frontiers in Behavioral Neuroscience

ORIGINAL RESEARCH
published: 19 January 2021
doi: 10.3389/fnbeh.2020.606590

The Critical Role of Head Movements for Spatial Representation During Bumblebees Learning Flight

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Bumblebees perform complex flight maneuvers around the barely visible entrance of their nest upon their first departures. During these flights bees learn visual information about the surroundings, possibly including its spatial layout. They rely on this information to return home. Depth information can be derived from the apparent motion of the scenery on the bees' retina. This motion is shaped by the animal's flight and orientation: Bees employ a saccadic flight and gaze strategy, where rapid turns of the head (saccades) alternate with flight segments of apparently constant gaze direction (intersaccades). When during intersaccades the gaze direction is kept relatively constant, the apparent motion contains information about the distance of the animal to environmental objects, and thus, in an egocentric reference frame. Alternatively, when the gaze direction rotates around a fixed point in space, the animal perceives the depth structure relative to this pivot point, i.e., in an allocentric reference frame. If the pivot point is at the nest-hole, the information is nest-centric. Here, we investigate in which reference frames bumblebees perceive depth information during their learning flights. By precisely tracking the head orientation, we found that half of the time, the head appears to pivot actively. However, only few of the corresponding pivot points are close to the nest entrance. Our results indicate that bumblebees perceive visual information in several reference frames when they learn about the surroundings of a behaviorally relevant location.

Keywords: active vision, hymenopterans, navigation, view-matching, optic-flow, visual homing, motion-parallax, visual learning

OPEN ACCESS

Edited by:
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Specialty section:
This article was submitted to Learning and Memory, a section of the journal Frontiers in Behavioral Neuroscience

Received: *15 September 2020*
Accepted: *23 November 2020*
Published: *19 January 2021*

Citation:
Doussot C, Bertrand OJN and Egelhaaf M (2021) The Critical Role of Head Movements for Spatial Representation During Bumblebees Learning Flight. Front. Behav. Neurosci. 14:606590. doi: 10.3389/fnbeh.2020.606590

1. INTRODUCTION

When describing a location of an object in its environment, we often narrate about its relationships to other items; for example, the mountain is on the right of the river. This description is based on an environmental representation from an allocentric perspective, i.e., it is the relation between the different objects which matters without explicit reference to the observer. However, while moving through this environment, the observer establishes from an egocentric perspective, a relation between the self and the objects in the environment. Both types of representations have been concluded to co-exist in the human brain (Burgess, 2006; Mou et al., 2006; Avraamides and Kelly, 2008). However, not only humans but many other navigating animals, even the ones with tiny brains, such as insects, are confronted with the problem of spatial representation (Wehner et al., 1996).