The velocity of objects traveling along compound trajectories affects firing properties of an identified locust motion-sensitive interneuron.

Jack Gray and Paul Dick

Dept. Biology, University of Saskatchewan,
Saskatoon, SK, S7N 5E2, Canada

jack.gray@usask.ca
www.usask.ca/biology/gray

University of Saskatchewan

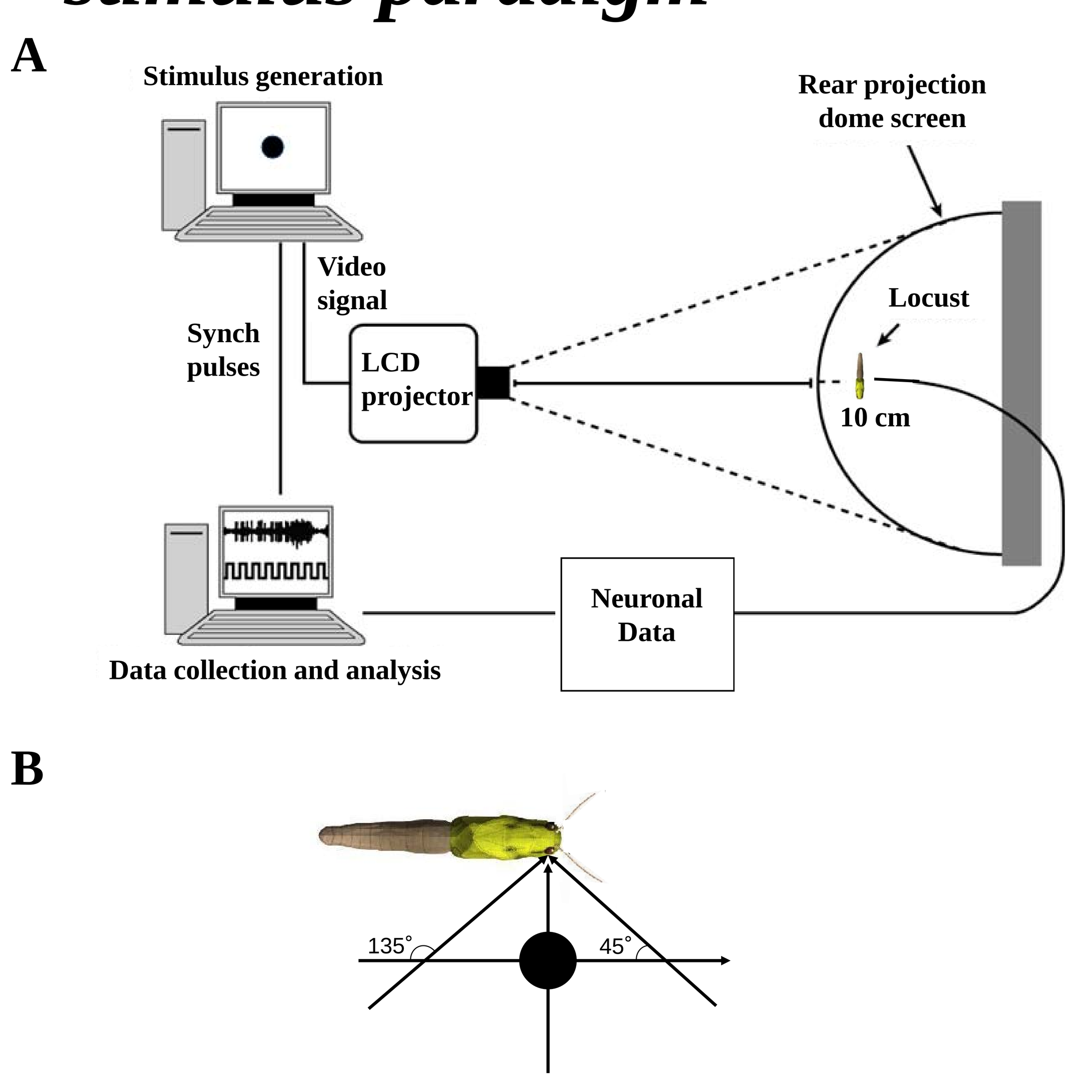
NSERC CRSNG

Gray Lab — Neuroethology of Insect Flight

Introduction

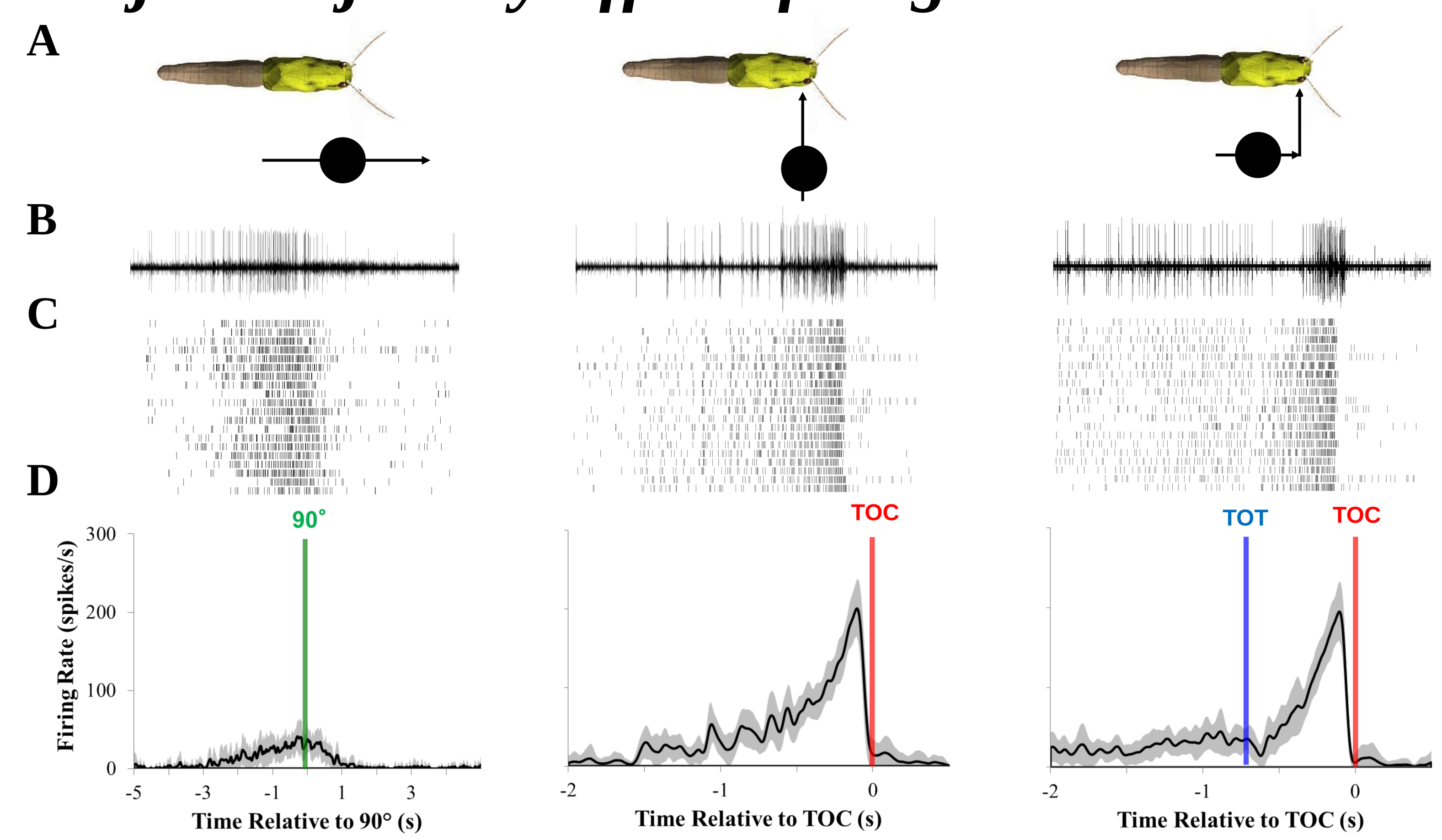
The visual environment of flying animals is made up of complex combinations of translating, receding, and looming visual stimuli. The locust visual system is capable of encoding these stimuli using a tractable, robust system. The Descending Contralateral Movement Detector (DCMD) is an important interneuron in the locust visual system that is involved in producing escape behaviours[1]). Characteristic responses of the DCMD to simple object motion are well described, demonstrating the utility of this neuron as a model for coding visual motion. While DCMD responds strongly to looming visual stimuli[2], data from recent studies that manipulated object velocity[3], shape[4], and trajectory[5] lead us to hypothesize that this system can encode more complex aspects of the visual environment. To test this hypothesis, we recorded DCMD activity from tethered locusts presented with computer generated discs that followed looming, translating, and compound trajectories at different velocities.

1 *Experimental setup and stimulus paradigm*



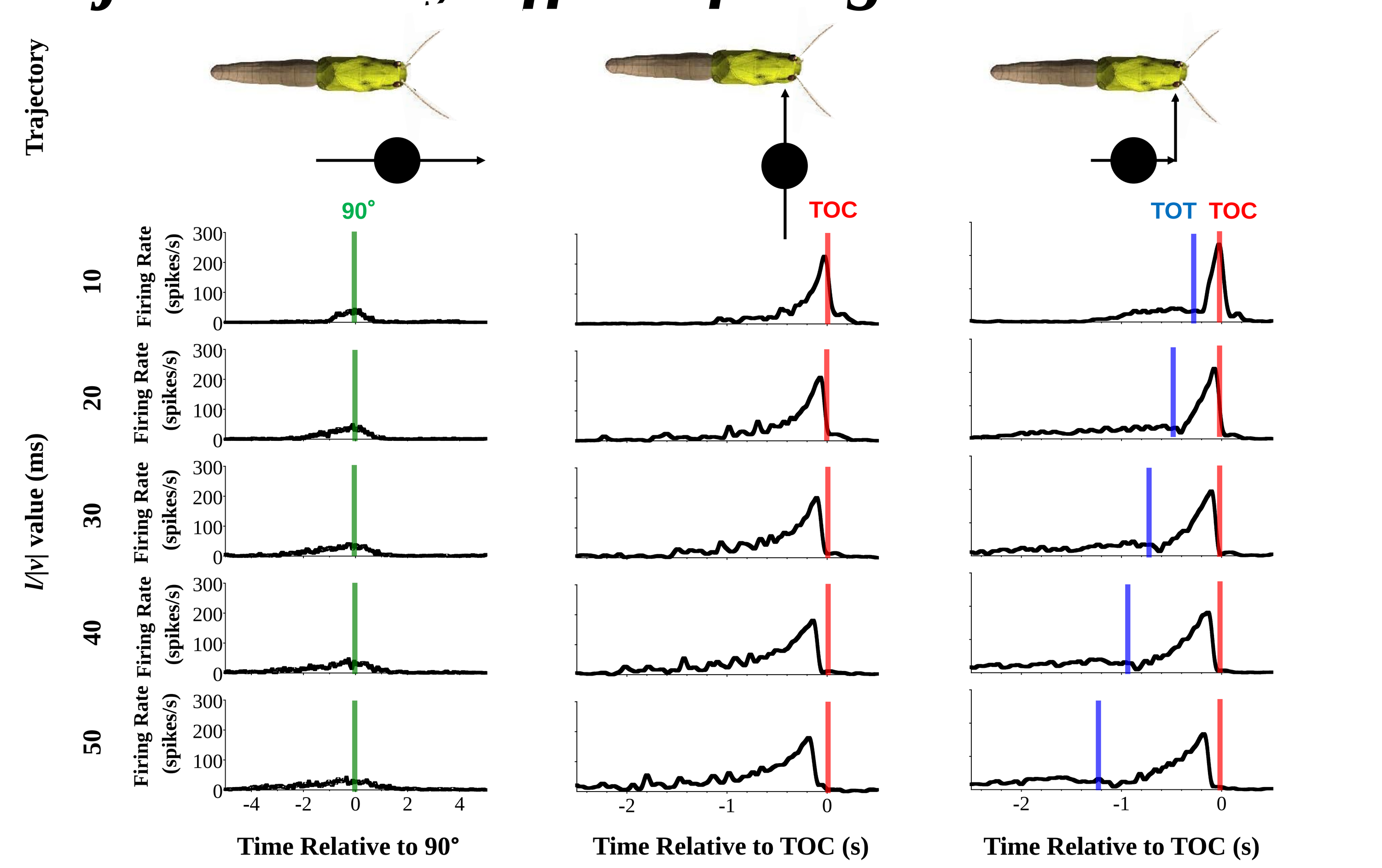
A) Experimental set up. Silver hook electrodes were used to record activity from the left connective of rigidly tethered locusts mounted within a hemi-spherical dome with the right eye aligned to the center of the dome. Stimuli were projected on to the dome by an LCD projector during recording of neuronal data. B) Overall stimulus paradigm. Black, 7-cm diameter computer-generated discs followed 5 unique trajectories at 5 different velocities. Discs transitioned between translating and looming at 3 different angles in the azimuthal plane. Looming objects can be characterized by the $l/|v|$ value, where l is the half size and $|v|$ is the absolute constant velocity during approach. Though translating objects did not approach, for consistency in data presentation we used $l/|v|$ values that matched those of looming discs. To produce different $l/|v|$ values, we varied the velocity between approaches, thus a smaller $l/|v|$ represents a greater approach velocity.

2 *Object trajectory affects firing rate modulation*



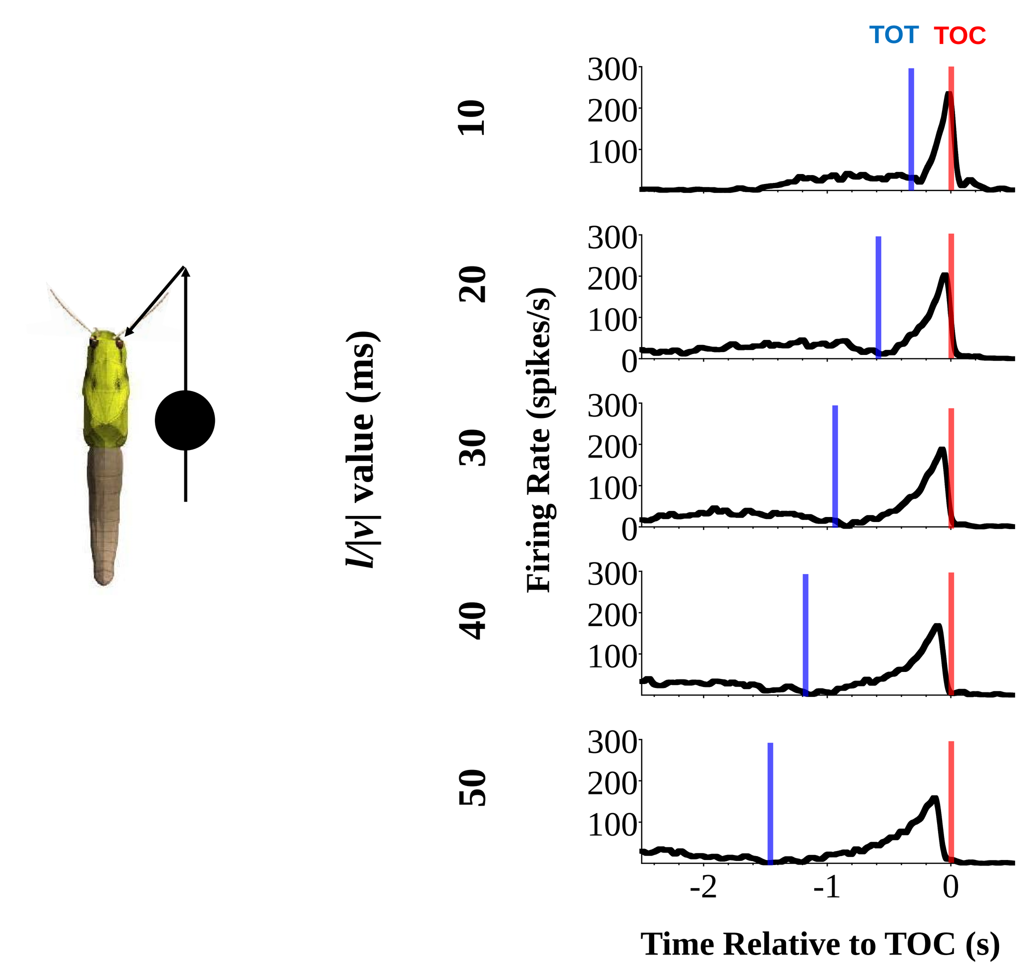
DCMD responses to three different trajectories (A, $l/|v|$= 30 ms). Raw neuronal recordings (B) from one animal showing DCMD firing. Raster plots (C) from 20 different animals showing DCMD spike times during approach. Peristimulus time histogram (D) fitted with a 50 ms Gaussian filter showing the average firing rate from 20 animals (grey shaded area shows the standard deviation). Translating objects evoked relatively little modulation of the firing rate, which peaked approximately at the time the object crossed 90°. Looming stimuli evoked a characteristic increase in the firing rate that peaked approximately 100 ms before the time of collision (TOC). Transitioning to looming evoked a decrease in the firing rate (valley) within 200 ms following the TOT, and a subsequent characteristic looming response.

3 *Object velocity affects firing rate modulation*



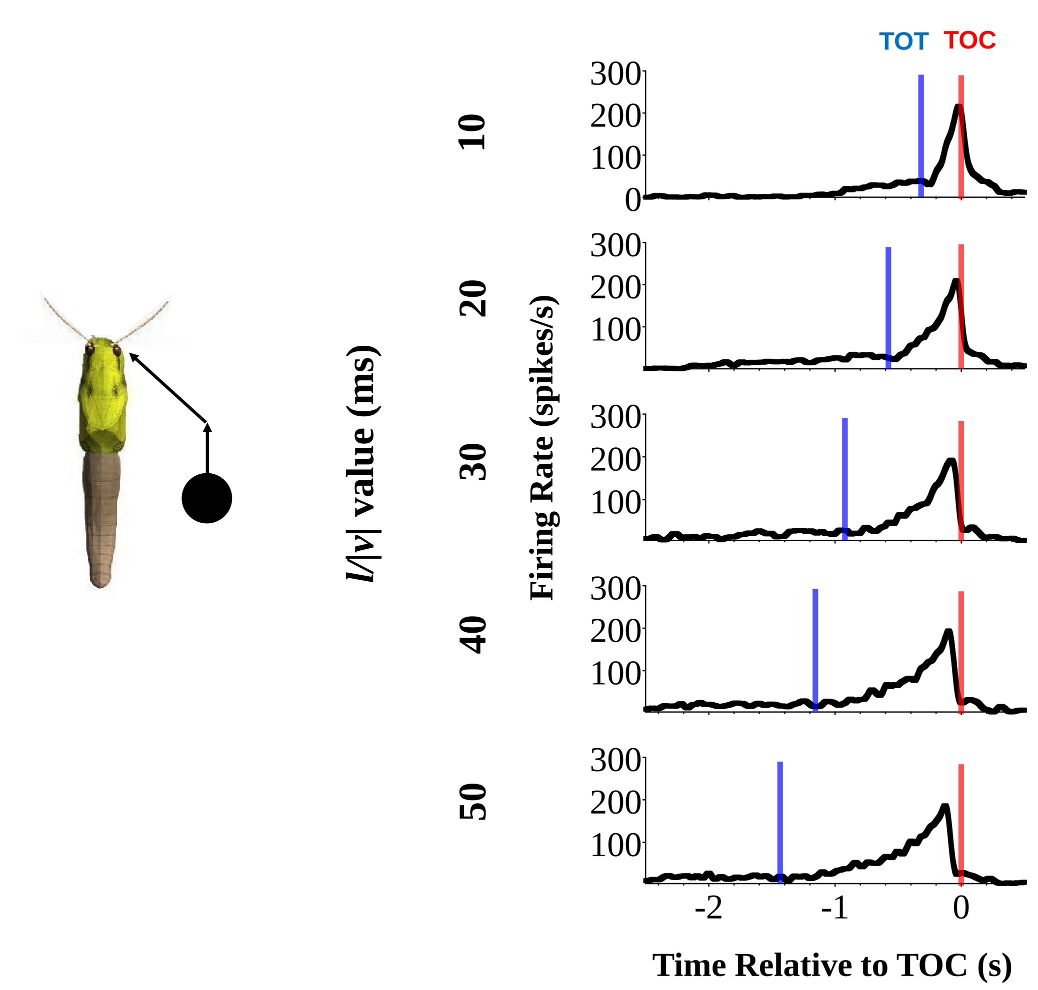
Response profiles (time histograms) for five $l/|v|$ values and three trajectories showing the average DCMD response (n=20 locusts). The time scale for translating stimuli is increased to better visualize the data. Green bars indicate the time at which the object crossed the midline of the locust's eye (90°). Red bars indicate TOC and blue bars indicate TOT. For all looming components, objects approached at 90°. The low amplitude peaks in response to translating stimuli increased in width with increasing $l/|v|$ (decreasing velocity). For looming stimuli, higher $l/|v|$ values produced lower amplitude, earlier peak firing rates. For all $l/|v|$ values, transition to looming evoked a clear valley which was followed by a characteristic increase in firing rate during the looming phase of the approach.

4 *Transition at 45° azimuth*



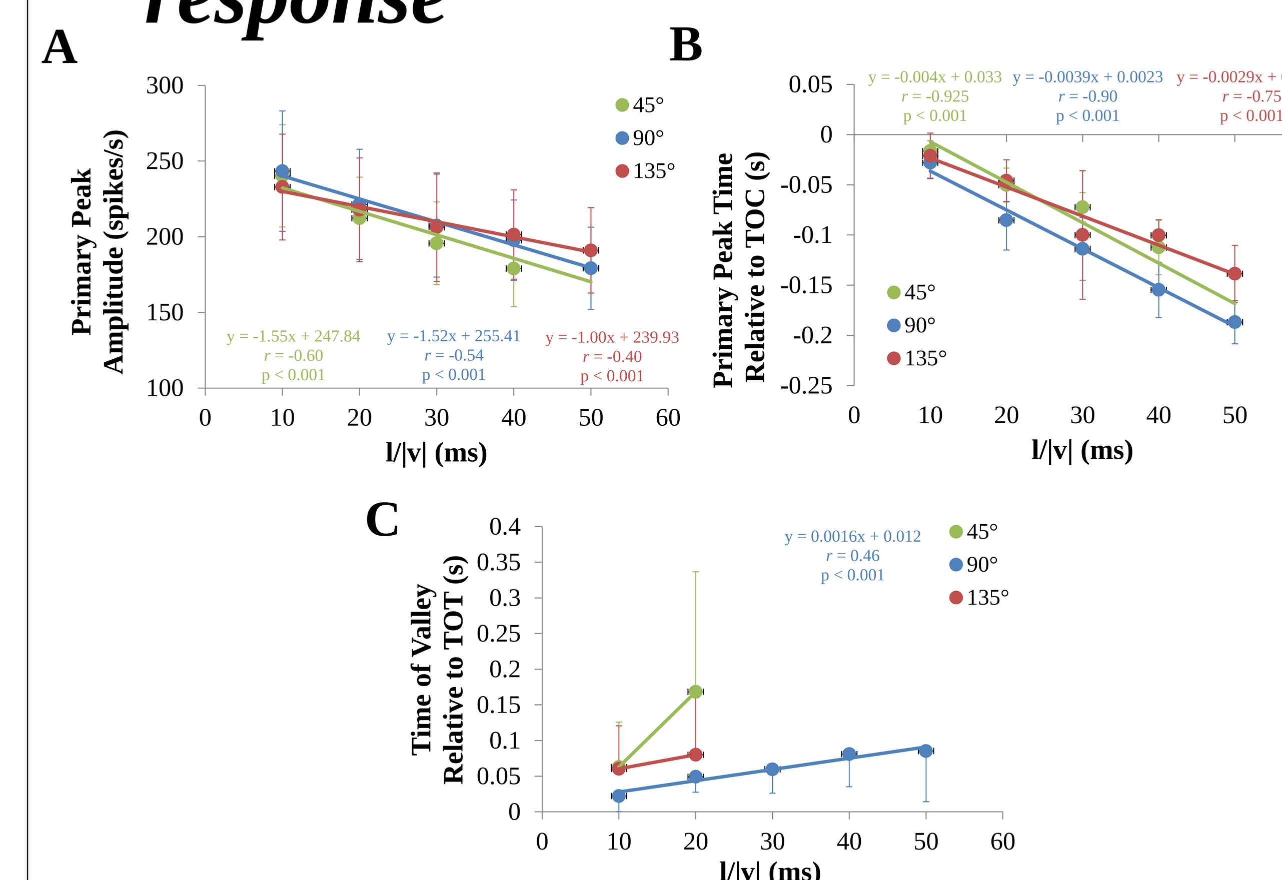
Response profiles for five different $l/|v|$ values showing the average DCMD response (n=20 locusts) to visual stimuli transitioning between translation and looming at 45° azimuth. Transitions at 45° evoked distinct valleys only for lower $l/|v|$ values (10 and 20). For $l/|v|$ values of 30 to 50, the response had decreased in a way similar to responses to pure translational motion.

5 *Transition at 135° azimuth*



Response profiles for five different $l/|v|$ values showing the average DCMD response (n=20 locusts) to visual stimuli transitioning between translation and looming at 135° azimuth. Transitions at 135° evoked distinct valleys only for lower $l/|v|$ values (10 and 20). For $l/|v|$ values of 30-50, there was very little modulation of the firing rate, regardless of a transition to looming.

6 *Parameters of the DCMD response*



Parameters of the DCMD response to visual stimuli transitioning from translation to looming at 45°(green), 90°(red), or 135°(blue). A: The amplitude of the TOC associated peak in firing rate decreased as the $l/|v|$ value increased. B: The primary peak occurred earlier with increased $l/|v|$ values. This suggests that the earlier transition does not affect the final response to looming. C: The timing of the valley relative to the TOT shows different responses with different approach angles. When approaching at 90° after translating, an increase in $l/|v|$ increased the time between the TOT and the valley. Due to the difficulty in identifying a valley for higher $l/|v|$ values, only the lowest two are given for trajectories that transition at 45° and 135°.

Summary

- DCMD produced low amplitude, broad peaks in firing rate in response to translational motion.
- Transitioning from translation to looming does not affect the relationship between the looming response and the $l/|v|$ value.
- Firing rate modulation is affected by combinations of velocity and trajectory.
- Future experiments will investigate how ensembles of motion-sensitive neurons respond to complex motion.

References

1 Santer et al. (2005). *J. Comp. Physiol. A.* 191: 61-73. 2.. Schlotterer. (1977). *Can J Zool.* 55:1372-1376; 3. Rind and Simmons. (2008) *J. Neurophysiol.* 77(2):1029-1033; 4. Guest and Gray. (2005). *J. Neurophysiol.* 95(3): 1428-1441; 5. McMillan and Gray. (2012) *In Press. J. Neurophysiol.*

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