Effects of Glutamate Uptake on the Response Dynamics of the Retinal Horizontal Cell

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Abstract

Glutamate is a principal neurotransmitter in lower vertebrate retina, which is employed by photoreceptors and bipolar cells^[1]. Photoreceptors encode a light signal as a concentration change of glutamate. In the dark, glutamate is tonically released from the photoreceptor terminal into the synaptic cleft, where it acts on channels in postsynaptic horizontal cells. Light-induced hyperpolarization of photoreceptor causes a decrease of glutamate release, and as a result, membrane potential change is generated in the horizontal cells. Since there are no extracellular enzymes to inactivate the glutamate action in the synaptic cleft, glutamate is thought to be removed from the cleft by an uptake mechanism in photoreceptor, or by diffusion away which is uptaken by glial cells. However, the real-time process of the glutamate release has not been measured^[2] because of a lack of experimental techniques for an intact retina.

Recently, we developed a computational method for estimating the input signal to a neuron by the ionic current model^[3]. In the present study, we combined the method with the electrophysiological experiment to reveal the synaptic transmission between photoreceptors and horizontal cells. Voltage responses of the horizontal cell were measured from the isolated carp retina, and the glutamate uptake was controlled by the uptake inhibitor, β HA. From these recordings we estimated the time course of concentration change of glutamate in the synapse by reversing the dynamics with the ionic current model of the horizontal cell.

The present results suggest that the concentration change of glutamate at the synapse between the photoreceptor and horizontal cell is controlled by the independent release and removal mechanisms. When the glutamate uptake was inhibited by the blocker, the light onset of the concentration change was dramatically slowed down, while the light offset represented a little change. These results imply that the fast removal of glutamate is mainly realized by the uptake carrier in the photoreceptor and the slow removal reflects the diffusion of glutamate from the synaptic cleft. The unchanged dynamics in the light offset suggests that the release mechanism of glutamate is fast enough to be controlled by the voltage response of the photoreceptor which may not be changed in the presence of the blocker.

References

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