Parallel motion-sensitive pathways encode approaches of looming objects

J. R. Gray[1*] and R. M. Robertson[2]

460.20

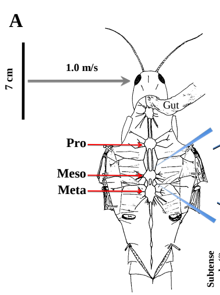
[1]Department of Biology, University of Saskatchewan jack.gray@usask.ca

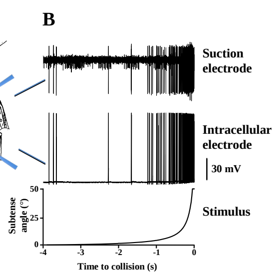
[2]Department of Biology, Queen's University robertrm@queensu.ca

Introduction

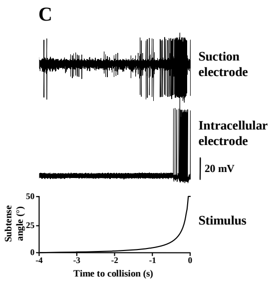
One motion sensitive pathway in the locust visual system consists of the Lobula Giant Movement detector (LGMD), its postsynaptic target, the Descending Contralateral Movement Detector (DCMD) and responds to expanding edges of looming objects(1,2). Responses are determined by the ratio of the half width of the approaching object (*l*) and its approach velocity (*v*) i.e. *l*/|*v*| (3). DCMD connects to motor elements of the wings and legs and is implicated in the initiation of escape behaviours (4).
To test for the presence of other looming-sensitive pathways in the locust visual system we used an extracellular suction electrode to record DCMD activity in semi-intact preparations and an intracellular electrode to record neural activity immediately posterior to the mesothoracic ganglion.
We observed a second, looming sensitive neuron based on comparisons to concurrent recordings of DCMD activity.
Because of the temporal properties of this other neuron's response profile we have named it the late DCMD (L-DCMD). Indeed, this finding suggests that, rather than constituting a single looming sensitive pathway, the DCMD is actually a class of neurons that are important for looming detection. These findings further suggest that detection of looming involves parallel pathways that are temporally scaled.

1 Setup and preparation

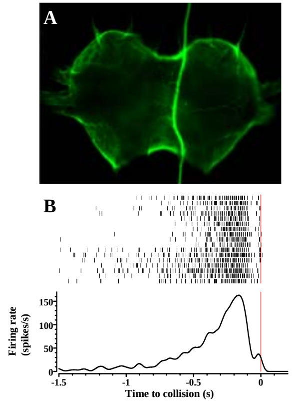




A) A dorsal preparation (1) was used to expose the thoracic ganglia. A suction electrode was placed on the connective anterior to the mesothoracic ganglion and an intracellular electrode was inserted into the posterior margin of the same ganglion. The suction electrode reliably recorded DCMD activity whereas the intracellular electrode recorded DCMD activity or activity from other, previously unidentified interneurons. During recordings, the locust was presented with a 7 cm diameter looming black disc approaching at 1.0 m/s. B. Sample recording of DCMD activity from both electrodes and the subtense angle of the disc on the locust's eye aligned to the time of collision. C. Sample recording of DCMD (suction electrode), another interneuron (intracellular electrode) and subtense angle aligned to time of collision. Because of the relatively late firing of this other interneuron we named in the Late DCMD (LDCMD). Pro, meso, meta refer to the pro-, meso- and metathoracic ganglia, respectively.

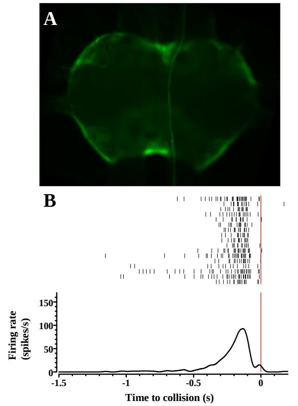


2 DCMD responses to looming



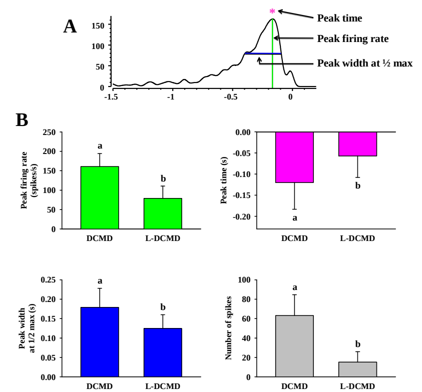
A) Lucifer yellow fill of the mesothoracic region of the DCMD axon showing the main branch, ventrally-directed branches along the midline and collaterals extending to right margin of the ganglion. B). Raster plots (top) from 17 different animals showing DCMD spike times during approach. Peristimulus time histogram (bottom) fitted with a 50 ms Gaussian filter shows a build up of the DCMD firing rate that peaks approximately 150 ms before collision. The red vertical line indicates time of projected collision.

3 LDCMD responses to looming



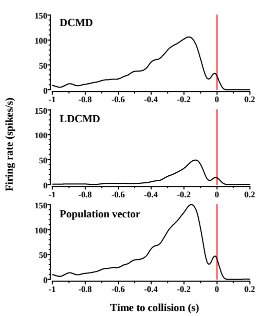
A) Lucifer yellow fill of the mesothoracic region of the LDCMD axon showing the main branch and ventrally-directed branches along the midline. There are no obvious collateral branches. B) Raster plots (top) from 17 different animals showing LDCMD spike times during approach. Peristimulus time histogram (bottom) shows a build up of the firing rate that peaks approximately 125 ms before collision. The red vertical line indicates time of projected collision.

4 Distinct LDCMD responses



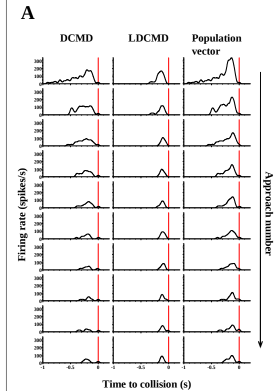
A) Parameters of the response profile describe DCMD firing during an approach. We measured the peak firing rate, the time of the peak relative to collision, the peak width at ½ the maximum firing rate and the number of spikes during approach (not shown). B) During an approach, LDCMD responded with a lower peak firing rate, later and narrower peak and produced fewer spikes. Different letters above bars indicate significant differences (t-test).

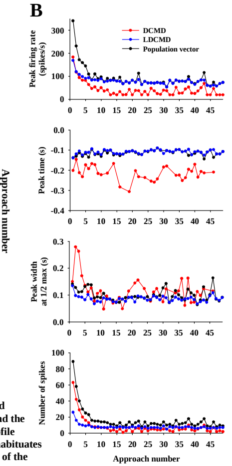
5 Population vector of DCMD and LDCMD response to looming



To examine combined activity of DCMD and LDCMD we generated an evenly weighted population vector (bottom graph) based on the sum of perievent time histograms of DCMD (top graph) and LDCMD (middle graph). The example shown here is from single approaches at 1.0 m/s (n= 22 animals). The population vector demonstrates a stronger response with a greater peak firing rate that occurs between DCMD and LDCMD peak firing.

6 LDCMD habituates less than DCMD





A) Response profiles (time histograms) for 10 repeated approaches showing responses of DCMD, LDCMD and the Population vector. B) Some of the response profile habituate during 49 repeated approaches. LDCMD habituates less than DCMD and contributes to maintained firing of the population vector.

Summary

- A second motion-sensitive neuron (LDCMD) responds to looming objects with an increasing firing rate during approach.
- Compared to DCMD, LDCMD produces a lower peak firing rate that occurs later in the approach.
- LDCMD is less sensitive to habituation than DCMD during repeated approaches.
- Future experiments will investigate how combined DCMD and LDCMD activity contribute to population coding of complex visual stimuli.

Acknowledgements

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References

[1]Schlotterer (1977) *Can. J. Zool.* 55:1372; [2]Rind and Simmons (1992) *J. Neurophysiol.* 68:1654; [3]Gabianni et al. (1999) *J. Neurosci.* 19:1122; [4]Gray et al. (2001) *J. Comp. Physiol.* 187:115