Multineuronal Responses to Complex Multimodal Sensory Cues During Behaviour

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Introduction

To understand how adaptive behaviour is produced and controlled by the nervous system, it is necessary to examine how functional groups of neurons interact with the animal's sensory environment and how these interactions are incorporated into ongoing behaviour. Animals exist in a closed-loop enviroment in which the behaviour itself continually modifies the context in which the system must operate, and thus the nervous system must be able to adapt to changing multimodal sensory cues. Therefore, the challenge is to examine simultaneous activity of groups of neurons operating under closed-loop conditions in an experimentally tractable system.

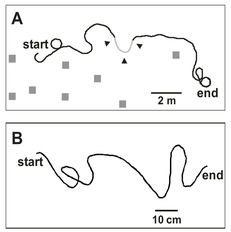
We recorded the activity of interneurons that connect the brain with the flight motor in male *Manduca sexta* while the moth was free to manoeuvre in a closed-loop flight simulator. The moth was able to control its visual environment with movements of its abdomen while presented with female 'pheromone', a compelling stimulus that elicits sterotypic flight behaviour.

Methods

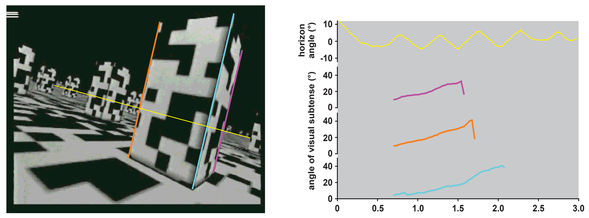
Male moths (Manduca sexta) were flown in a virtual reality-based flight simulator (see Gray et.al., 2002 for details) under closed and open-loop conditions and presented with a two component compound known to elicit odour-guided flight (Tumlinson et. al.,1989). Multineuronal activity in the CNS was recorded using multichannel silicon probes provided by the University of Michigan Center for Neural Communication Technology sponsored by NIH NIBIB grant P41-RR09754. Individual units were discriminated using Autocut cluster cutting software from Data Wave Technologies and analyzed with Neuroexplorer (NEX Technologies). Discriminated units were organized into functional ensembles using Principal Component Analysis (see panel 3).

2 Virtual flight tracks

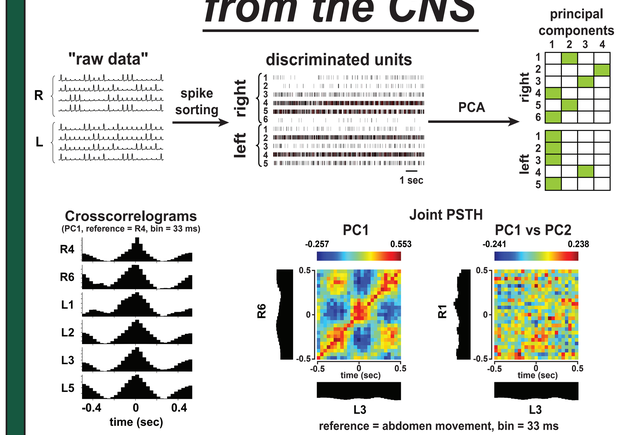
Virtual flight tracks were observed by running the environment rendering software on a second computer that was connected to the first over the internet and viewing the arena from above. The virtual track (A) is qualitatively similar to that produced by a free-flying moth during odour-guided flight (B). The arrowheads in A indicate pheromone presentation.



Visual parameter extraction

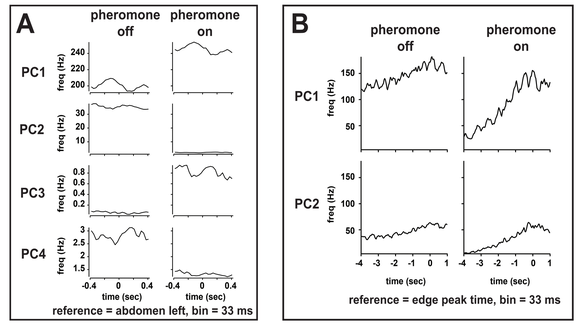


4 Ensemble recordings from the CNS



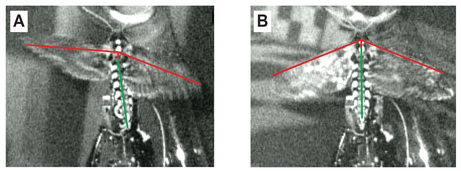
Spike times were arranged into 33 ms bins and run through a Principal Component Analysis (PCA). Discriminated units were grouped into components in which they had the greatest loading. The crosscorrelogram for PC1 confirms synchrony of the consituent units. The joint PSTH graphs show that units within PC1 (L3 and R6) fire synchronously relative to abdominal movement and that units in PC1 (L3) and PC2 (R1) do not.

6 Ensemble activity is context-dependent.

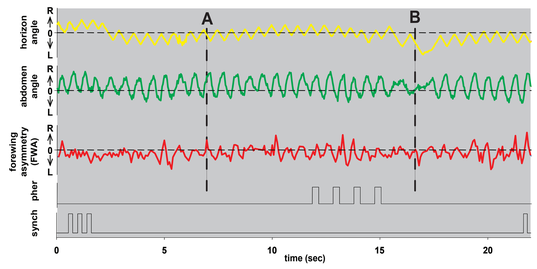


(A) The presence of pheromone modulates ensemble activity relative to abdominal movements during closed-loop flight. Data were taken from within different contexts (pheromone off or on) and centred around the time at which the abdomen began to rudder left. Note the difference in the base line frequency within the ensembles. (B) The response of ensembles to looming stimuli (expanding vertical edges) is modulated in the presence of pheromone suggesting that the sensitivity of visual interneurons changes depending on the multimodal context of the environment.

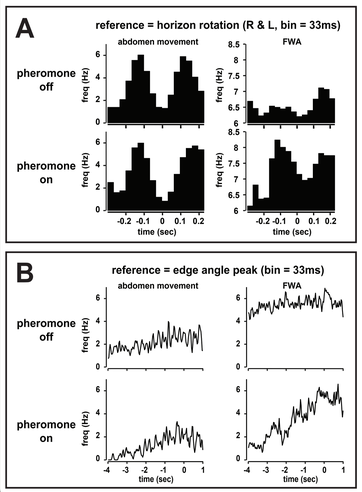
1 Kinematic analysis of closed-loop flight



Note the asymmetry of the leading edge of the forewings (red lines) and ruddering of the abdomen (green line) during a turn to the right (A). During straight flight (B) the wings are symmetrical and the abdomen extends straight back.

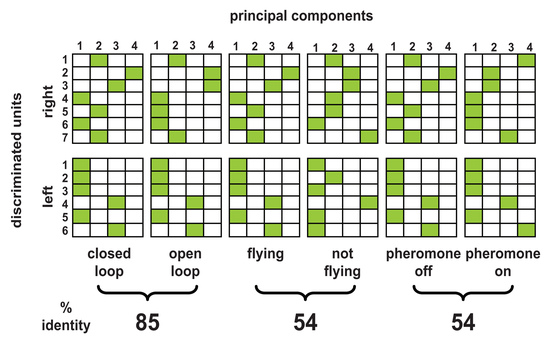


3 Behavioural responses to multimodal sensory cues



Under closed-loop conditions the presence of pheromone modulates establishment of FWA (A) and the frequency of FWA in response to looming edges (B) in one animal. Data from 4 animals (C) show that FWA frequency is higher in the presence of pheromone.
* denotes a significant difference ($p<0.05$) in the normalized FWA freq (paired t-test).

5 Ensemble composition is context-dependent.



- % identity was calulated by comparing the number of units in common across all principal components within each experimental condition.
- Ensemble composition was most highly conserved between closed and open-loop conditions but changed dramatically depending on whether the moth was flying or exposed to pheromone.

Conclusions / Future Goals

- Closed-loop behaviour in the flight simulator emulates free flight.
- Flight behaviour activity increases in the presence of pheromone.
- Interneurons connecting the brain with the flight motor are organized into functional ensembles that are modulated within a multimodal sensory environment.
- To understand more clearly how descending input influences flight behaviour we will examine detailed components of the sensory environment in relation to ensemble composition and activity.

References

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Tumlinson JH, Brennan MM, Doolittle RE, Mitchell ER, Brabham A, Manzomenos BE, Baumhover AH, Jackson DM (1989) Identification of a pheromone blend attractive to Manduca sexta (L.) males in a wind tunnel. Arch.Insect Biochem Physiol. 10:255-71

Acknowledgements

We thank Richard Schlichemeyer for digitizing the video data. Multichannel silicon probes were provided by the University of Michigan Center for Neural Communication Technology sponsored by NIH NIBIB grant P41-RR09754. Funding provided by the Natural Science and Engineering Research Council of Canada, the Canada Foundation for Innovation and the Defense Advance Research Projects Agency.