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수의학석사학위논문

A Cross-Correlation Study among Neurons Recorded with Multi-Channel Electrodes in Areas 17 and 18 in the Cat

고양이 17과 18영역에서 다중 채널 전극으로 기록한 신경세포들 간의 상호 상관 연구

2015년 8월

서울대학교 대학원

수의생명과학(신경과학)전공

이 가 영

ABSTRACT

A Cross-Correlation Study among Neurons Recorded with Multi-Channel Electrodes in Areas 17 and 18 in the Cat

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The primary visual cortex located in the occipital lobe of a cat's brain processes visual information that is converted into electrical signals through the lateral geniculate nucleus. The nerve cells of the primary visual cortex have a tendency to prefer particular visual stimuli and this is called 'response selectivity'. Multilateral research regarding nerve cells with these characteristics have been conducted since the 1950s but there has not yet been any studies which clearly reveal connections between nerve cells with response selectivity.

Therefore, this study collected neural signals through multichannel electrodes to verify connections between visual nerve cells using nerve cell reactions of 50 different visual stimuli. The collected nerve cells were stored as neural data using a data collection system and categorized by visual stimuli and of 100 channels, 31 channels with relatively clear reactions were selected. These 31 channels were divided into 6 cases according to stimuli type, channel number, and cell, and after cross correlation analysis, cross correlation values and graphs were drawn and finally, comparative analysis was performed. As a result, while connections with clear differences between nerve cells according to visual stimuli were not discovered, as cross correlation values of nerve cells for different channels during identical visual stimuli mostly appeared to be higher than cross correlation values for different visual stimuli, it was verified that connections between nerve cells that react to identical stimuli appear to be stronger.

Keywords: Cross-correlation analysis, Multi-channel electrodes, Visual stimulus, Primary visual cortex
Student Number: 2011-21691

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INTRODUCTION

In the visual information processing, image signals entered the eyes are converted into electrical signals by a photo-receptor cell and the signals are passed to a visual cortex area through the lateral geniculate nucleus (LGN). Neurons in the visual cortex respond differently according to the type of visual information passed by this process (Hubel, 1963). In particular, neurons in area 17 (primary visual cortex, V1) and area 18 (secondary visual cortex, V2) of the cat brain tend to favor a specific visual stimulus such as spatial frequency (Campbell *et al.*, 1969), speed (Cynader and Regan, 1982) and direction in moving sine wave stimulus and orientation (Ferster, 1986). The visual cortex neurons showing response selectivity represent a high firing rate for a favorite stimulus. Neural data is necessary for search of the response selectivity and micro-electrode mostly is used to collection of neuronal data. A single microelectrode inserted outside neurons mainly was used from 1950s to 1980s. After 1990s, use of multiple-electrode recording became increasing in neurophysiology and it is used to investigate movement of many neurons from various animal's brain simultaneously (Brown *et al.*, 2004). Thanks to progress of multiple-electrode technology neuroscientists are able to research how neurons interact in the information processing

process of the visual cortex and many studies about correlation between visual cortex neurons have been actively conducted with any amount of neural data (Eckhorn *et al.*, 1988; Nauhaus *et al.*, 2009). In these studies, it is important to select the data analysis tool that affects study result. Various analysis programs have also been consistently advanced and developed until now. At present, some software analysis tools have an all-purpose development environment that is already used in neuroscience research (Lidierth, 2009). For examples, FIND (Finding Information in Neural Data) is an analysis tool for neurons collected from a data acquisition system (Meier *et al.*, 2007) and a toolbox called MClust enables a user to perform automatically collect with single or multi electrode (Fraley and Raftery, 1999). A neural data obtained from multi-channel electrodes may have evidence or clue about certain interconnection among neurons during visual stimulus and could be suggest a crucial key in study of brain function. Thus, analysis and interpretation of experiment data are very important in studying neurophysiology than acquired any number of data through frequent experiment. This method is devised to draw theory about similarity between units and has been used in neuroscience research to investigate neural network and function of brain (Narayanan and Laubach, 2009). It's because the connection between neurons may have relevance to information delivery in the nervous system.

Studies about neurons have proposed that correlation between neurons could be enough to discover information for neural interactions (Quiroga-Lombard *et al.*, 2013). Thus, in this study, the cross-correlation between neurons in primary visual cortex was calculated by using 'crosscorr' function in MATLAB.

The visual information process and neurons of V1

When a cat recognized an object or images in front of eyes, the visual information transmitted to the left and right eyes was accepted through the nerves. The rough visual information of optic chiasm is transmitted to the secondary visual area at the occipital lobe in the back of brain through the LGN (Figure 1). Nerve cells in cat primary visual cortex collected by using multi-electrode arrays are have a tendency to prefer particular visual stimuli that have each different receptive field, direction, velocity, spatial frequency of drifting sinusoidal gratings and orientation.

Multi-electrode arrays

A present computer can gather various types of signals from multi-electrode arrays (MEA) (Figure 2) and simultaneously save large amounts of neuron spike data to a server. The MEA, the electro-physiology system, was often used to collect neural signals from the visual cortex. It has been improved for a

long time and more and more researchers will be used to experiment this system so as to study about certain function of neuron.

Cross-correlation method and 6 cases of analysis

Cross-correlation is a statistical method used to find whether selected two neurons have functionally relevant. This is sliding inner-product and measures similarity of two neuron's activity. In statistics, this method is used for comparing to the similarity between the entries of two signals. They are frame shifted in time relative to one another and the two values are multiplied at each of these frame shifts and added together (Taghva *et al.*, 2012). Recent many studies generally analyzed to confirm the correlation between neurons for same stimulus than completely different stimulus. This study was analyzed to check the correlation for different visual stimuli and cross-correlation analysis was used to find an error of data analysis program development by MATLAB. Obtained data were divided into 6 cases according to stimuli type, channel number, and cell. Correlation analysis between neurons was conducted following Table 1.

MATERIAL AND METHODS

Animal preparation

All experimental procedures were carried out according to the Seoul National University Animal Care and Use Committee. Each experiment used four adult cats weighing between 3.5~4 kg (Hanlym Lab. Animal Co.) of female and male. Atropine sulfate (0.2 mg/kg; Dai Han Pharm. Co., LTD.; I.M.) and dexamethasone disodium phosphate (1.0 mg/kg; Sinil Pharm. Co., LTD.; I.M.) were injected to decrease tracheal secretions. Cats were anesthetized with Ketamine (15 mg/kg; Korea United Pharm. INC.; I.M.) and Xylazine (1.5 mg/kg; I.M.) at first. During surgery, an endotracheal tube connected to an isofluorane gas anesthesia machine (Techbase Pty., LTD.) was inserted to artificial respiration. Four cats were anesthetized with 2−3% isofluorane (Hana Pharm. Co., LTD.). A stainless steel peg was set afterwards in the stereotaxic restraint and the head of the cat was placed in a modified stereotaxic frame (Boardthech, Korea). An operation was performed over the lateral gyrus of left hemisphere and dura mater was removed (Kim, 2010). After surgery, the isofluorane was maintained at 0.5−1% during neuronal response recording. The cat was paralyzed with gallamine triethiodide (10 mg/kg per hr; Myraxan, Yoo Young Pharm. Co., LTD.) and persistingly infused

(5−10 ml/h) through intravenous catheter. Respiratory pump (Clare ventilator, Australia) controlled respiratory volume and rate. The end−tidal CO was maintained constant as 3.8−4.2% and heart rate was monitored by a capnograph (BCI, Inc.). Body temperature was kept 37.5℃ with thermostatically controlled by heating water pad and electrocardiogram was constantly monitored. Retinal landmarks were checked by using topical applications of phenylephrine hydrochloride (Neosynephrin−POS, 10%; Ursa pharm. Co., LTD.) and atropine (0.1%) was used to dilate the pupils on an eye (Bergeron *et al.*, 1998). A zero power contact lens was put on the eyes to prevent dehydration and 5 mm artificial pupils were set in the front of the right eyes to improve image resolution. A spherical lens (2 ~ 3 diopters) was set in the front of the left eye to adjust the span while the other eye was covered.

Visual stimulus presentation and receptive field

Visual stimulus was made with Visionworks for Electrophysiology (Vision Research Graphics, USA) and shown on the 19 inch monitor (Samsung Model 950NF, Korea). The monitor had a 1024 x 768 pixel resolution and 85−Hz refresh rate and set 57cm from the cat eyes (Figure 3). To find receptive field, moving bar passed on the computer screen at 16 different orientations (22.5 degrees interval). Drafting sinusoidal gratings appeared within a small patch (1~2 deg. x

15 deg. or 15 deg. x 1~2 deg.). In a particular orientation and spatial frequency, the stimulus was shown during 1 sec along the length axis (at 11 different locations with 1.3 deg. intervals between −7 and +7 degrees from the center). Between stimuli, resting discharge was recorded. This test provides a response profile across the width axis. Each test was repeated at 16 different directions. The 16 receptive fields could be mapped at 16 directions. From these, only one receptive field from each channel that showed the strongest response was chosen for receptive field mapping.

Electro−physiological recording

Neurons in primary visual cortex were recorded by using a Utah electrode array (UEA, Bionic Technologies, Inc., USA). The UEA was inserted to a depth of 1 mm at lateral gyri and the junction of the lateral and gather neuron's response for visual stimulus. And then, the neural signals were amplified (5000) and filtered (250−7500 Hz). A data acquisition system (Bionic Technologies Inc., USA) digitized (8 bits, selectable resolution of 0.5−8 V per bit, 30000 samples per second).

Types of visual stimuli

Used 50 vane visual stimuli (rotating windmill pattern: Figure 4) were viewed in a circle (15 deg. × 15 deg.). The rotation stimulus was a windmill pattern, comprising two to ten alternate

black and white sectors, rotating at various rotations per minute (rpm). The number of vane of rotating windmill pattern was five (2, 4, 6, 8, and 10) and the number of rotating speed was ten (five clockwise and five anticlockwise: 50.0, 38. 9, 27. 8, 16.7, 5.6, −5.6, −16.7, −27.8, −38.9 and −50.0 rpm). These sets repeated 4 times.

Data analysis

When neural data have a number of noisy spikes and internal dynamics, the neuron can' t be arranged by the time of occurring. To extract a neuron activity for certain stimulus in obtained data, inter spike interval duration was used. The neurons that represented a good response for certain stimulus were chosen. The neuron was sorted by the response time of the first spike. A response of neurons was classified as the reaction of a single neuron by using MATLAB Sorting Programs v2.0 Beta (Bionic Technologies, Inc., USA). And then cross-correlation analysis code developed to calculate the similarity between two neurons (reference neuron and target neuron) was used. Usually, spike data are analyzed by computational function like crosscorrelogram, joint PSTH, autocorrelogram and so on. Of these, cross-correlation analysis uses one as a reference neuron and other neuron as a target neuron and shows firing rate of the two neurons occurred in designated time (Figure 5). This analysis allowed us to combine a

physiological measure of the strength and type of connection between neurons with a characterization of their receptive field properties. And cross-correlation graphs were drown by accumulating a histogram of time differences between the occurrences of spikes in the two recorded neurons (Ts'o *et al.*, 1986).

RESULTS

All spike data for 50 vane stimuli collected from multi-electrode array with 100 channels and roughly 700 cells (100 channels x 7 cells) were obtained in four cats (Figure 6). The data was classified as each channel by type of stimulus. The data again classified as a channel was sorted as each neuron. Spike data of each neuron was drawn raster plots that have total 4 trials for a stimulus (Figure 7). The raster plot is composed active response during stimulus and spontaneous response during resting. Each trial of the raster plot is used to research cross-correlation of two neurons. Before the analysis, the raster plot of several channels among entire data was discarded for further analysis. Usually, removed channel data mainly have instability of the recording or an insufficient number of spikes for cross-correlation study. In this paper, total 31 channels that represented best response for 50 vane stimuli were sorted (Figure 8). Cross-correlation analysis about these channels was computed by six test ways.

Comparison of cross-correlation graphs

The raster plot of two neurons is essential to cross-correlation analysis. One of the two neurons is reference neuron and the other is target neuron. The two neurons have shown spike

trains to a vane stimulus (Figure 9A). Cross-correlation analysis should be tested when the same stimulus was applied to two cells at the same time. Only 4 analyses can be tested because stimulus was applied four times. If the stimulus time is different, can this correlation analysis shows a different result? It is proper to test cross-correlation analysis even though the stimulus time is different. Therefore, sixteen tests were applied. For a comparison, cross-correlation analysis was applied as well when the reference cells and target cells are the same. When different cells were used for this analysis, the different cell could be collected from the same channel or different channel. Cross-correlation analysis is carried out total sixteen times; 4 trials of reference neuron and 4 trials of target neuron by turns and cross-correlation graphs are drawn by all trials of reference neuron and target neuron (Figure 9B). For example, cross-correlation analysis of two neurons for a vane stimulus conducted 16 times. First cross-correlation analysis uses first trial of reference neuron and first trial of target neuron. And second cross-correlation analysis uses first trial of reference neuron and second trial of target neuron.

Same neuron within same channel during identical stimulus

A raster plot of same neuron during identical stimulus is identical (Figure 10) and cross-correlation graph is similar to

auto-correlation graph that has peaks commonly located zero. Actually, this cross-correlation analysis is the same to autocorrelation analysis that has peaks of graph are close to zero (Figure 11). Like this, when reference neuron and target neuron have same raster plot, maximum value of peak is 1.0 (Table 2).

Different neuron within same channel during identical stimulus

Each raster plot of reference neuron and target neuron is different in a rough way (Figure 12). Cross-correlation graphs mostly have unsettled shape (Figure 13). Its cross-correlation maximum value is 0.959799 (Table 3) and mean of maximum and minimum is 0.46888.

Different neuron within the different channel during identical stimulus

The raster plot of two neurons is shown Figure 14. All in all, peaks are located near zero and the form of graphs has mostly bilateral symmetry (Figure 15). 'Crosscorr' function values of it are overall low as maximum value is 0.505902 (Table 4) and mean of maximum and minimum is 0.393061.

Same neuron within same channel during different stimulus

Different stimulus means that stimulus of two neurons has each

different x value and y value (Figure 16). These raster plots are shown Figure 17. Unlike cross-correlation graph of same stimulus, its graphs are mostly asymmetry and peak values are low (Figure 18). Also, cross-correlation values are distributed from 0.354792 to 0.873572 (Table 5) and mean of maximum and minimum is 0.614182.

Different neuron within same channel during different stimulus

These raster plots are shown Figure 19. Cross-correlation graphs and peaks of graph are mostly irregular (Figure 20). 'crosscorr' function values are distributed from 0.979883 to 0.266773 (Table 6) and mean of maximum and minimum is 0.623328.

Different neuron within different channel during different stimulus

The raster plot of two neurons is shown Figure 21. Peaks of graphs wasn't clear and graph area was wide (Figure 22). Cross-correlation values are almost low among entire 6 analysis values as expectation (Table 7) and mean of maximum and minimum is 0.159623.

DISCUSSION

Six tests of cross-correlation analysis were conducted by using neural data obtained from V1 of cat. Each cross-correlation test was compared all raster plots and calculated analysis value with 'crosscorr' function of MATLAB. Until now, the results of cross-correlation study showed that the activities of neurons simultaneously recorded in V1 of cat are associated with relation between neurons. Correlation between neurons informed formerly in the cat for the interactions between neurons of V1 and V2 (Nelson et al., 1992). These clues are revealed in peaks and values of the cross-correlation in this paper. A peak width of cross-correlation was known as an important element in a number of neuroscience researches about neurons recorded from the identical cortex (Swadlow et al., 1998). The reason why peaks of cross-correlation graphs have several dissimilar widths might be related to or neuron's position or type of stimulus. In fact, the autocorrelation value of neurons was clear in the cross-correlation graph (Nowak et al., 1999). But, cross-correlation values of 5 tests for 50 vane stimuli were extremely diverse. That might be affected by spike signals that were very unsettled to detect neural response and activity. The spike signals might be caused by several interrupt elements such as a visual stimulus, state of

cat, experiment environment and so on. For such a reason almost experiment can't have identical results and to investigate neural network and to obtain similar results also is difficult.

CONCLUSION

In this study, there are a few differences and similarities that didn't have regular and certain pattern between cross-correlation graphs of six tests. And cross-correlation values of different channel during identical stimulus are mostly high than different channel during different stimulus. Thus, peaks of graph and cross-correlation values for different channel during different stimulus are symmetric and low during different stimulus.

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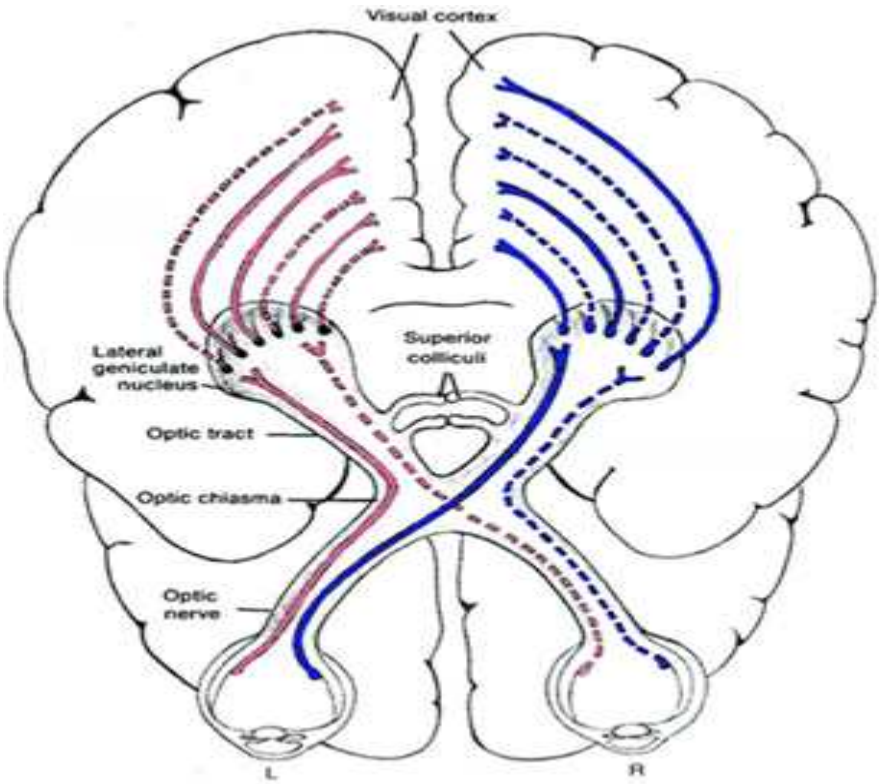

Figure 1. Visual processing system. When the visual information is coming into the eyes, it is converted into an electrical signal by photo-receptor cells and the signals are passed to a visual cortex region through the lateral geniculate nucleus (LGN).

(Retrieved may. 3, 2015, from http://www.skidmore.edu/~hfoley/Perc3.htm)

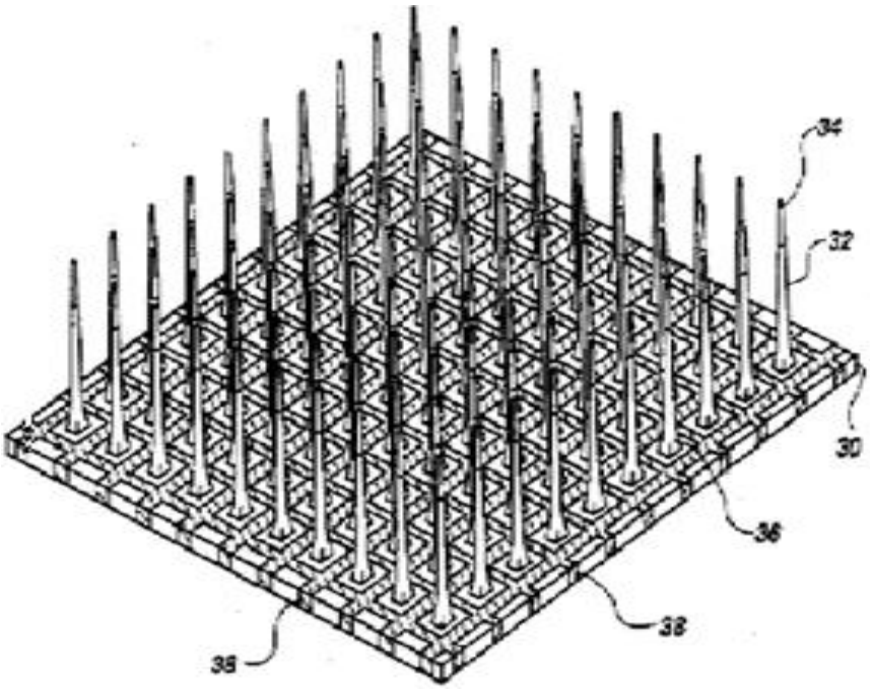

Figure 2. Schematic of the multi-electrode array. It is an implantable multi-electrode array. In this array, signals are only received from the tips of each electrode, which controls the amount of information that can be obtained in a lump. And its arrays are manufactured with set parameters and dimensions.

(Retrieved may. 3, 2015, from http://en.wikipedia.org/wiki/Multielectrode_array)

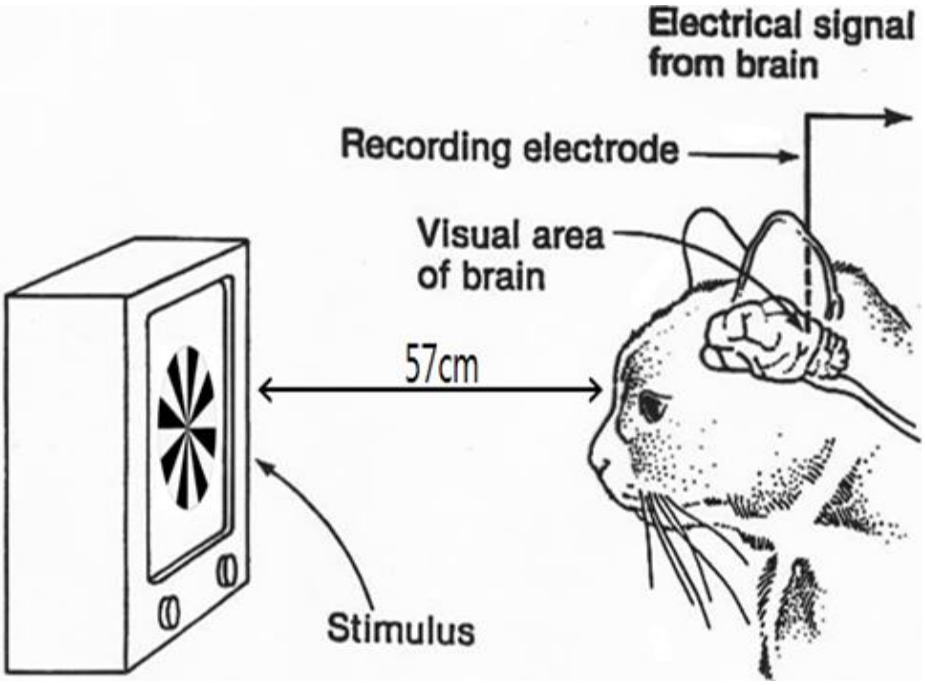

Figure 3. Visual stimulus presentation and neural signal recording. Stimuli were displayed on 19-inch monitor placed 57cm from the cat eyes. Neural activity was recorded from areas 17 and 18 of a paralyzed cat which eyes were watching visual stimulus by using a multi-electrode array. The neural activity was collected by a 100-channels data acquisitions system.

(Retrieved may. 3, 2015, from http://emptyallcages.com/2013/04/02/top-ten-most-outrageous-animal-research-experiments-for-2012)

During identical stimulus	During different stimuli
Same neuron	Same neuron
Different neurons within the same channel	Different neurons within the same channel
Different neurons within the different channels	Different neurons within the different channels

Table 1. Six cases of cross-correlation analysis. Cross-correlation analysis was conducted after neural data were divided into 6 cases according to stimuli type, channel number, and neuron,

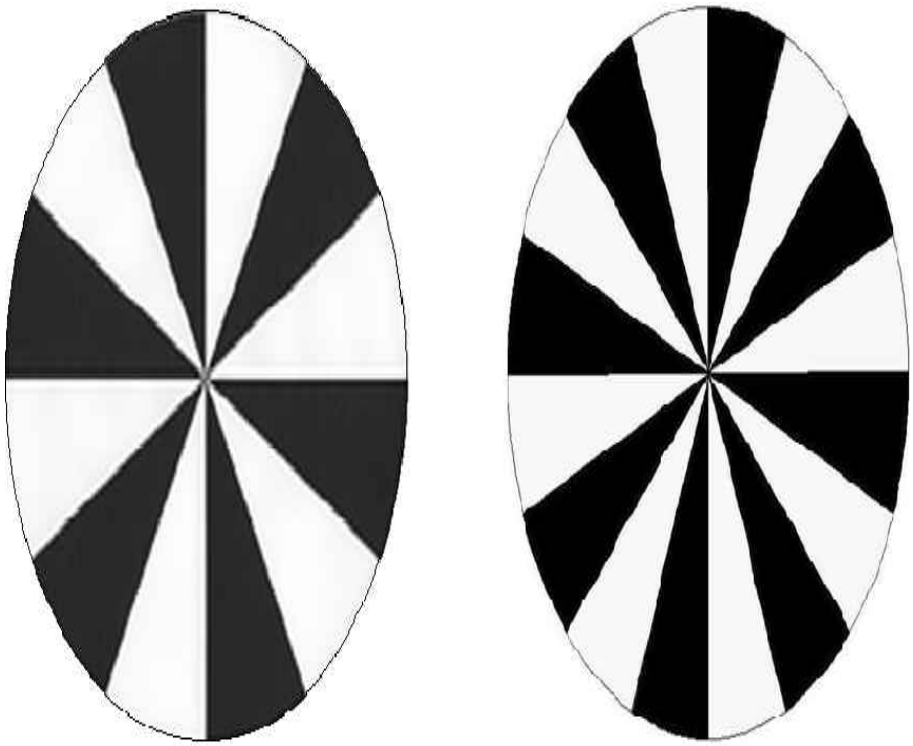

Figure 4. Two windmill patterns. The number of left vane is 6 and the number of right is 8. The number of their rotating speed is ten types (five clockwise and five anticlockwise: 50.0, 38. 9, 27. 8, 16.7, 5.6, −5.6, −16.7, −27.8, −38.9 and −50.0 rpm).

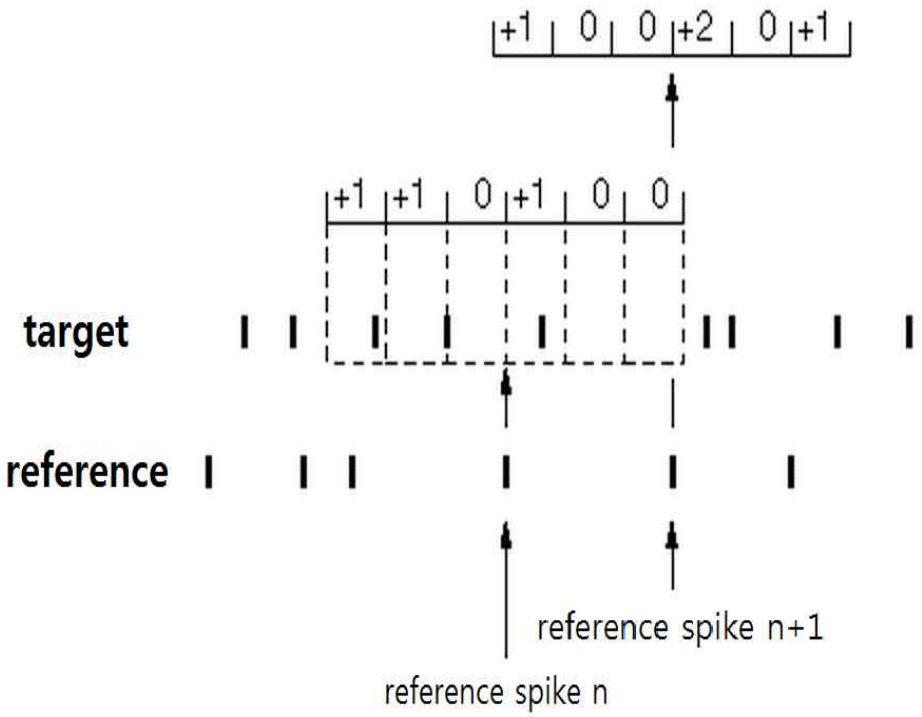

Figure 5. Cross-correlation procedure. It compares the output of the target neuron and the reference neuron. The spike trains of the reference neuron will provide the reference marker. For each spike existed in the reference spike train, center a window, broken into small segments of time called bins.

(Retrieved may. 3, 2015, from http://www.med.upenn.edu/mulab/crosscorrelation.html)

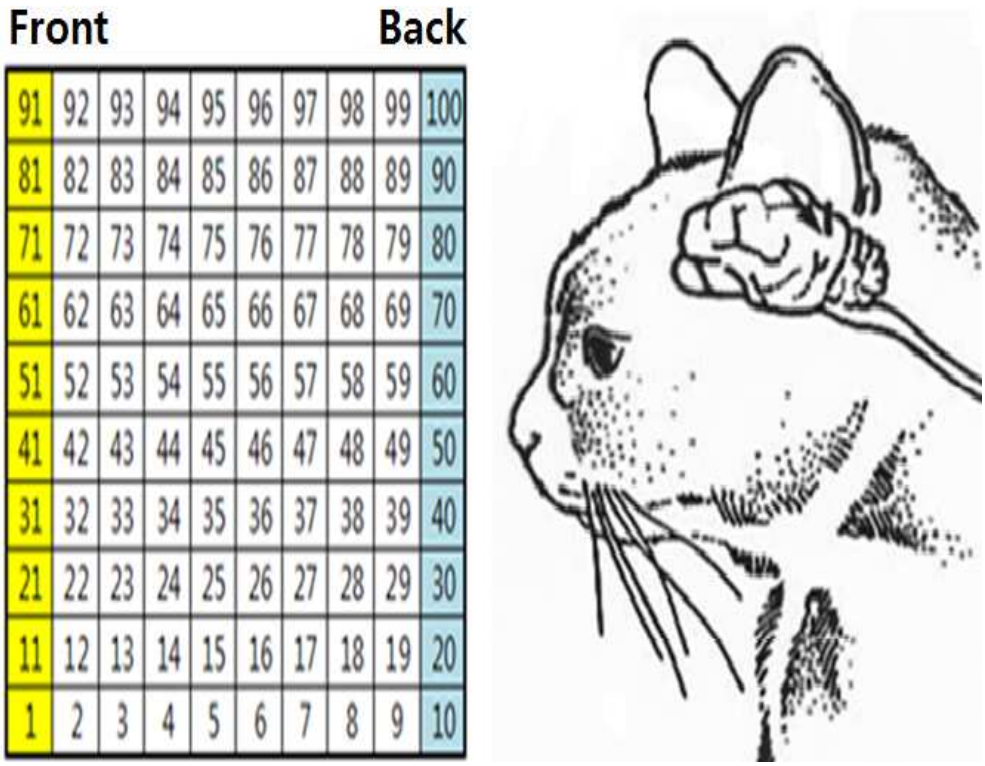

Figure 6. Direction of multi-electrode array (MEA) insertion in visual cortex. The MEA inserted in primary visual cortex has 100 channels (10 x 10 channels). The front of the MEA (yellow column) is inserted toward cat eyes. The rear of the MEA (blue column) is inserted toward back of the head.

91	92	93	94	95	96	97	98	99	100
81	82	83	84	85	86	87	88	89	90
71	72	73	74	75	76	77	78	79	80
61	62	63	64	65	66	67	68	69	70
51	52	53	54	55	56	57	58	59	60
41	42	43	44	45	46	47	48	49	50
31	32	33	34	35	36	37	38	39	40
21	22	23	24	25	26	27	28	29	30
11	12	13	14	15	16	17	18	19	20
1	2	3	4	5	6	7	8	9	10

Figure 7. Number of channels in MEA represented good response. These 31 channels among 100 channels showed best responses for a total of 50 vane stimuli and cells in these channels have sufficient numbers of spike train to cross-correlation analysis.

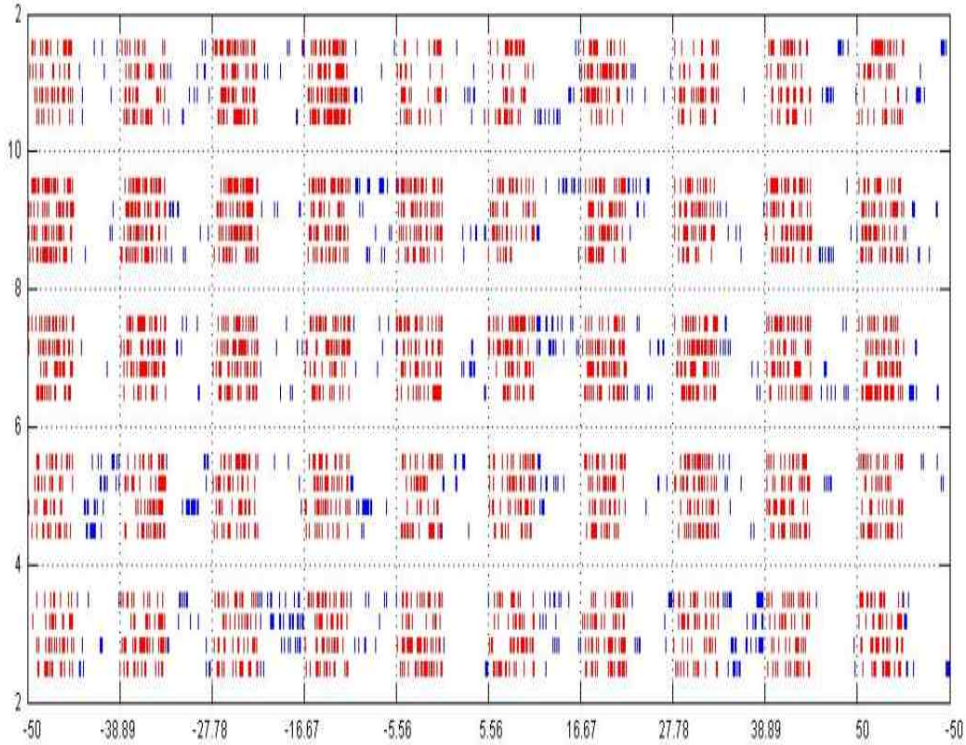

Figure 8. Entire raster plots of a channel for 50 vane stimuli (channel47_unit1_vane_data file13). A neural activity that occurred in a certain channel can be drawn as raster plot. A component in this raster plot means response of a neuron for specific stimulus that has x value (the number of vane) and y value (speed of rotating windmill pattern). Raster plots in the component were reaction about stimulus repeated 4 times. Red raster plots are active responses during stimulus and blue raster plots are spontaneous responses during resting.

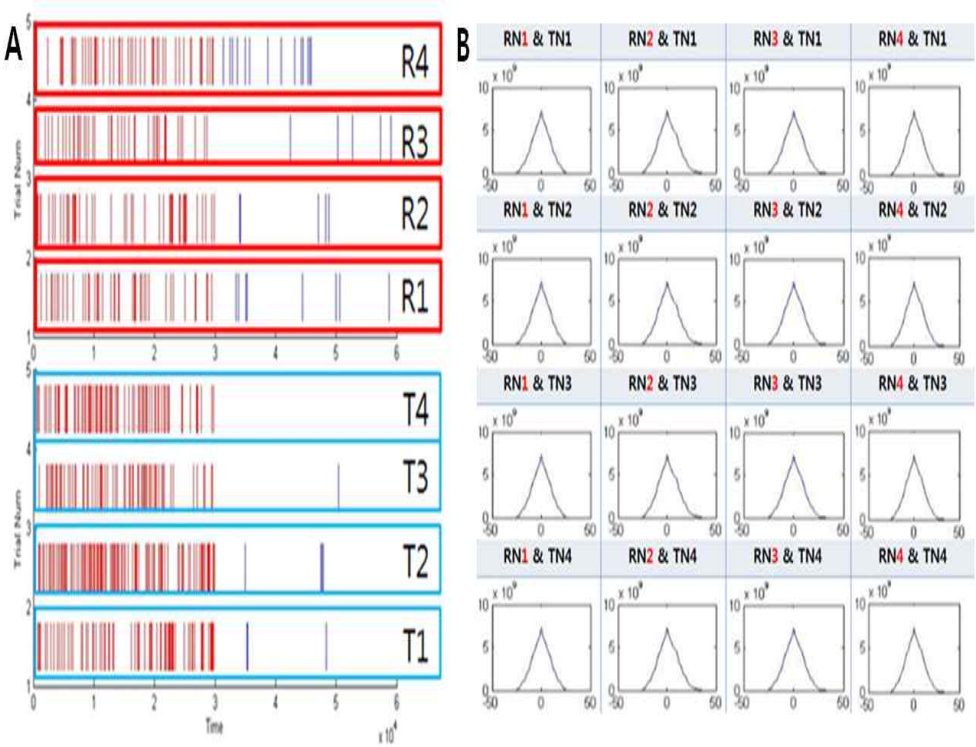

Figure 9. Raster plots of two neurons and cross-correlation graphs. (A) Raster plots of reference neuron (up) and target neuron (down). Reference neuron (R) and target neuron (T) separately have spike trains for a vane stimulus repeated 4 times. (B) Cross-correlation graphs of two neurons. Cross-correlation analysis for a stimulus was conducted with each trial of reference neuron and target neuron.

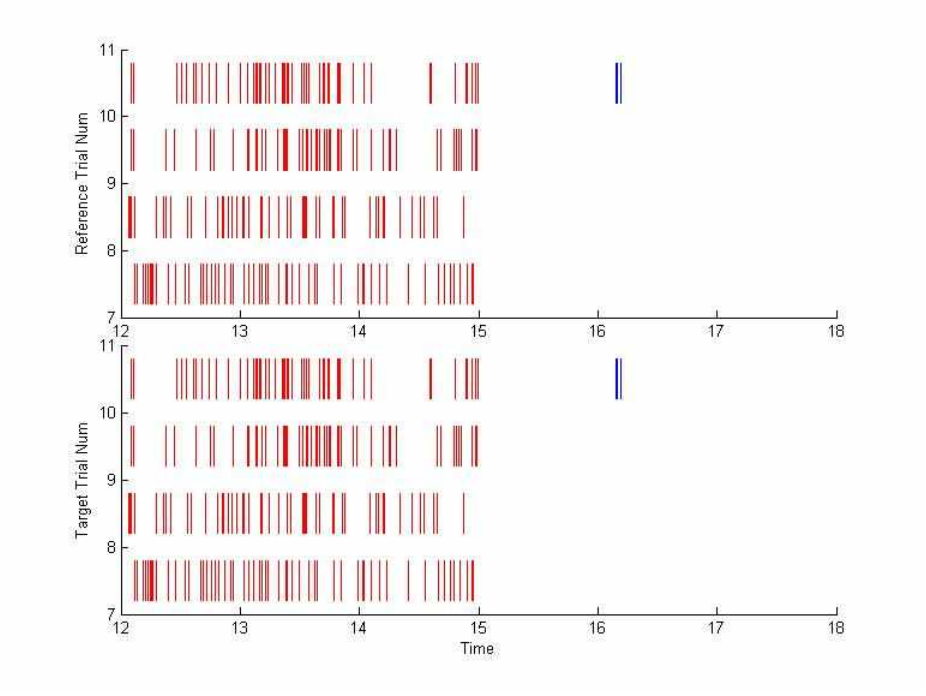

Figure 10. (RN: ch68_u0_st12, TN: ch68_u0_st12) Raster plots of same neuron within same channel during identical stimulus.

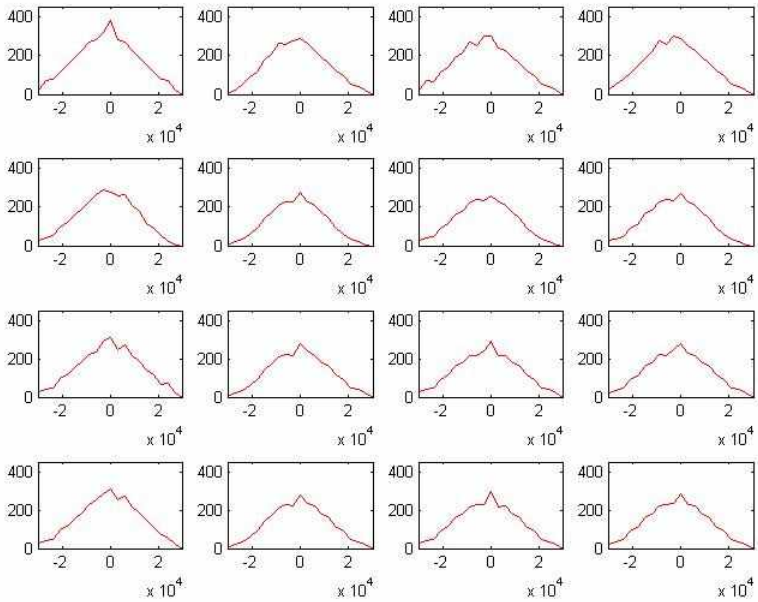

Figure 11. (RN: ch68_u0_st12, TN: ch68_u0_st12) Cross-correlation graphs of same neuron within same channel during identical stimulus.

	R1	R2	R3	R4
T1	1	0.792107	0.473782	0.522017
T2	0.792107	1	0.578834	0.681311
T3	0.473782	0.578834	1	0.90903
T4	0.522017	0.681311	0.90903	1

Table 2. (R: ch68_u0_st12, T: ch68_u0_st12) Cross-correlation values of same neuron within same channel during identical stimulus. These values were calculated by using 'crosscorr' function in MATLAB.

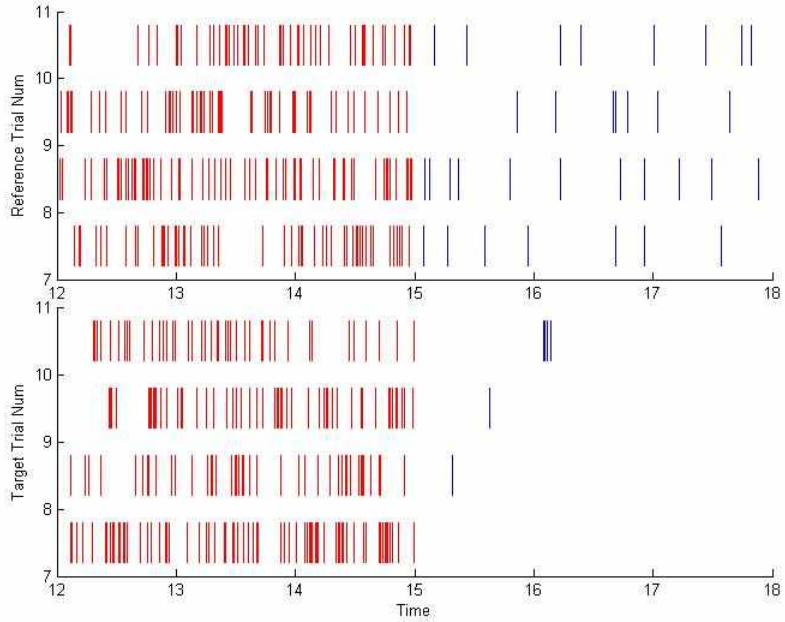

Figure 12. (RN: 46_u0_st12, TN: 46_u1_st12) Raster plots of different neurons within same channel during identical stimulus. Reference neuron and target neuron have different raster plots.

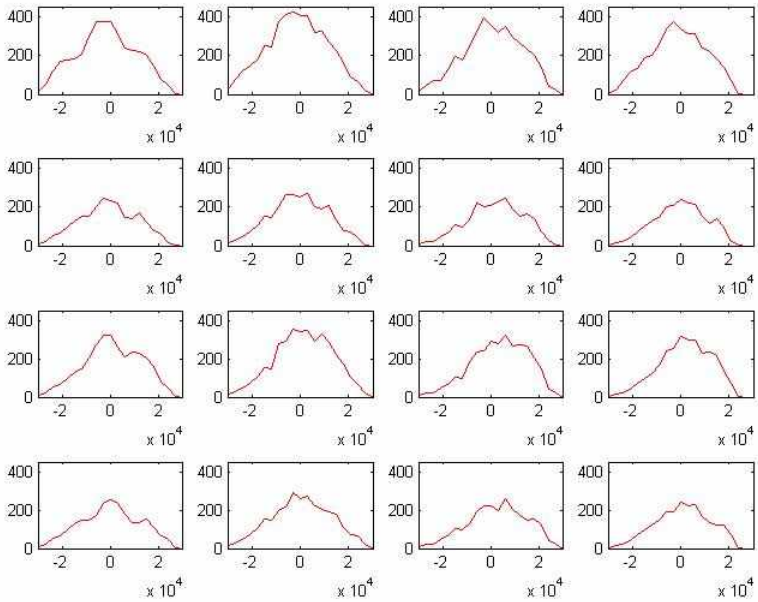

Figure 13. (RN: 46_u0_st12, TN: 46_u1_st12) Cross-correlation graphs of different neuron within same channel during identical stimulus. Shape of graphs overall is irregular.

	R1	R2	R3	R4
T1	0.634507	-0.02204	0.499306	0.576202
T2	0.801038	0.55386	0.644728	0.889965
T3	0.181199	0.959799	0.72325	0.424242
T4	0.531031	0.223614	0.816009	0.519648

Table 3. (R: 46_u0_st12, T: 46_u1_st12) Cross-correlation values of different neuron within same channel during identical stimulus. This values were calculated by 'crosscorr' function in MATLAB.

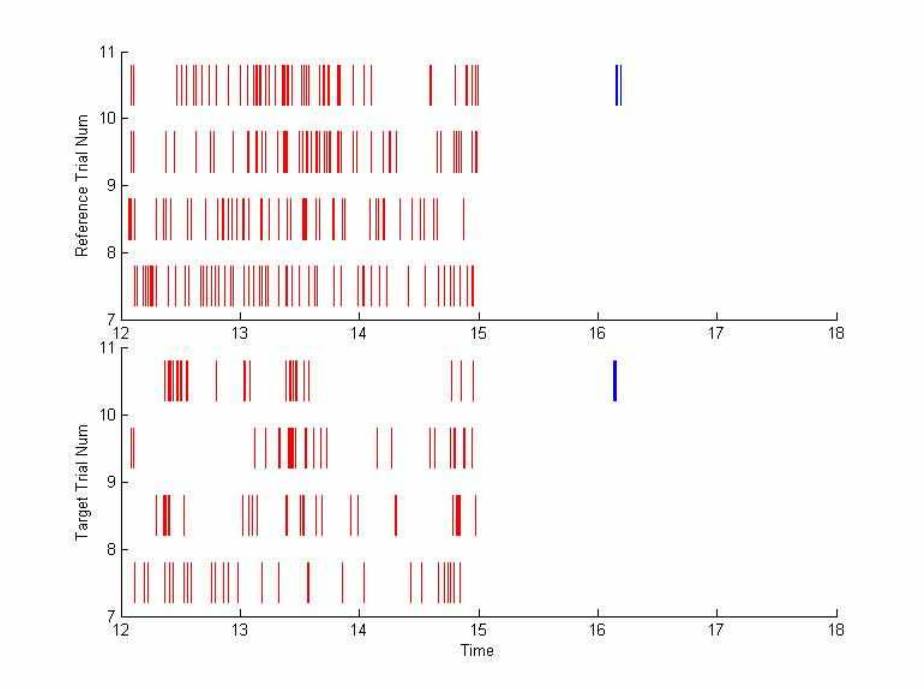

Figure 14. (RN: ch68_u0_st12, TN: ch49_u1_st12) Raster plots of different neuron within different channel during identical stimulus.

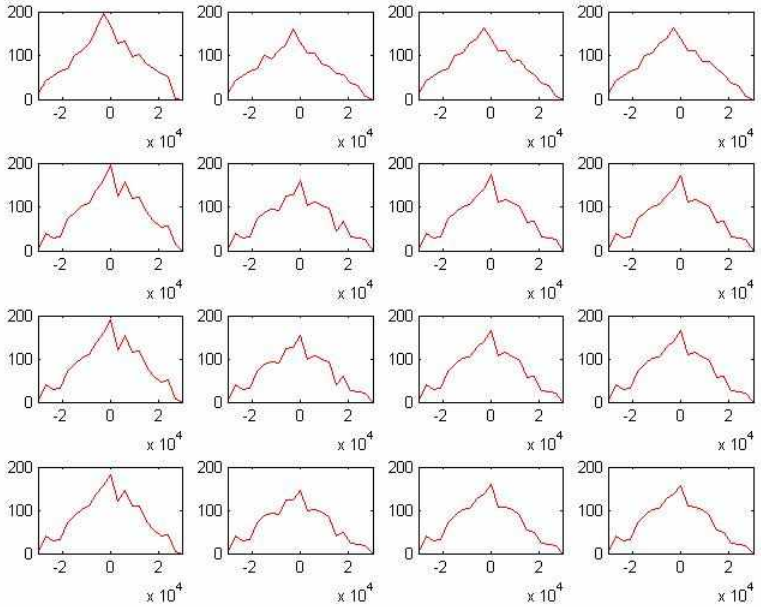

Figure 15. (RN: ch68_u0_st12, TN: ch49_u1_st12) Cross-correlation graphs of different neuron within different channel during identical stimulus. Forms of graphs are mostly bilateral symmetry.

	R1	R2	R3	R4
T1	0.399504	0.490414	0.496761	0.505902
T2	0.366627	0.477114	0.483855	0.494415
T3	0.282531	0.403867	0.40689	0.409498
T4	0.280219	0.313804	0.315823	0.317628

Table 4. (R: ch68_u0_st12, T: ch49_u1_st12) Cross-correlation values of different neuron within different channel during identical stimulus. This values were calculated by 'crosscorr' function in MATLAB.

s41	s42	s43	s44	s45	s46	s47	s48	s49	s50
s31	s32	s33	s34	s35	s36	s37	s38	s39	s40
s21	s22	s23	s24	s25	s26	s27	s28	s29	s30
s11	s12	s13	s14	s15	s16	s17	s18	s19	s20
s1	s2	s3	s4	s5	s6	s7	s8	s9	s10

Figure 16. Stimulus position in the whole of raster plots of a neuron. Each stimulus has separate x value and y value. Y−axis is the number of vane set that have 2, 4, 6, 8, 10 value and x−axis is speed of rotating that have five clockwise and five anticlockwise: 50.0, 38. 9, 27. 8, 16.7, 5.6, −5.6, −16.7, −27.8, −38.9 and −50.0 rpm.

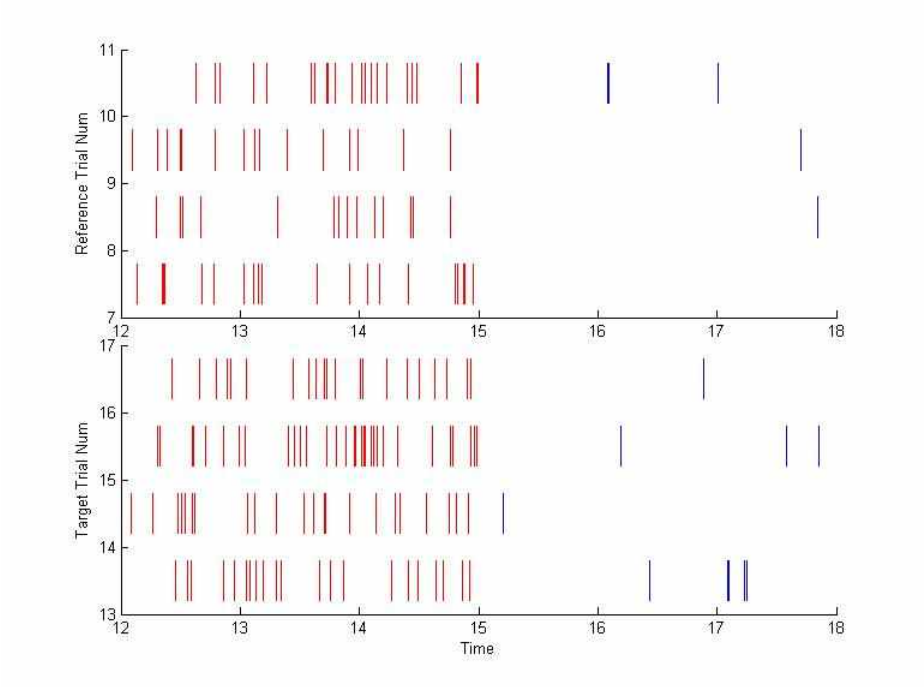

Figure 17. (RN: ch47_u1_st12, TN: ch47_u1_st13) Raster plots of same neuron within same channel during different stimulus.

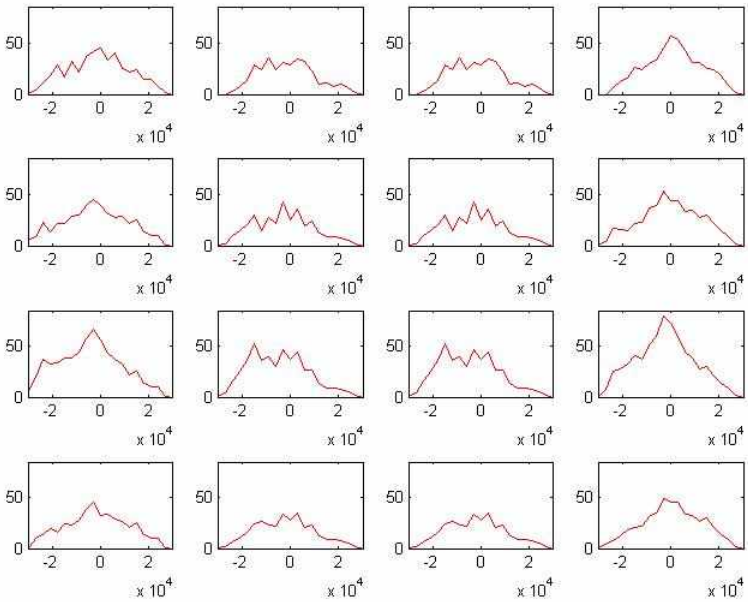

Figure 18. (RN: ch47_u1_st12, TN: ch47_u1_st13) Cross-correlation graph of same neuron within same channel during different stimulus.

	R1	R2	R3	R4
T1	0.873572	0.494932	0.494932	0.354792
T2	0.863488	0.435772	0.435772	0.39441
T3	0.769042	0.617249	0.617249	0.598166
T4	0.515717	0.75532	0.75532	0.770029

Table 5. (R: ch47_u1_st12, T: ch47_u1_st13) Cross-correlation values of same neuron within same channel during different stimulus. This values were calculated by 'crosscorr' function in MATLAB.

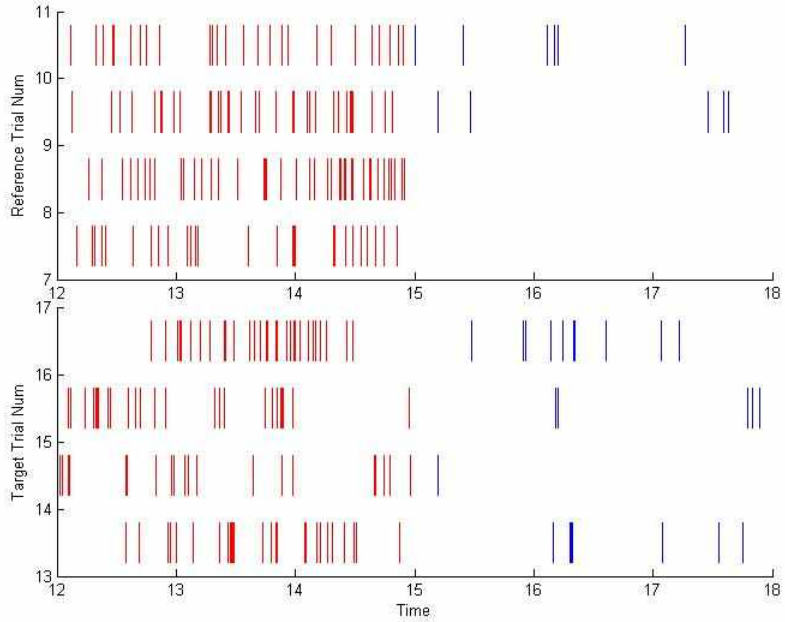

Figure 19. (RN: ch25_u0_st12, TN: ch25_u1_st13) Raster plots of different neuron within same channel during different stimulus.

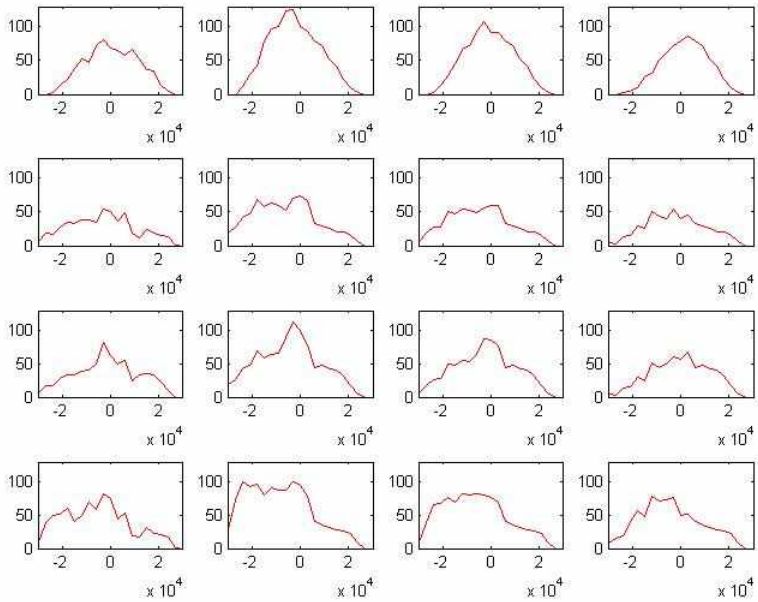

Figure 20. (RN: ch25_u0_st12, TN: ch25_u1_st13) Cross-correlation graphs of different neuron within same channel during different stimulus.

	R1	R2	R3	R4
T1	0.979883	0.66832	0.710134	0.712837
T2	0.688126	0.449358	0.519634	0.633583
T3	0.591968	0.500237	0.824591	0.739128
T4	0.440716	0.266773	0.69352	0.524843

Table 6. (R: ch25_u0_st12, T: ch25_u1_st13) Cross-correlation values of different neuron within same channel during different stimulus. This values were calculated by 'crosscorr' function in MATLAB.

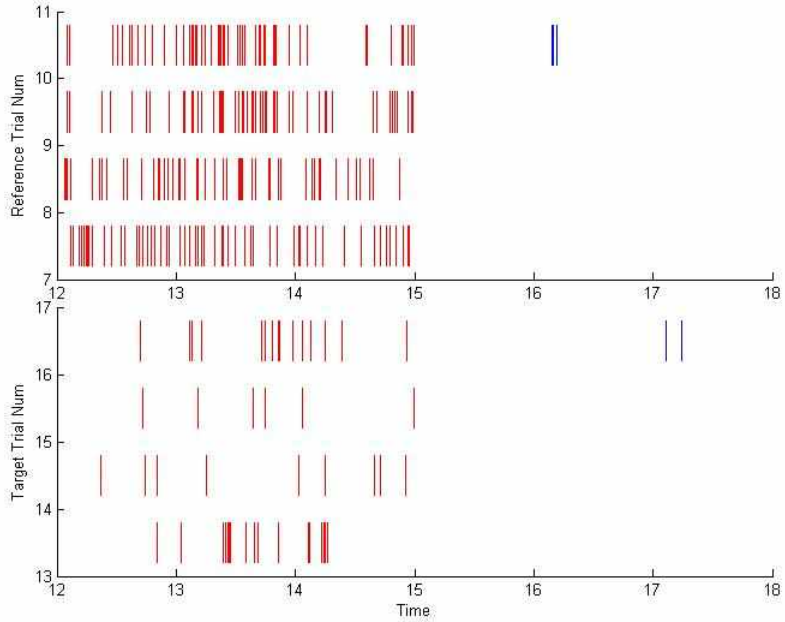

Figure 21. (RN: ch68_u0_st12, TN: ch49_u1_st13) Raster plots of different neuron within the different channel during different stimulus.

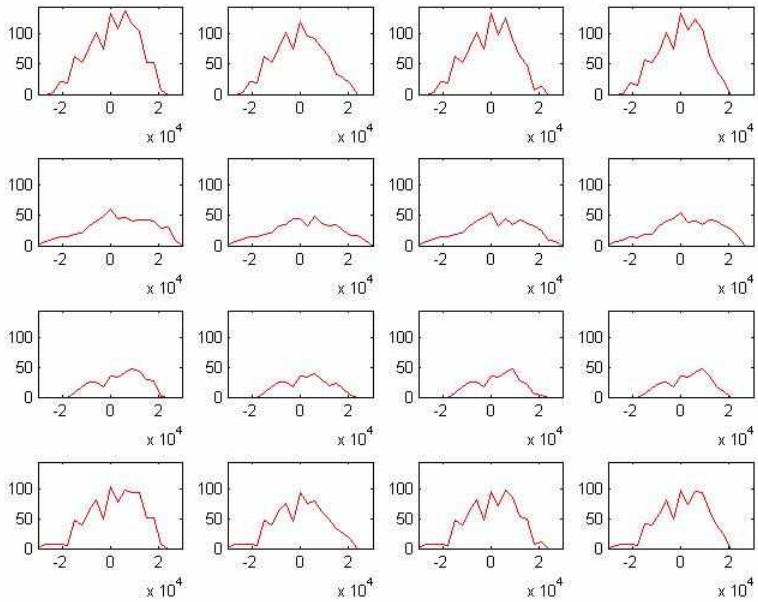

Figure 22. (RN: ch68_u0_st12, TN: ch49_u1_st13) Cross-correlation graphs of different neuron within the different channel during different stimulus.

	R1	R2	R3	R4
T1	0.154865	0.293538	0.21157	0.189459
T2	0.076954	0.066782	0.069349	0.089476
T3	0.025707	0.034233	0.03414	0.049509
T4	0.208223	0.127431	0.191876	0.236958

Table 7. (R: ch68_u0_st12, T: ch49_u1_st13) Cross-correlation values of different neuron within different channel during different stimulus. This values were calculated by 'crosscorr' function in MATLAB.

국문초록

고양이의 17, 18영역에서 다중 채널 전극으로 기록한 신경세포간의 상호상관 연구

이가영

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고양이 뇌의 후두엽에 위치한 일차 시각 피질은 외측슬상핵을 통해 전기적 신호로 변환되어 들어오는 시각정보를 처리한다. 일차 시각피질의 신경세포는 특정한 시각자극을 선호하는 경향이 있는데 이것을 '반응 선택성'이라고 한다. 이런 특성을 갖는 신경세포에 관한 다각적 연구는 1950년대부터 현재까지 수행되고 있으나 반응 선택성을 갖는 신경세포들 간의 연관성을 명백히 밝힌 연구는 아직까지 이루어지지 않았다. 따라서 본 연구에서는 50개의 서로 다른 시각자극에 대한 신경세포들의 반응을 가지고 시각 신경세포들 간의 연관성을 확인하고자 다중채널 전극을 통해 신경 신호를 수집하였다. 수집한 신경 신호는 데이터 수집 장치를 이용하여 신경 데이터로 서버에 저장하여 시각자극 별로 분류한 다음, 100 채널 중에서 비교적 뚜렷한 반응을 보이는 31개의 채널을 선별하였다. 이 31개의 채널은 자극의 종류, 채널 번호,

세포에 따라 6가지의 경우로 나누어 상호 상관 분석을 시행하여 상호 상관 값과 그래프를 도출해 최종적으로 비교 분석하였다. 그 결과, 시각 자극에 따른 신경세포들 간의 명백한 차이와 연관성을 발견하지는 못했지만 동일한 시각자극에 대한 신경세포 간의 상호 상관 값이 상이한 자극에 대한 상호 상관 값보다 대체적으로 높게 나타난 것을 통해 동일한 자극에 대해 반응하는 신경세포들 간의 연관성이 더 강하게 나타남을 확인할 수 있었다.

주요어: 상호 상관 분석, 다중채널 전극, 시각 자극, 일차 시각 피질

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