

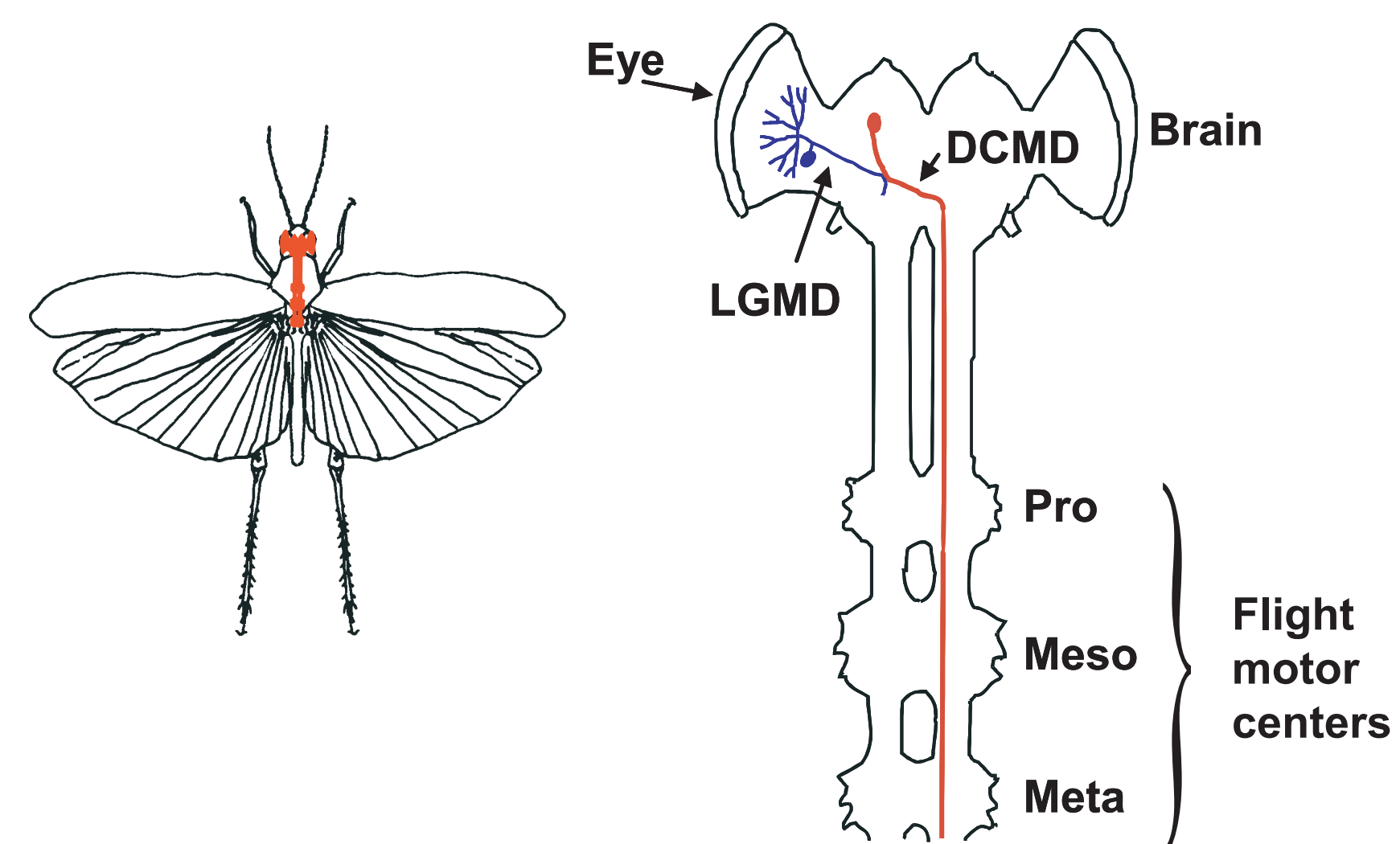
Introduction

To produce effective collision avoidance behaviours, the nervous system must be able to extract salient sensory cues related to looming stimuli (objects approaching on a direct collision course). In a natural environment animals are often confronted with complex spatiotemporal patterns of visual information. However, little is known of how looming sensitive neurons are influenced by visual complexity. The locust visual system contains a well defined neural pathway composed of the lobula giant movement detector (LGMD) and its postsynaptic target, the descending contralateral movement detector (DCMD), that is highly responsive to looming stimuli^{1,2,3,4}. Previous results⁵ predict that this pathway should be able to respond to approaches of multiple objects approaching from different trajectories. Some of the data presented (Figs. 2-9) have been published previously⁶.

Objectives:

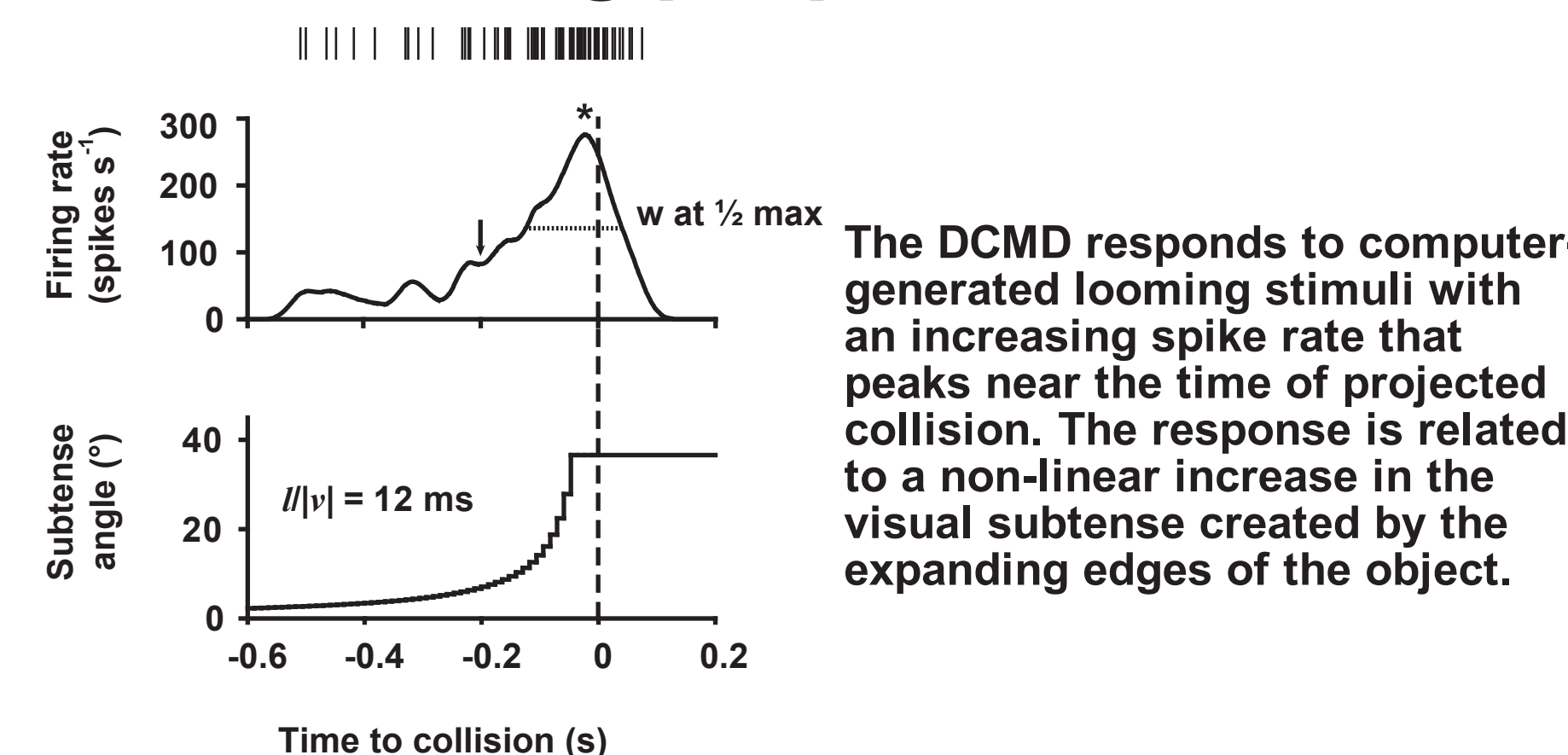
- 1) To test the effects of object shape on DCMD looming responses.
- 2) To test the effects of paired object approaches on DCMD looming responses.
- 3) To determine if changes in trajectory during approach influence DCMD response profiles.

1 Locust LGMD/DCMD



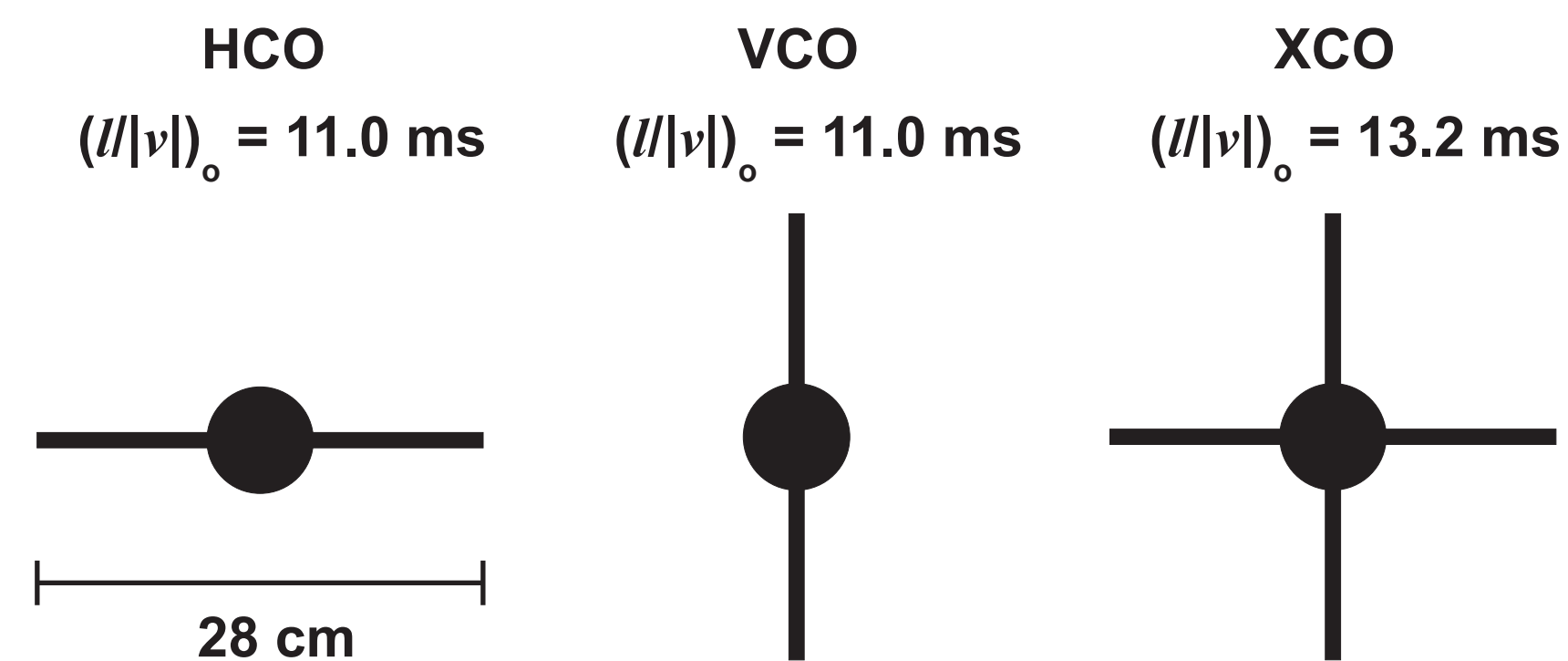
The DCMD receives information from the contralateral eye via the LGMD and connects to flight motor centers in the thoracic ganglia. DCMD activity was recorded from the connective between the brain and prothoracic ganglion.

2 DCMD firing properties

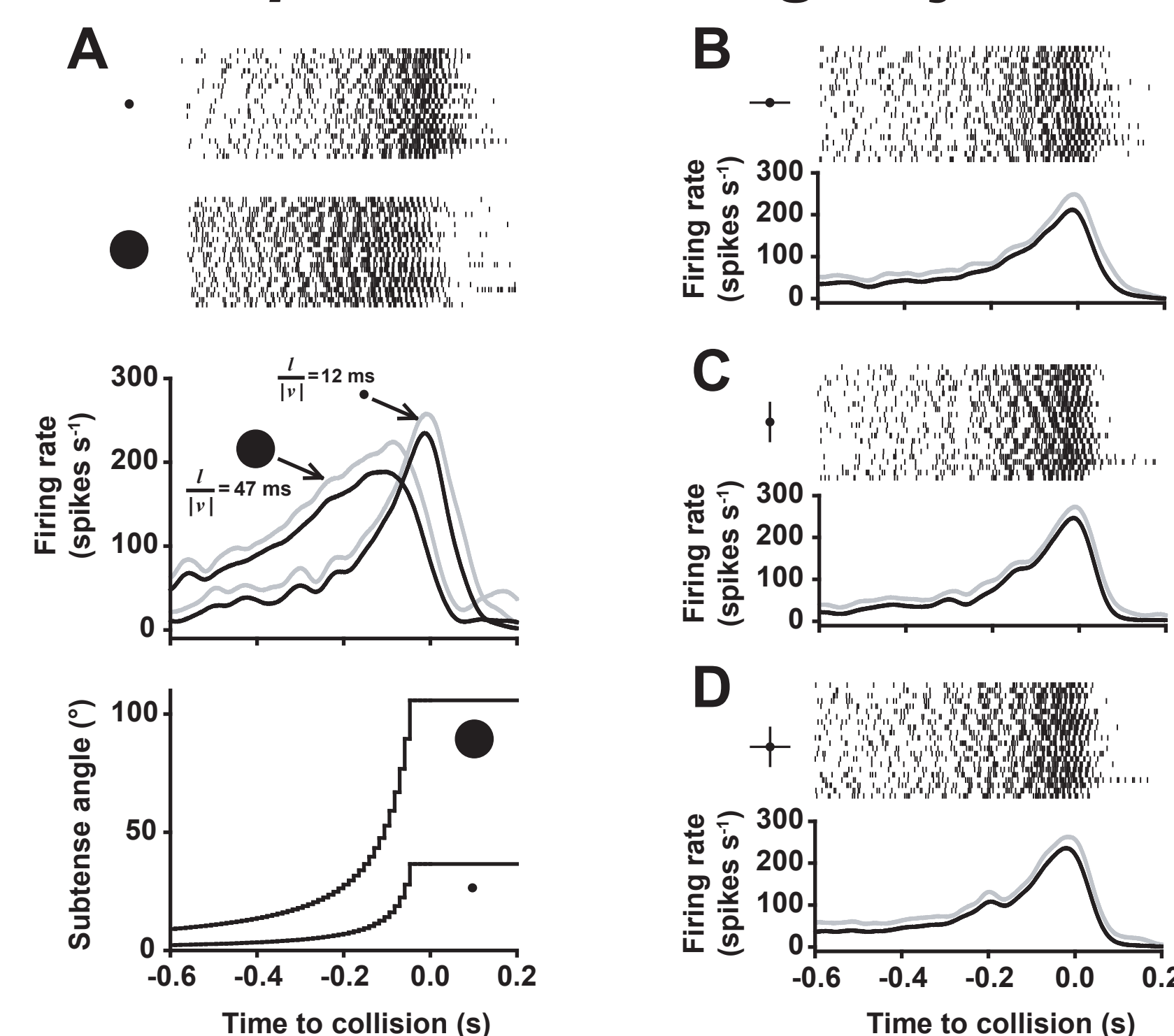


Compound objects

3 Compound object shape

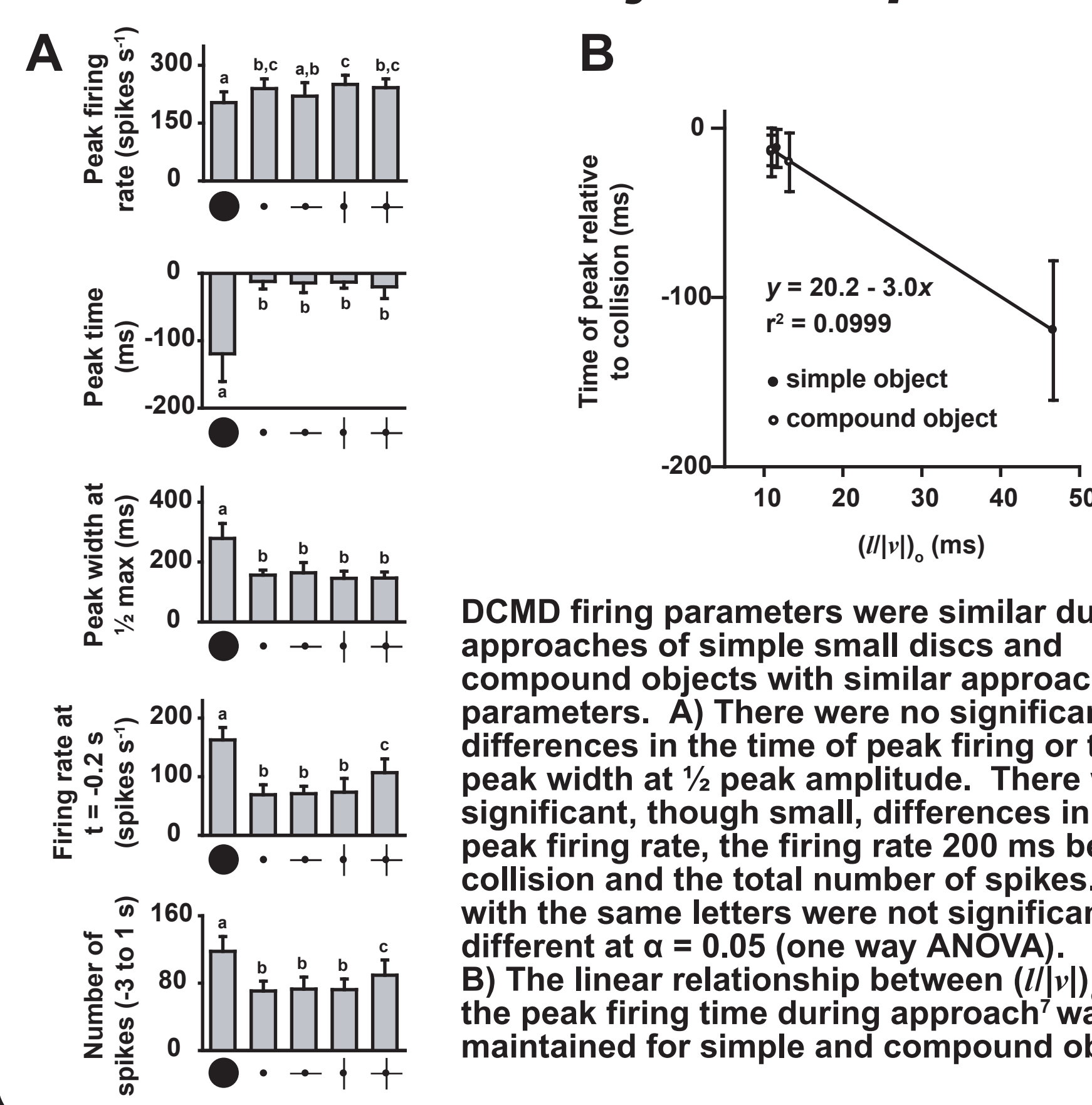


4 DCMD responses to simple and compound looming objects



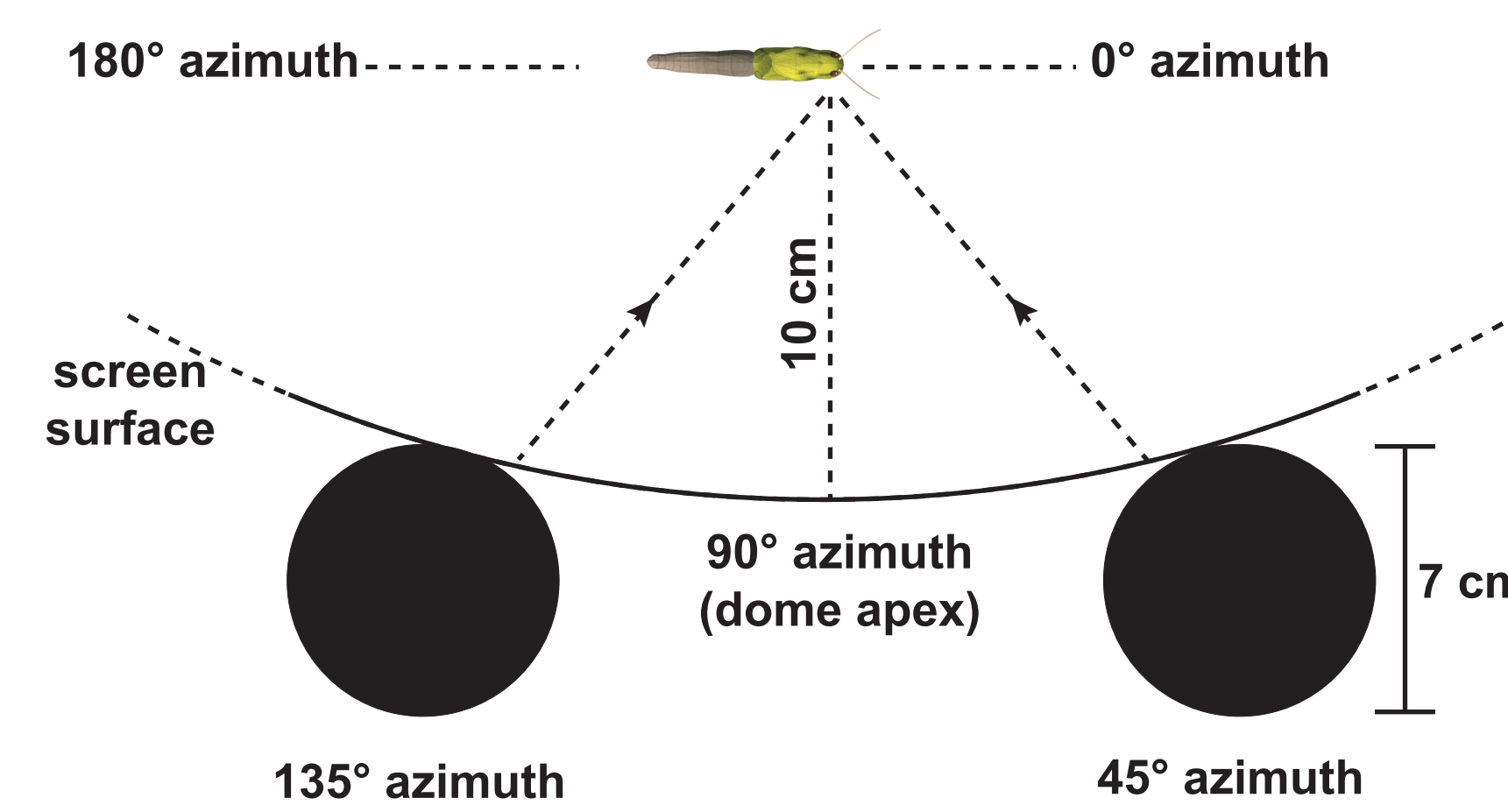
Response profiles are similar for compound objects $(|l|v|)_0 = 11 - 13.2$ ms and simple objects with similar approach parameters $(|l|v|)_0 = 12$ ms. (mean (black line) + SD (grey line)).

5 Invariance to object shape

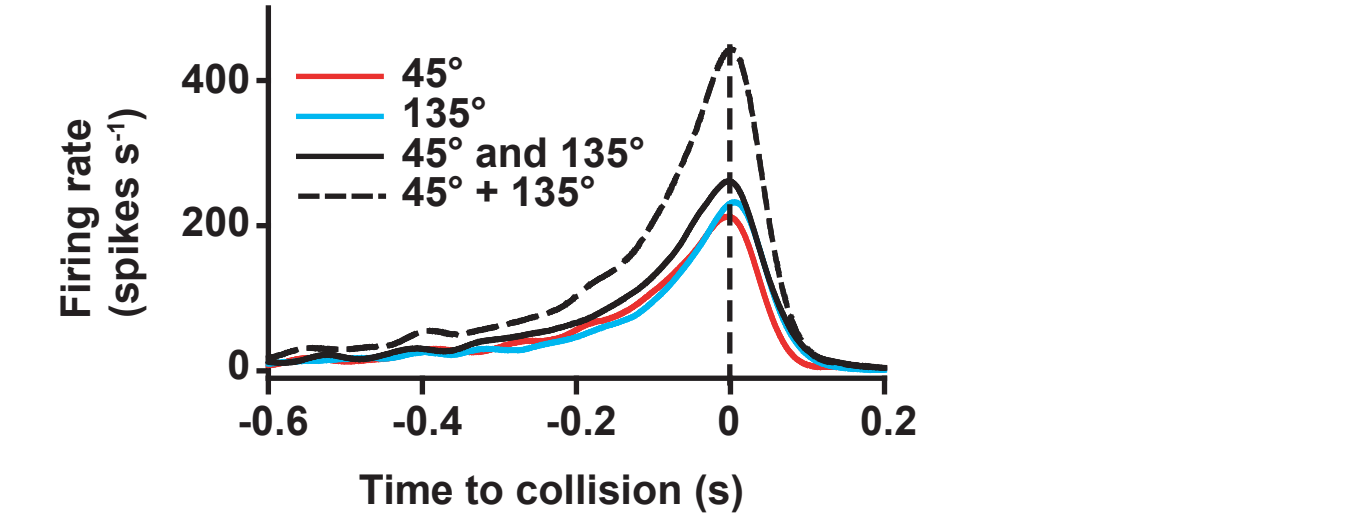


Paired objects

6 Approach parameters

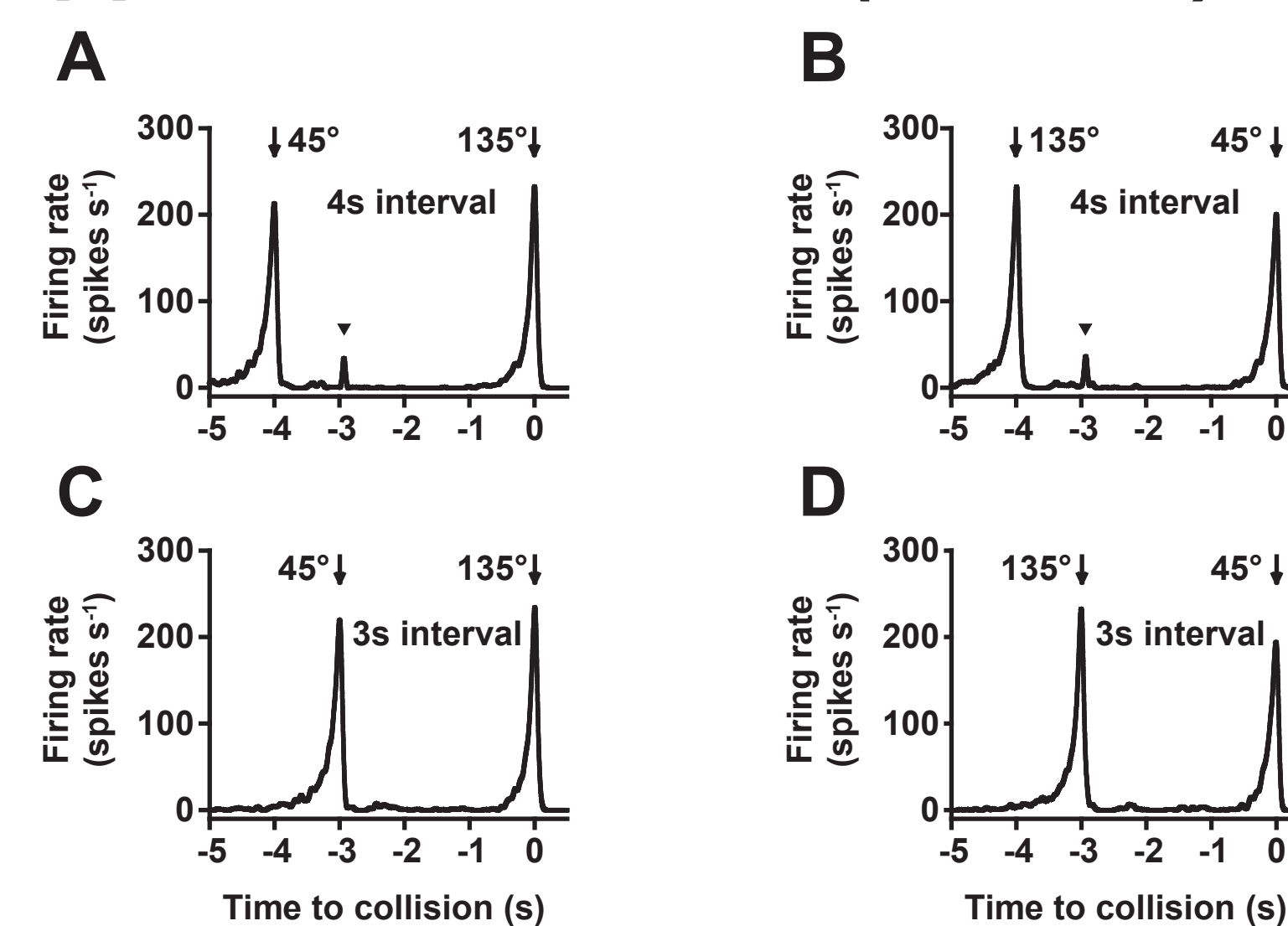


7 Sublinear response to simultaneous approaches



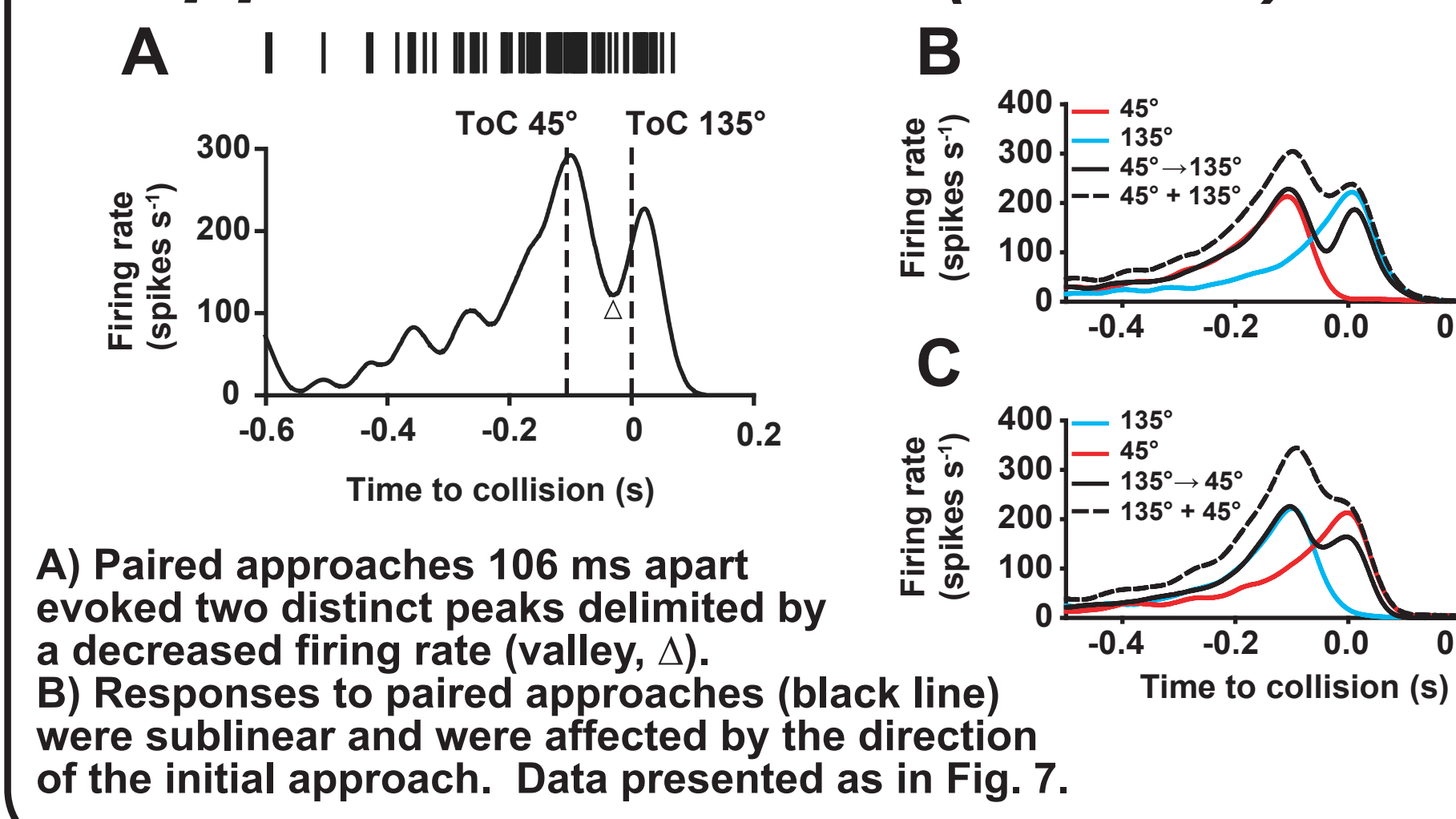
Mean plots of smoothed histograms for single approaches from 45° (red line) and 135° (blue line) are overlaid with plots of the response to simultaneous approaches (black line) and the predicted linear sum of individual approaches (dashed line).

8 No effect of non-overlapping approach intervals (4 or 3 s)



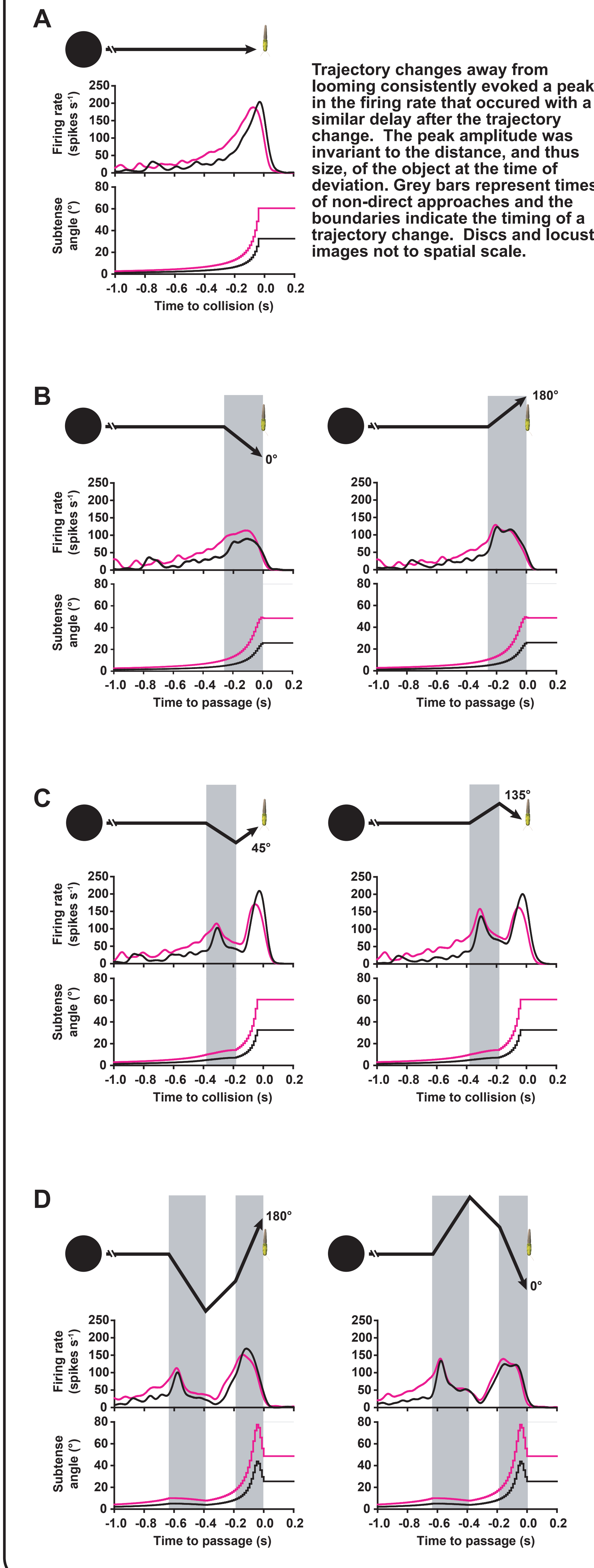
Responses were not affected by previous approaches from a different region of the visual field. Initial approaches were from 45° (A, C) or 135° (B, D). Approaches from 135° evoked larger responses than did approaches from 45°.

9 Sublinear response during short approach intervals (106 ms)



Compound trajectories

10 Response modulation induced by changing trajectory



Summary

Compound objects

- Looming compound objects evoke characteristic DCMD responses.
- Similar $|l|v|$ values evoke similar response profiles, irrespective of object complexity.

Paired objects

- Previous approaches from different regions of the visual field 3 or 4 seconds earlier do not affect responses to later approaches.
- Simultaneous or closely timed approaches evoke sublinear responses.
- Looming responses are affected by the direction of approach.

Compound trajectories

- Changes to non-looming trajectories during an approach evoke transient, delayed increases in the firing rate.

Conclusions

- Encoding of object approach properties is relatively insensitive to object shape.
- Responses to individual looming objects during simultaneous or closely timed paired approaches are strongly sublinear.
- DCMD activity is affected by the timing and direction of trajectory changes during an approach.

Future studies

- Test for DCMD habituation during repeated approaches of objects traveling along varying paths.
- Test effects of trajectory changes from initial non-looming to looming.
- Examine effects of compound trajectories on behavioural responses of loosely tethered flying locusts.
- Record DCMD activity of flying animals presented with the same stimuli used here.

References

- 1 Hatsopoulos N. et al. *Science* 270, 1000 (1995)
- 2 Simmons P.J. and F. C. Rind *J. Neurophysiol.* 68(5), 1667 (1992)
- 3 Judge S.J. and F. C. Rind *J. Exp. Biol.* 200, 2209 (1997)
- 4 Schlotterer G.R. *Can. J. Zool.* 55(8), 1372 (1977)
- 5 Gray J.R. *J. Exp. Biol.* 208(13), 2515 (2005)
- 6 Guest B.B. and J.R. Gray *J. Neurophysiol.* 95, 1428-1441 (2006)
- 7 Gabbiani F. et al. *J. Neurosci.* 19(3), 1122 (1999)

Acknowledgements

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