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An experimental setup for decoupling optical invariants in honeybees' altitude control

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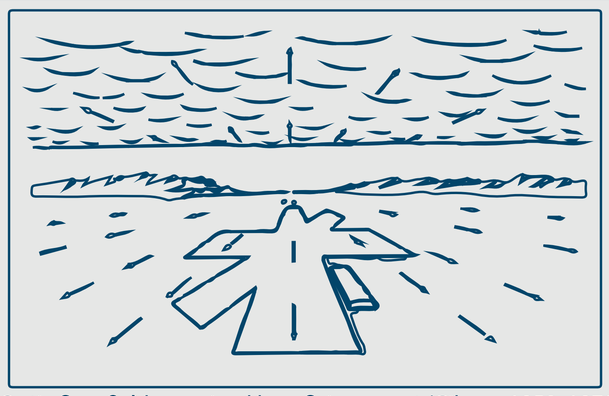
Main question: Perceiving a complex visual environment, what optical invariant does *Apis mellifera* focus on to stabilize its altitude?

Bases and aims

Optic flow: vector field of the apparent motion of objects, surfaces, and edges in a visual scene caused by the relative motion between an agent and the scene.

Optical invariants: particular properties of the optic flow unaltered when the agent is moving.
Two optical invariants are particularily relevant for a ground_following task:
- **optical speed rate of change** $\dot{\omega}$ [used by bees and pilots]
- **splay angle rate of change** $\dot{s}$ [used by pilots]

Aims: (1) To determine if bees also use splay angle rate of change for performing ground-following tasks
(2) To set the priority and weight system by which bees use these two optical invariants to control their altitude

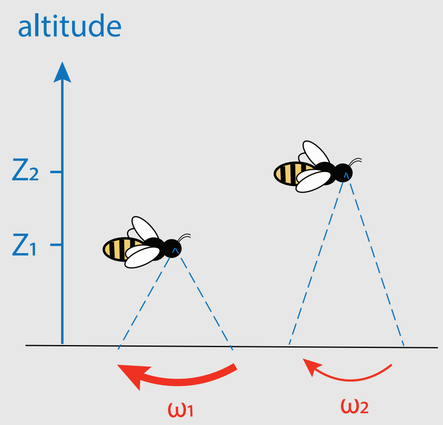


Optic flow field perceived by a flying agent (Gibson 1950, 1979)

Optical speed (OS) experienced by a flying agent

OS (ω) is the speed of environment's image scrolling the retina when an agent is moving.
- **OS increases** for an agent **going down** ($\dot{\omega} > 0$)
- **OS decreases** for an agent **going up** ($\dot{\omega} < 0$)

--> **optical speed rate of change** ($\dot{\omega}$) **is informative about altitude change**



ω = OS
$\dot{\omega}$ = OS rate of change
Vx = agent's speed
z = agent's altitude

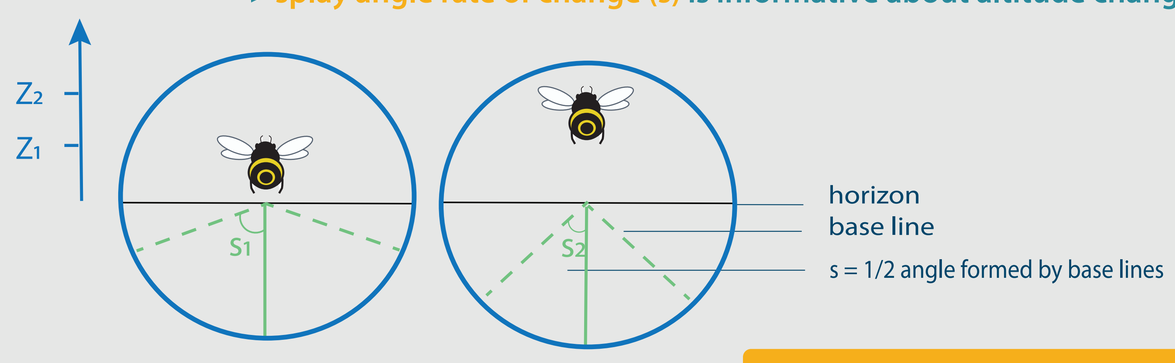
To maintain a constant flight altitude --> keep $\dot{\omega} = 0$

observed in bees [1, 2, 3, 4, 7]

Splay angle rate of change experienced by a flying agent

Base lines join at the image's focus of expansion forming the **splay angle (s)**:
- **angle's value increases** in the visual field of an agent **going down** ($\dot{s} > 0$)
- **angle's value decreases** in the visual field of an agent **going up** ($\dot{s} < 0$)

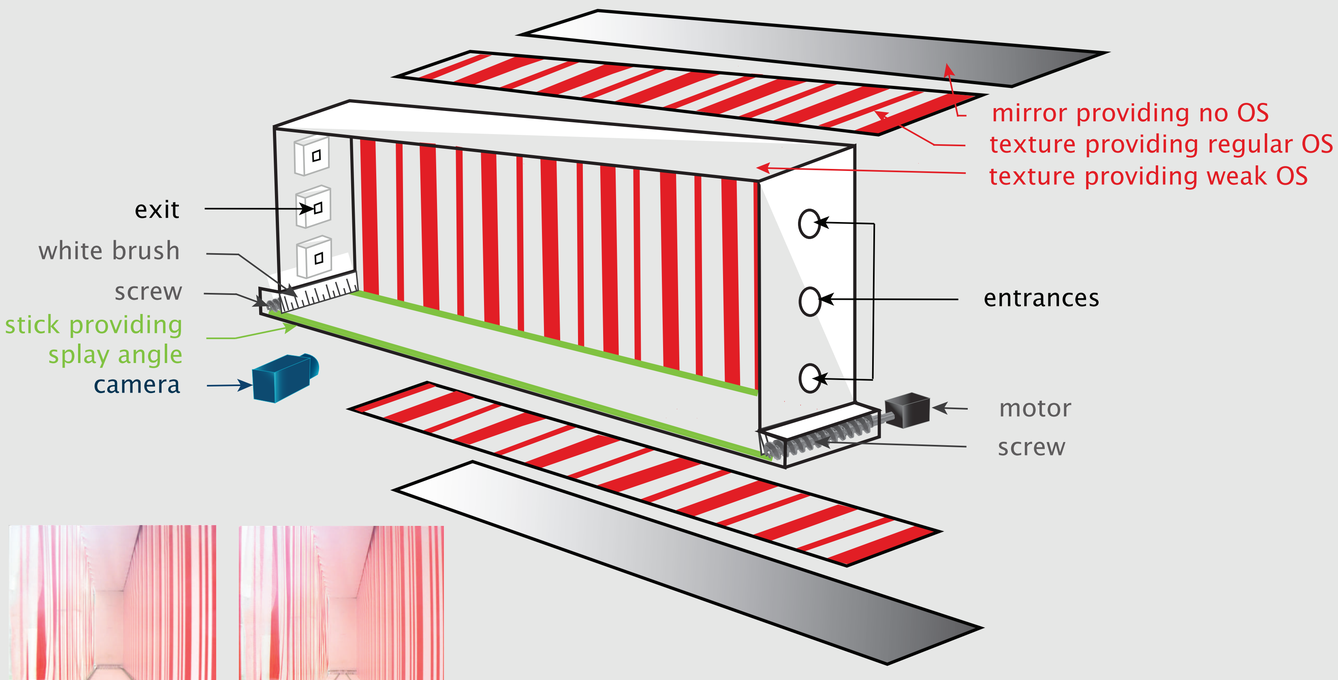
--> **splay angle rate of change** ($\dot{s}$) **is informative about altitude change**

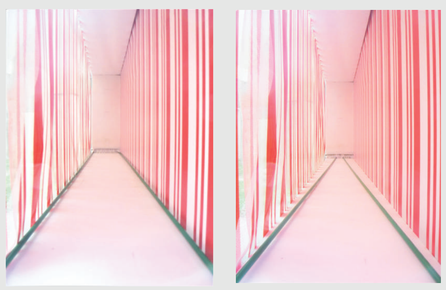


To maintain a constant flight altitude --> keep $\dot{s} = 0$

observed in humans [5, 6]

Experimental setup

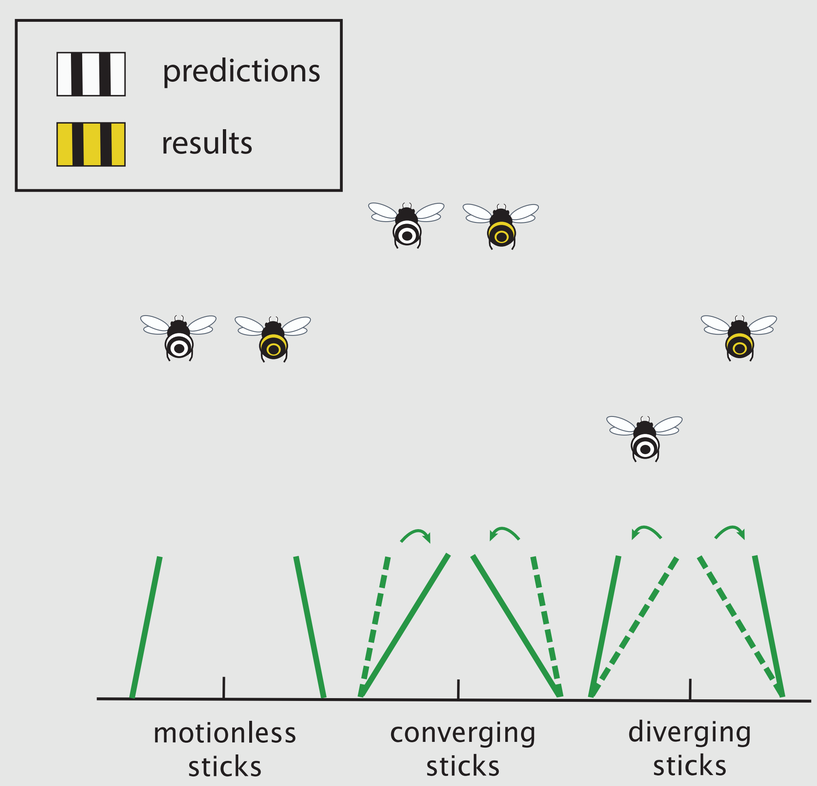




Weak OS available
Regular splay angle

Weak OS available
Narrow splay angle

Predictions and results



- A bee perceiving a **splay's enlargement** will interpret a **loss of altitude**, so it will **go up** to maintain a null splay angle rate of change (s=0). ✓
- A bee perceiving a **splay's narrowing** will interpret a **gain in altitude**, so it will **go down** to maintain a null splay angle rate of change. ✗
- A bee perceiving **weak OS** will take into account splay angle's rate of change in priority so it will show **broader altitude changes**. ?

Highlights

- An experimental setup was designed to investigate whether the splay angle rate of change is implicated in bees' altitude control
- A flight tunnel was built enabling specific manipulations of two optical invariants
- Splay angle rate of change is used by bees to control their altitude in a ground-following task

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