Vision and navigation in bees and birds and applications to robotics

Mandyam Srinivasan

Queensland Brain Institute
and Institute of Electrical and Electronic Engineering
University of Queensland
and
ARC Centre of Excellence in Vision Science

Sam Baker, Daniel Bland, Natalie Bland, Nikolai Liebsch,
Richard Moore, Gavin Taylor, Saul Thurrowgood, Dean Soccol

Peculiarities of insect vision

Small interocular separation

Therefore, stereo vision is difficult

Insects rely heavily on image motion cues to infer object distance, perceive the world in 3-D and navigate in it

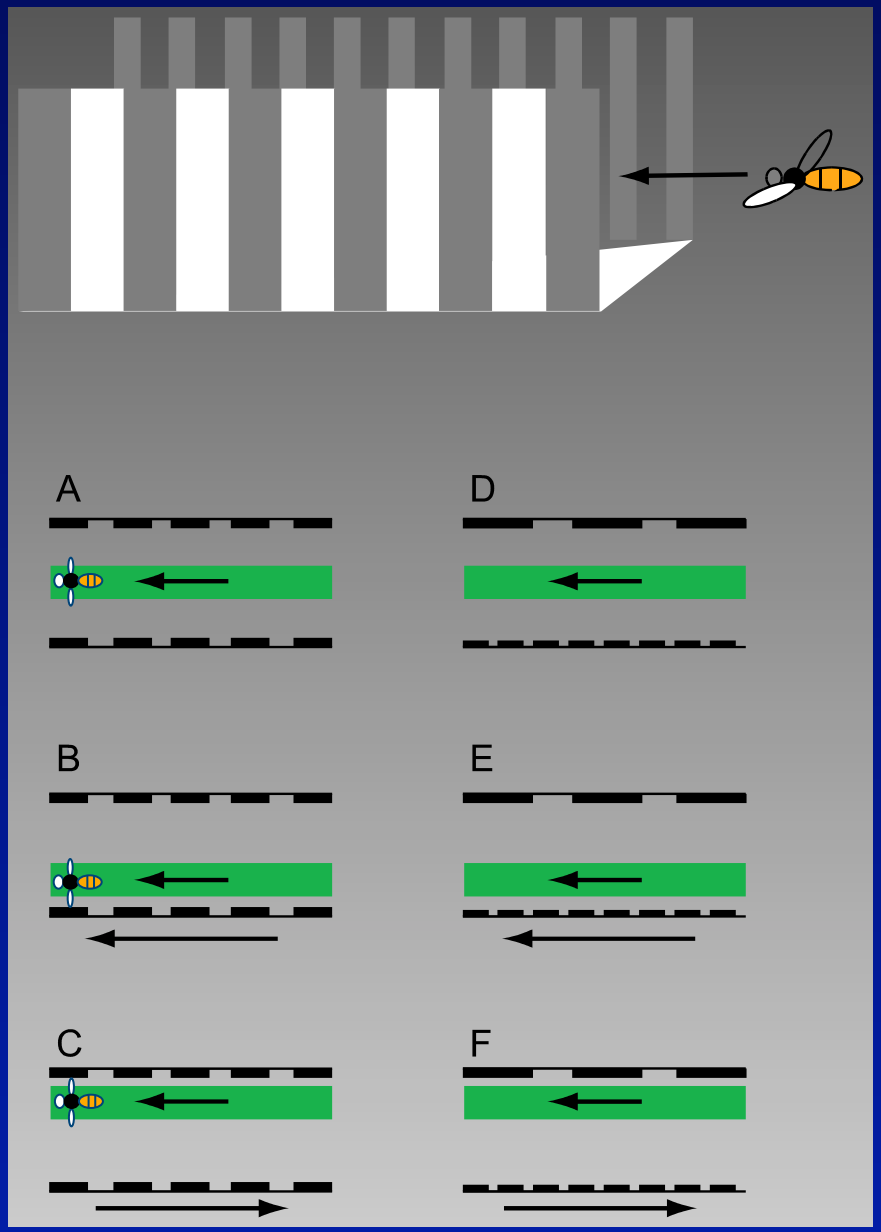
Dr. Miriam Lehrer

University of Zürich

Bees negotiate narrow gaps by balancing the image velocities in the two eyes

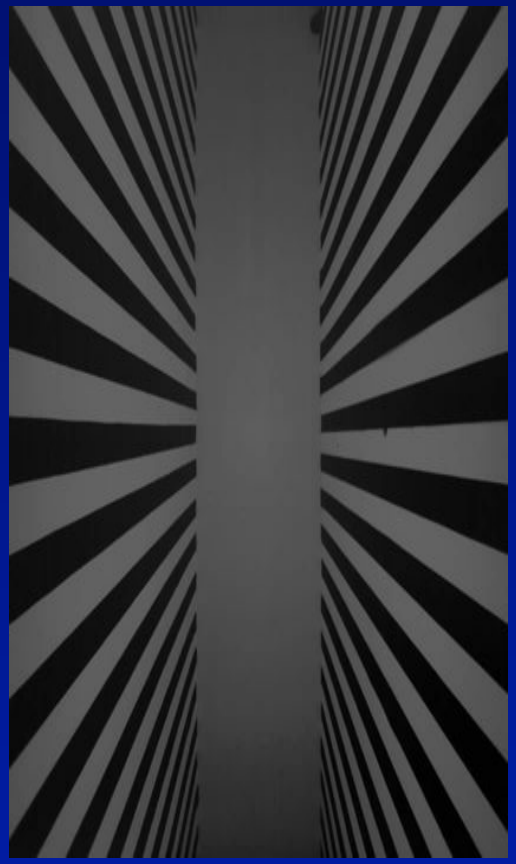
Kirchner & Srinivasan
Naturwissenschaften (1988)

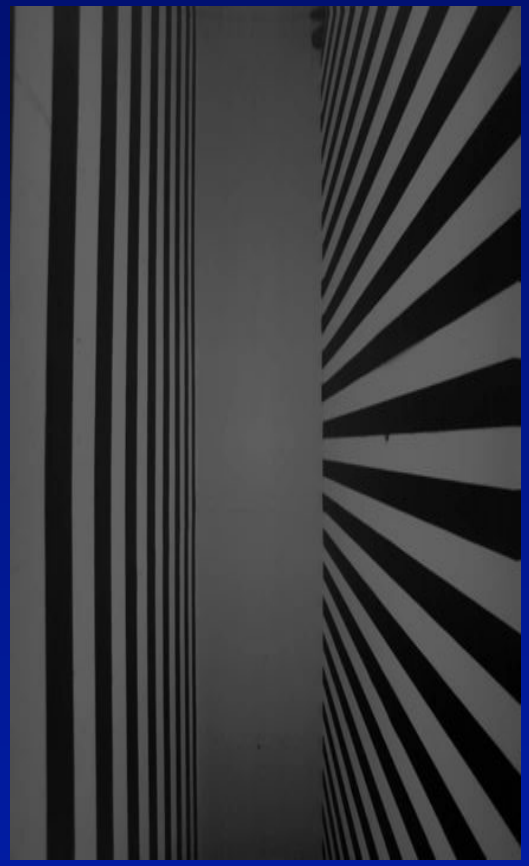
Srinivasan, Lehrer, Kirchner & Zhang
Vis. Neurosci. (1991)



Centering response in budgerigars

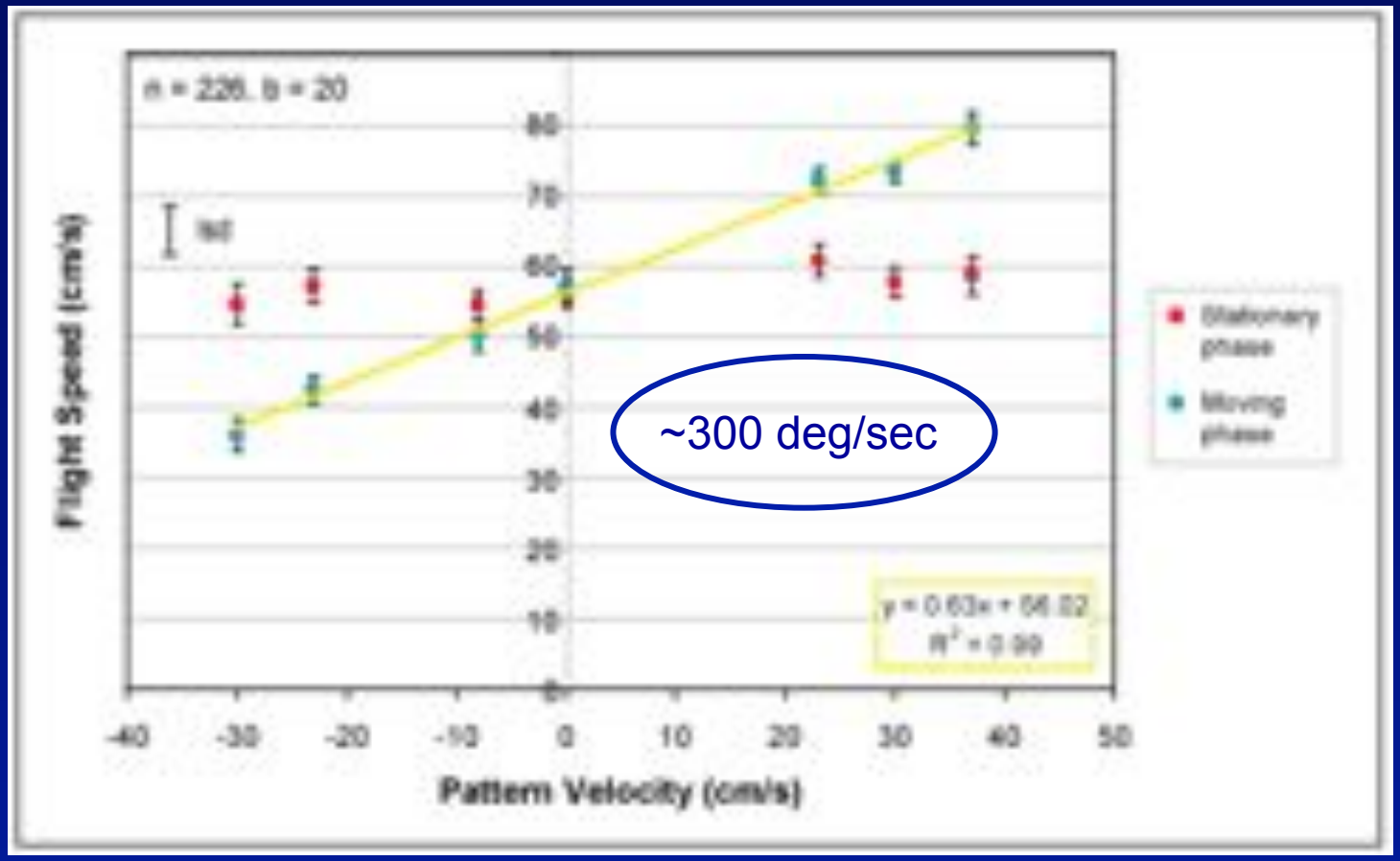
P. Bhagavatula, C. Claudianos, M. Ibbotson, M.V. Srinivasan
*Current Biology (*2011)

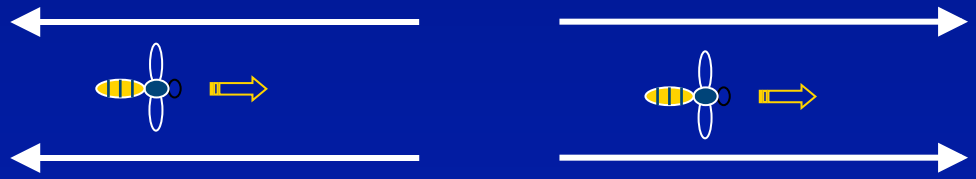




N.S.

Visual control of flight speed - bees

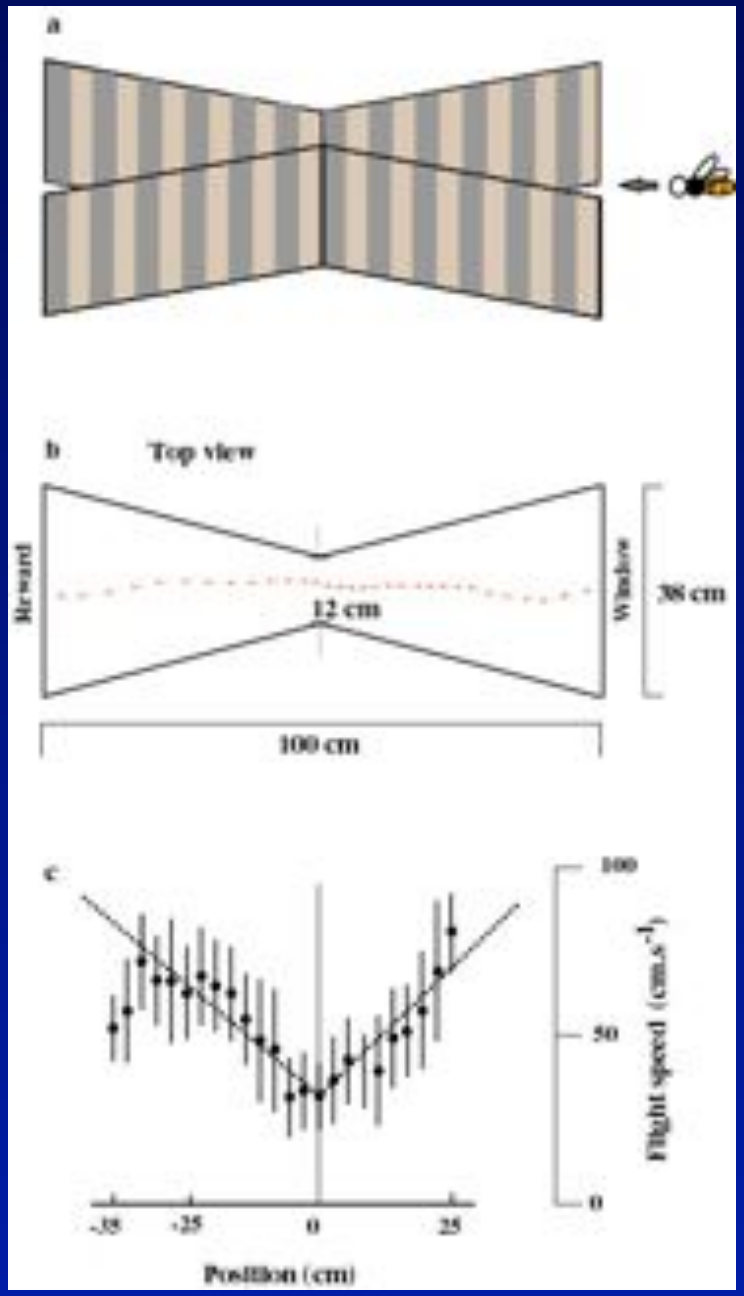




Baird, Srinivasan, Zhang and Cowley, J Exp Biol (2005)

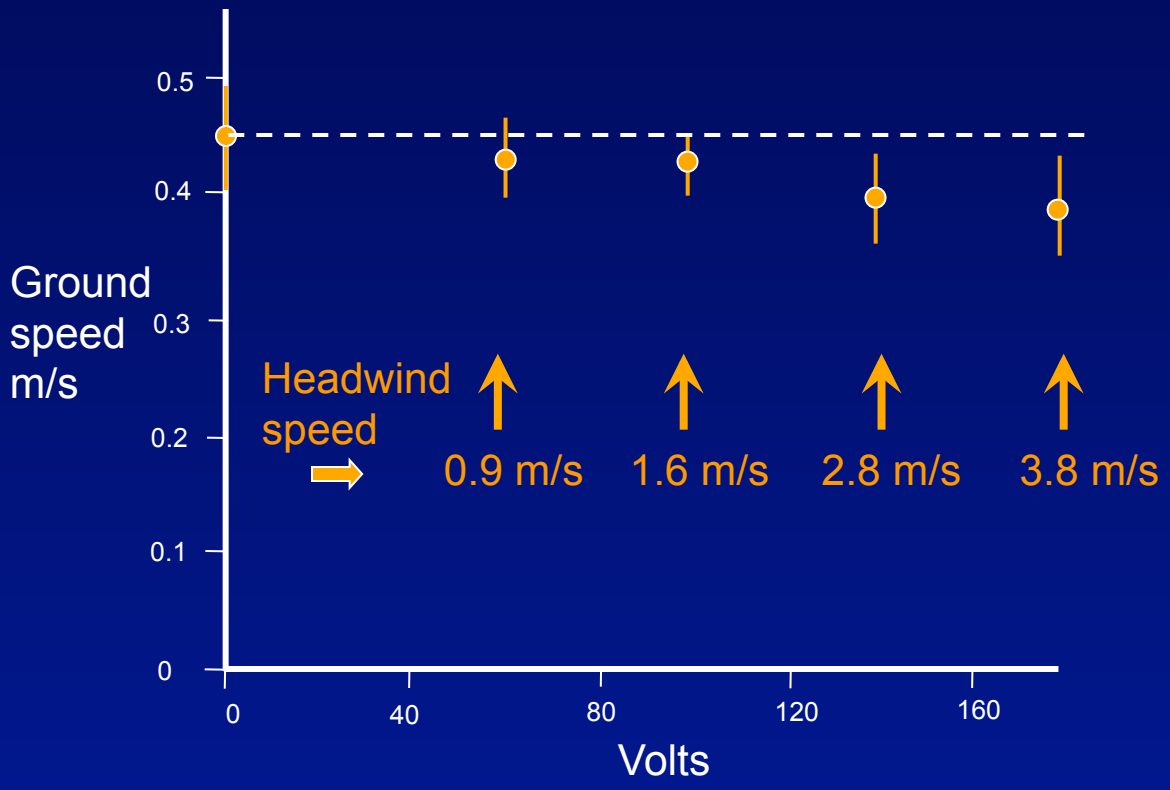
Control of flight speed

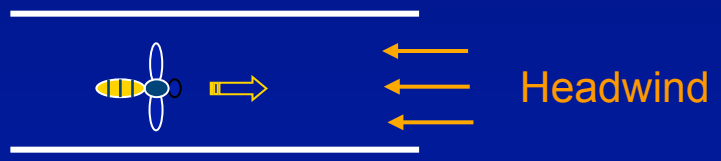
Speed of flight is regulated by holding the global image velocity constant



Srinivasan, Zhang, Lehrer & Collett
J. Exp. Biol. (1996)

Battling headwind



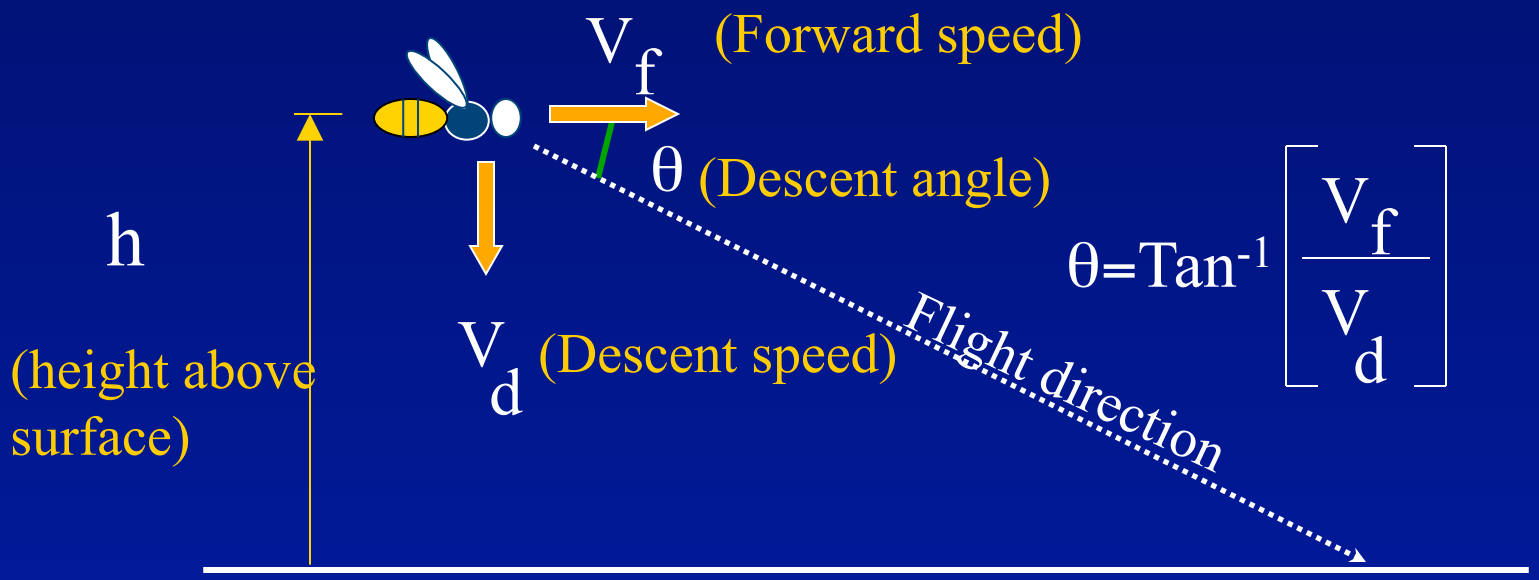


Barron and Srinivasan, *J. Exp. Biol.* (2006)

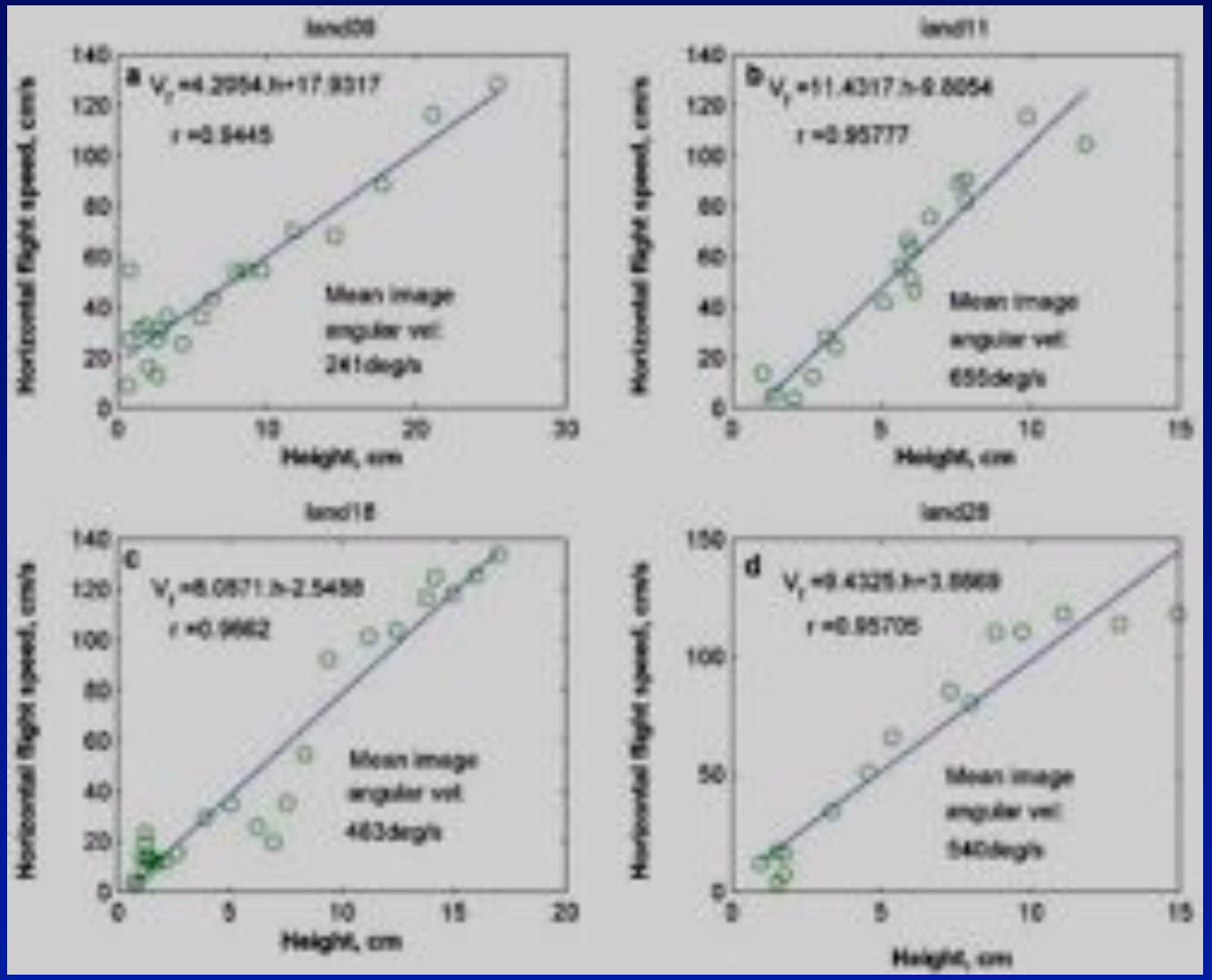
Landing

How does a bee perform a smooth, grazing landing ?

Landing parameters



Horizontal flight speed versus height



Srinivasan, Zhang, Chahl, Barth & Venkatesh, *Biol. Cybern* (2000)

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Current Opinion in Neurobiology

Cori Bargmann & Edvard Moser, Editors

August 2011

Sensory and motor systems

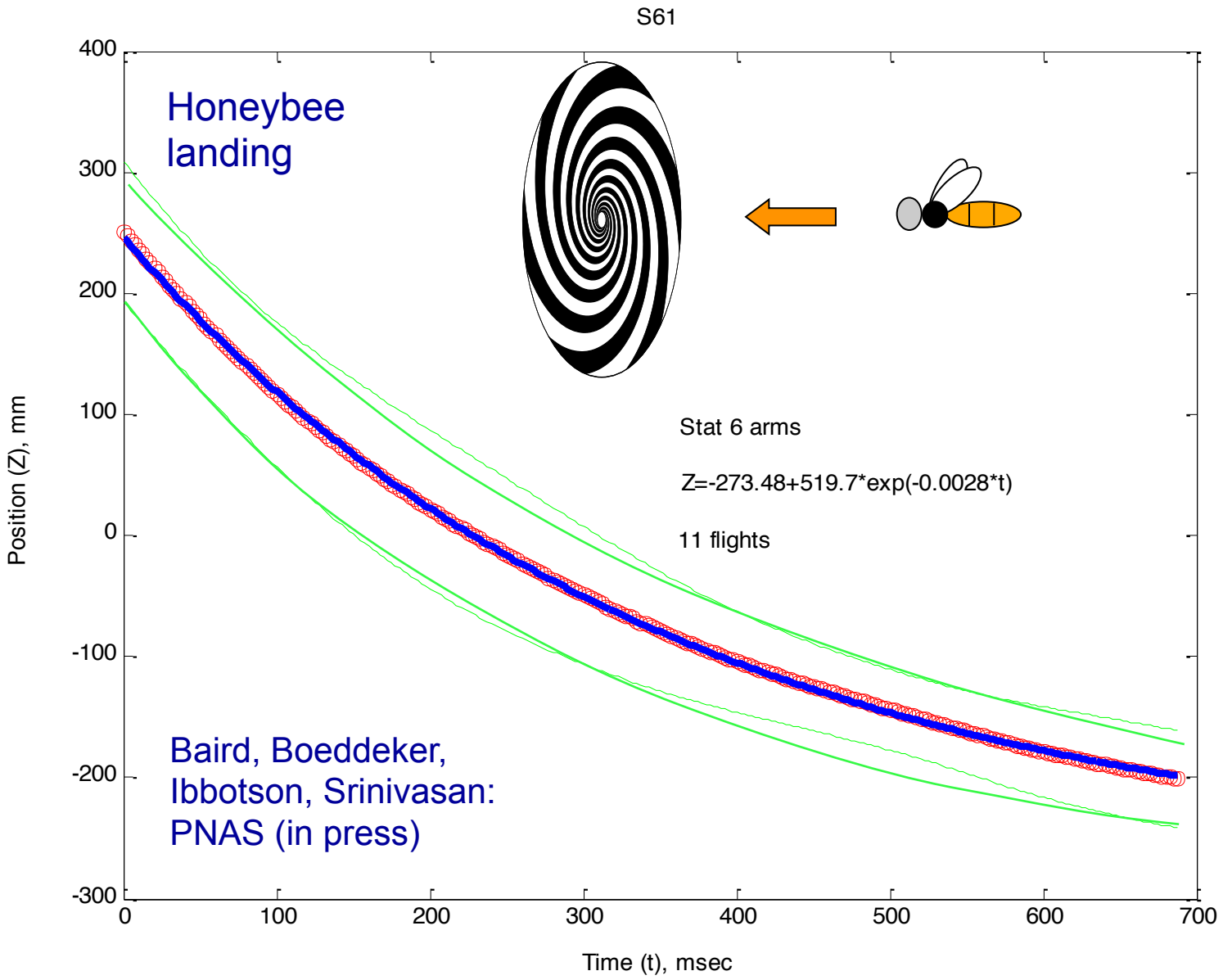
Edited by Sascha du Lac and Rachel Wilson

October 2011 Networks, circuits and computation
December 2011 Neurobiology of disease
February 2012 Neurotechnology
April 2012 Neuroethology
June 2012 Synaptic structure and function

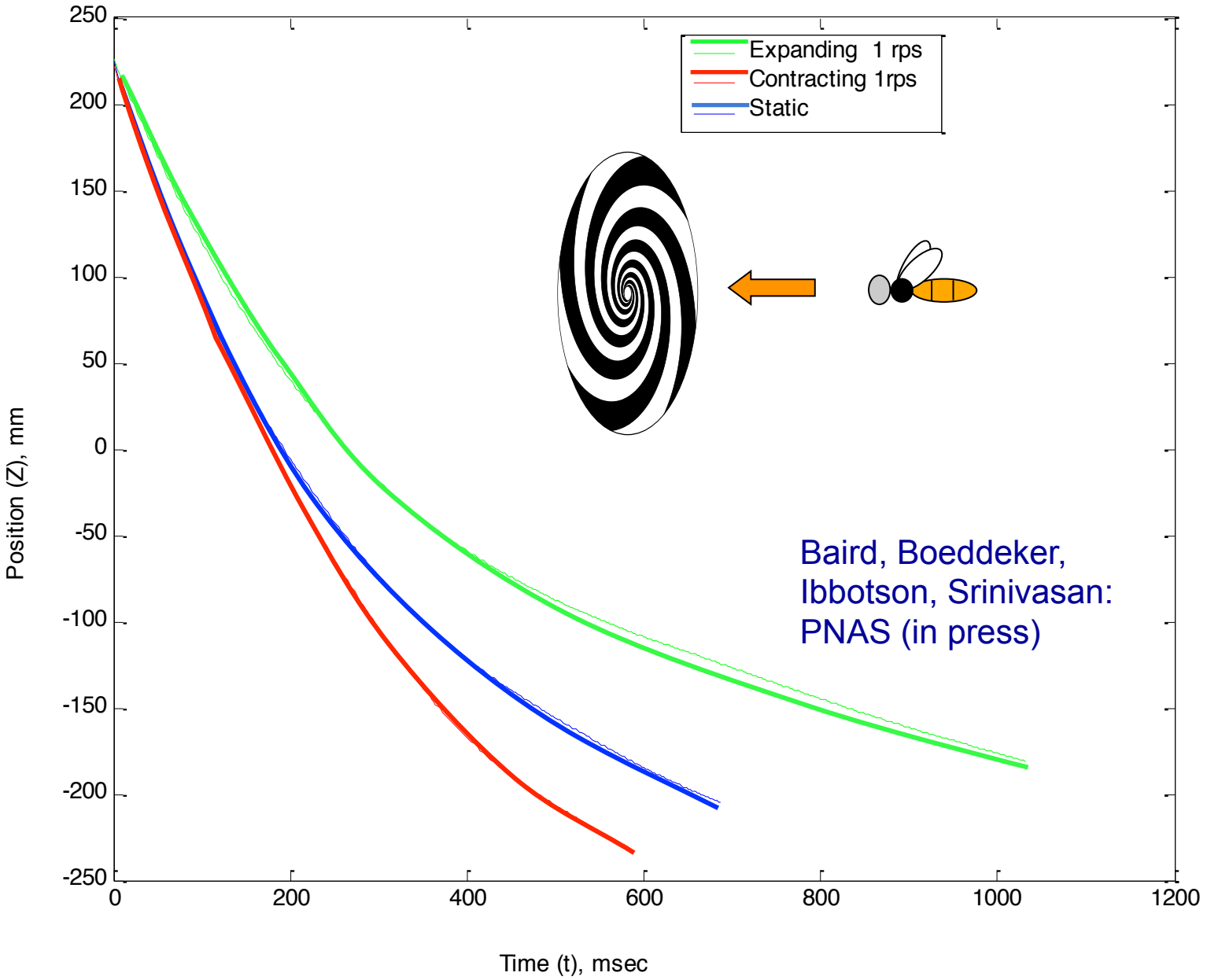
Landing on a vertical surface

With Emily Baird, Norbert Boeddeker, Michael Ibbotson

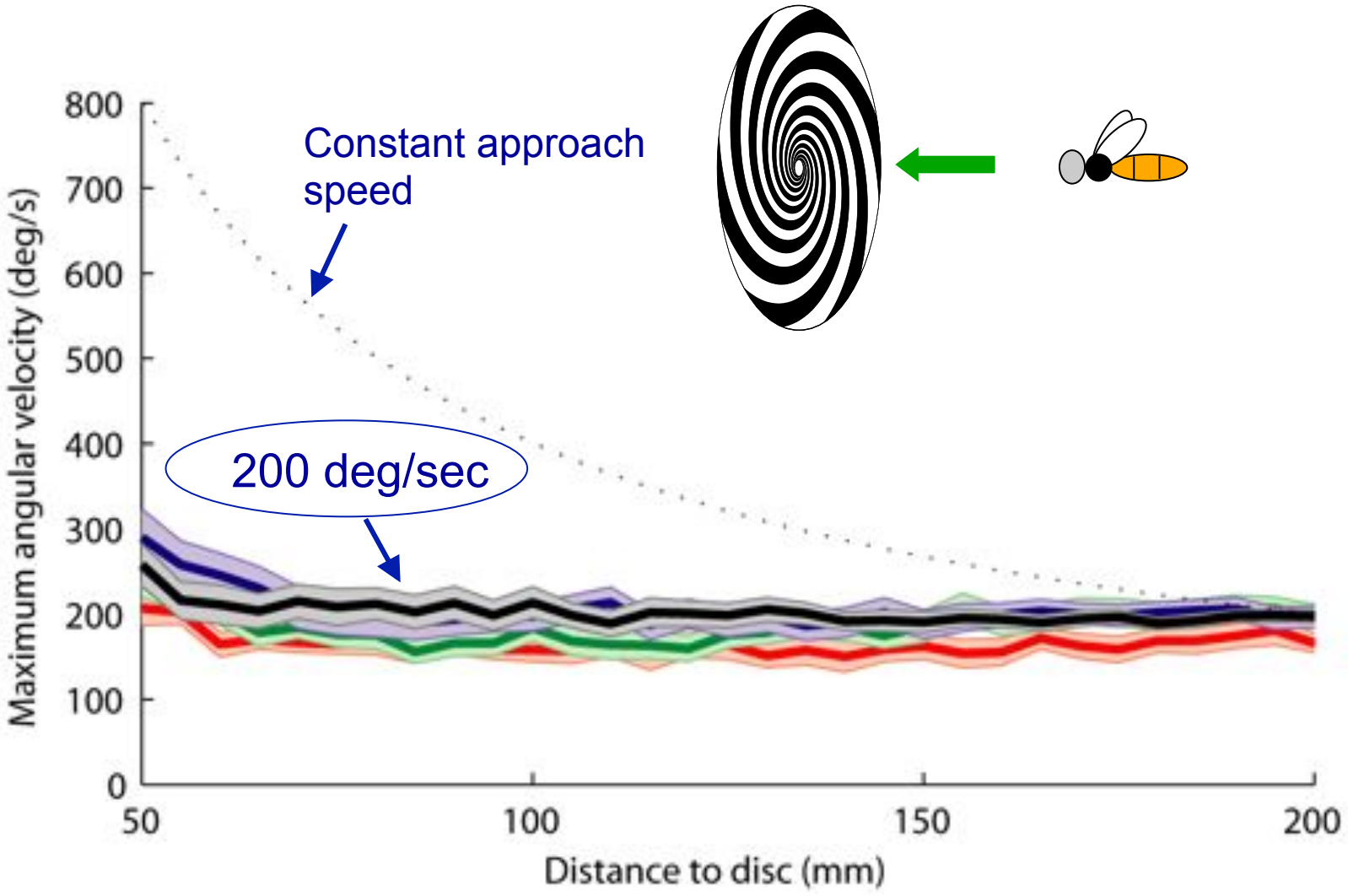
Distance decreases exponentially as a function of time,
suggesting that approach speed is controlled by holding rate of image expansion constant



Test of hypothesis: Expanding spiral reduces approach speed; contracting spiral increases it

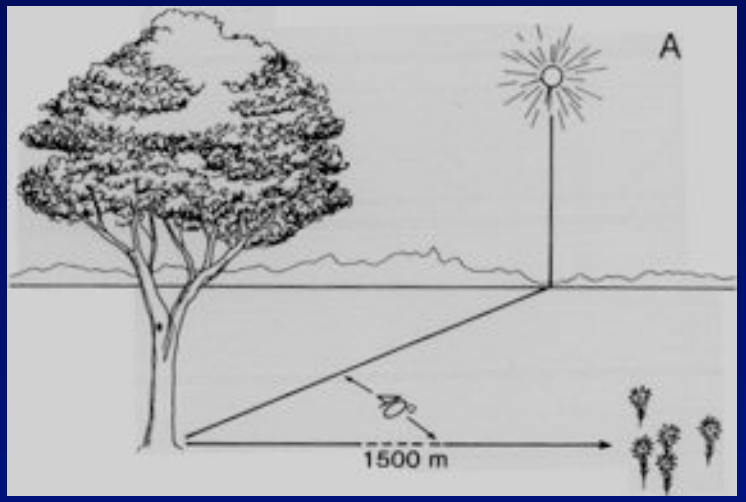


Baird, Boeddeker, Ibbotson, Srinivasan: PNAS (in press)

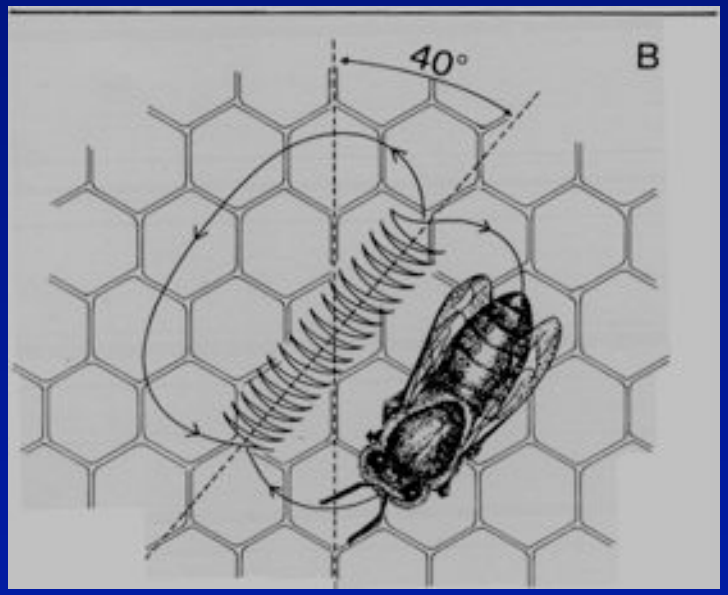


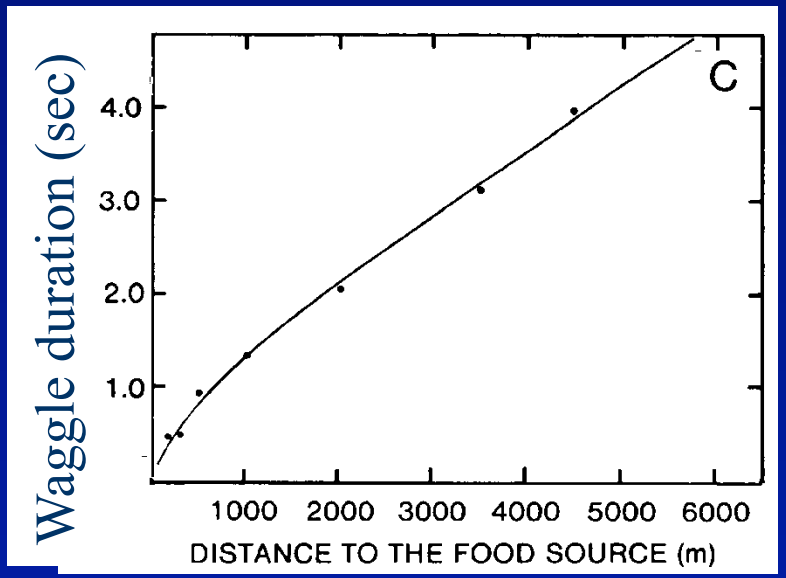
Honeybee odometry

The waggle dance



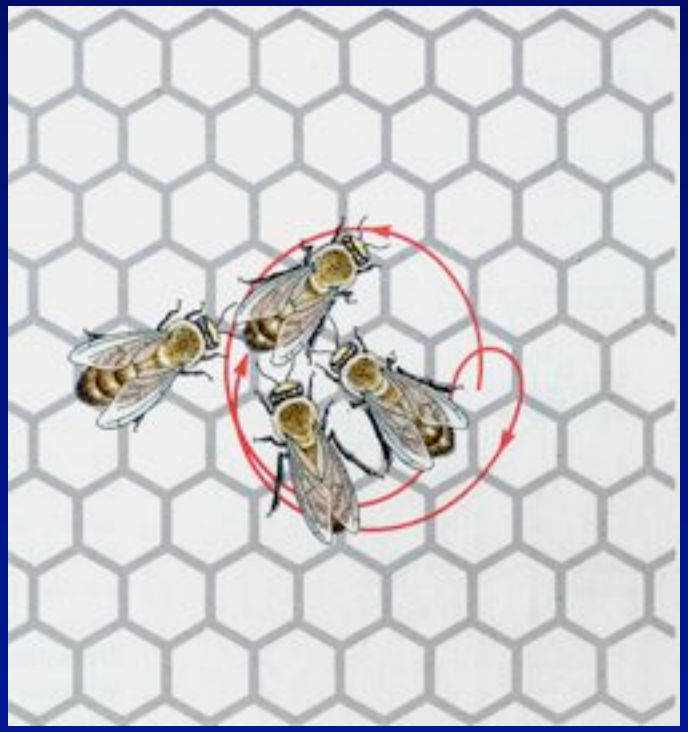
Q: How does a bee work out how far she has flown?





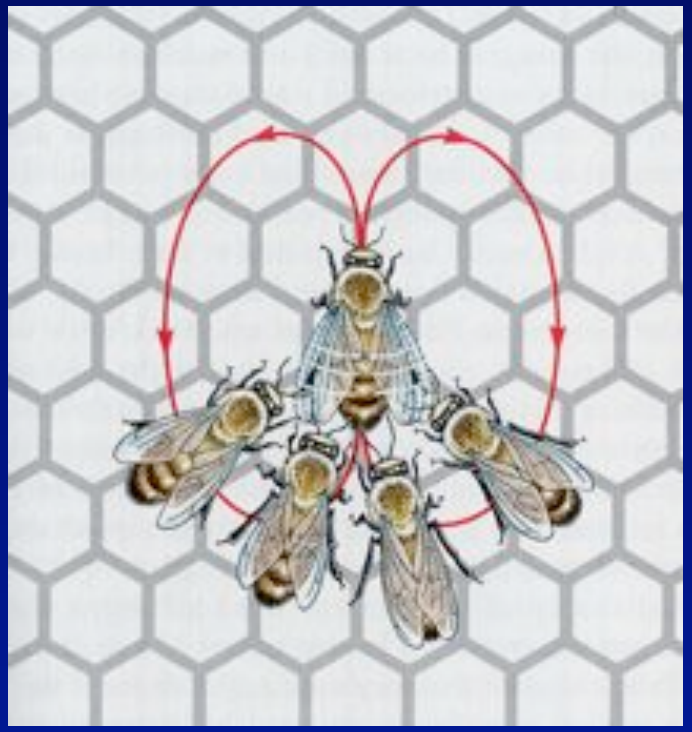
Karl von Frisch


1H00M00S



Round dance

(feeder distance < 50m)



Waggle dance

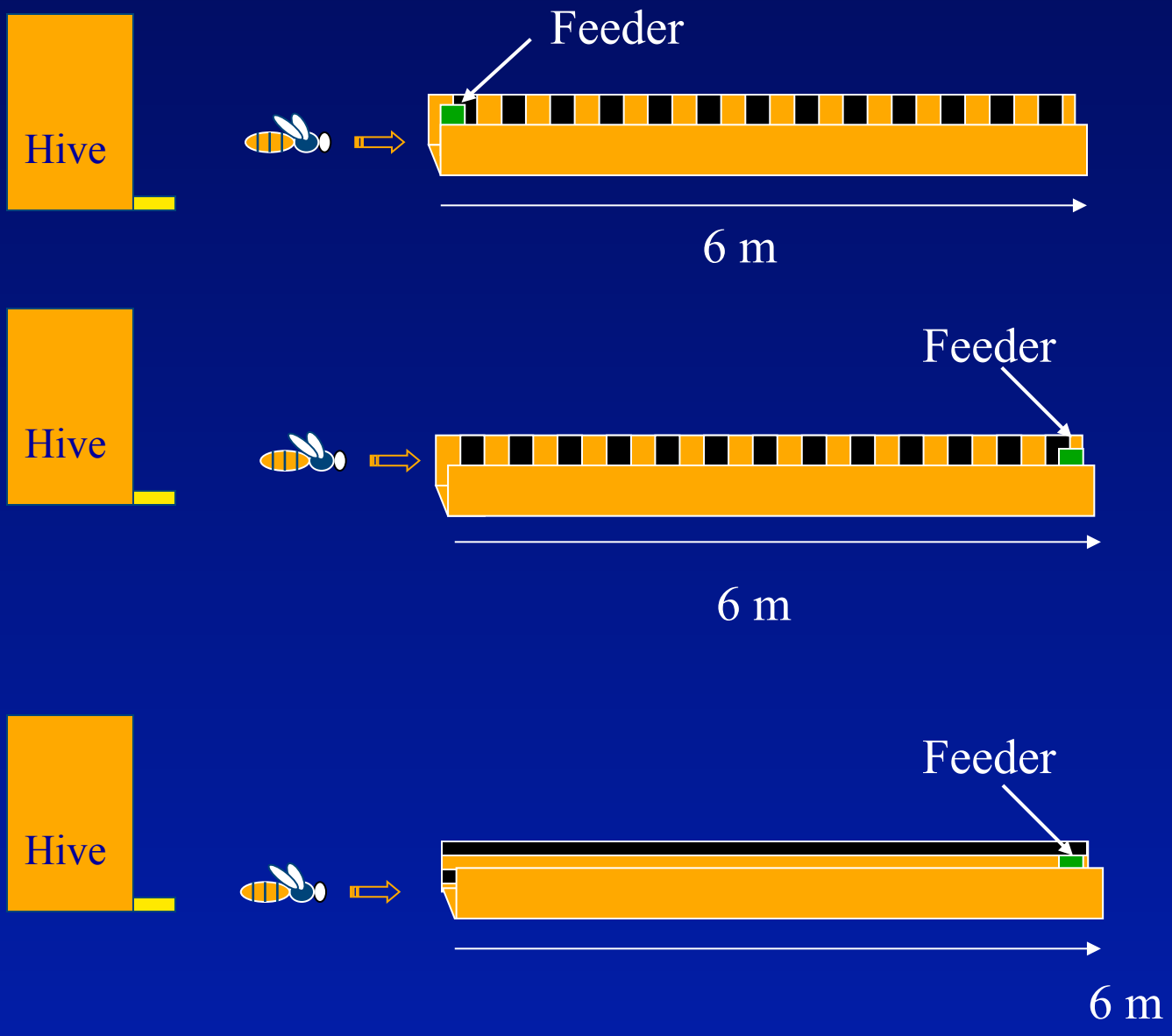
(feeder distance > 50m)

Honeybee navigation:

How does a bee estimate how far it has flown?

Srinivasan, Zhang, Altwein & Tautz, *Science* (2000)

Esch, Zhang, Srinivasan & Tautz *Nature (2001)*



Dance signal

Round dance

~ 0 m

Waggle dance

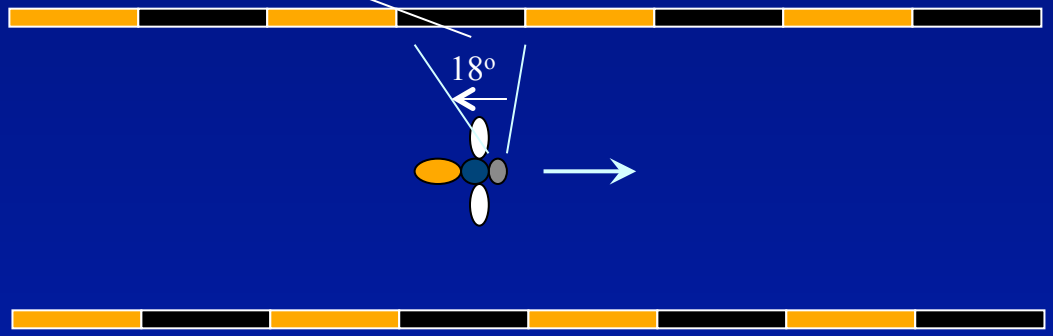
~ 200 m

Round dance

~ 0 m

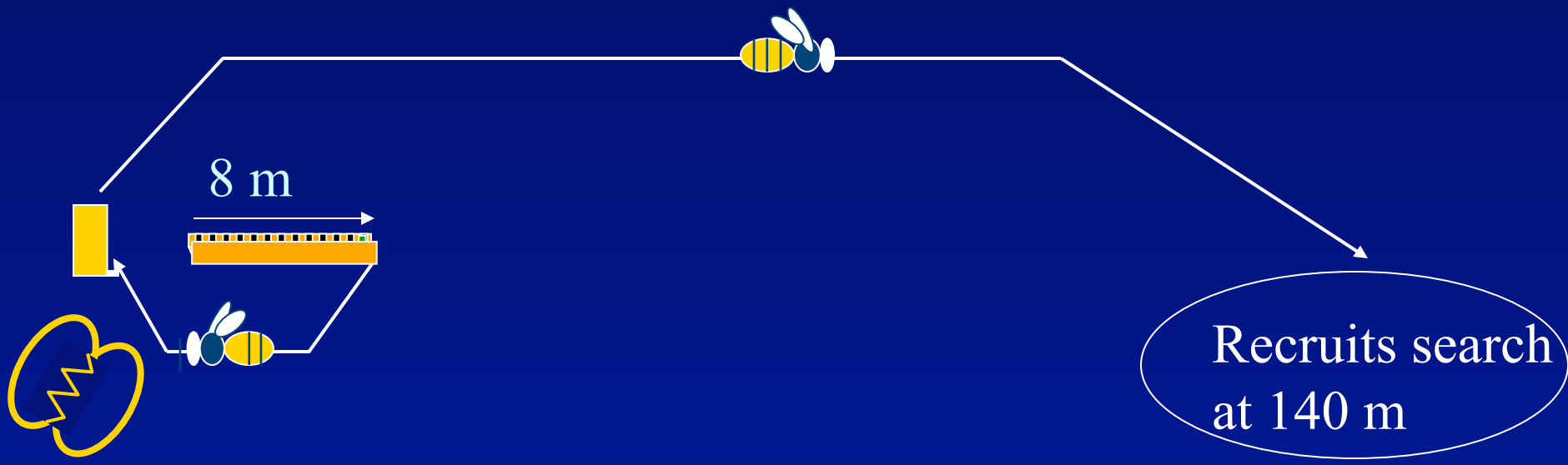
Visual calibration of the honeybee's odometer and dance

1 msec of waggle corresponds to
18° of image movement in the eye during flight



Srinivasan, Zhang, Altwein & Tautz, *Science* (2000)

How do the recruits respond to the dancing tunnel bees?



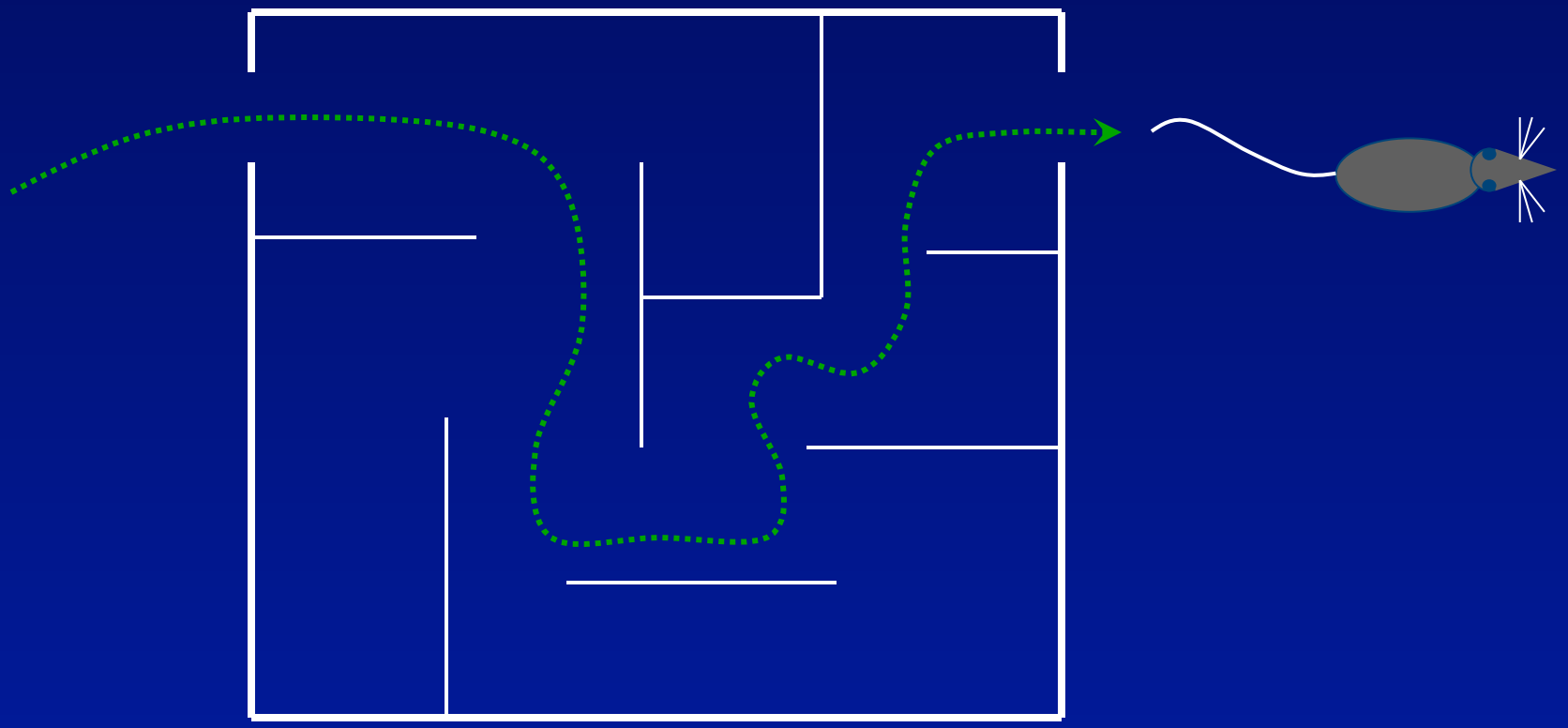
Scouts returning from 8 m tunnel signal a distance of 140 m

Esch, Zhang, Srinivasan & Tautz
Nature (2001)

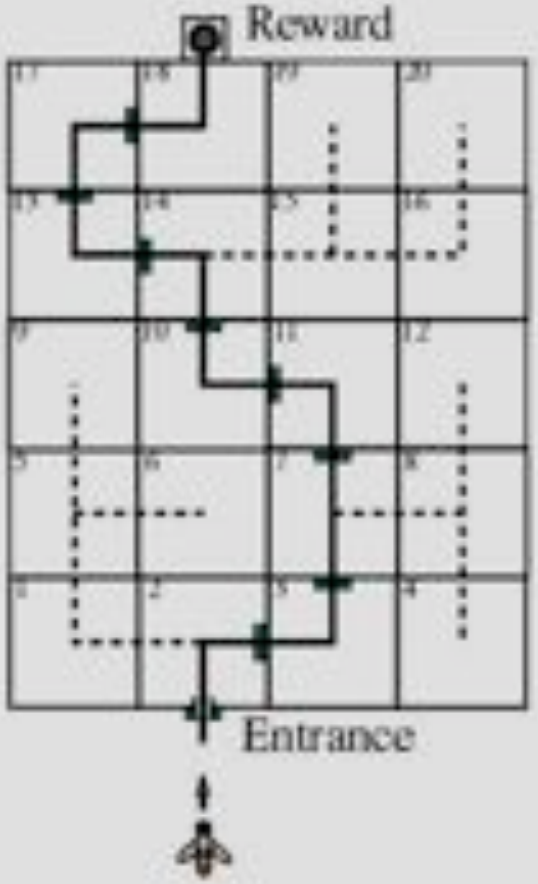
Honeybee perception and ‘cognition’

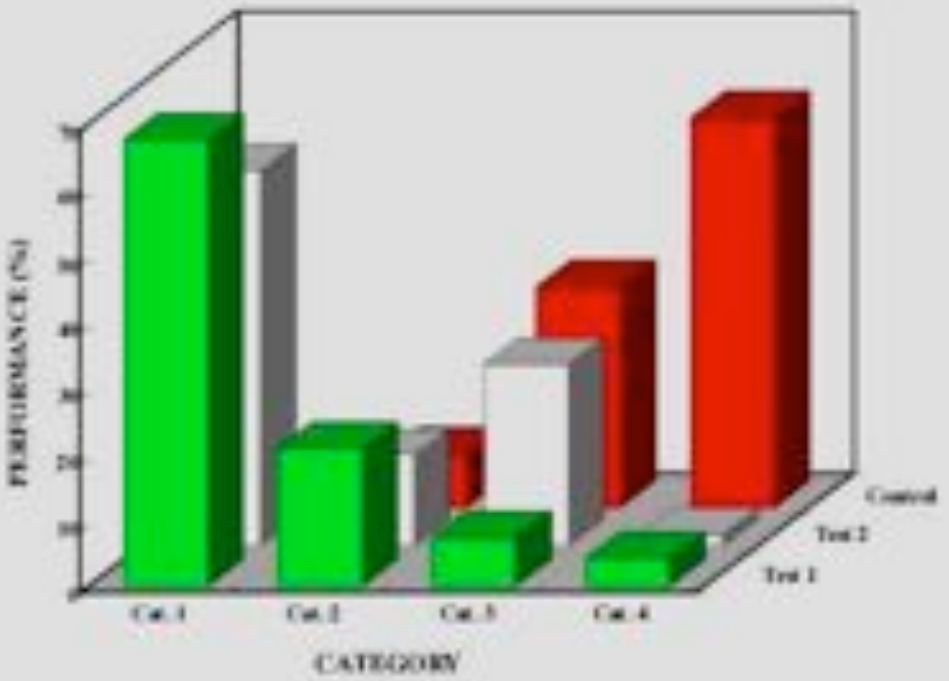
Image courtesy Jeff Wilson and Judith Reinhard

Maze learning



MAZE NAVIGATION: Following a colour mark

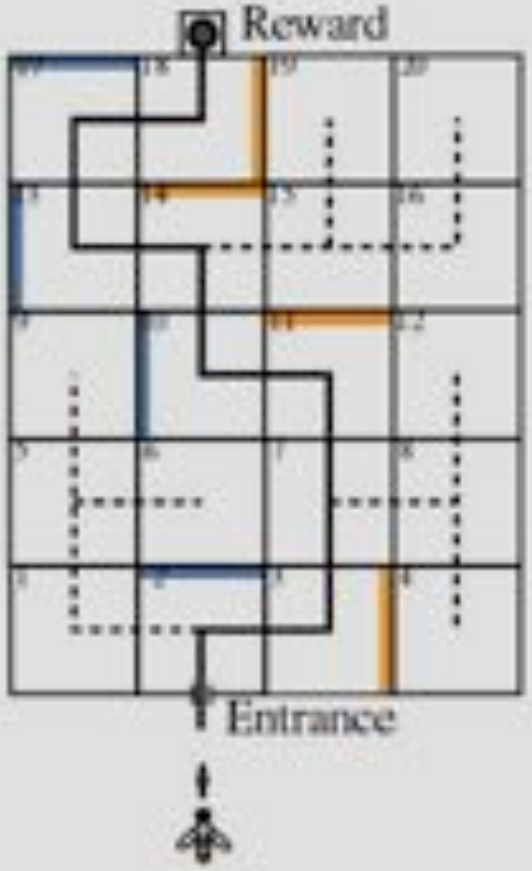


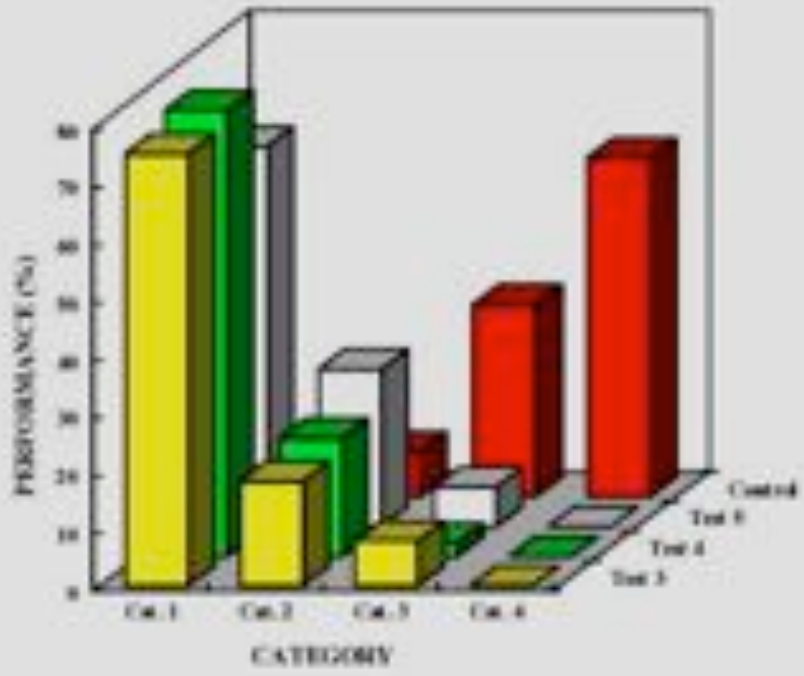


Zhang, Bartsch & Srinivasan
Neurobiology of Learning & Memory (1996)

Maze navigation: following a colour mark

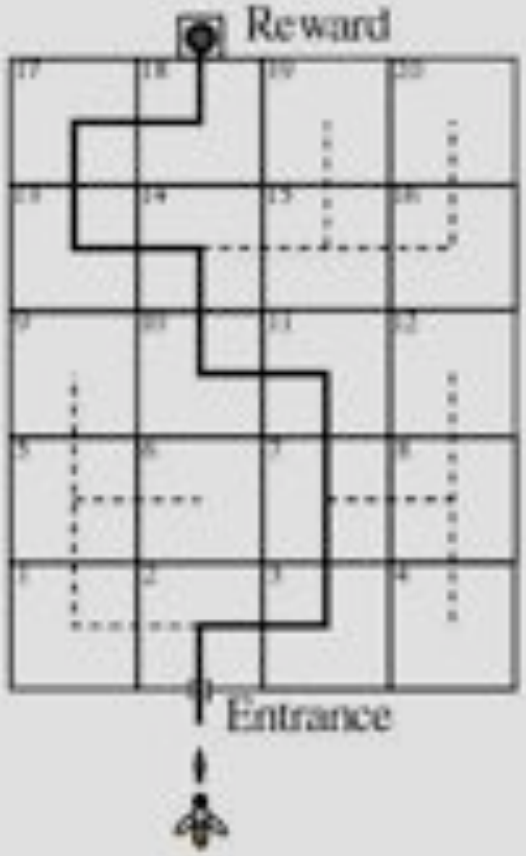
MAZE NAVIGATION: Using colour as an abstract navigational cue

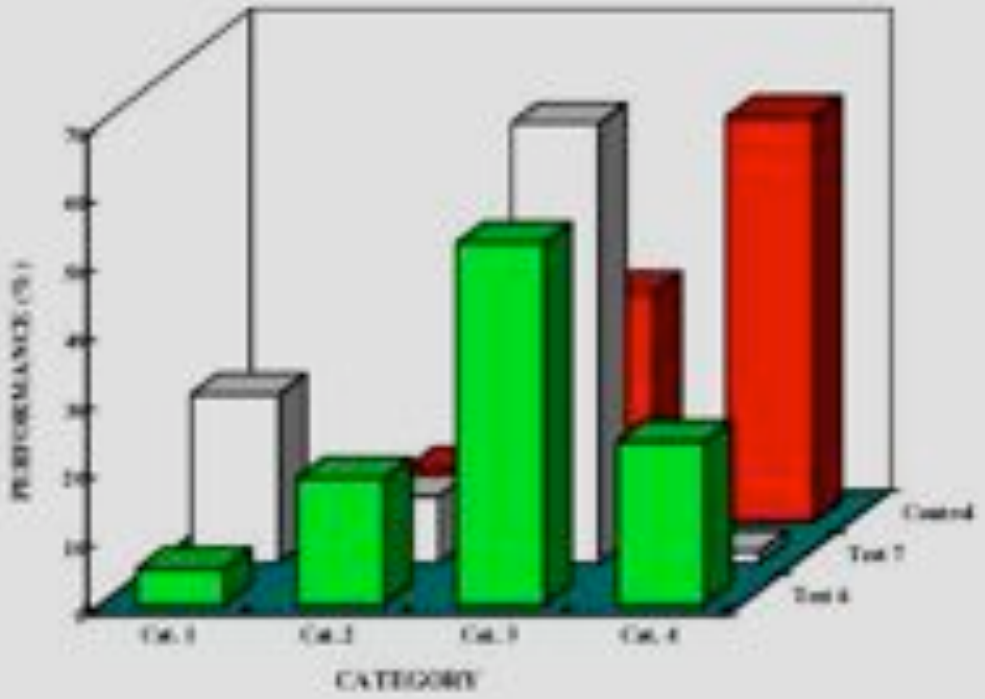




Zhang, Bartsch & Srinivasan
Neurobiology of Learning & Memory (1996)

MAZE NAVIGATION: No cues



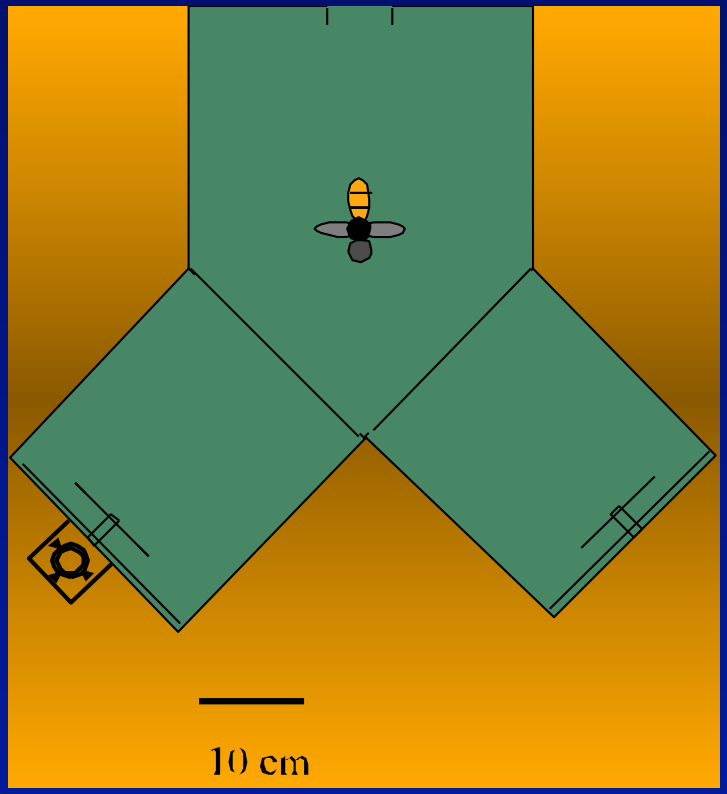


Zhang, Bartsch & Srinivasan
Neurobiology of Learning & Memory (1996)

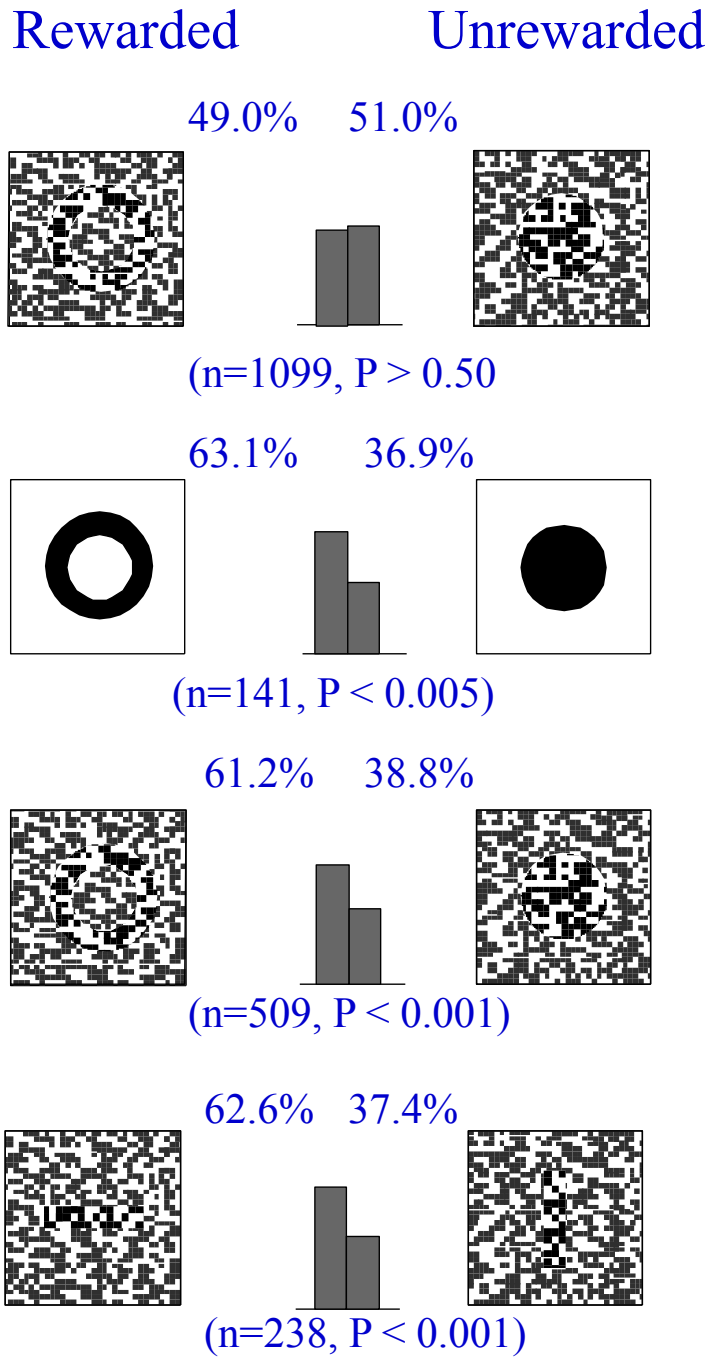
Music in the wind

Bev Doolittle

"Top-down" processing in honeybees



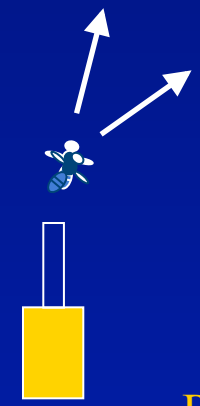
Zhang & Srinivasan
Nature (1994)



Associative recall

Can scent trigger memories of locations?

Training paradigm

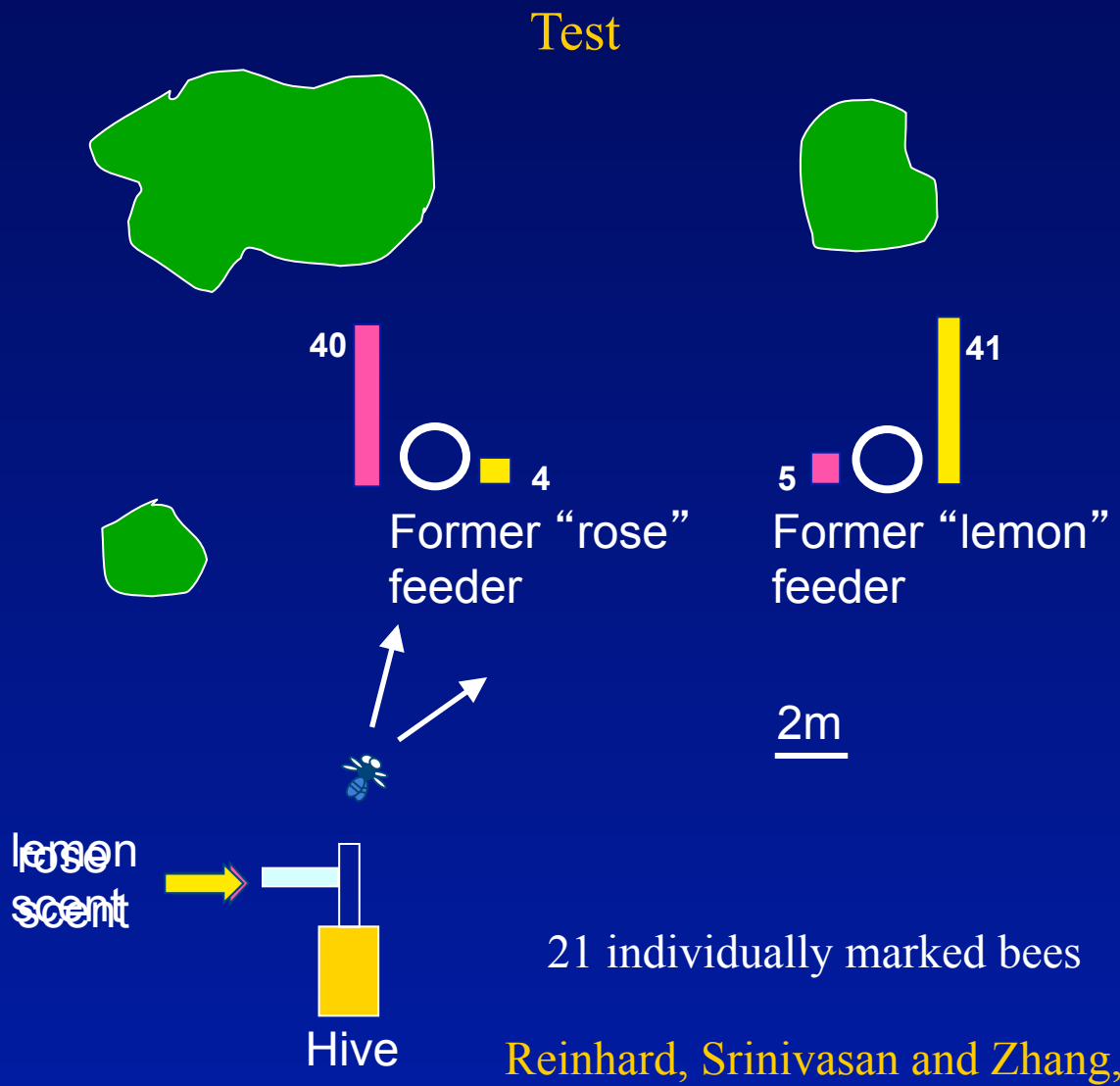


2m

21 individually marked bees

Reinhard, Srinivasan and Zhang, *Nature* (2004)

Can scent trigger memories of locations?



21 individually marked bees

Reinhard, Srinivasan and Zhang, *Nature* (2004)