Group 3-11

Neural Mechanisms of Visual Flow Perception

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We propose a hypothesis of population representation of visual flow by the activity profile of MST (Medial Superior Temporal area) cells. This hypothesis states that the perception of many kinds of visual flow (translation, expansion, contraction, rotation) and of motion aftereffects caused by those flows would be directly related to the activity profile of a population of cells in area MST responding selectively to those flows.

To test this hypothesis, we examined properties of perception of wide-field visual flow and of the motion aftereffect by such flow through psychophysical study on human subjects, and compared perceptual properties with response properties of MST cells measured during and after visual flow stimulation by single cell recordings from anesthetized monkeys.

We have confirmed that we experience compelling motion aftereffect whose direction is opposite to the adapting stimuli. Directionally-selective MST cells decreased their activities after prolonged exposure of visual flow moving in the preferred direction, whereas enhanced their activities after presenting the flow moving in the opposite direction. These response properties strongly support proposed population representation hypothesis. We can consistently explain properties of the perception of transparent visual flow (in which two sets of randomdots moved in different directions, and it gave the percept of two independent flows) and of flow-induced motion aftereffect (single motion in the direction opposite to the integrated motion of two sets of flows) in terms of the population representation hypothesis by assuming the existence of two-subtypes of MST cells. These cells were referred to as component cells and integration cells according to the direction tuning properties for bi-directional transparent flow.

Our physiological investigation verified the presence of two-subtypes of MST cells.

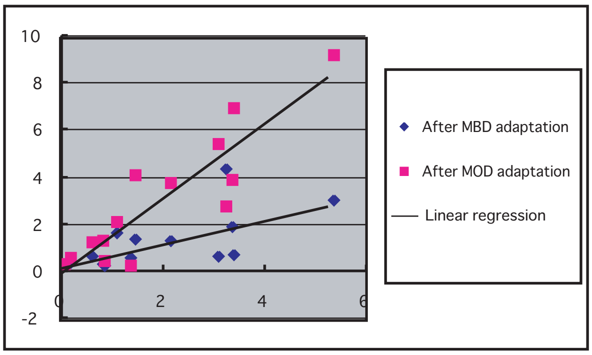

Fig.1 Comparison of the spontaneous discharge rate of D cells in MST during one second after terminating the adapting stimulus. D cells show directionally-selective responses to translational visual flow. Abscissa: spontaneous discharge rate (impulses/sec) observed after presenting SF (stationary field). Ordinate: spontaneous discharge rate (impulses/sec) observed after presenting MBD (motion in best direction) (blue diamonds) or MOD (motion in opposite direction) (red squares). Regression coefficient of regression line for SF vs. MBD stimulation was 0.51. Regression coefficient of regression line for SF vs. MOD stimulation was 1.58. Data were compiled from fourteen D cells.

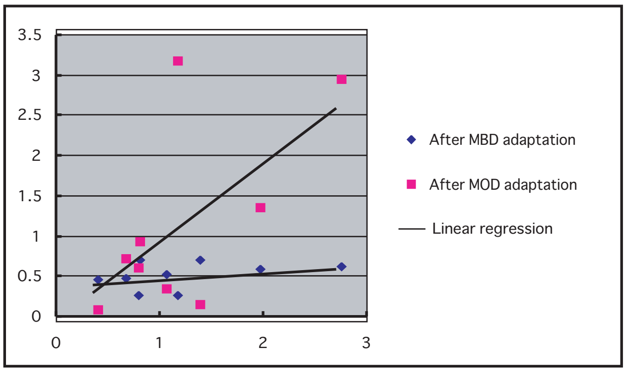

Fig.2 Comparison of the spontaneous discharge rate of R cells and E/C cells in MST during one second after terminating the adapting stimulus. R cells respond selectively to clockwise rotation or counter-clockwise rotation and E/C cells respond selectively to Expanding or contracting visual flow. Abscissa: spontaneous discharge rate (impulses/sec) observed after presenting SF (stationary field). Ordinate: spontaneous discharge rate (impulses/sec) observed after presenting MBD (motion in best direction) (blue diamonds) or MOD (motion in opposite direction) (red squares). Regression coefficient of regression line for SF vs. MBD stimulation was 0.51. Rregression coefficient of regression line for SF vs. MOD stimulation was 1.58. Data were compiled from 4 R-cells and 6 E/C cells.

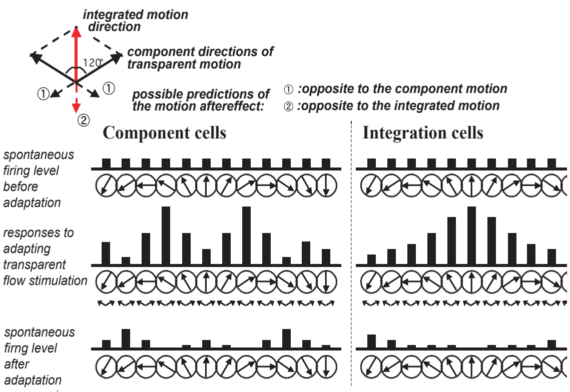

Fig. 3 Predicted profiles of the firing levels of MST D cells before, during, and after presenting bi-directional transparent motion. In both component cells and integration cells, spontaneous discharge levels among D cells before exposing to adapting stimulus are well-balanced.

Component cells (left figures) show maximal responses when preferred direction of the cell coincides with either of two sets of coherent flow in the transparent motion. Thus, two peaks appear in the profile of the firing level of D cells. On the other hand, integration cells show best responses when preferred direction of the cell coincides with the direction of integrated motion of two sets of coherent visual flows in bi-directional transparent flow, resulting in the appearance of single peak of response profile.

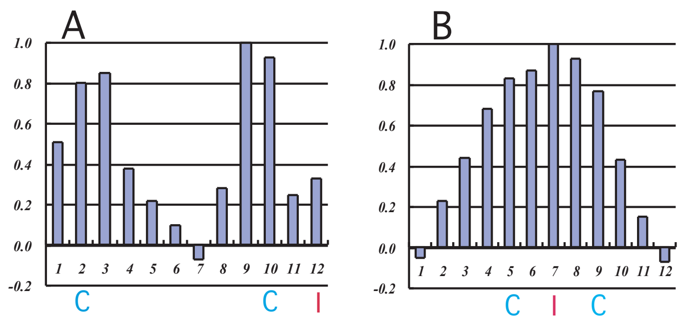

Fig.4 Representative responses from a component cell (A) and from an integration cell (B) in MST to bi-directional transparent motion. Tuning properties of cells to the transparent flow are plotted by changing the direction of the stimulus at 30 degrees step by maintaining the directional difference of superimposed flows at 120 degrees. Relative response profile normalized by the maximal response is shown in the graph. Number attached at the bottom indicates the successive change of the direction of transparent flow stimulus at 30 degrees step.
Note that the component cell responded best when the direction of either flow (indicated by C) in bi-directional transparent motion matched with the best direction of the cell, whereas the integration cell responded best when the direction of integrated motion (indicated by I) in bi-directional transparent flow matched with the best direction of the cell.