Facilitation in Dragonfly Target Motion Detecting Neurons

James Robert Dunbier

Discipline of Physiology
The School of Medical Sciences
The University of Adelaide

November 2013

A thesis submitted for the degree of Doctor of Philosophy

Thesis Abstract

Dragonflies are masters of visually guided aerial pursuit. Their visual systems overcome the challenges presented by the environment in which they live and behave. These adaptations come from multiple stages of processing. Perhaps the most important adaptations are those that allow for the detection, identification, pursuit and capture of small moving features in a complex visual environment. Perching Libellulid dragonflies execute prey capture flights with a 97% success rate from a stationary start point (average pursuit time, 184ms, Olberg et al., 2000). The Australian hawking dragonfly, *Hemicordulia tau*, performs similar prey capture flights on the wing. *H. tau* also engages in longer duration territorial and courtship pursuits of conspecifics and other anisopterans, which can last tens of seconds. These chase sequences include changes in velocity and direction, as well as the possibility of target occlusion by background features. The dragonfly brain has been found to contain neurons specialised to respond to small moving target-like objects (O'Carroll, 1993; Olberg, 1986). These small target motion-detecting (STMD) neurons likely play an important role in some or all of these pursuit flights. One of these neurons, the centrifugal STMD 1 (CSTMD1) (Geurten et al., 2007), has recently been shown to respond more robustly following periods of slow continuous target motion (Nordström et al., 2011). This enhancement of response following target motion or self-facilitation is fascinating and was the focus of enquiry throughout this thesis.

I probed this facilitation by quantifying neuronal response to stimulation from intracellular, *in vivo* recordings from dragonfly small target motion detecting neurons, mostly CSTMD1 and the newly identified and characterised neuron BSTMD1 (work from this thesis, published in Dunbier et al., 2012). The key results of the thesis confirmed

that the slow onset time course first observed in CSTMD1 (Nordstrom et al., 2011) was in fact due to a facilitation rather than slow kinetics (using a new computational model). This facilitation effect is most pronounced when targets move at velocities slower than what was previously thought to be optimal in CSTMD1 (Geurten et al., 2007). Further, the facilitation is evident in other wide-field STMD neurons like BSTMD1. The facilitation is disrupted if targets are instantaneously displaced a few degrees from their current location. I investigated this mechanism more fully in the next publication. Presenting single target stimuli that moved along an initial 'priming' path before undergoing spatial, temporal or combined discontinuities in their trajectories, I found that facilitation is initially spatially localized. When larger spatial displacements were combined with a delay in reappearance, however, responses were significantly elevated, even for a 20° displacement with a 500ms delay in reappearance. Backward displacements (i.e. across previously traversed location) yield strongly inhibited responses. This suggests that facilitation is mediated by a process of local gain modulation that actively spreads from the last seen location of a stimulus and in the approximate direction of travel. Such predictive modulation of local target salience may be a key mechanism for selective attention during target tracking.

Thesis Declaration

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

I give consent to this copy of my thesis when deposited in the University Library, being made available for loan and photocopying, subject to the provisions of the Copyright Act 1968.

The author acknowledges that copyright of published works contained within this thesis resides with the copyright holder(s) of those works.

I also give permission for the digital version of my thesis to be made available on the web, via the University's digital research repository, the Library catalogue and also through web search engines, unless permission has been granted by the University to restrict access for a period of time.

_____

James Robert Dunbier

Acknowledgements

I owe my supervisors David O'Carroll and Steve Weiderman tremendous thanks for their support throughout my thesis. I appreciate their roles as both mentors and friends.

Thanks to all the members, students and associates of the O'Carroll lab who have been present at one stage or another and helped me throughout my candidature: Pat Shoemaker, Karin Nordström, Ximena Nelson, Paul Barnett, Daniel Zurek, Julia Schuckel, Adam Kane, Bob Piddington, Doug Bolzon, Joanne Wilkins, Yun Leung (Esther), Sharn Perry, Melissa Walker, Sarah Overduin, Shaliza Mohamad, Kerry Halupka, Liliana Ciobanu and Jessica Proctor.

Finally, a big thanks to my family: Mum, Dad and Anna.

Common Acronyms

Binocular small target motion detector 1 (BSTMD1)

Central nervous system (CNS)

Centrifugal Horizontal (CH)

Centrifugal small target motion detector 1 (CSTMD1)

Chlordimeform (CDM)

Descending contralateral motion detector (DCMD)

Elementary small target motion detector (ESTMD)

Elementary motion detector (EMD)

Facet diameter (D)

Feature detecting (FD)

Horizontal system (HS)

Interommatidial angle ($\Delta\varphi$)

Large monopolar cell (LMC)

Lobula plate tangential cell (LPTC)

Lobula giant motion detector (LGMD)

Rhabdom diameter (d)

Rhabdom length (l)

Region of interest (ROI)

Small field small target motion detector (SF-STMD)

Small target motion detector (STMD)

Target selective descending neuron (TSDN)

Vertical System (VS)

Author's Comments

All publications within this thesis are in the exact form of the original article as published or as prepared for submission in cases where the article is not yet published, with the following exceptions:

Typesetting has been altered so that there is a consistent format throughout the entire thesis.

The figures have been inserted into the text at appropriate places, which may differ from the final published version of the papers.

Figures are referenced throughout the text as they are in the published or prepared versions of the papers, but are captioned based on their chapter and figure number, e.g. Figure 1 in Chapter 2 is captioned as Figure 2-1.

Table of Contents