氏名	小　島　　淳
学位（専攻分野）	博士（学術）
学位記番号	総研大甲第５６号
学位授与の日付	平成 ５ 年 ３ 月２３日
学位授与の要件	生命科学研究科　生理科学専攻 学位規則第４条第１項該当
学位論文題目	Tonic Activity during Visuo-oculomotor Behavior in the Monkey Superior Colliculus
論文審査委員	主　査　教　授　亘　　弘 教　授　彦　坂　興　秀 教　授　山　岸　俊　一 教　授　丹　治　　順（東北大学）

論文内容の要旨

The superior colliculus is a phylogenetically old structure located in the midbrain. It plays a key role in orienting response - movements of the eye, head, and body toward a newly appearing, salient object. Underlying this response is multimodal sensory inputs (e.g., direct visual inputs from the retina) and heterogeneous motor outputs (e.g., projections to brainstem saccade generators). However, the brain receives sensory inputs continually in parallel, and there must be the mechanism for selection to determine to which stimulus the animal should respond. Such selection requires cognitive processes such as attention, memory, and movement preparation.

The objective of the present research was to examine whether the superior colliculus is involved in such cognitive processes. For this purpose we trained monkeys to perform a series of behavioral tasks and recorded single cell activity from the superior colliculus while the animal was performing the tasks.

In these tasks the monkey was required, during a time period (2-3 sec), to select a stimulus, remember its position, or prepare for an eye movement. The neural activity related to these processes was expected to appear as a tonic, sustained spike discharge during the period. To analyze the nature of the tonic activity we used three main tasks (overlap saccade task, delayed saccade task, and attention task) and additional control tasks.

In the overlap saccade task (SACO), the monkey was required to make a saccade to remembered position of peripheral light spot which had been cued during fixation. In the attention task (ATT), the monkey was required to detect dimming of the peripheral spot light, without making an eye movement. We assumed that these tasks would selectively or preferentially reflect different aspects of cognitive processes - movement preparation, memory, and attention.

We used three monkeys. After training of these tasks, monkeys were implanted with a head holder on the skull and search coil monocularly in order to monitor eye positions (Robinson 1963), under anesthesia with pentobarbital sodium. Extracellular action potential was recorded by a glass coated elgiloy electrode.

We recorded 141 neurons showing tonic activities in the superior colliculus. The superior colliculus consists of three layers: the superficial, the intermediate, and the deep layers. Based on previous reports which had been accepted unanimously, neurons without saccadic activity (n=33) were considered to be in the superficial layer, while neurons with saccadic activity (n=108) were in the intermediate layer. We later confirmed this assumption by histological examination.

These neurons also discharged physically after visual stimuli and/or around saccade. Tonic activities had preferential retinotopic fields, which were similar to the visual receptive fields and the saccadic movement fields of the same neurons.

Depending on the predominance of the activities during the delay period among the three tasks (SACO, SACD, ATT), we classified the tonic neurons into four types: (1) visuomotor (activity was significantly greater in SACO), (2) mnemonic motor (SACD dominant)< (3) visual attention (ATT dominant), and (4) nonspecific (others; no single task was dominant).

In the intermediate layer, more than a third of tonic neurons were found to be selective for one of the tasks: visual attention (n=13), visuomotor (n=13), and mnemonic motor (n=15). The other neurons (n=67) were of non-specific type. In the superficial layer, specific types were less common: visual attention (n=3) and visuomotor (n=4). Mnemonic motor type was not found. The other neurons (n=26) were of non-specific type.

In conclusion, the tonic neurons in the superior colliculus, especially in its intermediate layer, are involved in information processing underlying memory of the target location, the preparation of saccade and the peripheral attention. Their signals may be sent to the phasic responsive neurons in the superior colliculus and/or the brainstem saccade generators, and modulate saccadic eye movements. Furthermore, they may be sent to the thalamic neurons, to which the neurons in the intermediate layer project. The superior colliculus might participate in the processes in which memory-, preparation-, and attention-related signals are maintained. These processes may be accomplished by multiple loop circuits formed with the cerebral cortex, thalamus, basal ganglia, and superior colliculus.

論文の審査結果の要旨

本論文は、サル上丘のニューロンが記憶・注意・運動の準備という認知的な活動を示すことを明らかにした論文であり、学術博士にふさわしい内容を有すると判断された。

中脳の上丘は「定位反応」において中枢的な役割をもつことはよく知られている。このことは、突然現れたものを感知してその方向に眼球・頭・身体を向けるという、動物にとってもっとも基本的な行動である。しかし、これが単なる反射的なメカニズムではなく、「判断」と「選択」が要求される行動である。

本研究の目的は、このような判断と選択に必要な情報が、上丘のニューロンによってどのように伝達されているかを明らかにすることであった。いくつかの視覚・眼球運動課題を訓練したサルの上丘から単一ニューロン活動を記録し、比較した結果、記憶・注意・運動準備のそれぞれを特異的に反映するような持続的な活動を示すニューロンが中間層に存在することを発見したのである。

この結果は、これまで精密な「神経機械」として理解されていた上丘の機能にあらたな側面をつけ加えるものであり、高く評価される。論文の構成と文章（英文）も適当なものである。

しかし、記憶や注意という認知的活動を動物実験を使って定義し、評価することは依然として実験的段階であり、その妥当性は常に再検討されなければならない事が指摘された。これは本研究が継続されるに当たっての課題であろう。