth.

論文審査の結果の要旨

本研究は、サル大脳皮質の視覚連合野V4野が「細かい奥行き知覚の生成に関わっているかどうか」を検討し、以下の点を明らかにした。

１．細かい視差弁別課題を、サルが「相対視差」情報を利用して遂行している。

２．この課題遂行中のV4細胞の感度とサルの行動感度の比較をし、一部の細胞が行動と同等の感度を持ち、細胞集団としては、細胞の方が動物個体より感度が低い。

３．V4細胞活動の試行間変動は、サルの奥行き判断の試行間変動と相関する。

４．奥行き判断と相関した活動は、刺激提示後、短潜時（60-70ミリ秒）で現れ始める。

５．V4野に局所電気刺激を与えると、刺激部位の細胞の好む奥行き方向にサルの奥行き判断がバイアスされる。

上記の結果は、V4細胞の活動が直接的に、細かい奥行き知覚の形成に関わっていることを示している。また、V4野の神経細胞活動を人為的に上昇させることで知覚判断がバイアスされるという結果は、どのような知覚でも示されたことはなく、V4野と視知覚を因果的に結びつけた初めての成果である。

本研究成果は両眼立体視の脳内メカニズムに関する理解を進めたものとして学位に値すると考える。