Modeling Response Facilitation in Small-target-sensitive Visual Neurons

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Abstract

Flying insect species like dragonflies are capable of predicting the path or location of their target even if the target has occluded by some object for some period of time. This ability to predict the path is supported by a processing mechanism which is called response facilitation. We have modeled this predictive aspect of response facilitation in small-target- sensitive visual neurons in dragonflies. This facilitation is known to increases sensitivity to small objects that move along continuous paths and is thought to increase reliability of small target detection. Because the locus of facilitation that is induced by a moving target propagates in visual space even after a small target stimulus ceases, we have proposed that it could be supported by traveling wave phenomena in retinotopically-organized regions of the visual system. Accordingly, we have proposed a biological substrate: a network of cells (quite possibly astrocyte-like glia) in which calcium waves are initiated by target stimuli and propagate via diffusion with the participation of regenerative mechanisms.

Introduction

Detecting and tracking moving targets within a visual scene is a complex task, yet it is of great importance to animals that rely on catching/ chasing their targets for food and mating. Over thousands of years, many species of animal have evolved neural mechanisms for target analysis. Flying insect species like dragonflies show amazing ability to track the path or location of the target that move against the visually cluttered background again and again. It has also been stated that dragonflies capture prey with a success rate of 97% even in the presences of some distraction (Corbet, 1999).

Small target motion detector (STMD) neurons are likely to be involved in this behavior as they display an impressive selectivity for small moving objects (Nordstrom et al. 2009; Nordstrom and O'Carroll, 2009). As of now two relatively higher-order functions had been identified that appear to support this behavior: One is selective attention that allows STMDs to respond to single

target at a time (Wiederman & O'Carroll, 2013); and second is a type of facilitation that enhances the response of an STMD to a continuously- moving target (Dunbier, Wiederman, Shoemaker, O'Carroll, 2012). Our project focuses on the second mechanism. A number of the experiment have been conducted to characterize the process of facilitation and it has been observed that facilitation is predictive in nature.

In this project, we investigate the predictive aspect of response facilitation by assuming that it might be supported by the propagation of calcium waves in a network of astrocyte-like cells. We model such a network and then further analysis is done on the propagation of calcium signals in the presence and absence of an external stimulus that corresponds to moving the target in the real world. We also do a comprehensive parametric study of our model outlining how and why it behaves with different values of parameters and thus characterizing the facilitation mechanism.

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