Response of a locust motion sensitive neuron and flight muscle activity during flight steering

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Introduction

Flying animals display a variety of adaptive behaviours to avoid predators and collisions with conspecifics during flight. The locust Descending Contralateral Movement Detector (DCMD) is a well characterized motion-sensitive visual neuron that responds with an increased firing rate, peaking near the time of collision (TOC) of an approaching object[1]. Increasing stimulus complexity (number and shape of objects or object trajectory changes) affects the amplitude and temporal properties of the DCMD response profile[2]. This is the first experiment to examine DCMD responses during flight steering. Results show significant differences in DCMD firing rate and burst firing rate responses between non-flying and flying conditions. DCMD bursting, high frequencies of spikes in succession, occurred in non-flying and flying locusts, suggesting that bursting is critical for coding object approach This indicates that bursting responses change with respect to stimulus direction and that bursts are an important component of coding to coordinate motor output during collision avoidance behaviour. Moreover, bursting events are shown to correspond to muscle synchrony events responsible for initiation of turns and stops.

Materials and Methods

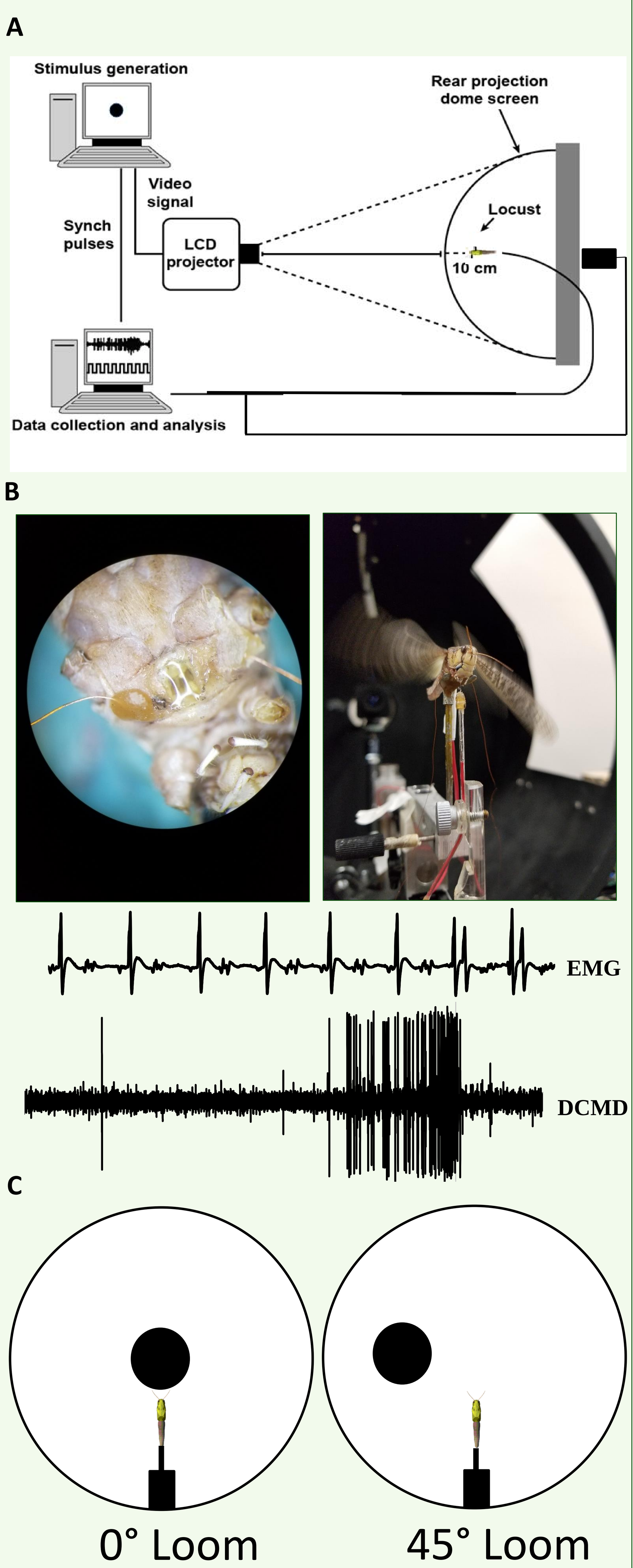

Fig.1: DCMD activity was recorded from the ventral nerve cord using a silver wire single hook electrode. EMG electrodes were inserted into right and left first basalar m97 flight muscles, responsible for depression and pronation of forewing. (A) Locusts were attached to a ridged tether and, following electrode placement, placed in experimental setup. (B) Images of electrodes and final placement of the locust in setup (above), raw traces of EMG and DCMD recordings (below). (C) A simulated 14cm disk was projected onto the dome and travelled at 3m/s, from 0° or 45°.

Flight Affects DCMD Responses to Looming Objects

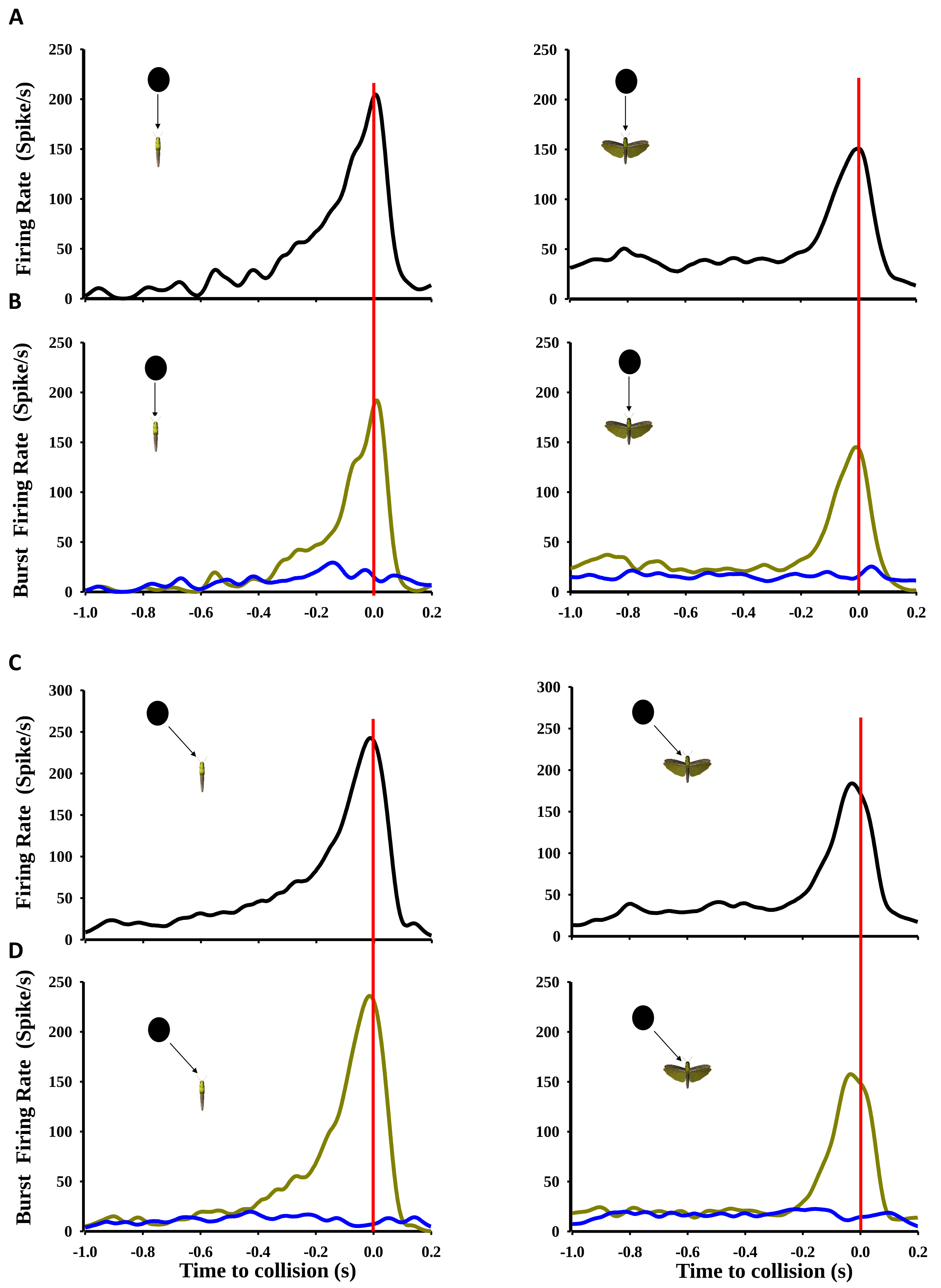

Fig. 2: (A ,C) loom trajectory (0° and 45°) show PeriEvent histograms of DCMD firing rate for non-flying (left) and flying (right) locusts (n=16). (B,D) shows burst firing rate of the DCMD (yellow) and firing rate of isolated spikes (blue). Red vertical lines represent time of collision (TOC). For the 0° loom, peak firing rate and burst firing rate was significantly lower during flight (*p*=.011, *p*=.028) and peak position was significantly earlier during flight for both firing rate and burst firing rate for the 0° loom (*p*=.003, *p*=.004). For the 45° loom, peak firing rate and burst firing rate was significantly lower during flight (*p*=.007, *p*=.005). Peak width at half height for both firing rate and burst firing rate at the 45° loom were significantly lower during flight (*p*=.005, *p*=.013). Note how the response curve is conserved between firing rate and burst firing rate, where as the isolated spikes fail to represent the overall response.

DCMD and Muscle Synchrony

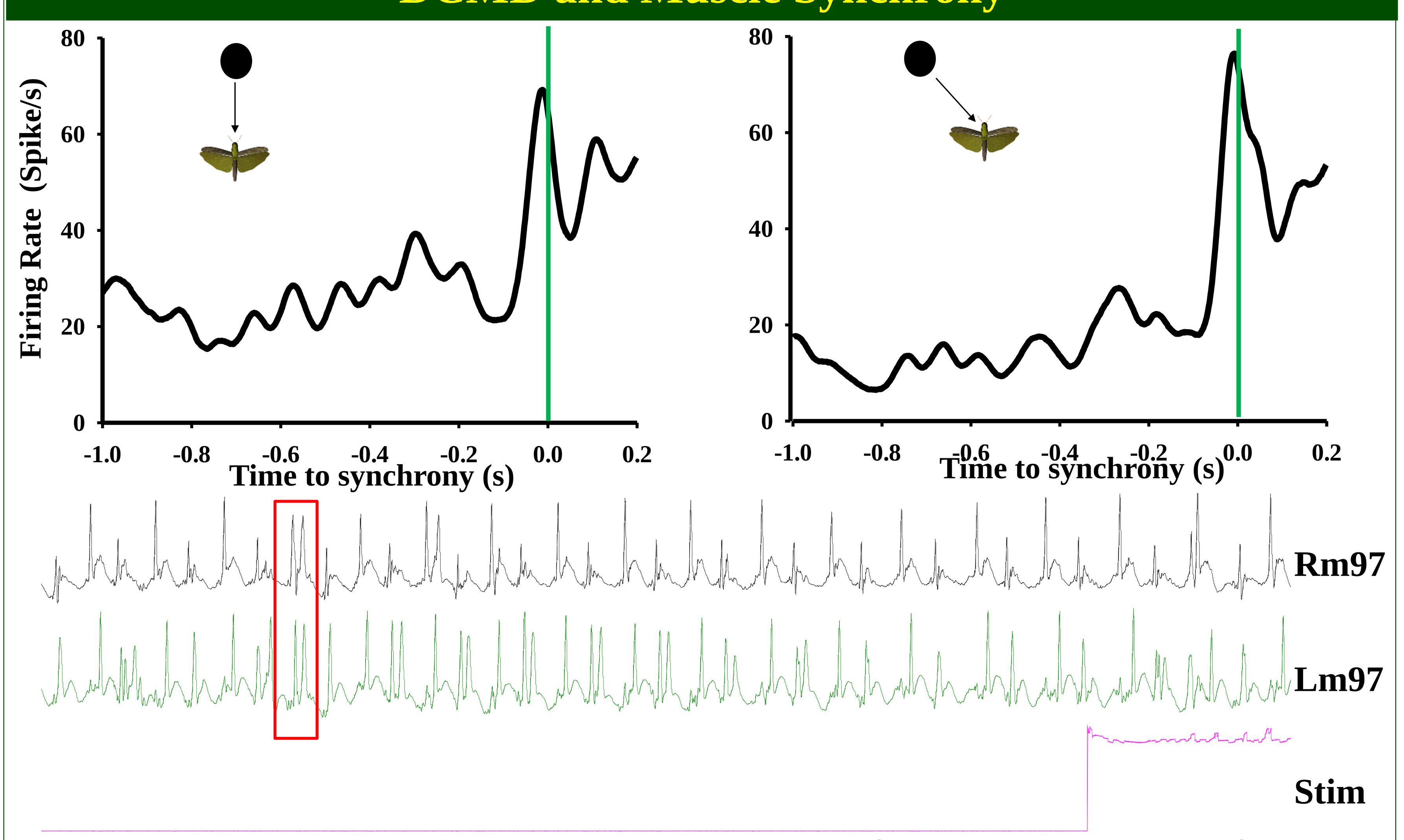

Fig 3. Top panels are PeriEvent histograms showing the DCMD firing rate relative to time of Right m97 and Left m97 synchrony (vertical teal line). Lower panel shows raw EMG traces and time of synchrony (TOS) shown by the red box, in response to a 45° loom. Pink trace shows an upwards inflection which represents TOC. Note Increases in firing rate immediately before synchrony for both 0° and 45° looms.

Bursting and Timing of Muscle Synchrony

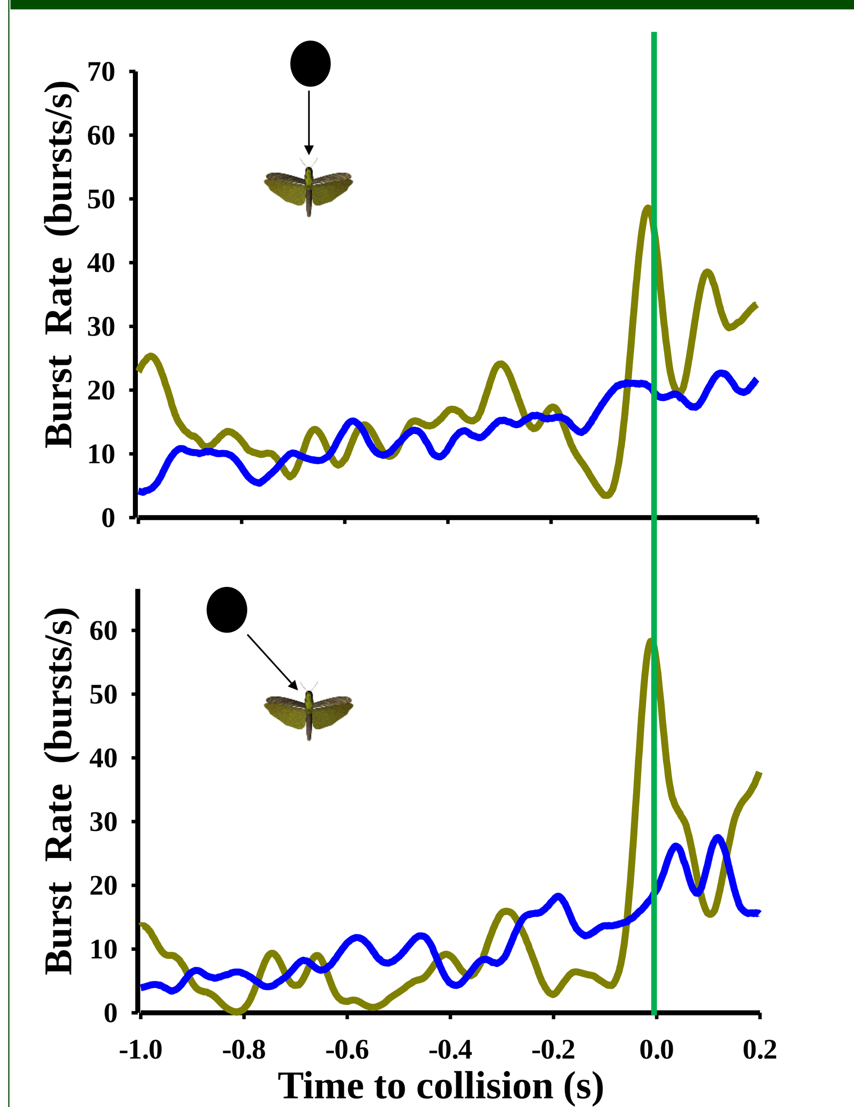

Fig.4: PeriEvent histograms showing DCMD burst firing rate relative to TOS for 0° and 45° looms. The teal vertical = TOS. Burst rate increased relative to baseline prior to synchrony for both 0° and 45° looms. There was no significant difference between peak firing rate, peak timing or peak width at half height. Note isolated spikes (blue line) do not increase significantly compared to burst activity (black line) approaching synchrony.

SUMMARY

- Flight affects DCMD response to a looming object
- During flight, DCMD displays a lower firing rate and burst firing rate for both 0° and 45° looms
- Peak width at half height was smaller in 45°, suggesting a finer tuned response to directionality
- Burst firing rate may be a more dependable representation of collision avoidance
- Both firing rate and burst firing rate increased prior to muscle synchrony in both 0° and 45° looms.

REFERENCES & ACKNOWLEDGMENTS

References

1. Rind F. C., and Simmons J.. 1992. J. Neurophysiol. 68:1654–1666.

2. McMillan G. A., and Gray J. R.. 2012. J. Neurophysiol. 108:1052–1068

Acknowledgements

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