Parallel motion-sensitive pathways encode approaches of looming objects

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Introduction

Our motion-sensitive pathway in the locust visual system consists of the Lobula Giant Movement detector (LGMD), the prototypic 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 behaviors (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 ganglia and an intracellular electrode was inserted into the posterior margin of the same ganglion. B) DCMD activity whereas the intracellular electrode recorded DCMD activity or activity from either, previously unidentified interneurons. C) During recordings, the locust was presented with a 7 cm diameter looming black disc approaching at 1.0 cm/s. D) Sample recordings of DCMD activity from both electrodes and the subtense angle of the disc on the locust's eye aligned to time of collision. E) The blue vertical line indicates time of collision (1.0 cm/s).

2 DCMD responses to looming

A) Locomotion of the mesothoracic region of the DCMD axon showing the main branch, one ventral collateral and another collateral extending to edge margins of the ganglion. B) Raster plots (top) from 7 different animals showing DCMD spike times during approach. Post-hoc time histogram (bottom) 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) Locomotion of the mesothoracic region of the LDCMD axon showing the main branch and one collateral extending along the midline. There are no obvious collateral branches. B) Raster plots (top) from 7 different animals showing LDCMD spike times during approach. Post-hoc time histogram (bottom) shows a build up of the firing rate that peaks approximately 120 ms before collision. The red vertical line indicates time of projected collision.

4 Distinct LDCMD responses

A) Parameters of the response profile show for DCMD firing during escape approach. We measured the peak firing rate, the time of the peak relative to collision, the peak width at half max, 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 DCMD habituates less than LDCMD

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

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References