WHY ARE GRASSHOPPERS SO HARD TO CATCH?

THE MOTION DETECTOR NEURONS BEHIND THE GRASSHOPPER'S VISUAL & MOTOR SENSITIVITY TO APPROACHING OBJECTS

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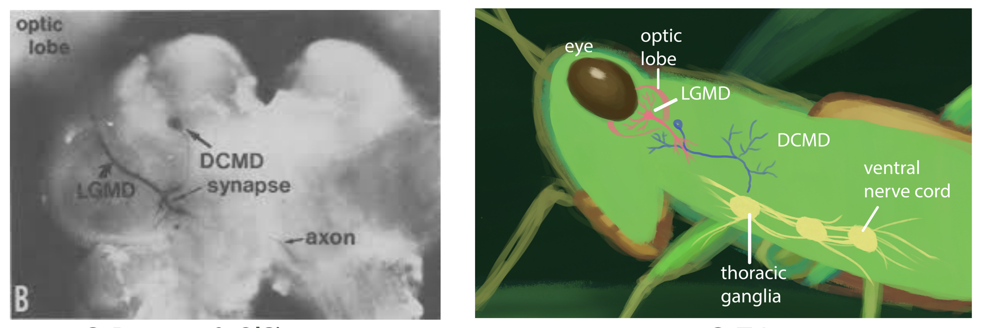
INTRODUCTION

- Grasshoppers can see an approaching object, such as a predator, and quickly hop away to avoid collision with the object.



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- The grasshopper visual system includes two types of motion detector neurons: The lobula giant motion detector (LGMD) neurons are excited by approaching visual stimuli and in turn excites its postsynaptic target, the descending contralateral motion detector (DCMD) neuron that responds to movements detected by the opposite (contralateral) eye by exciting motor neurons[4].
- The DCMD response could be modeled by multiplying object's angular velocity & size on the retina[1,2].
- The LGMD & DCMD together make up an early warning system to generate the see-and-jump escape behavior in face of possible collision with approaching objects[4].
- I use Backyard Brains' (BYB) open source equipment to extracellularly record & analyze the activity of the DCMD when the grasshopper is exposed to approaching visual stimuli.

METHODS

GRASSHOPPER PREPARATION

Grasshopper is anesthetized by storage in the fridge for 15min, then mounted ventral side up on corkboard on top of the BYB SpikerBox, head and thorax exposed. The head is pulled back by thread to expose neck connectives (2 white strips) where the recording hook electrode is placed around the contralateral connective, where the DCMD's axon is. Reference electrode is grounded in abdomen or thorax.

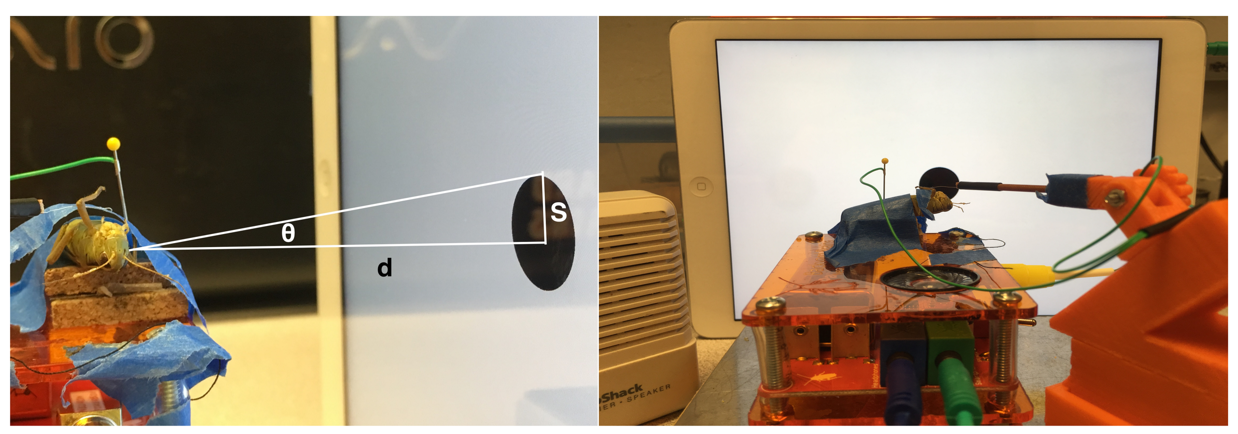

Figure 1. Experimental setup (left) Grasshopper is exposed to visual stimulus on iPad while the SpikeRecorder application records DCMD activity. **(right)** Experimental conditions. θ, angle between object edge and focus of expansion; S_{obj}, radius of circle object; d, distance between screen/stimulus and eye.[1]

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RESULTS

WHEN DOES THE DCMD PEAK IN FIRING RATE DURING THE APPROACH OF A VISUAL STIMULUS?

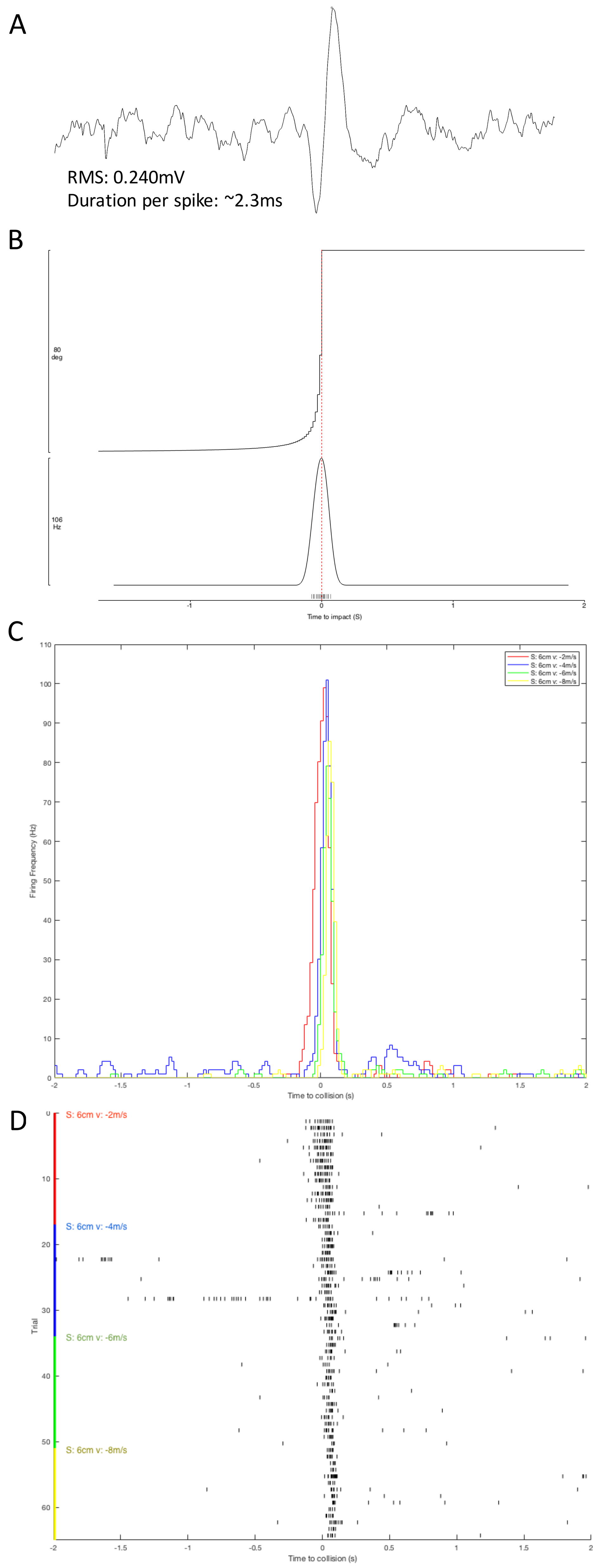


Figure 3. DCMD response to approaching objects. d: 10cm; S_{ob}: 6cm; v: -2, -4, -6, -8m/s; trials per pair of S_{obj} and v: 30; ITI: 45s. Collision at 0s. DCMD firing peaks around collision for objects approaching at -2m/s, and after collision for objects approaching faster. **(A)** A single DCMD spike, approximately 2.3ms from onset of depolarization to end of refractory period. **(B)** DCMD activity over time and change in angular size **(C)** Perievent histogram (PETH; bin size: 0.03) of DCMD firing frequency 2 seconds before and after simulated collision between eye and object. **(D)** Raster plot of DCMD spiking pattern across each pair of S_{obj} and v over time.

WHAT IS THE 'IDEAL' INTERTRIAL INTERVAL TO AVOID HABITUATION OF DCMD RESPONSE TO THE STIMULUS?

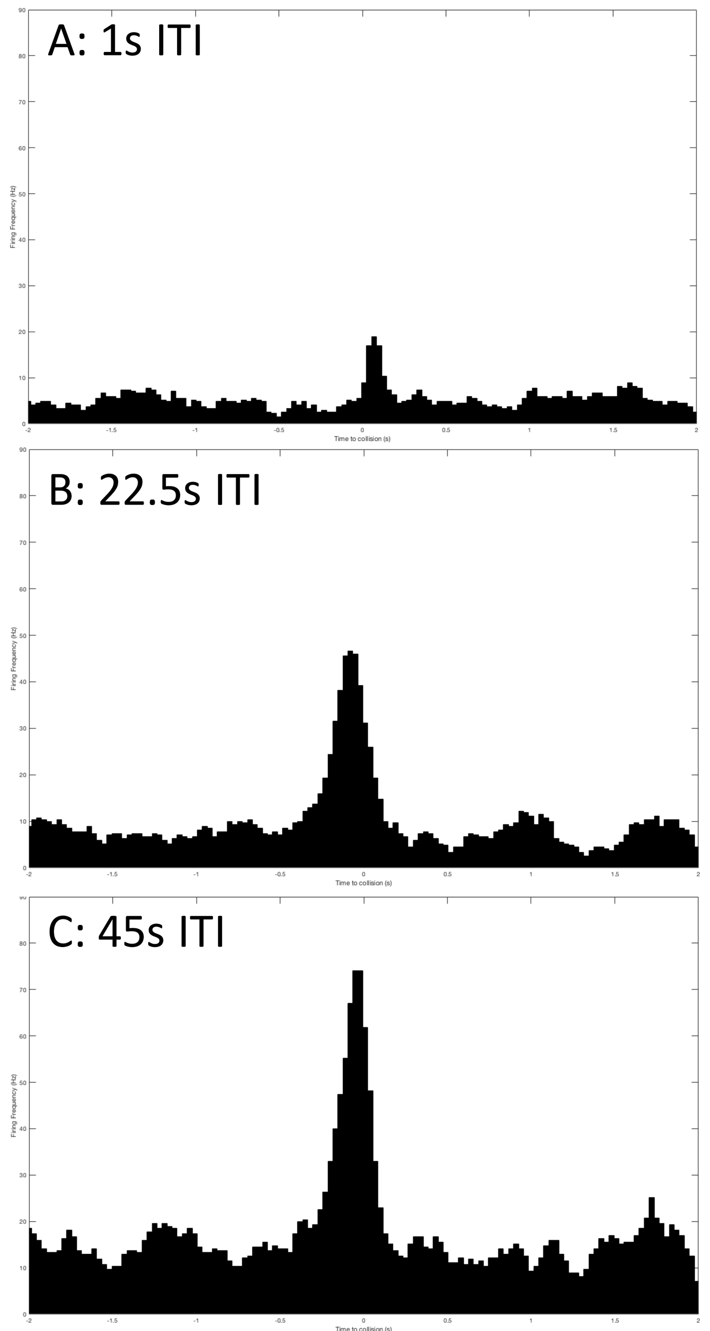


Figure 2. DCMD response to varying intertrial intervals. Peak firing frequency is around 20, 45, and 75 Hz for 1, 22.5, 45s ITI, respectively. The 45s ITI shows the most consistent and frequent firing of the DCMD, and is the ITI of choice for other experiments.

WHAT IS THE EFFECT OF STIMULUS CONTRAST INTENSITY / SCREEN BRIGHTNESS ON DCMD RESPONSE?

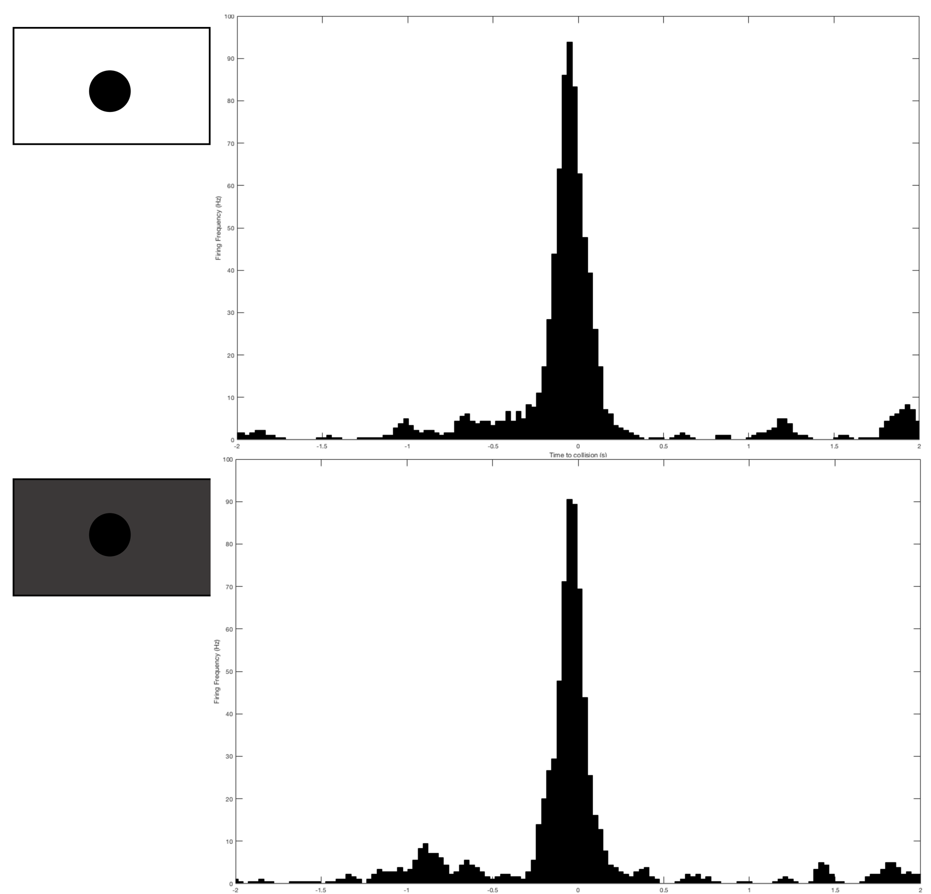
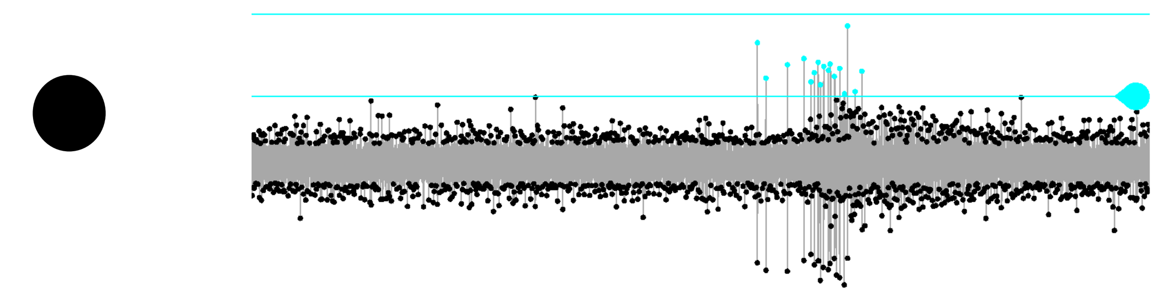


Figure 3. DCMD response to varying iPad screen brightness. (top) At maximum brightness, DCMD firing rate is consistent and peak at 95Hz. **(bottom)** At miminum brightness, firing rate (90Hz) is not significant different from activity pattern at full screen brightness.

METHODS

VISUAL STIMULI & SPIKE RECORDING

The BYB SpikeRecorder iPad application provides both the visual stimuli and recording and analysis of DCMD activity. Visual stimuli consist of expanding dark circles (of various sizes and velocities) on a white background to simulate an approaching and colliding object. Parameters in the application include: distance between subject and stimulus/screen, object size and velocity, intertrial interval, and number of trials. Recordings are done in the dark for maximal contrast intensity. Spikes are sorted from noise.



DATA ANALYSIS

Data is imported from the application into MatLab. A database of the experimental data (recording and spike timestamps, stimulus angles, time of collision) is created. Perievent time histograms and raster plots are plotted to visualize firing rate and timing of spikes in relation to stimulus.

CONCLUSION

- DCMD firing rate peaks around time of collision with an approaching object. The neuron encodes the angular size and velocity of an object, peaking when the image on the retina reaches a certain angular size.
- The 'ideal' ITI to prevent habituation of the DCMD response is 45s.
- Varying screen brightness to alter the contrast intensity between stimulus and screen background does not have a significant effect on the DCMD firing, suggesting that grasshoppers are able to detect objects that do not contrast highly with the background.

Future directions:

- Perform mathematical and software tests to ensure the accuracy of calculated time of collision in iPad SpikeRecorder application, to make sense of the instance of peak DCMD firing after the time of collision.
- Compare DCMD response to approaching vs receding objects.
- Use a wider range of visual stimuli of various colors, background clutters, and motion to further investigate grasshopper/insect vision.

REFERENCES

1. Gabbiani et al. 1999. Computation of object approach by a wide-field, motion-sensitive neuron. *J.Neurosci* 19(3):1122–1141.
2. Hatsopoulos et al. 1995. Elementary computation of object approach by a wide-field visual neuron. *Science* 270(5238):1000-1003.
3. Pearson & O'Shea. 1984. Escape behavior of the locust. *Springer US.*
4. Rind & Simmons. 1992. Orthopteran DCMD neuron... *J.Neurophys* 68(5): 1654-1666.

Grasshopper anatomy illustration by Cindy Trieu.
SpikeRecorder application by Stanislav Mircic.