Sensory bursts in a single motion sensitive pathway of the locust

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1. ABSTRACT

The descending contralateral movement detector (DCMD) is part of a neuronal pathway that is specifically tuned to small looming objects[1] and has lateral projections that synapse with motor neurons involved in collision avoidance[2]. DCMD responses are typically described in terms of rate coding[1,3,4], yet responses to looming often display observable oscillations in mean firing rates and tight clustering of spikes in raw traces; an indication of the presence of bursting. We tested 20 locusts with 30 looming stimuli known to generate behavioural responses. We found frequent and shorter inter-spike intervals (ISIs) ranged from 1-8ms, while longer less frequent ISIs ranged from 40-50ms. A subsequent burst analysis revealed inter-burst frequencies of ~25Hz (within the range of the wingbeat frequency of a flying locust[5,6]). We propose that the DCMD employs a bimodal coding strategy to relay information regarding looming objects.

2. EXPERIMENTAL SETUP

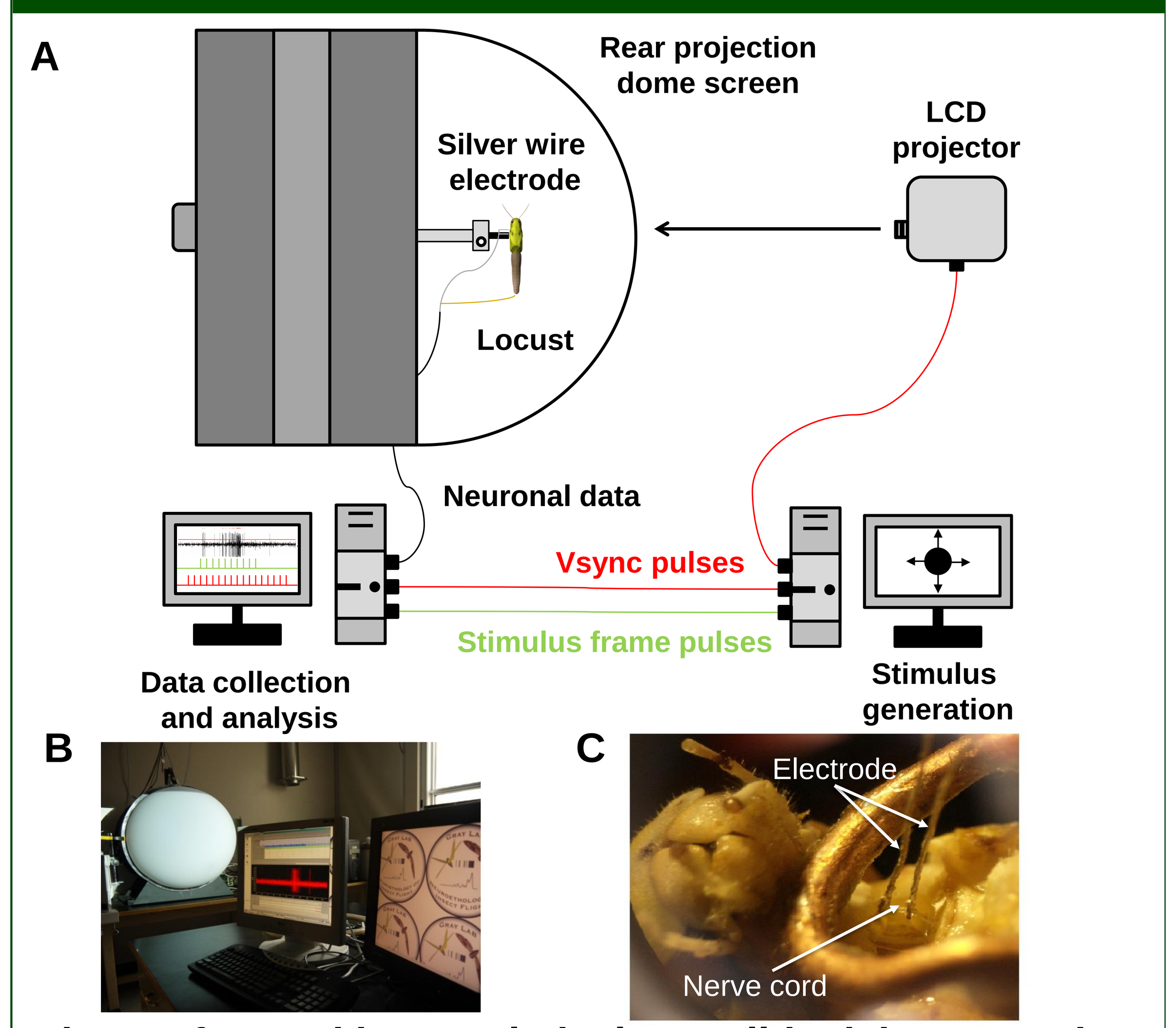


Fig 1. After making a relatively small incision exposing the ventral nerve cords, locusts (*Locusta migratoria*) were mounted onto a fixed platform within a flight simulator (A). Stimuli (7 cm black disc travelling at 300 cm/s aligned with the center of the right eye) were projected onto the dome screen (B) and neural recordings were taken from exposed underlying paired connectives of the ventral nerve cord anterior to the prothoracic ganglia (C and Fig. 2A); n=20 locusts and n=30 presentations.

3. LOOMING RESPONSES

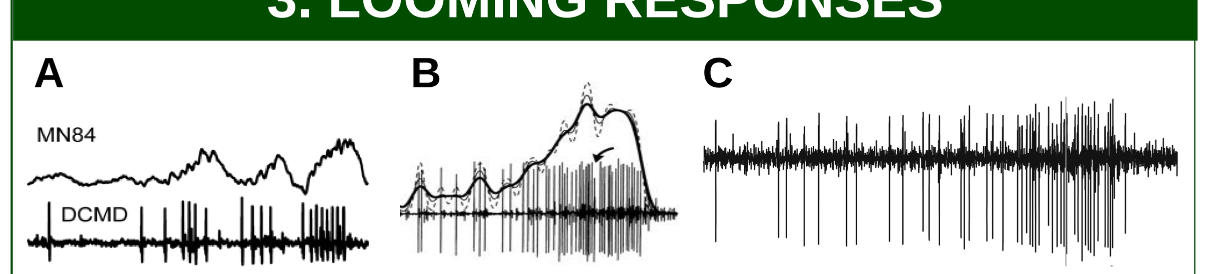
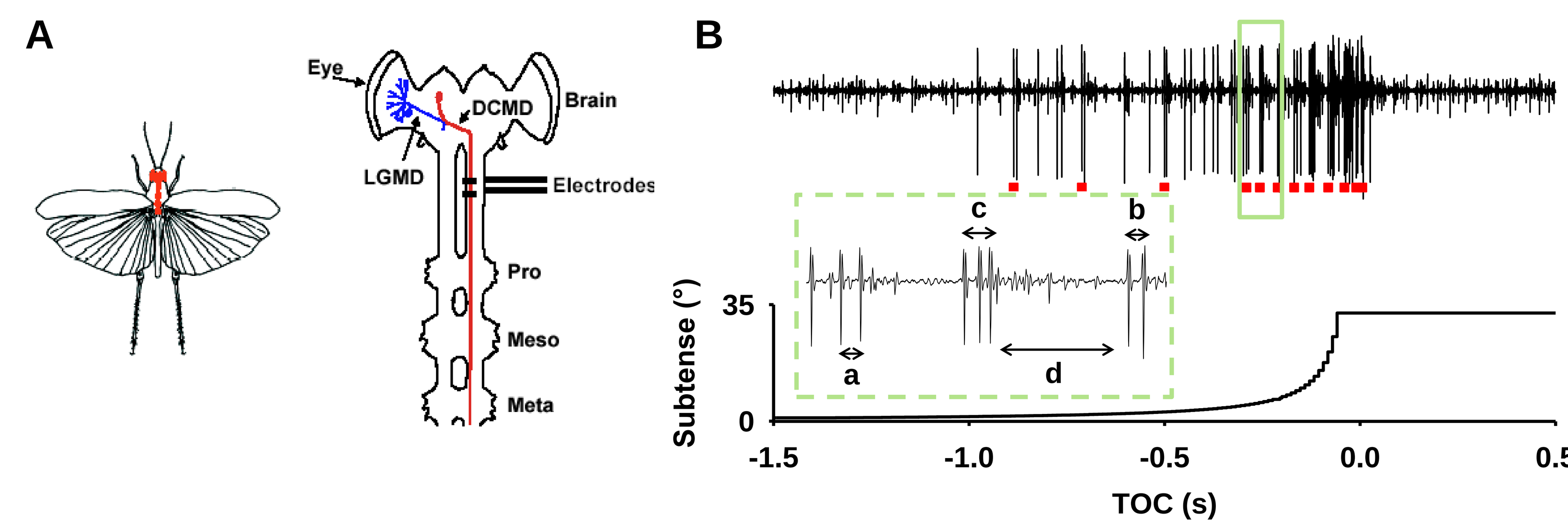


Fig. 2. DCMD responses to looming stimuli from previous work show evidence of bursting (A[3], B[8], and C[9]).

4. ISOLATION OF DCMD ACTIVITY AND QUANTIFICATION OF BURSTS



(a) Max. interval to start/maintain burst (8ms)
(b) Min. number of spikes in a burst (2)
(c) Min. burst duration (2ms)
(d) Min. inter-burst interval (9ms)

Fig 3. A) Visual information is transmitted to the DCMD in a 1:1 spike ratio via the lobula giant movement detector (LGMD, A). B) Extracellular recording aligned to the perceived time of collision (TOC). DCMD spikes were isolated based on threshold analysis. Increases in the stimulus subtense angle causes an increase in DCMD firing frequency that peaks before the time of collision (TOC). DCMD spike times were used for analysis and bursts (red squares in B) were identified using a burst assay (subset of data from above trace).

5. DISTRIBUTION OF DCMD SPIKES PROVIDE EVIDENCE OF BURSTING

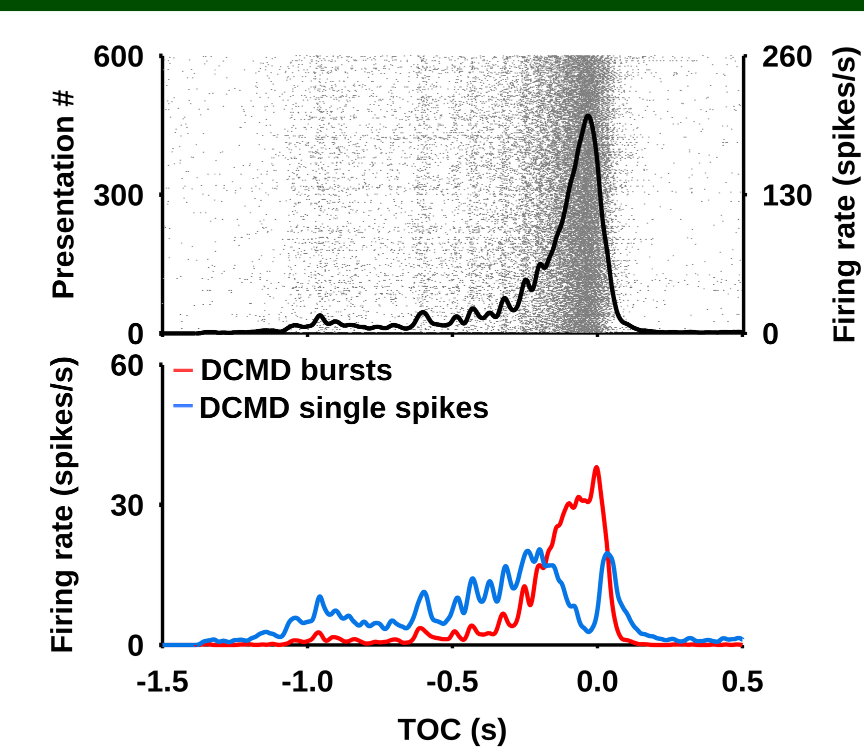


Fig. 4. Top) Vertical banding patterns are present in this TOC-aligned perievent raster plot (grey) representing 600 individual responses and mirrored by distinct oscillations in the mean DCMD firing rate (peristimulus time histogram (PSTH) - black line). Bottom) PSTHs show that while DCMD bursts (red line) and single spikes (blue line) increase up to 200ms before TOC, bursting dominates the response leading up to TOC.

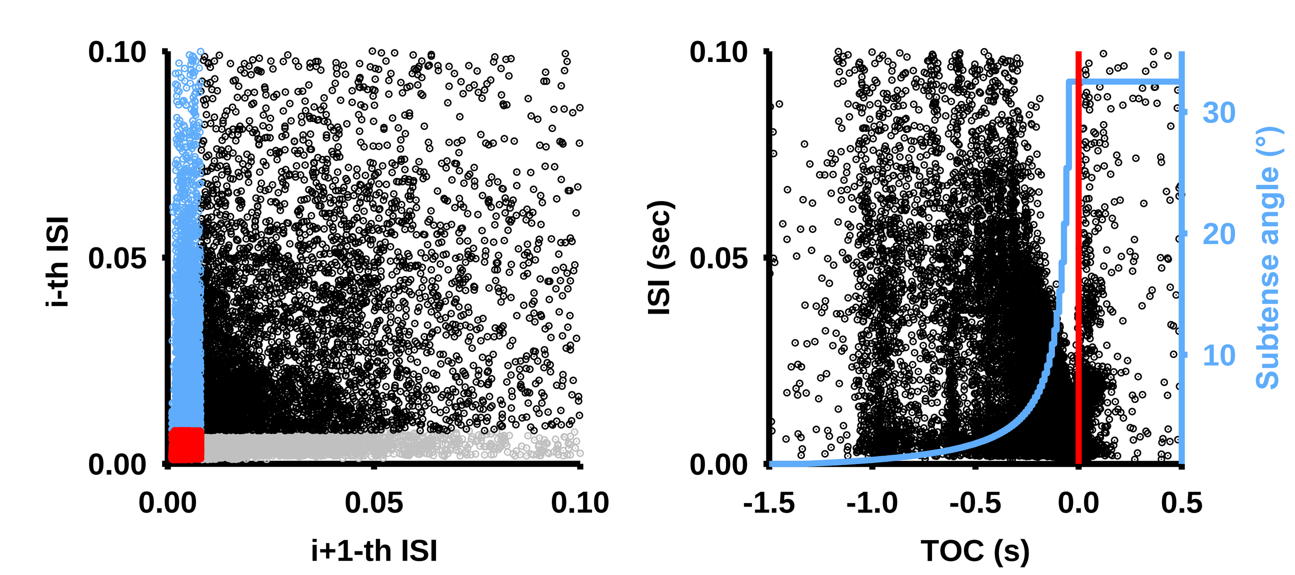


Fig. 5. Left) Typical of a bursting neuron, the interspike interval (ISI) return map (top) has a fan-shaped distribution with a tight cluster of points at the origin (red, intraburst interval) and two other clusters along the axes (grey and blue, interburst intervals); the more scattered clusters may be the ISIs between single spikes (black). Right) Reflecting the mean DCMD PSTH, ISIs shorten as the stimulus subtense angle (blue line) increases toward TOC (red vertical line). However, the relatively constant ISI distribution in short intervals reveals a bimodal distribution of ISIs.

6. ISI HISTOGRAMS AND AUTOCORRELATIONSSHOW BIMODAL DISTRIBUTIONS

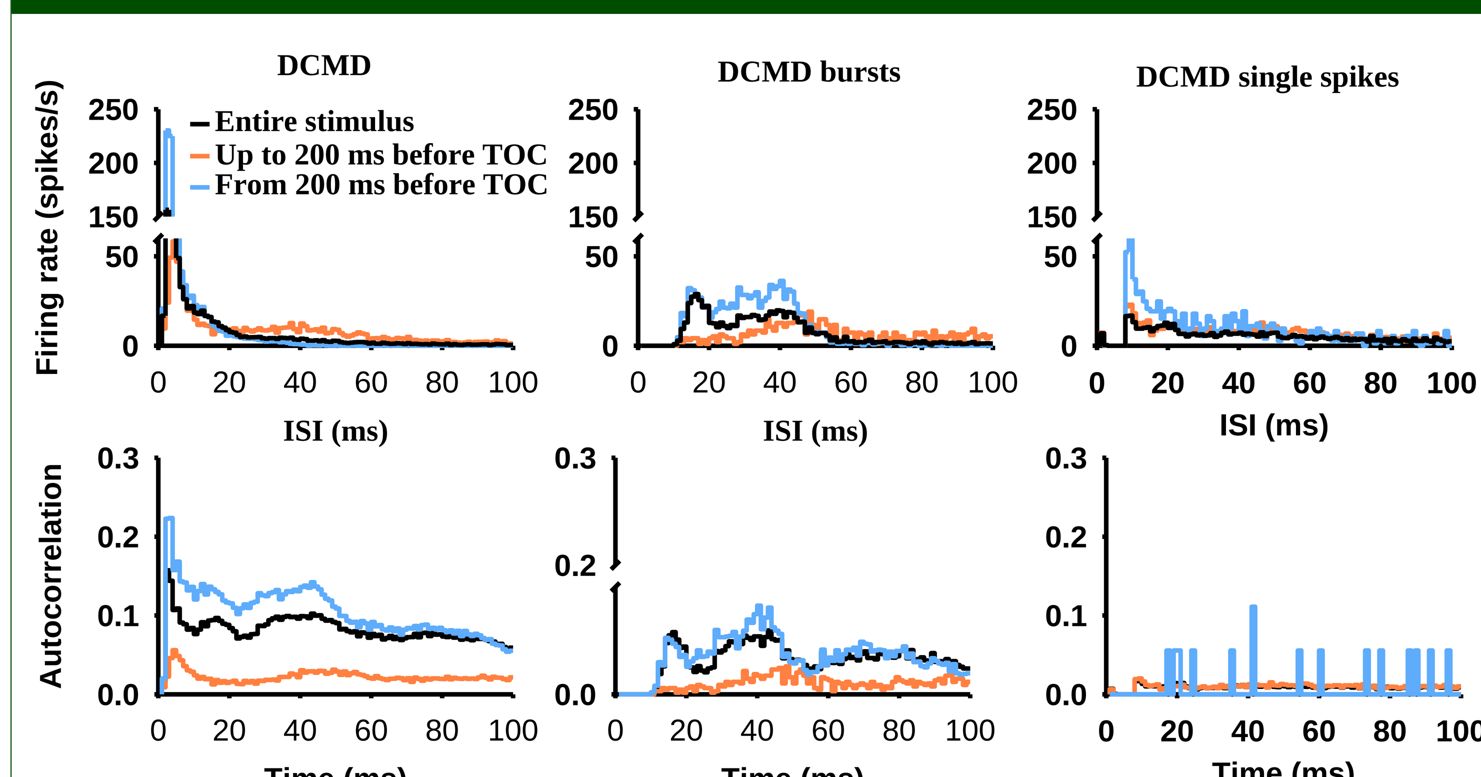


Fig. 4. ISI histograms and autocorrelations of DCMD responses for mean response (left), DCMD bursts (middle), and single spikes (right). The bimodal distribution of ISIs (represented more clearly in the data leading up to 200ms before TOC) are indicative of a bursting neuron showing shorter ISIs from 1-8ms and a second group with longer ISIs around 40ms. The ISIs of the bursts was relatively unimodal and occurred around 40ms. These trends are reflected in the associated autocorrelation. Overall, there was no clear trend in the distribution of single spikes.

7. CONCLUSIONS

- Evidence of bursting (particularly up to 200ms before TOC) based on distribution of spikes and autocorrelations: peak burst ISI and autocorrelation occurred around 40ms (or 25Hz)
- Results suggest a behavioural implication of bursting: previous studies have shown that low DCMD firing rates that occur around 200ms before TOC may trigger avoidance steering responses in rigidly tethered locusts[10]
- Given that the average wingbeat frequency of a flying locust is ~25 beats/s, our findings provide evidence to drive future experiments to test if DCMD bursting may have a role in gating non-rhythmical sensory input (object motion) to coordinate rhythmical modulation of wing kinematics linked to avoidance behaviour.

8. REFERENCES

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9. ACKNOWLEDGEMENTS

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