Locust flight muscle activity and body orientation in response to objects moving along complex trajectories

UNIVERSITY OF SASKATCHEWAN

Sinan Zhang and John R. Gray, Dept. Biology, University of Saskatchewan

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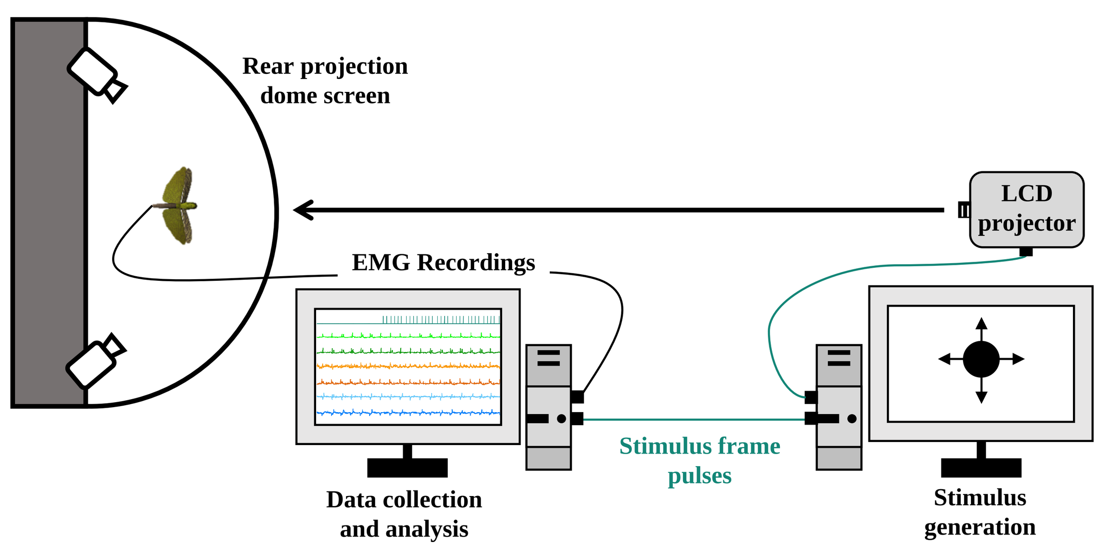
INTRODUCTION

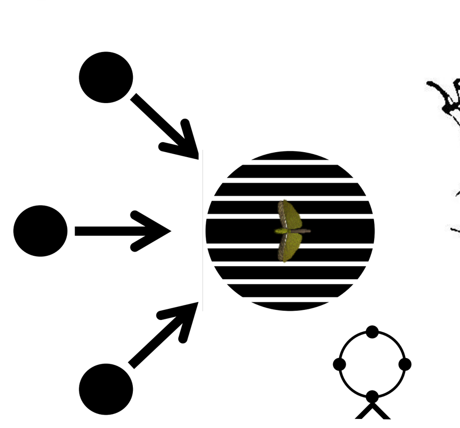
Locusts (*Locusta migratoria*) are ideal model systems to study complex behaviours, such as flight responses to objects approaching on a collision course. Thus far, flight muscle activity, wing kinematics and aerodynamic forces of locusts have been recorded during collision avoidance behaviour and measured from rigidly-tethered locusts flying in open-loop conditions. However, loosely-tethered flying locusts are capable of changing orientation in response to looming stimuli within a single wing beat, and generate avoidance responses within a single downstroke. To better understand neural control of flight steering, we placed a loosely-tethered flying locust inside an existing flight simulator, and presented visual stimuli of objects moving along complex trajectories.

METHODS

Loosely tethered locusts (n=3) were placed in the center of a rear projection dome screen. Head-on air flow (v=3m/s) was provided to maintain straight flight. Visual stimuli (7 cm disc travelling at 3 m/s) were projected from different directions (left 45°, right 45°, 0°), with a flow field background (B). Four markers on the tether monitored 3D body position. (C) We recorded from 6 flight muscles known to be associated with steering.



A) Experimental setup, including visual stimuli projection, high speed cameras and EMG recordings



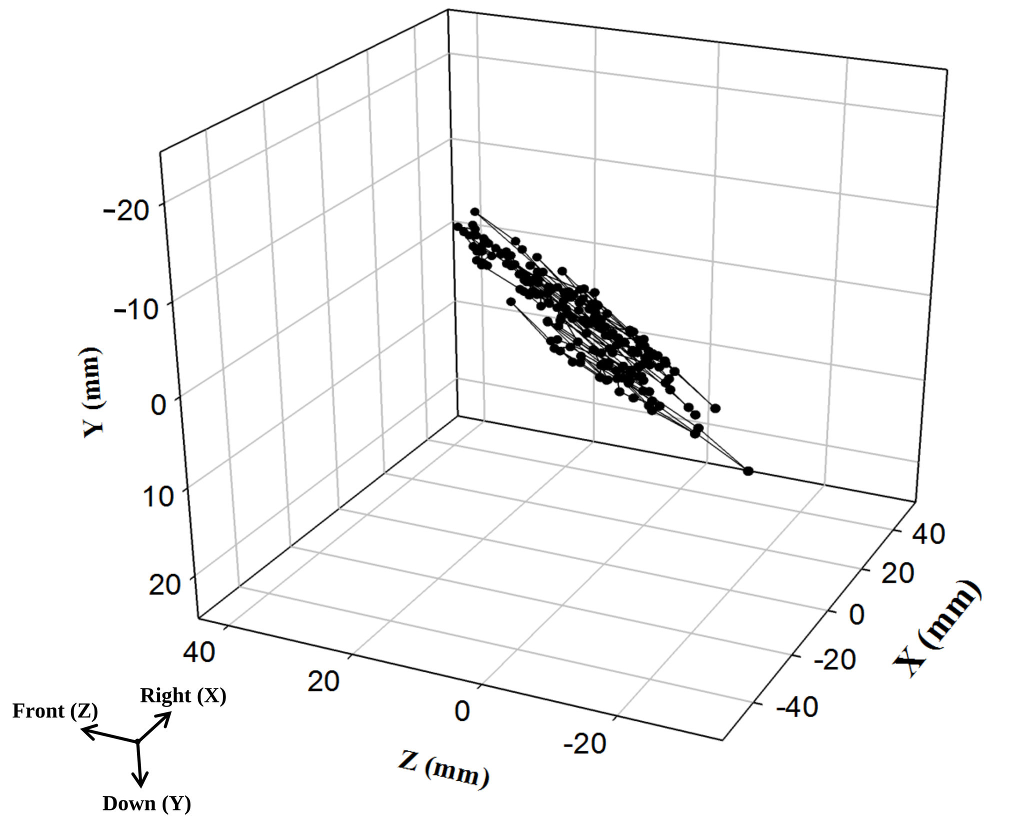
B) Visual stimuli with flow field background and tether

C) Muscles recorded in this experiment: M97 (forewing 1st basalar), M99 (forewing subalar), and M127 (hindwing 1st basalar)

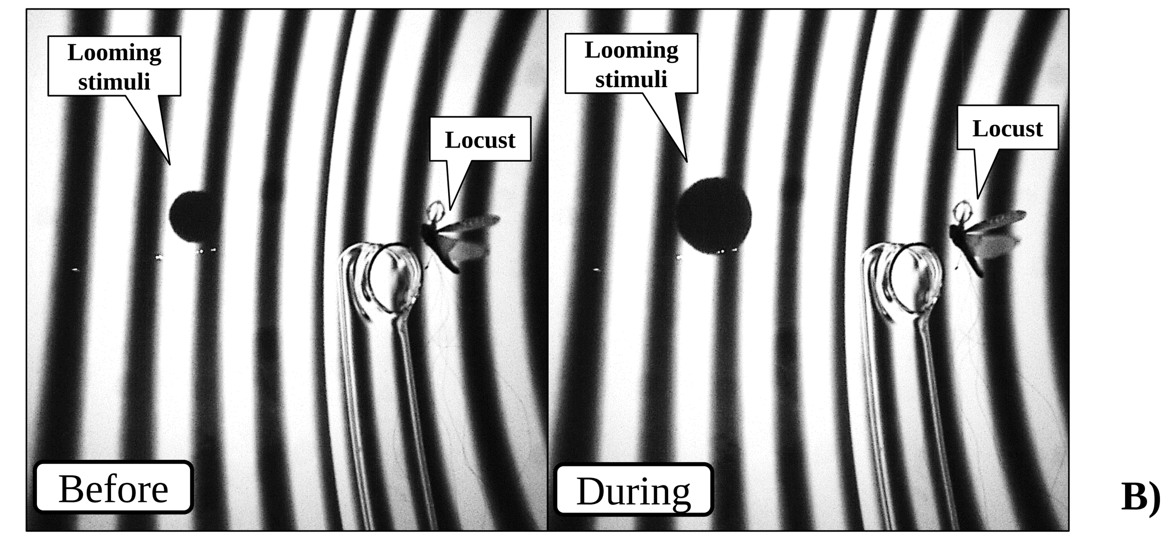
RESULTS

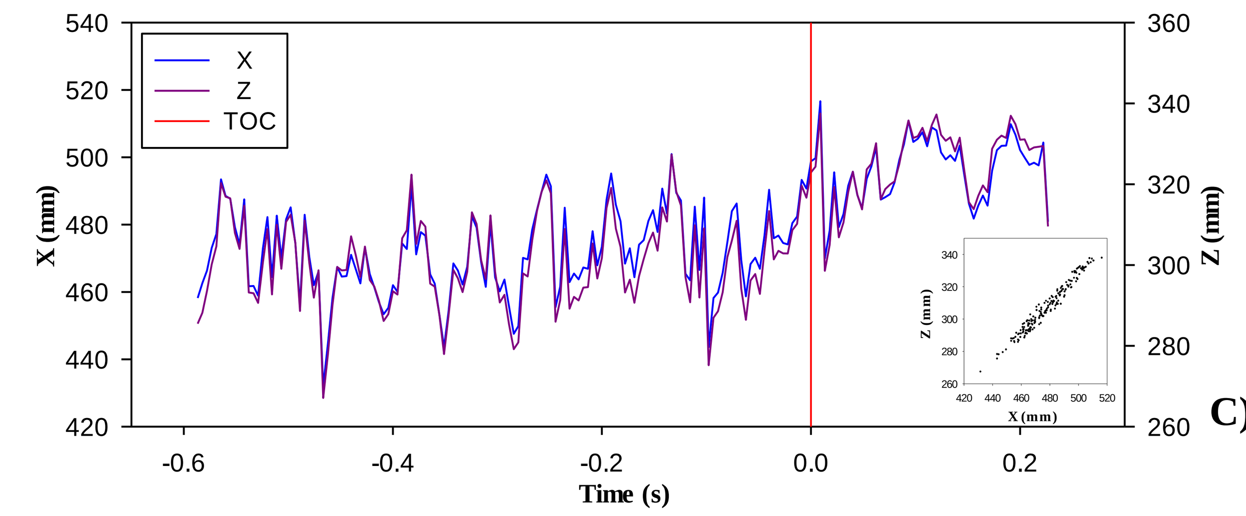
Behavioural responses during collision avoidance

High speed camera recordings (1028 x 1028 pixels at 225fps) revealed the trajectory of locust flight during collision avoidance. Images from two cameras, allowed 3D tracking of the locust position. A) 3D tracking results showing the locust generating a maintained right turn while avoiding the disc coming from left at 45°. B) Video capture from one camera, showing positions of the locust before and during avoidance behaviour; C) Movement in x and z planes showing the overall right turn (changes in the y plane were minor). Time aligned with TOC (Time of collision).



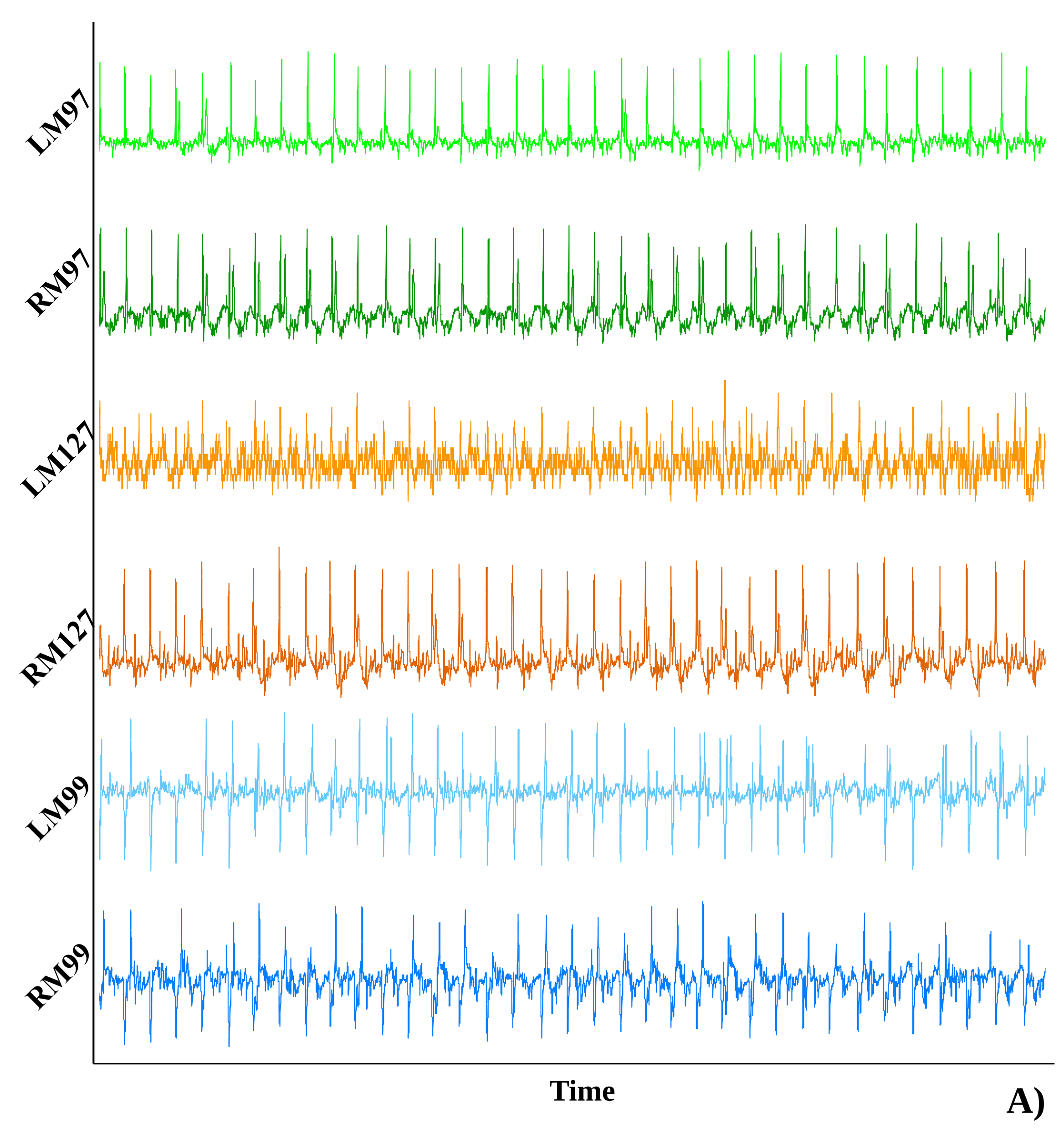
A) 3D motion tracking of a locust avoiding a disc looming from the left at 45°. The coordinate system is right-handed: positive x to the right, positive y down, positive z to the front (from the locust's perspective of view)

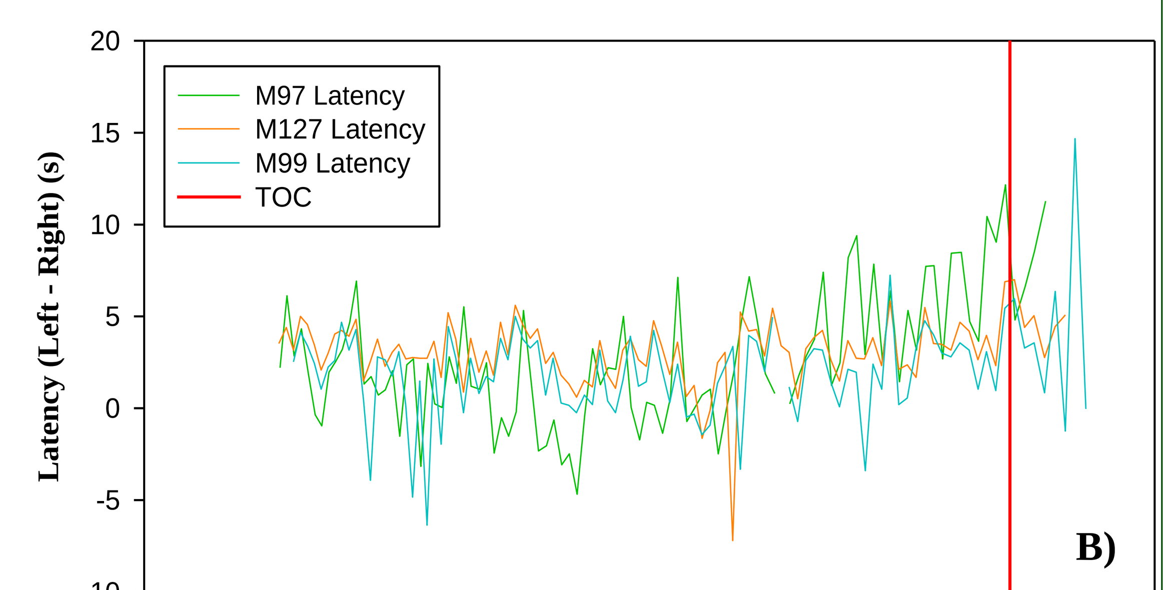


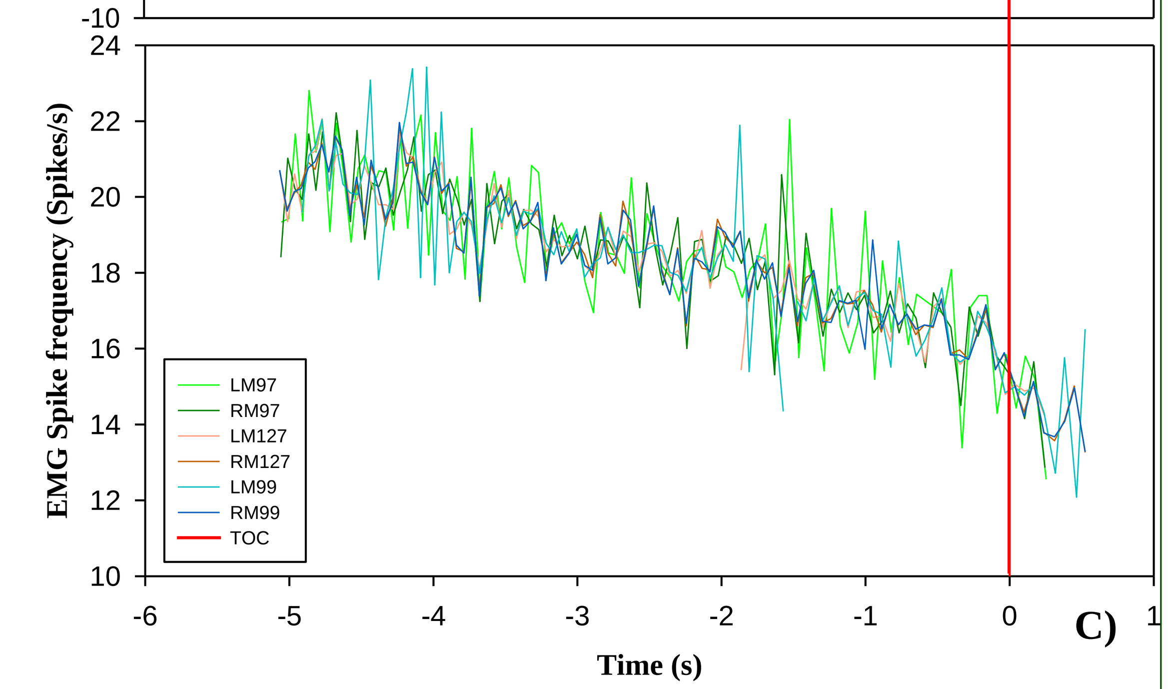


Muscle activity and corresponding physiological changes

Activity of 3 bilaterally paired steering muscles were also recorded during collision avoidance. Previous studies have shown that the timing of these muscles are associated with attempted steering manoeuvres. A) Sample EMG recordings (Left 45° looming); B) Bilateral latency increases indicating a steering behaviour; C) EMG spike frequency (reflecting wing beat frequency) decreased as the disc approached.

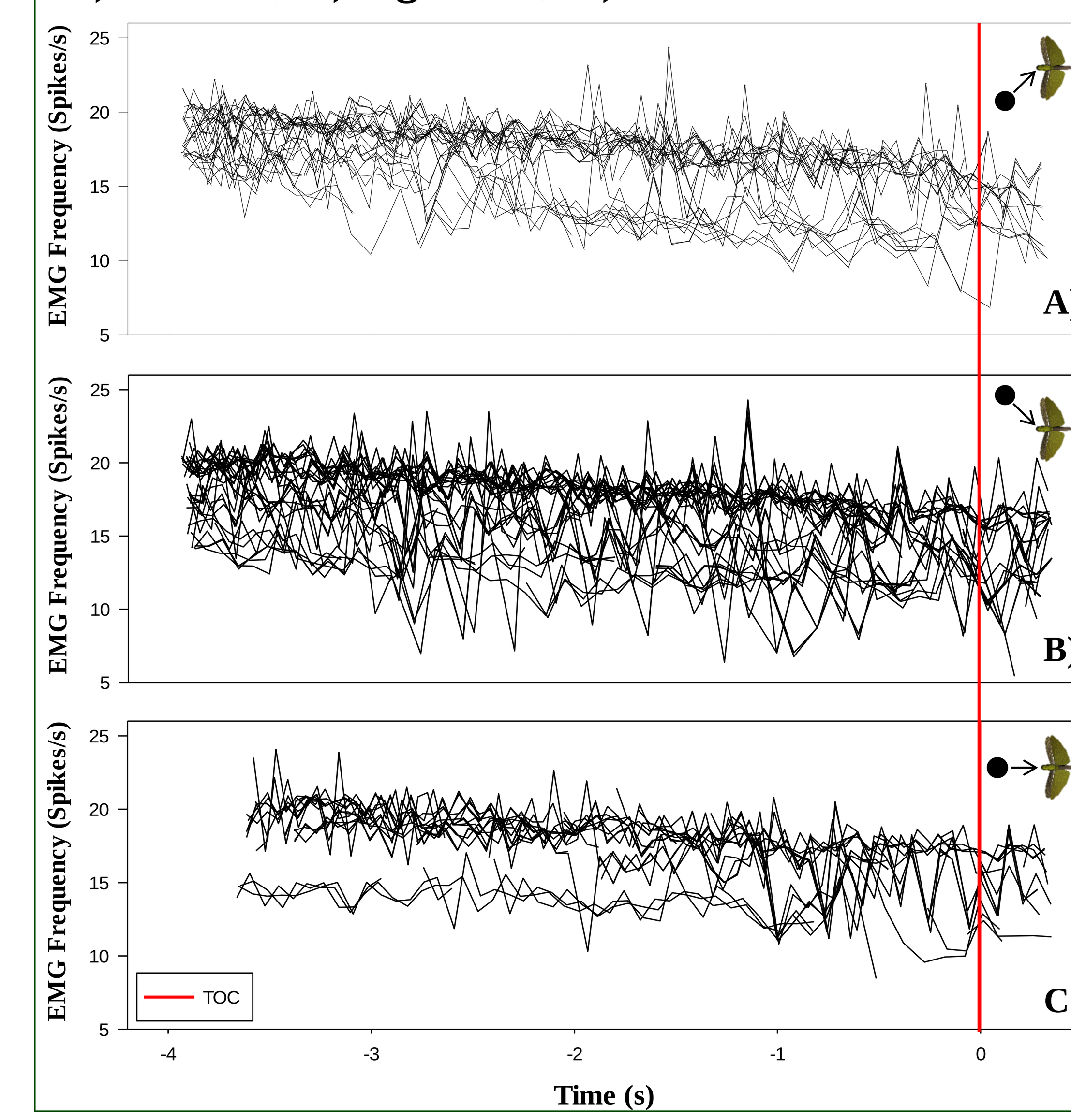






Stimuli-independent EMG frequency change

EMG spike frequency across all three types of looming stimuli, displaying a stimuli-independent decreasing trend over time.
A)Left 45°; B)Right 45°; C)0°.



SUMMARY

- Locusts generate steering behaviour during collision avoidance, without preference in directions
- Changes in flight direction can be reflected by the latency between bilateral flight muscle spikes
- Within a flow field background, wing beat frequency decreased during object approach.

ACKNOWLEDGEMENTS & REFERENCES

Acknowledgements

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References

[1] McMillan, G. A., Loessin, V., & Gray, J. R. (2013). The Journal of experimental biology, 216(17), 3369-3380. [2] Silva, A. C., McMillan, G. A., Santos, C. P., & Gray, J. R. (2015). Journal of neurophysiology, 113(1), 218-231. [3] Santer, R. D., Simmons, P. J., & Rind, F. C. (2005). Journal of Comparative Physiology A, 191(1), 61-73. [4] McMillan, G. A., & Gray, J. R. (2012). Journal of neurophysiology, 108(4), 1052-1068.