Coordination of Translation and Rotation in Insects: a Behavioural Homology with Rodents?

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Background

In previous studies it has been shown that in vertebrates the ground plan of locomotor behavior consists of a transition from extensive mobility to immobility through an increase and then a gradual decrease in forward translation, accompanied by a concurrent gradual increase in whole body rotation around the hindquarters (shut-down of behavior). The opposite transition from immobility to extensive mobility involves an increase and then decrease in rotation around the hindquarters, accompanied by a concurrent gradual increase in forward translation (warm-up) [1,2,3].

Aims

Here we examine the similarity between the mobility gradient exhibited in vertebrates and the shut down and build up of mobility exhibited in fruit flies under the influence of cocaine. To accomplish this aim we characterize the dynamic relationship between rotation, turning, and progression, in fruit flies walking on a flat surface.

Methods

We use high-resolution computer-vision tracking of the animal's position and body orientation within a drug administration apparatus that controls the flow of cocaine via an evaporation chamber. The behavior, which is performed in a large circular arena (diameter of 150mm) is continuously recorded for an extended period of time (from minutes to several hours). Our analyses of the process include a novel phase-space representation of body rotation, translation and path curvature that illustrates the qualitative aspect of the phenomenon, presenting the moment-to-moment dynamics quantitatively.

Results

We discover an intricate interplay in the active management of these three degrees of freedom which, upon cocaine administration, exhibit a sequence that appears to correspond to the shut-down described in vertebrates. Specifically, progression decreases as rotation around the hindquarters increases and then subsides to complete immobility (Figure 1A). As the fly recovers, the inverse sequence of transition from immobility, to extensive rotation in place around the hindquarters followed by a gradual increase in forward translation (warm-up) is observed (Figure 1B).

Implications

Our results in flies thus bears an intriguing similarity to the mobility gradient exhibited in vertebrates suggesting that part of the mobility gradient is homologous in the two phyla.

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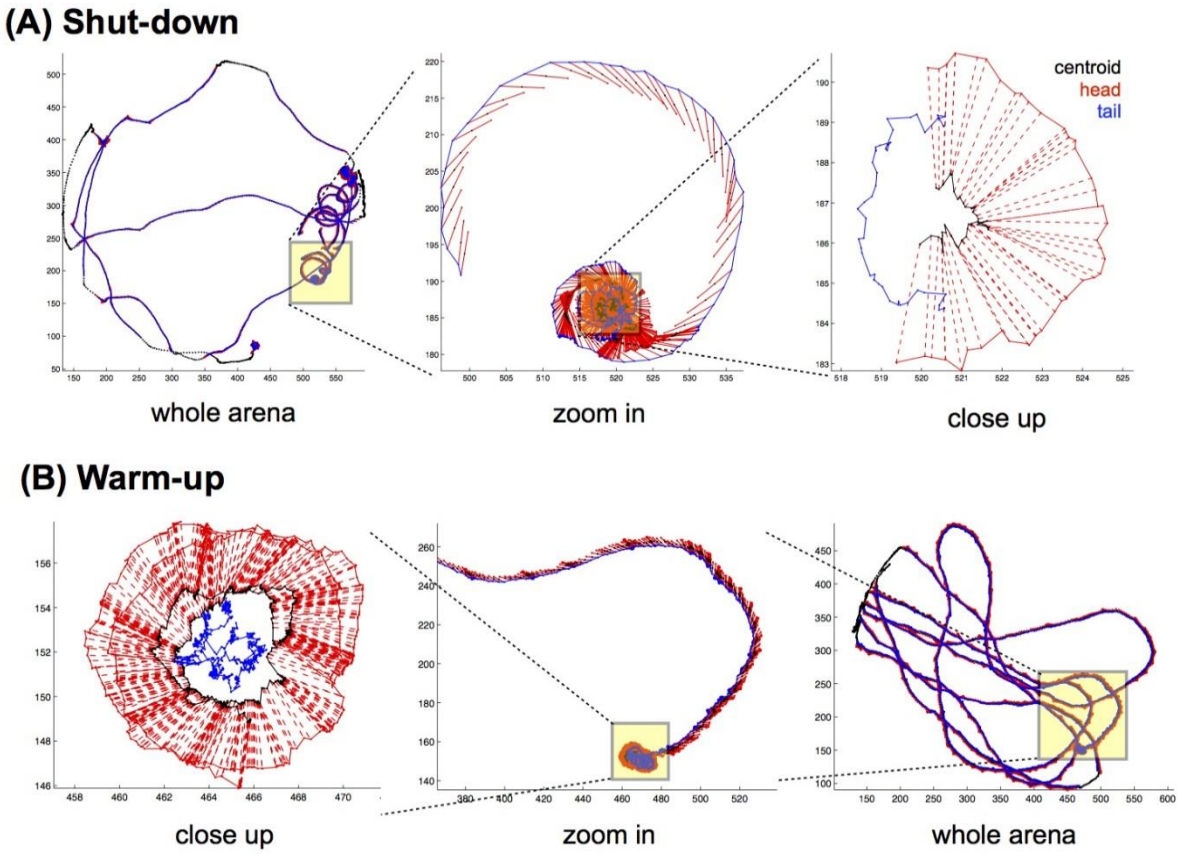

(A) Shut-down: (Left) Trajectory of a cocaine treated fly in the arena. As the drug takes effect there is a transition from a path with low curvature to increasingly higher curvature until complete cessation of translation. (Middle) Zoom in reveals that in this case during this interval the front angle (heading direction) of the fly leads while the fly shifts its weight (direction of progression) maintaining a stable angular interval between path direction and front direction. In the last stage of shutdown, translation is eliminated and the fly rotates in place until full immobility. (Right) Further zoom in displaying a 180 degrees body rotation in place. As shown, the fly rotates around an axis located closer to the rear part of its body. The red, black and blue lines trace the head, centroid and tail trajectories.

(B) Warm-up: (Left) Following pronounced arrest as drug effect wears off, the fly proceeds with pure rotation around its hindquarters. This corresponds to the initial phase of transition out of immobility. The red, black and blue lines trace the head, centroid and tail trajectories. (Middle) Zoom out depicts the gradual increase in forward translation along a path whose curvature is gradually decreasing. (Right) As warm-up progresses, the fly resumes extensive forward locomotion increasingly resembling normal behavior.

References

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