

**Flow in Flight**  
Symposium Proposal  
International Conference on Perception and Action  
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Organizer: William H. Warren

1. Are biological agents governed by similar visuo-motor mechanisms to fly?

Julien R Serres<sup>1,2</sup>, Mathieu Thomas<sup>1,3</sup>, Aimie Berger Dauxère<sup>1</sup>, Thomas Rakotomamonjy<sup>3</sup>, Gilles Montagne<sup>1</sup>, Franck Ruffier<sup>1</sup>, Antoine HP Morice<sup>1</sup>

<sup>1</sup> Aix Marseille Univ, CNRS, ISM, 163 Av. de Luminy, 13 009 Marseille, France

<sup>2</sup> Institut Universitaire de France (IUF), 1 rue Descartes, 75 231 Paris cedex 05, France

<sup>3</sup> ONERA, DTIS, FR-13661 Salon, cedex Air, France

julien.serres@univ-amu.fr

While it is still impossible for flying drones to land autonomously by sight, a bee is able to land on a moving flower and a helicopter pilot is able to land on the deck of a ship. Biological agents are thus able to perform similar navigational tasks with ease despite their differences in size, inertia or visual acuity (Berger Dauxère et al., 2021). Their prowess is essentially a result of the optic flow from which optical invariants are taken to regulate their movement or make decisions. Our studies on bees show that not only is optic flow essential for their altitude control (Serres et al., 2022), but also that they are able to detect different optical invariants to control their altitude (Berger Dauxère et al., 2022), thus bringing them closer to the perceptive abilities of pilots (Morice et al., 2021; Thomas et al., 2021, 2023). Our studies on very different biological agents: bees and pilots, thus allow us to better understand how optic flow is exploited according to the agent's movement constraints. The compilation of results between these different agents allows us not only to develop "ecological" piloting aids for pilots, but also automatic pilots to robotize aircraft.

Keywords: ground-following, ship landing, altitude control, honeybees, helicopter pilots

International Conference in Perception and Action (ICPA 2023)  
Symposium “Flow in Flight”

Are biological agents governed by similar visuo-motor  
mechanisms to fly?

Presented on June 28, 2023, at Guadalajara, by

**Julien R Serres<sup>1,2</sup>, Mathieu Thomas<sup>1,3</sup>, Aimie Berger Dauxère<sup>1</sup>,  
Thomas Rakotomamonjy<sup>3</sup>, Gilles Montagne<sup>1</sup>, Franck Ruffier<sup>1</sup>,  
Antoine HP Morice<sup>1</sup>**



1 Aix Marseille Univ, CNRS, ISM, 163 Av. de Luminy, 13 009 Marseille, France

2 Institut Universitaire de France (IUF), 1 rue Descartes, 72 231 Paris cedex 05, France

3 ONERA, DTIS, FR-13661 Salon, cedex Air, France

## Human's visual system vs. honeybee's visual system

Even though insects have so few photoreceptors in their visual system, they can navigate precisely in space and perform similar tasks as pilots



Photoreceptors : ~ 100,000

Acuity: ~ 2°

Neurons: ~ 1,000,000

Size : 0.013m

Travelled distance: ~ 13km

x 2520

÷ 100

x 100 000

x 131

x 18



Photoreceptors : ~ 252,000,000

Acuity : ~ 0.02°

Neurons : ~ 100,000,000,000

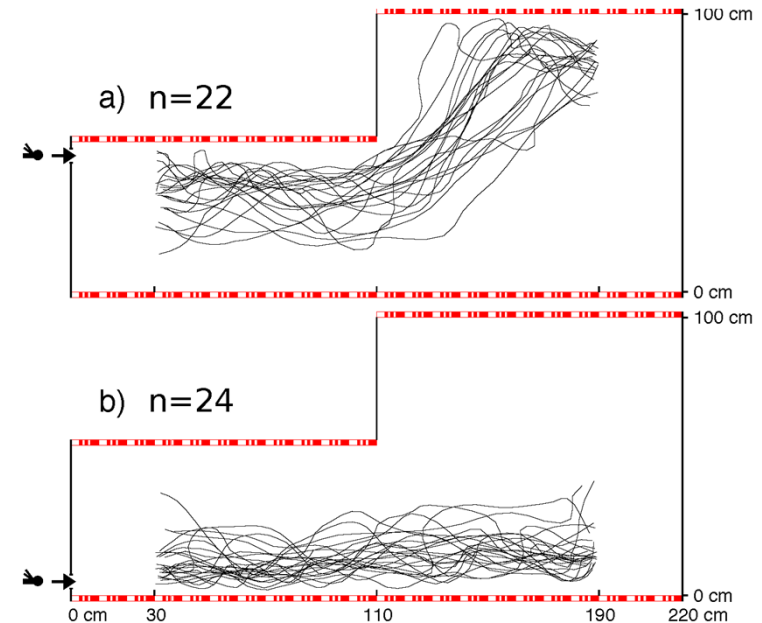
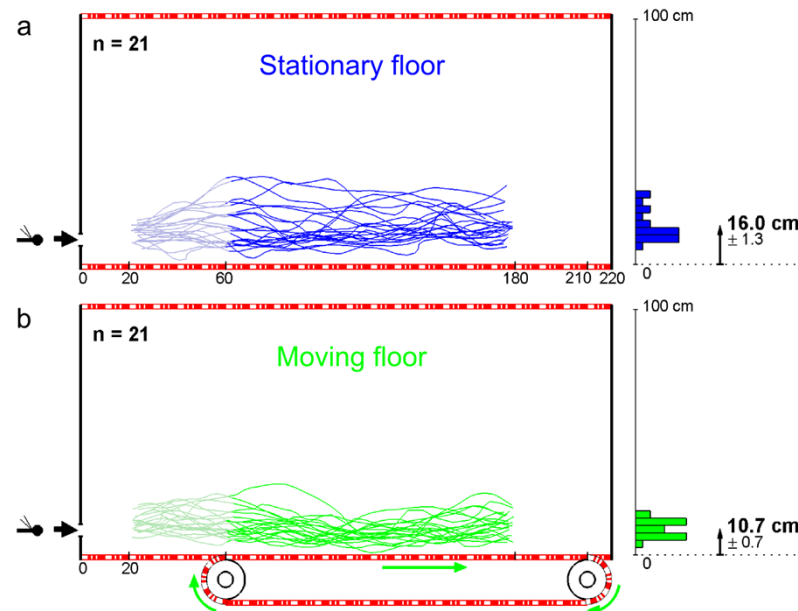
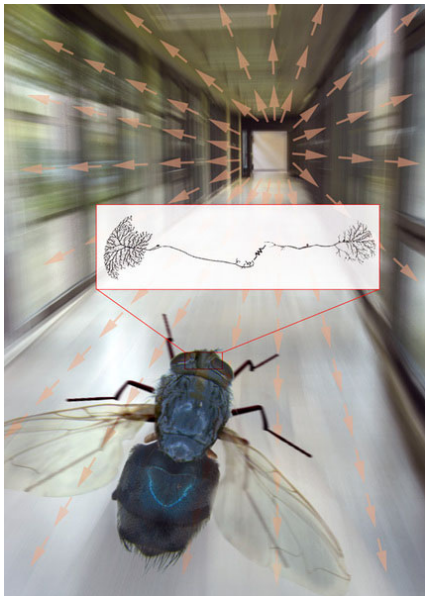
Height : 1.70 m

Olympic Triathlon distance: ~ 51 km

Ironman distance: ~ 226 km

Hypothesis: Flying insects use the same optical variables as pilots to fly.

# “Preferred optic flow pattern” hypothesis



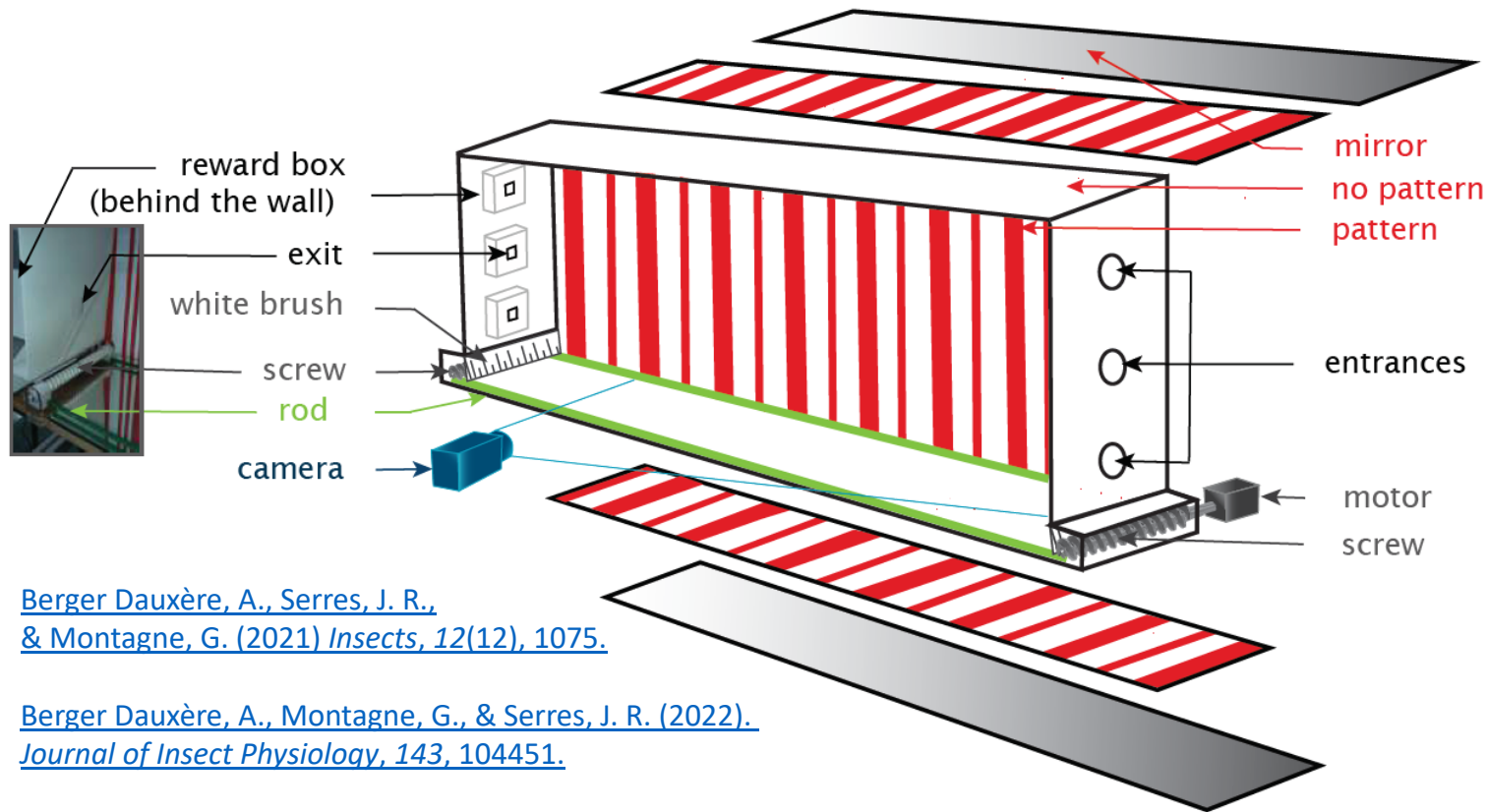
[Farrow, K., Haag, J., & Borst, A. \(2006\). \*Nature Neuroscience\*, 9, 1312e1320.](#)

[Portelli, G., Ruffier, F., & Franceschini, N. \(2010\). \*J. of Comp. Physiol. A\*, 196\(4\), 307-313.](#)

[Portelli, G., Serres, J. R., & Ruffier, F. \(2017\). \*Scientific reports\*, 7\(1\), 1-10.](#)

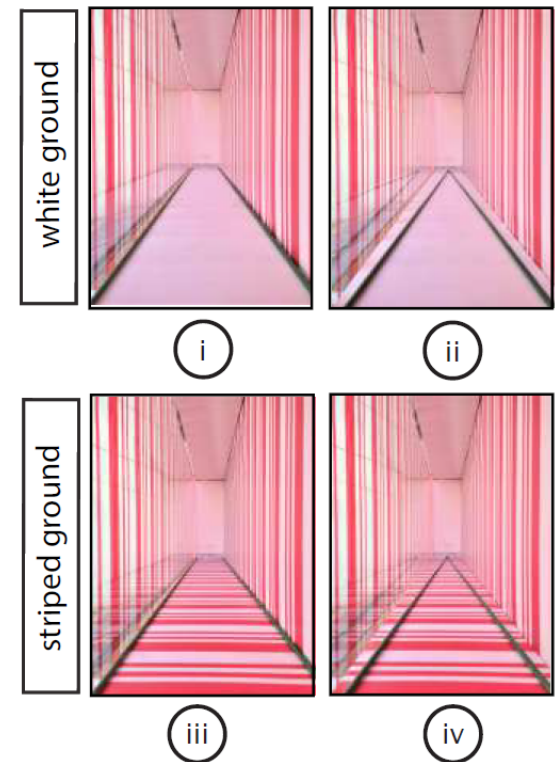
- Altitude control in honeybees is heavily based on optic flow
- The optical speed rate of change  $\dot{\omega}$  [used by bees and pilots]

# Experimental set-up to manipulate other optic flow properties



[Berger Dauxère, A., Serres, J. R., & Montagne, G. \(2021\) \*Insects\*, 12\(12\), 1075.](#)

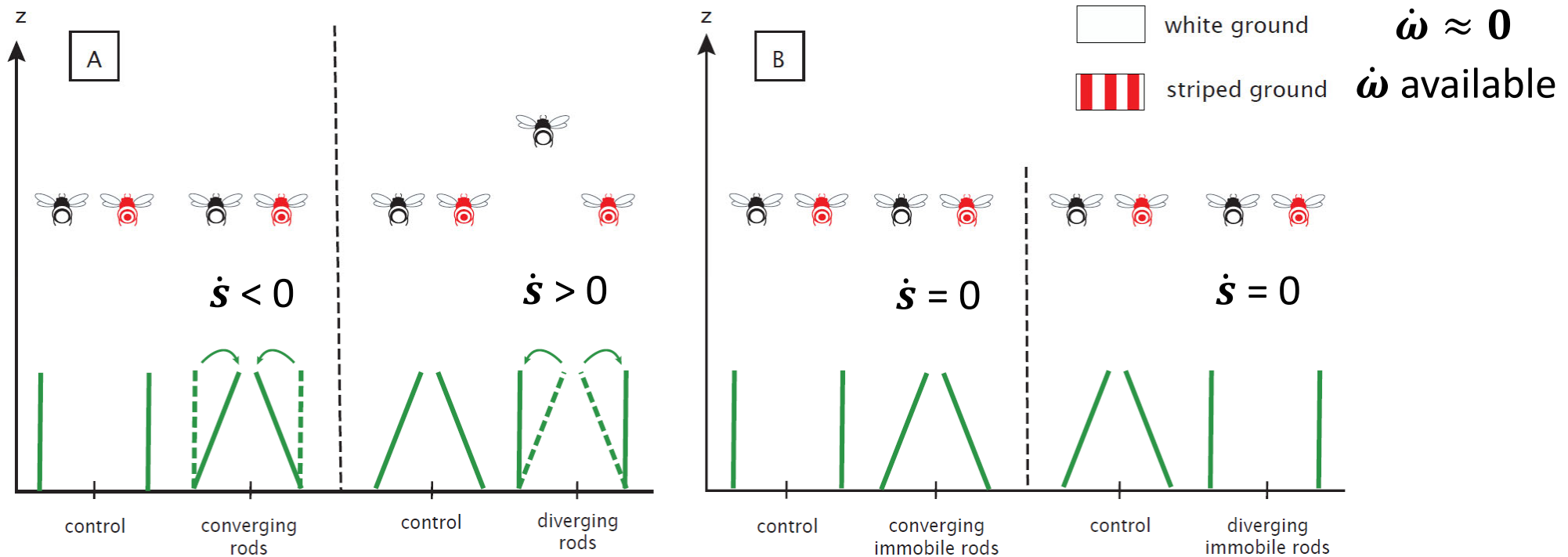
[Berger Dauxère, A., Montagne, G., & Serres, J. R. \(2022\). \*Journal of Insect Physiology\*, 143, 104451.](#)



- Manipulation of the Splay Angle Rate of Change  $\dot{s}$  [used by pilots]
- Independent manipulation of optical invariants:  $\dot{s}$  or  $\dot{\omega}$

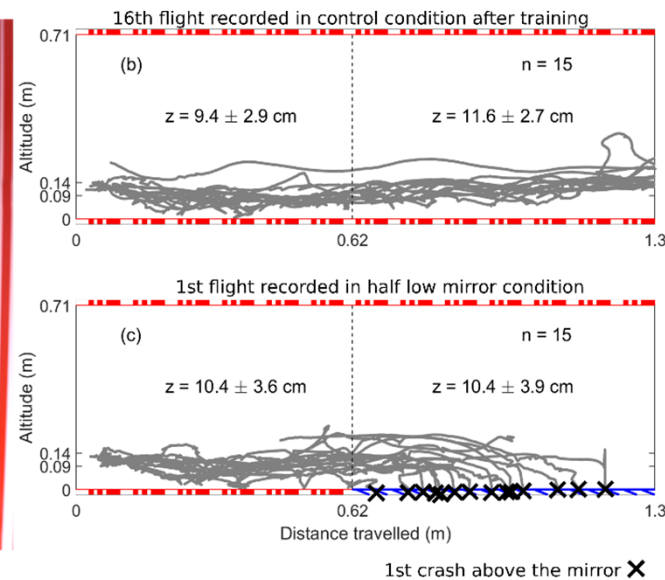
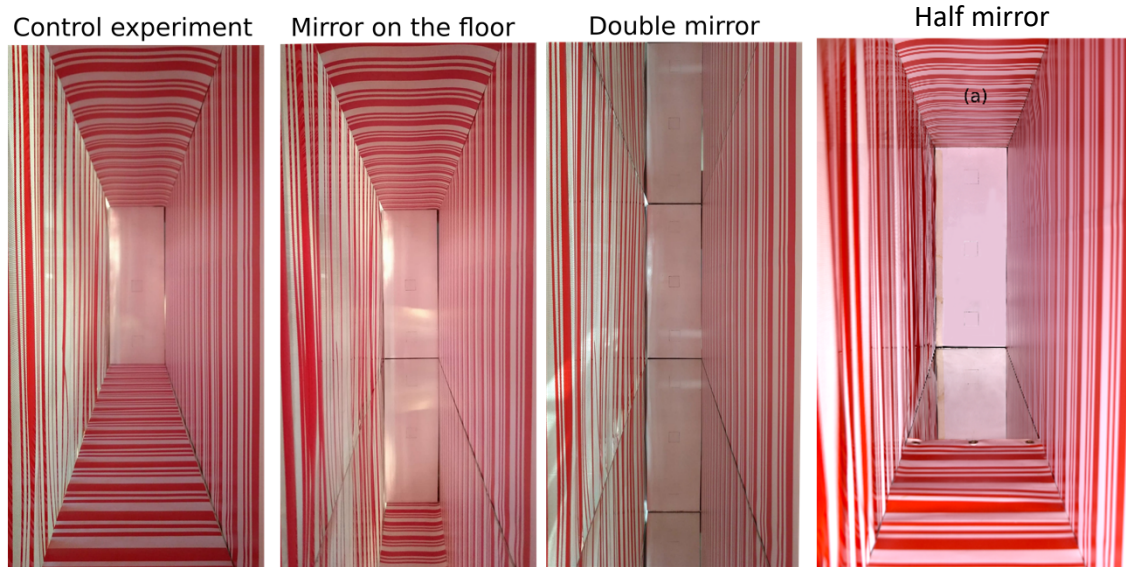
# Results: Honeybees use multiple invariants to control their altitude

[Berger Dauxère, A., Montagne, G., & Serres, J. R. \(2023\). \*Insects\*, 14\(4\), 313.](#)



- $\dot{s}$  and  $\dot{\omega}$  are used by bees [and pilots] to control their altitude
- $\dot{s}$  is used by bees only if  $\dot{\omega}$  is less accessible

# Results: Deprivation of optical invariants

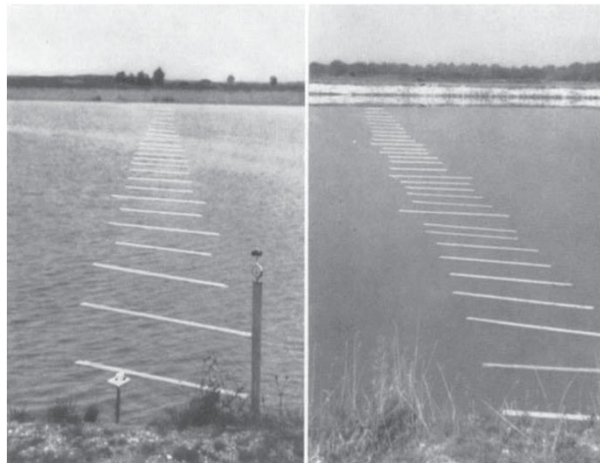


[Serres, J. R., Morice, A. H., Blary, C., Miot, R., Montagne, G., & Ruffier, F. \(2022\). \*Biology Letters\*, 18\(3\), 20210534. \[https://youtube.com/shorts/YhGLc\\\_9pxxl\]\(https://youtube.com/shorts/YhGLc\_9pxxl\)](#)

- Deprivation of both  $\dot{s}$  and  $\dot{\omega}$  leads bees to collide with the ground
- Only optical invariants coming from the ground are used by bees

# Conclusion about altitude control in honeybees

- Our experimental set-up reproduces the seminal experiment of Heran & Lindauer (1963).
- Honeybees rely on the ventral part of optic flow for altitude control, not lateral parts.
- Honeybees use two optical invariants:  $\dot{s}$  and  $\dot{\omega}$  as pilots do (Gibson 1950; Flach *et al.* 1992).
- Lack of texture (snow, sand, still water) leads to a loss of altitude and then a collision.
- **Next step: understanding how honeybees land on a moving platform to help pilots...**



Double mirror



From NewScientist (October 27, 2021)  
Josie Ford



Honeybees landing on a moving platform (2022). First prototype.

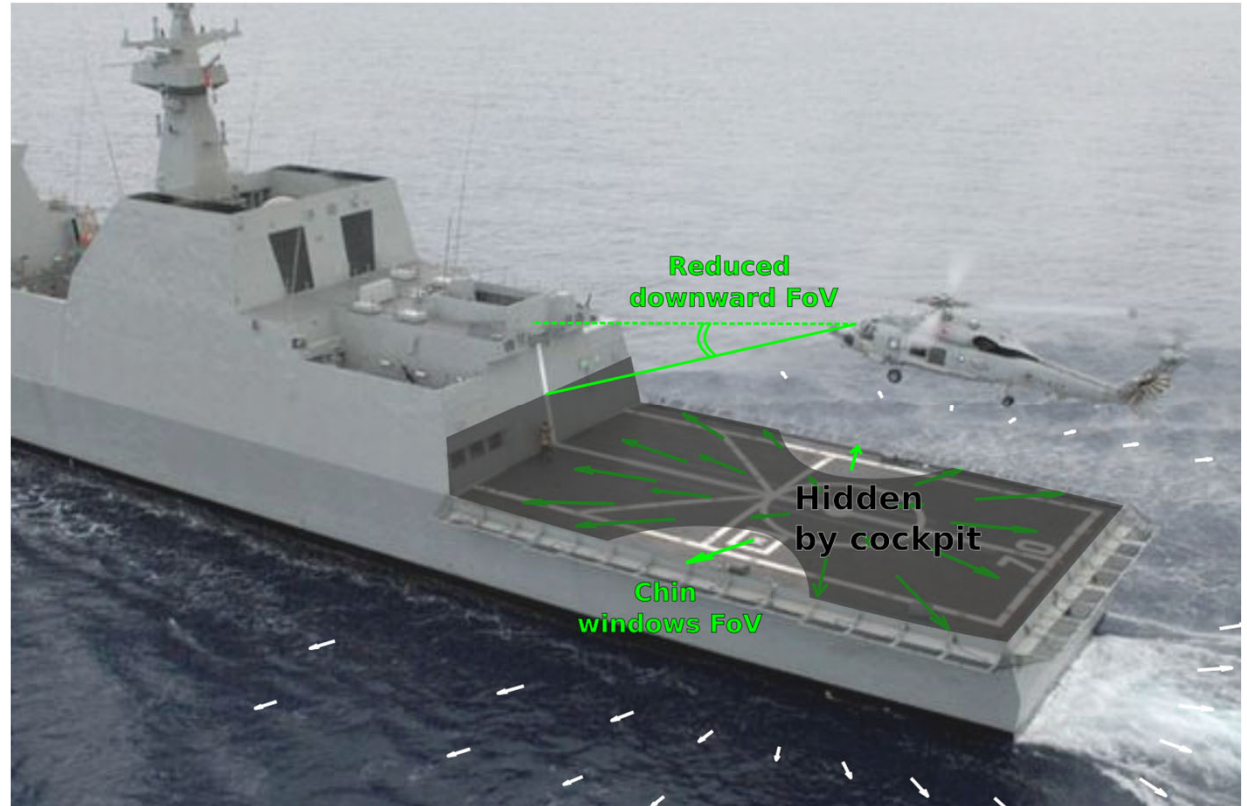
Heran, H., & Lindauer, M. (1963). *Zeitschrift für vergleichende Physiologie*, 47(1), 39-55.



# Helicopters ship landing: A high-risk task



Lynx helicopter landing on ship in rough sea  
From YT Ronaldo Barbieri (January 4, 2013)  
<https://www.youtube.com/watch?v=NJIZTL2ZyEw>



[Morice, A.H. et al. \(2021\). PLoS one, 16\(8\), e0255779.](https://doi.org/10.1371/journal.pone.0255779)

## Experimental set-up in virtual reality



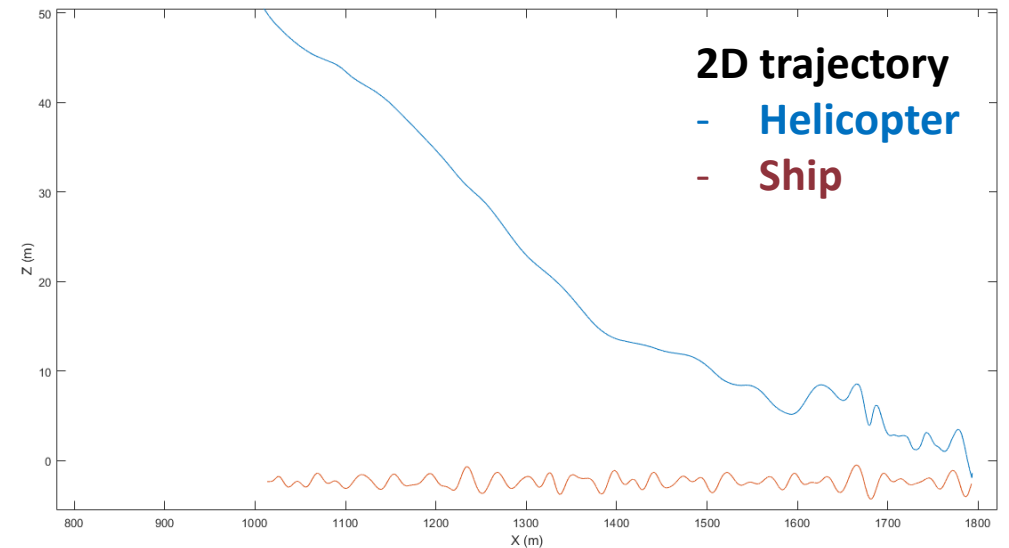
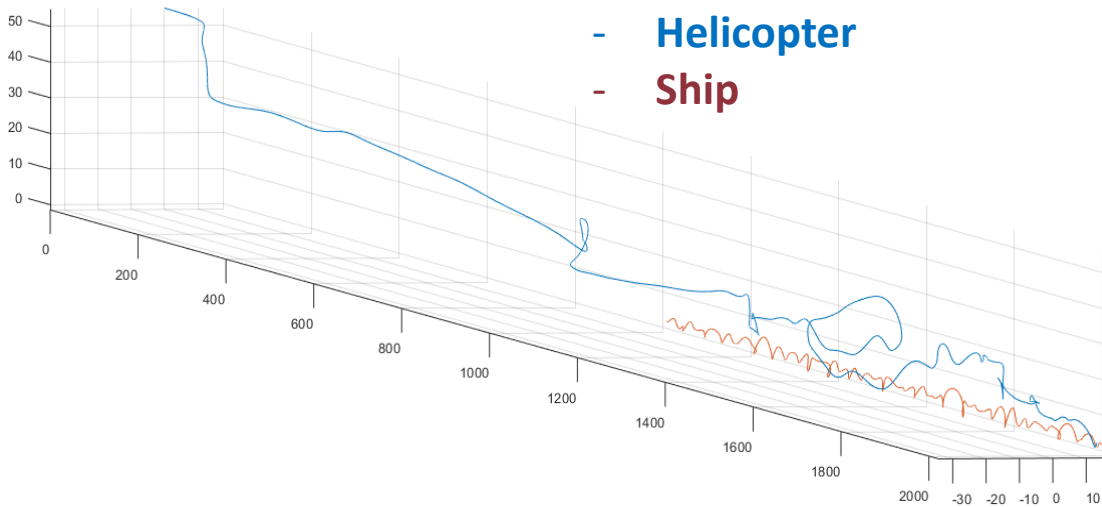
- Four experienced operational pilots from the Brazilian Armed Forces
- Two states of sea
  - Calm sea
  - Moderate sea
- Dataset
  - 53 ship landings in calm sea
  - 82 ship landings in moderate sea

[Thomas, M. et al. \(2021\). \*The International Journal of Aerospace Psychology\*, 31\(2\), 135-148.](#)

# Experimental set-up in virtual reality

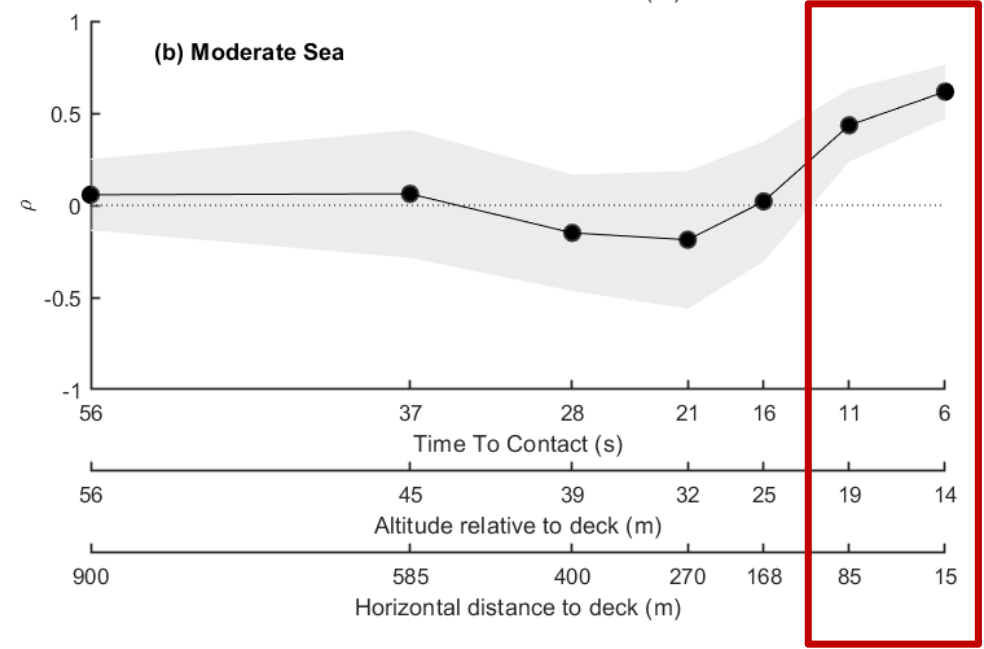
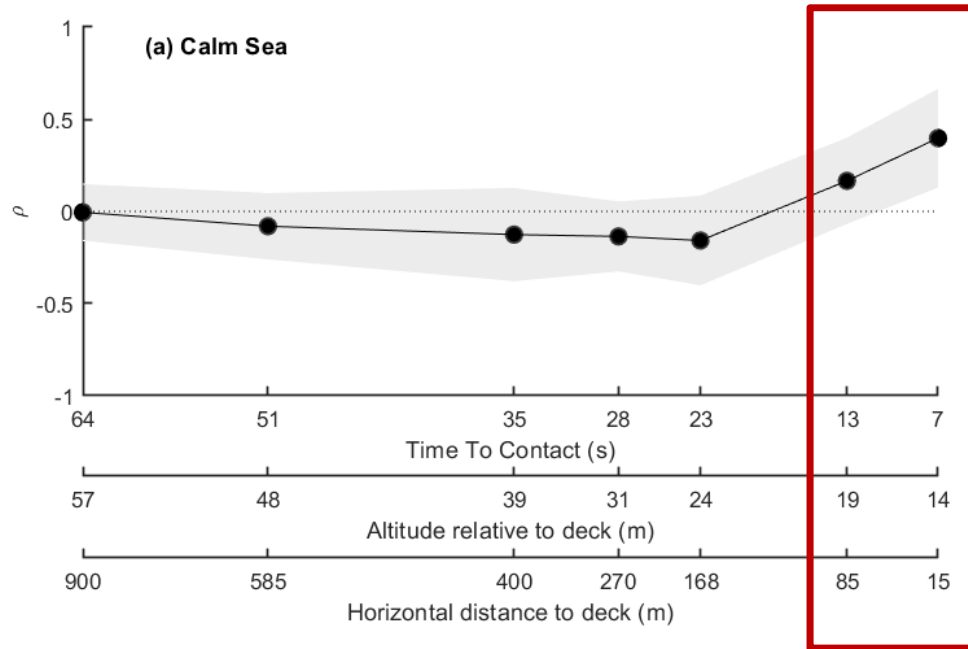
## 3D trajectory

- Helicopter
- Ship



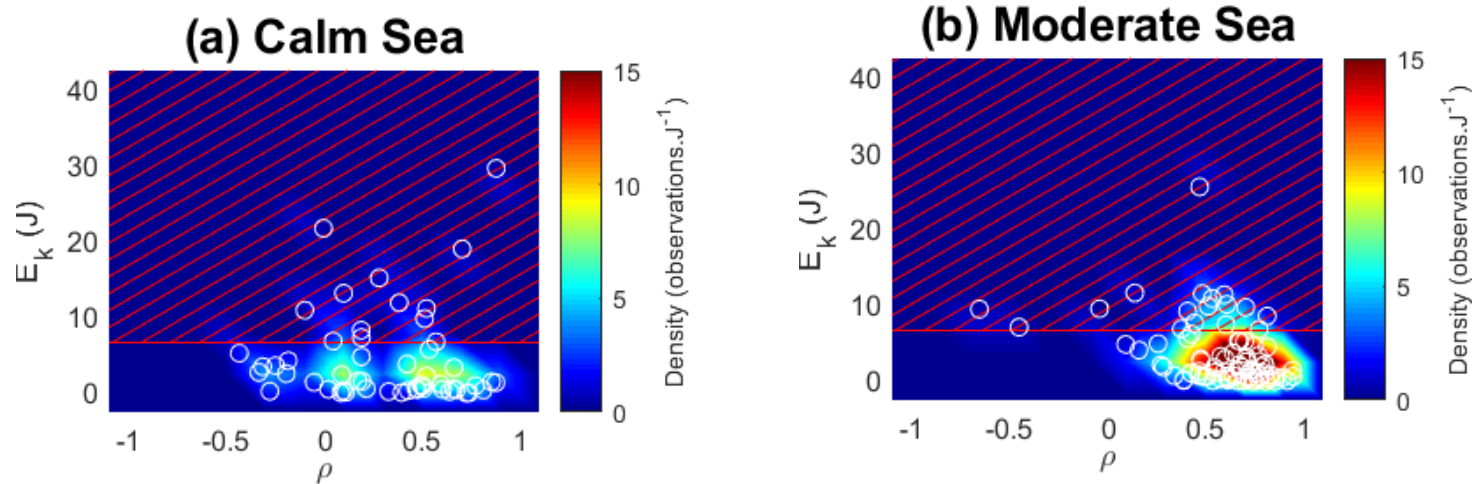
- Pilots' objective: to land (approach, hover, touchdown)
- Measurements: ship and helicopter trajectories

# The pilots synchronize with the deck during the hover and landing phases



[Thomas, M. et al. \(2021\). \*The International Journal of Aerospace Psychology\*, 31\(2\), 135-148.](#)

## The pilots minimize relative energy impact when landing on a ship deck

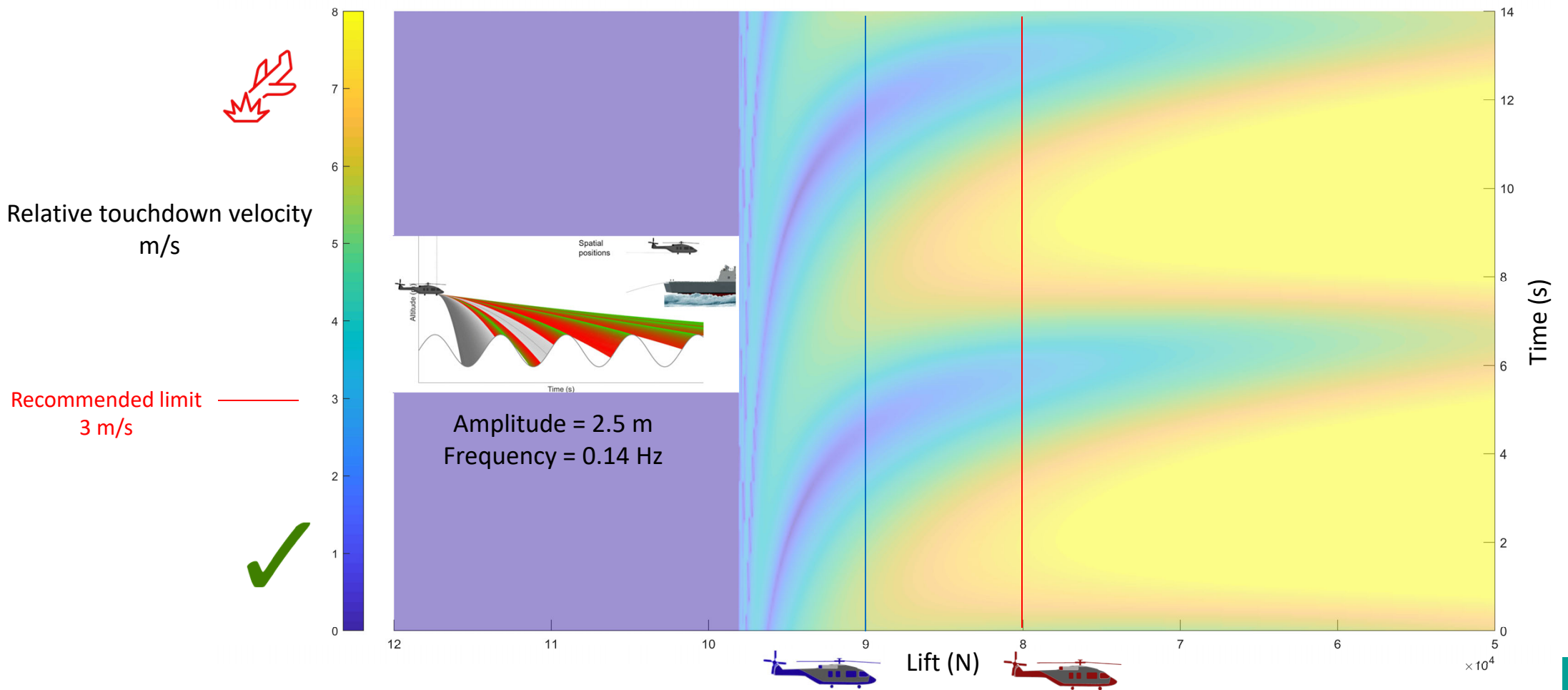


- A stronger synchronization results in lower relative energy impact in moderate sea condition.
- New hypotheses:
  - Synchronising to increase docking possibilities? → a wider time window
  - Synchronising to improve docking possibilities? → more opportunities

[Thomas, M. et al. \(2021\). \*The International Journal of Aerospace Psychology\*, 31\(2\), 135-148.](#)

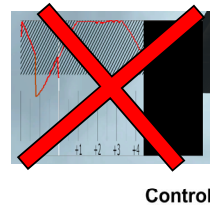
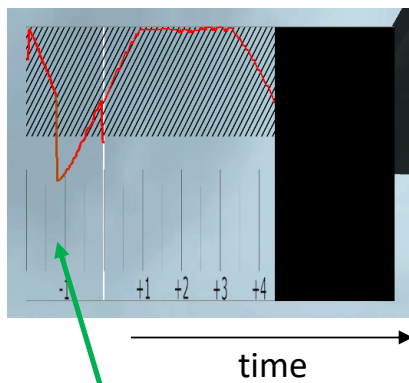
# Landing opportunities in the form of energy

## Can a visual assistance be used to improve the perception of landing possibilities?

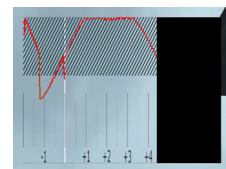


# Visual assistance based on the prediction of impact conditions in augmented virtuality

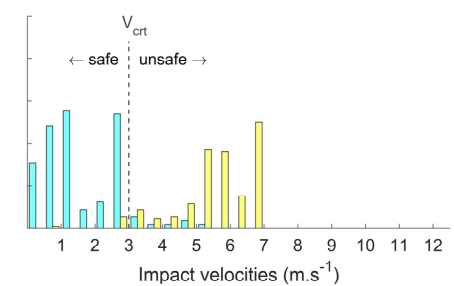
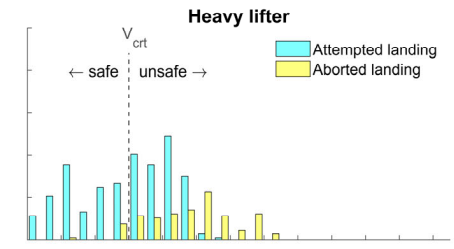
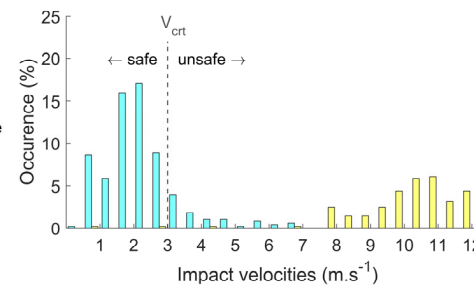
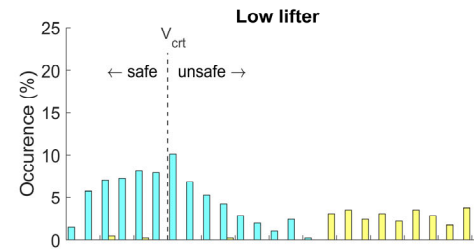
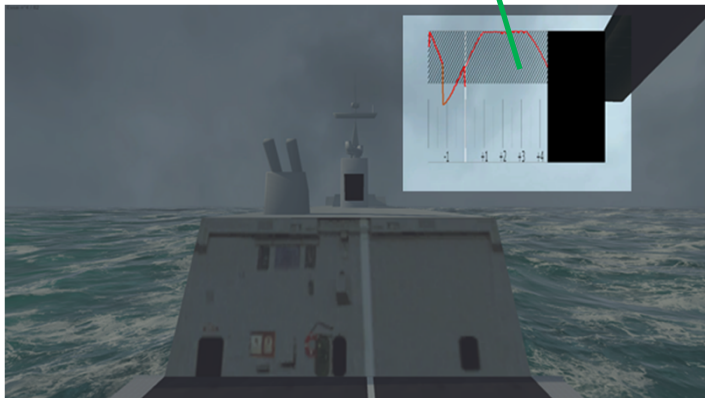
Projection of relative energy impact



Control



Assistance

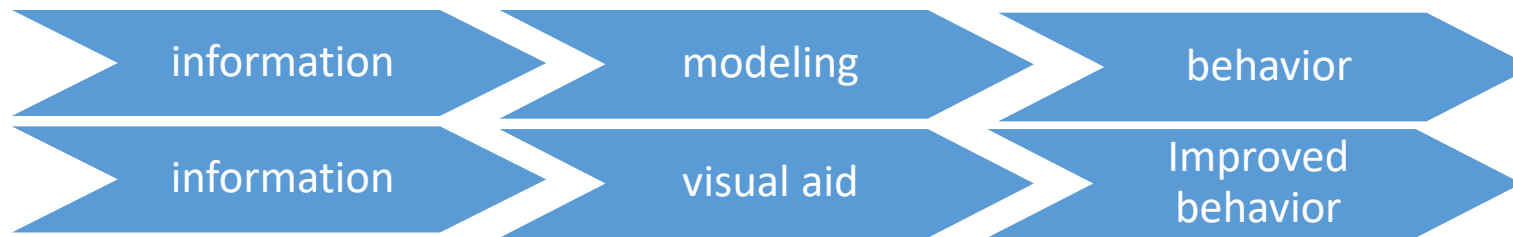


- The visual aid leads safer landings.
- Whatever the helicopter power-weight ratio, landings are safer.

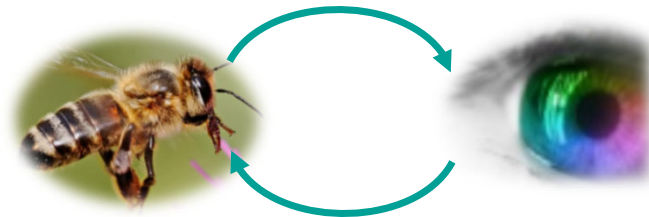
[Thomas, M., et al. \(2023\). Scientific Reports, 13\(1\), 5119.](#)

## General conclusion and discussion

- Pilots position themselves in favorable conditions before initiating the landing (cancelling the relative speed)
- Pilots explore the deck's oscillation properties (exploratory movements)
- Formalize and test pilots strategies in order to help them with visual aids (prediction of impact)



- Understanding how honeybees land on a moving platform could better formalize the task
- A formalization of this OF-based task will help ergonomists to design “more ecological” visual aids
- Law of control vs. affordance in honeybees landing still remains an open question!





Thank you for your attention



Thank You!

