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 environment 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 stereotypic flight behaviour.

Methods
Male moths (Manduca sexta) were flown in a virtual reality-based flight simulator (Gray et al., 2002 for details) under closed and open-loop conditions and sponsored by NIH NIBIB grant P41-RR09754.

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 crosscorrelogram for PC1 confirms synchrony of the constituent units. The joint PSTH graphs show that units within PC1 (L3 and R6) fire synchronously relative to abdominal movement and that units in PC2 (Fig R) do not.

Kinematic analysis of closed-loop flight
Note the asymmetry of the leading edge of the forewings (red lines) and curving of the abdomen (green lines) during a turn to the right (A). During straight flight (B) the wings are symmetrical and the abdomen extends straight back.

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 for each animal, the greatest loading is context-dependent. The crosscorrelogram for PC1 confirms synchrony of the constituent units. The joint PSTH graphs show that units within PC1 (L3 and R6) fire synchronously relative to abdominal movement and that units in PC2 (Fig R) do not.

References

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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.

Note
FWA in response to looming

Fig R

33 ms