University of Sussex

Ant navigation:

Understanding the simple mechanisms behind apparently complex behaviours

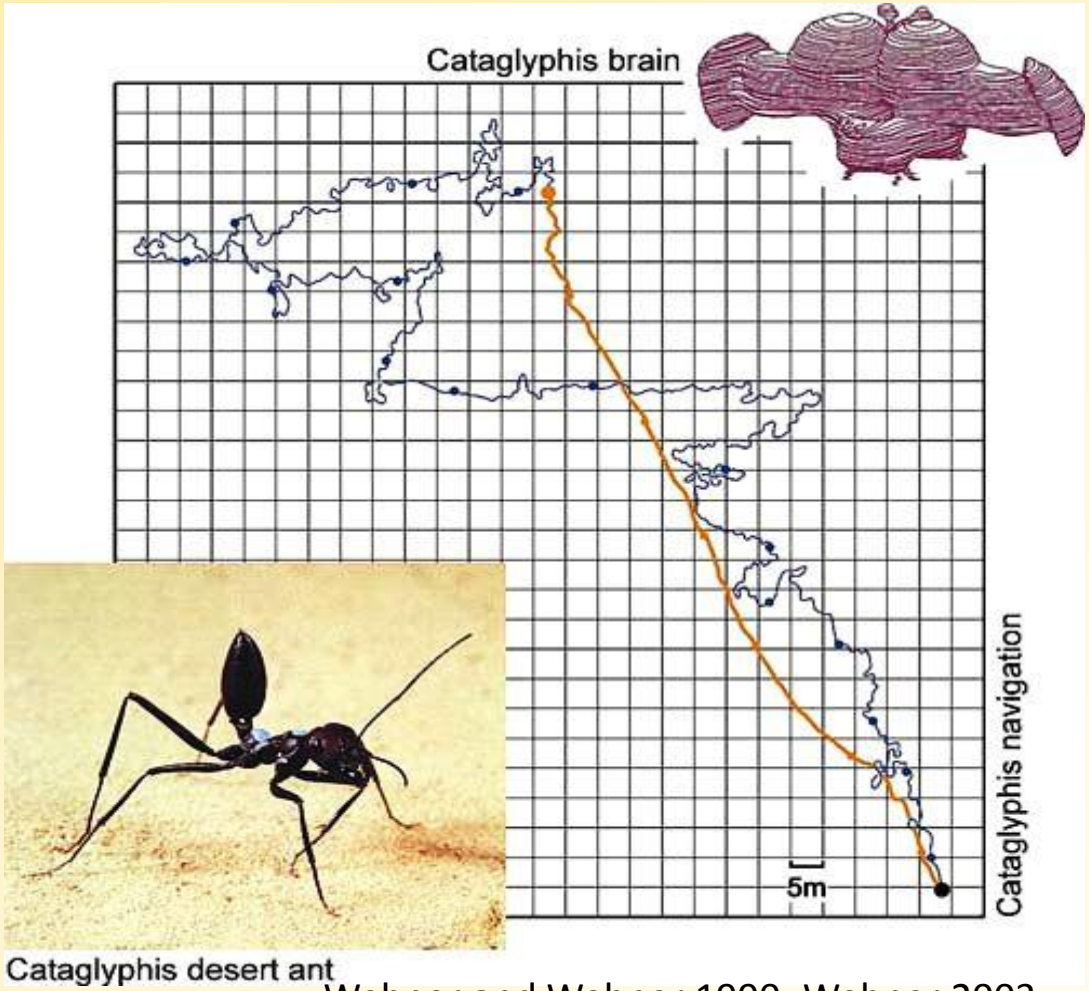
Antoine Wystrach

Melophorus bagoti

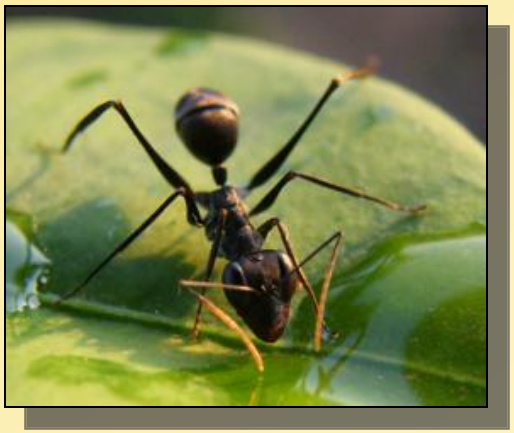
➢**Central place foragers**

Navigational mechanisms

✓ **Effective, Robust**



Wehner and Wehner 1990; Wehner 2003



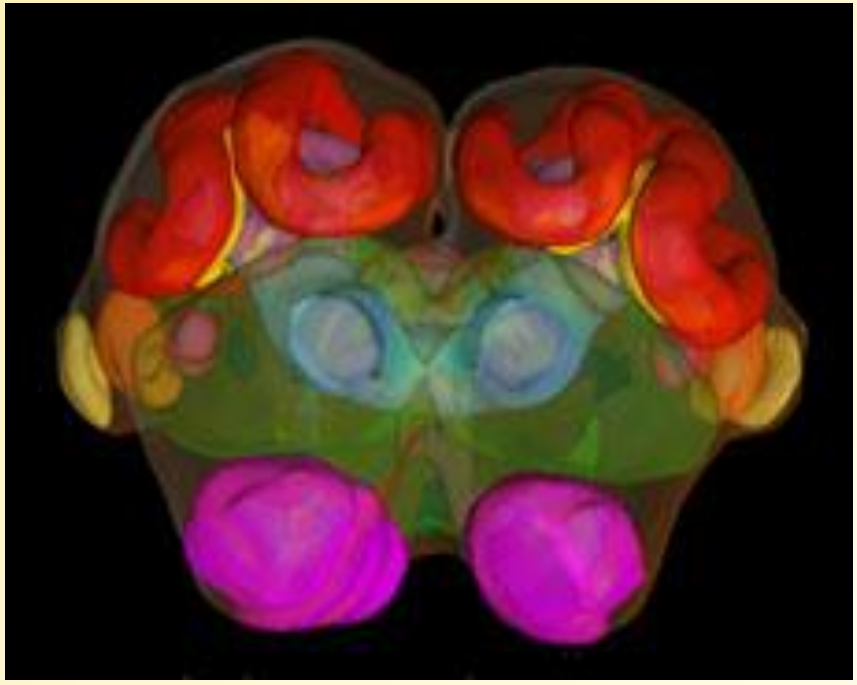
➢Tiny Brain (1mm^3)

Navigational mechanisms

- ✓ Effective, Robust
- ✓ Relatively simple

↓

Parsimonious, Efficient




Melophorus bagoti

Gigantiops destructor

The ants' navigational toolkit

Path Integration

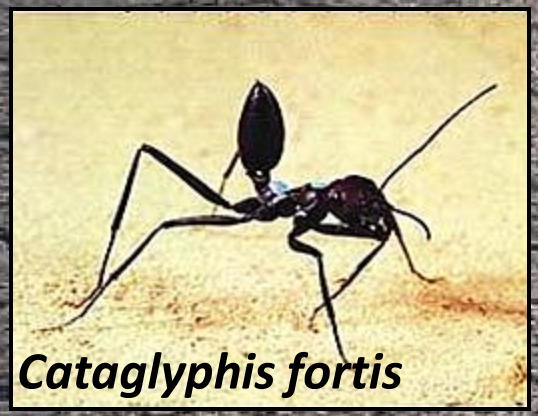
Landmark navigation

Systematic Search

Path Integration

Direction (celestial compass)

Distance (odometer)



Cataglyphis fortis

Food item

Nest

Wehner 1982…… 2012

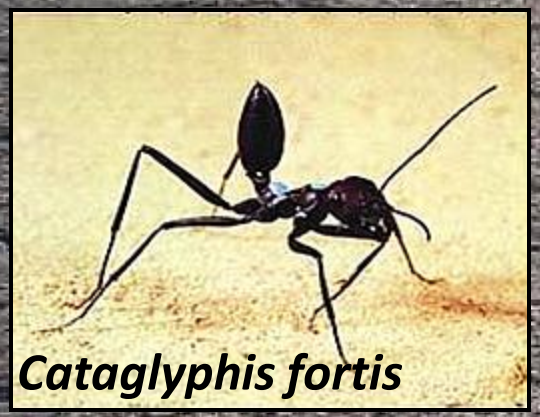
Problems of Path Integration

- Accumulate errors

Path Integration

Direction (celestial compass)

Distance (odometer)



Cataglyphis fortis

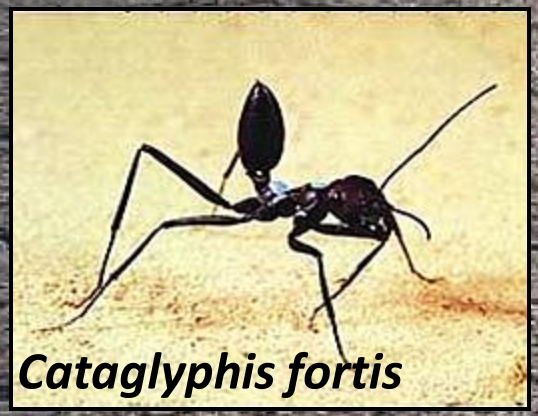
Problems of Path Integration

- Accumulate errors
- Passive displacement

Path Integration

Direction (celestial compass)

Distance (odometer)



Food item

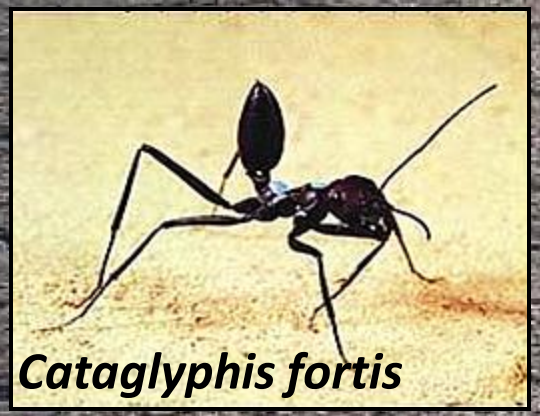
Nest

Wehner and Srinivasan 1981. J. comp. phys

Systematic Search

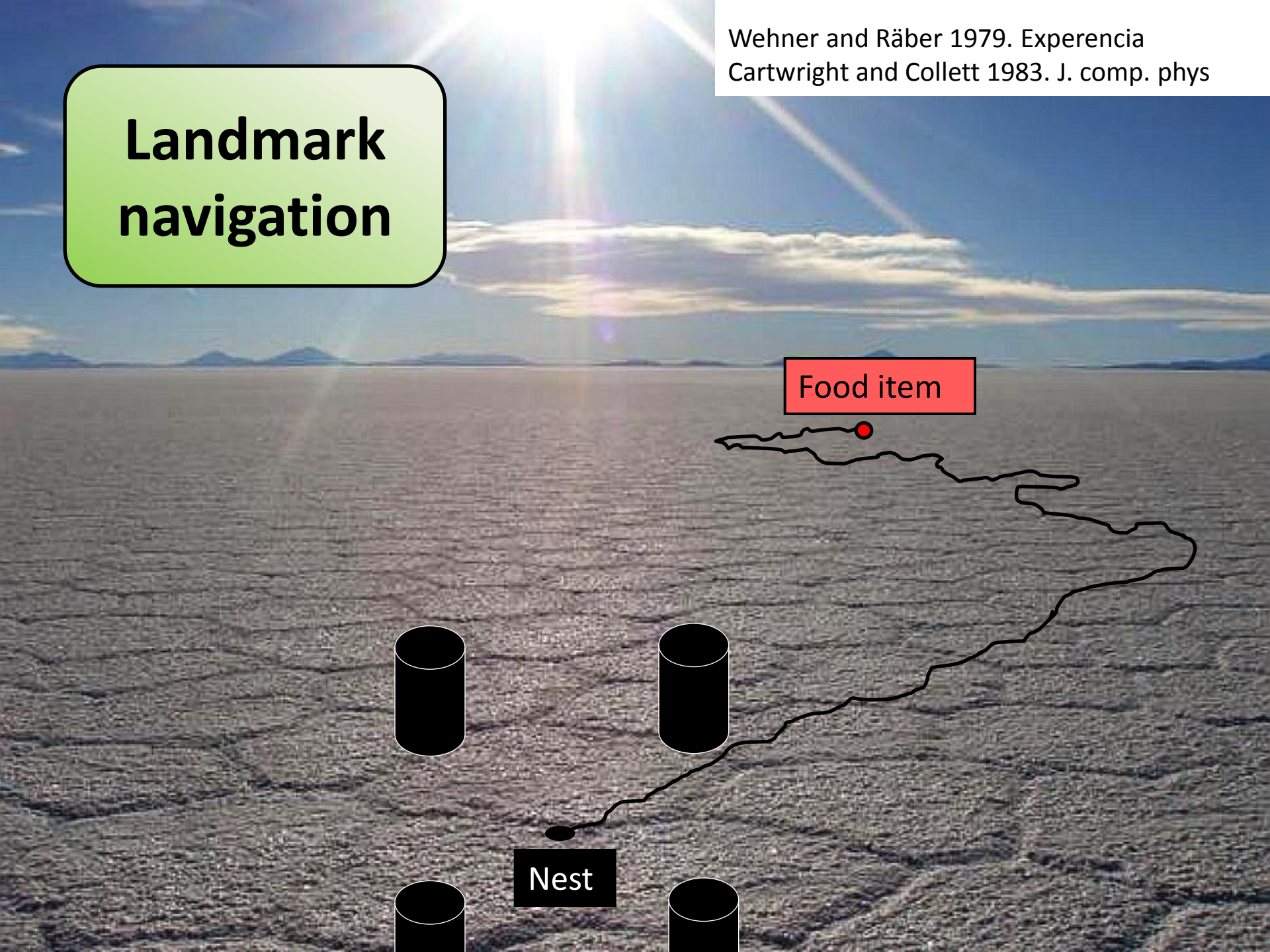
Problems of Path Integration

- Accumulate errors
- Passive displacement



Landmark navigation

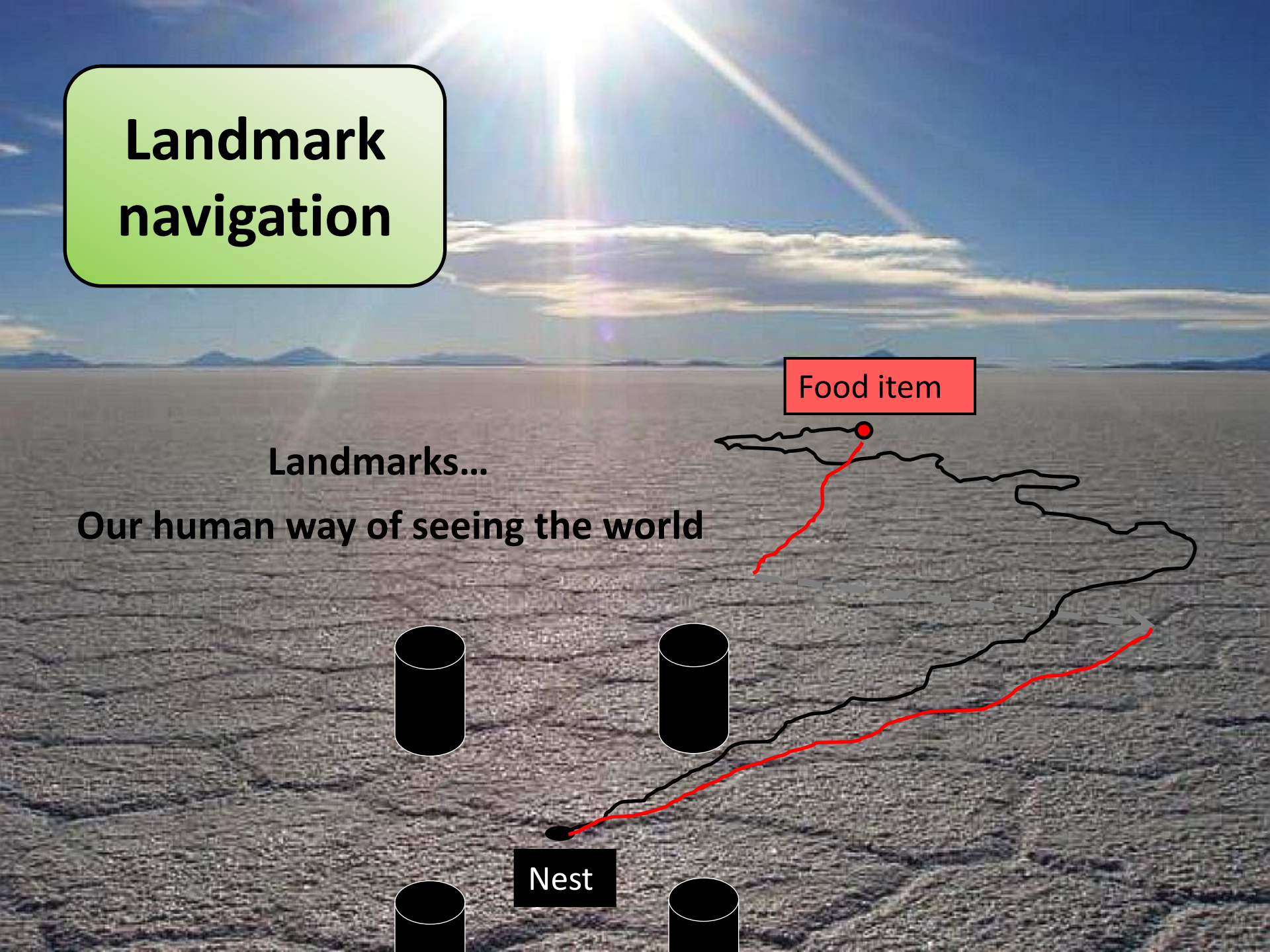
Wehner and Räber 1979. Experencia
Cartwright and Collett 1983. J. comp. phys



Landmark navigation

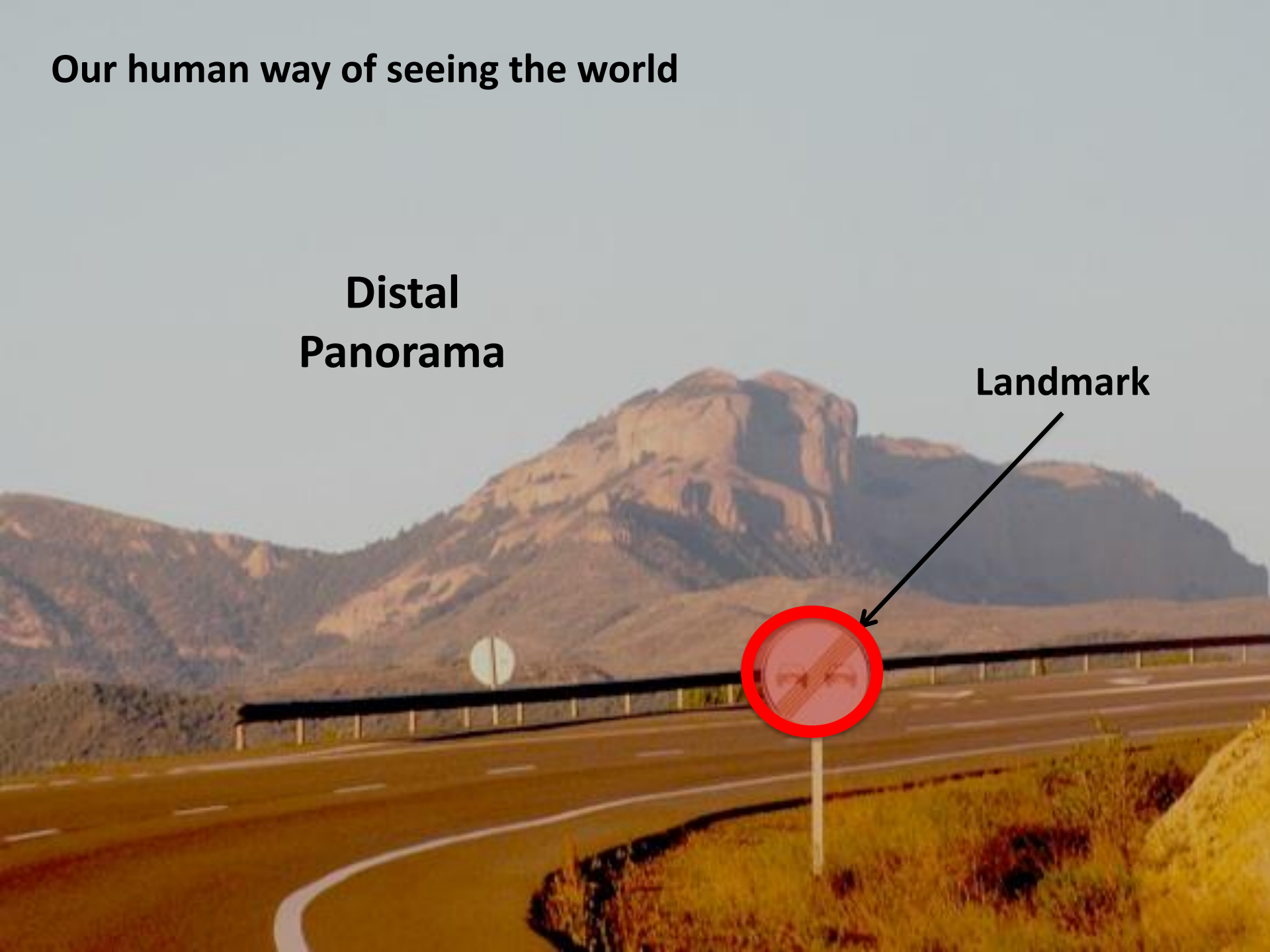
Landmarks…

Our human way of seeing the world



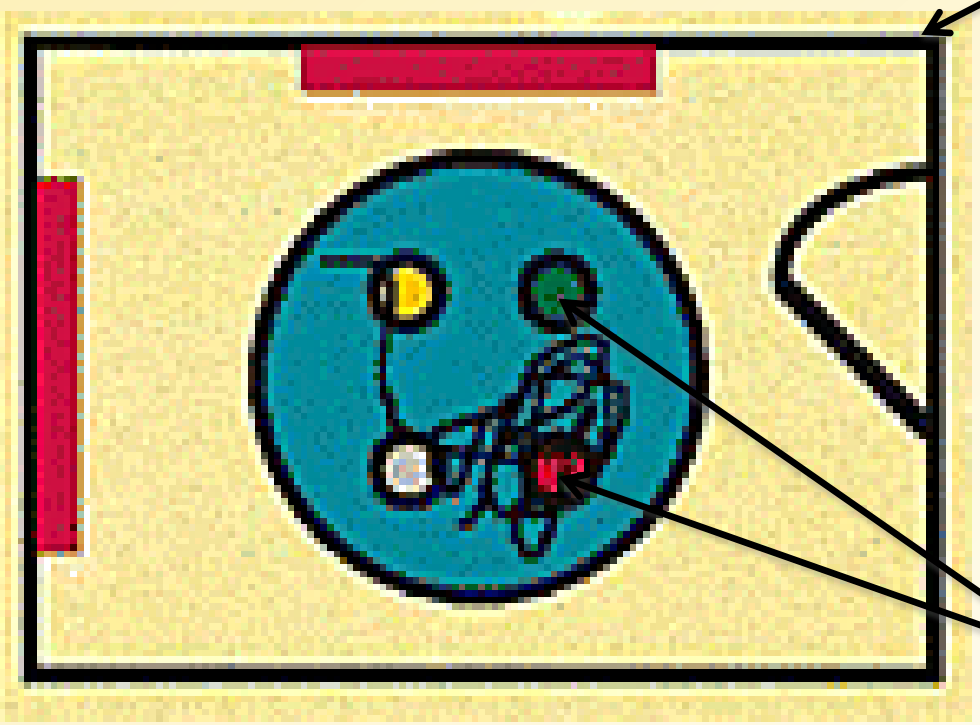
Our human way of seeing the world

Our human way of seeing the world



Our human way of seeing the world

…..and designing experiments



Our human way of seeing the world

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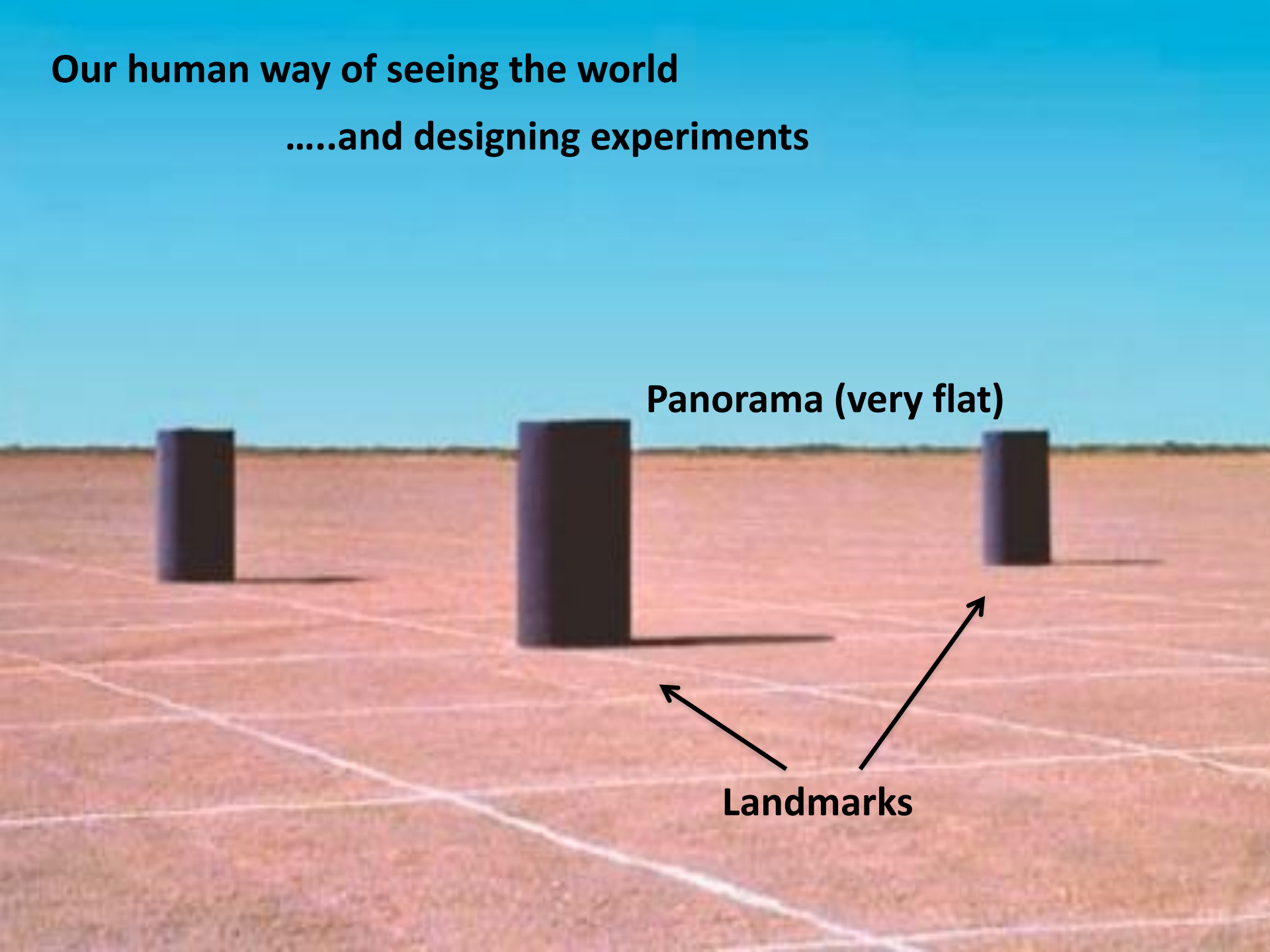
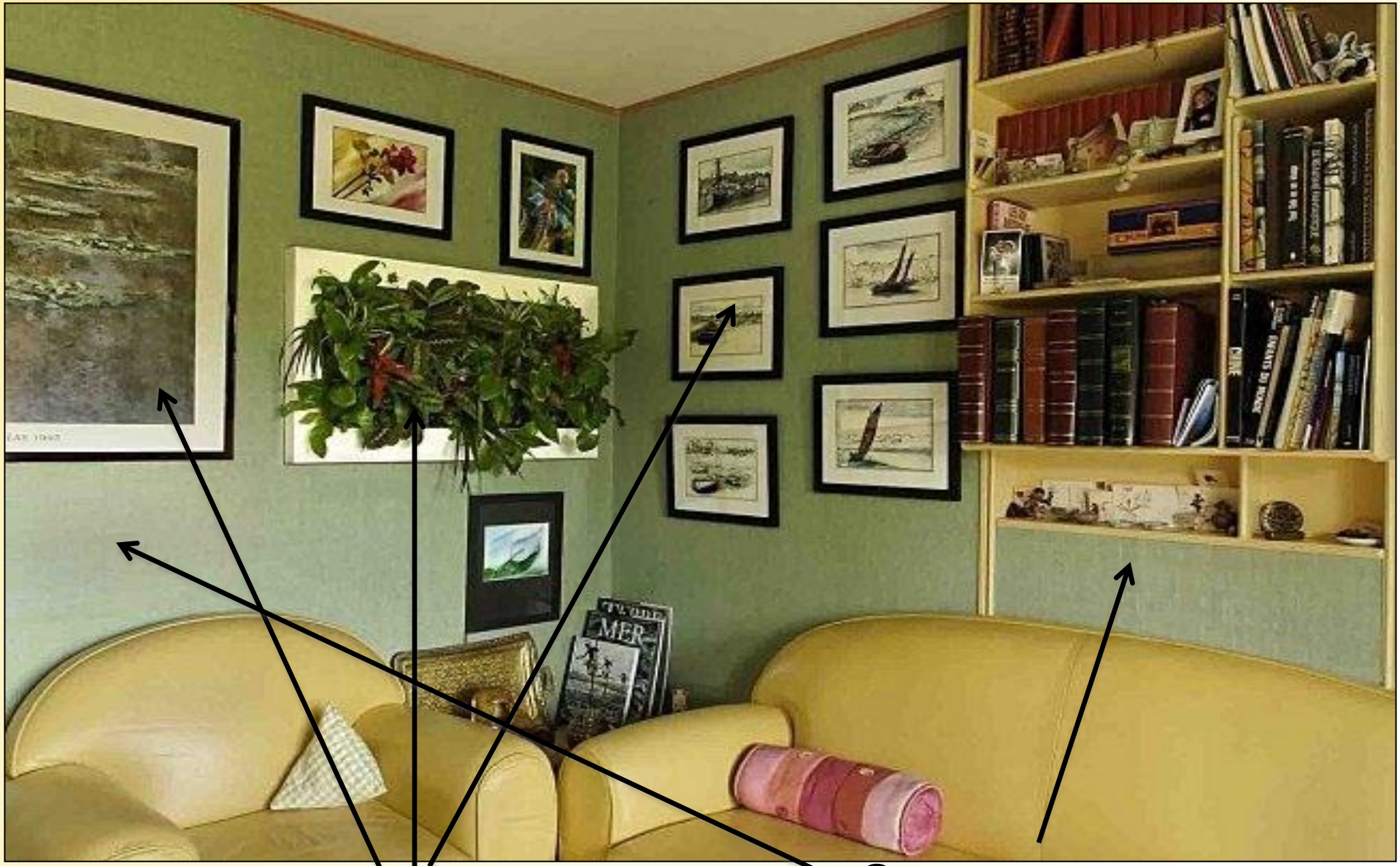


Our human way of seeing the w orld



Our human way of seeing the w orld

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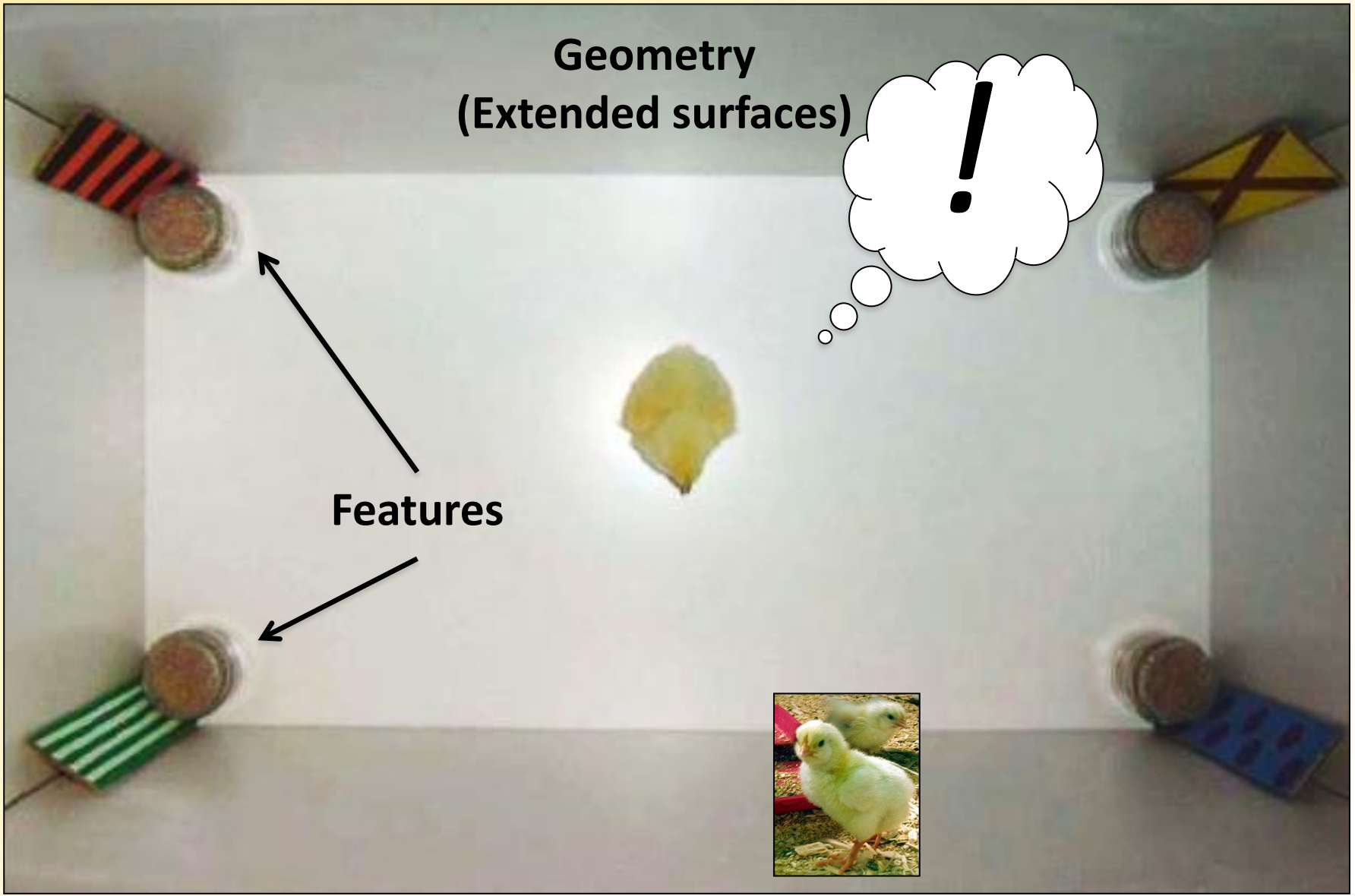
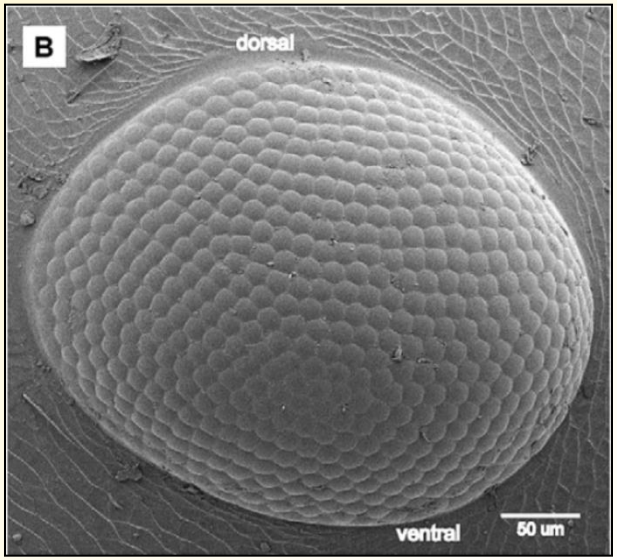


A little bit more objective…

A little bit more objective…

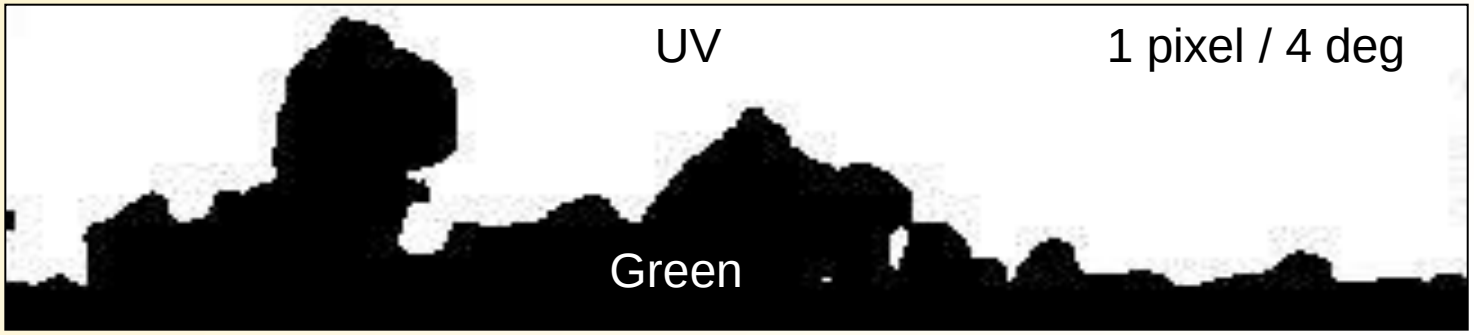
Melophorus bagoti compound eye:
Acuity = 4 deg



(Schwarz et al., 2003. Arthr. Struct & Devlop.)


1 pixel / 4 deg


1 pixel / 4 deg


UV
1 pixel / 4 deg
Green

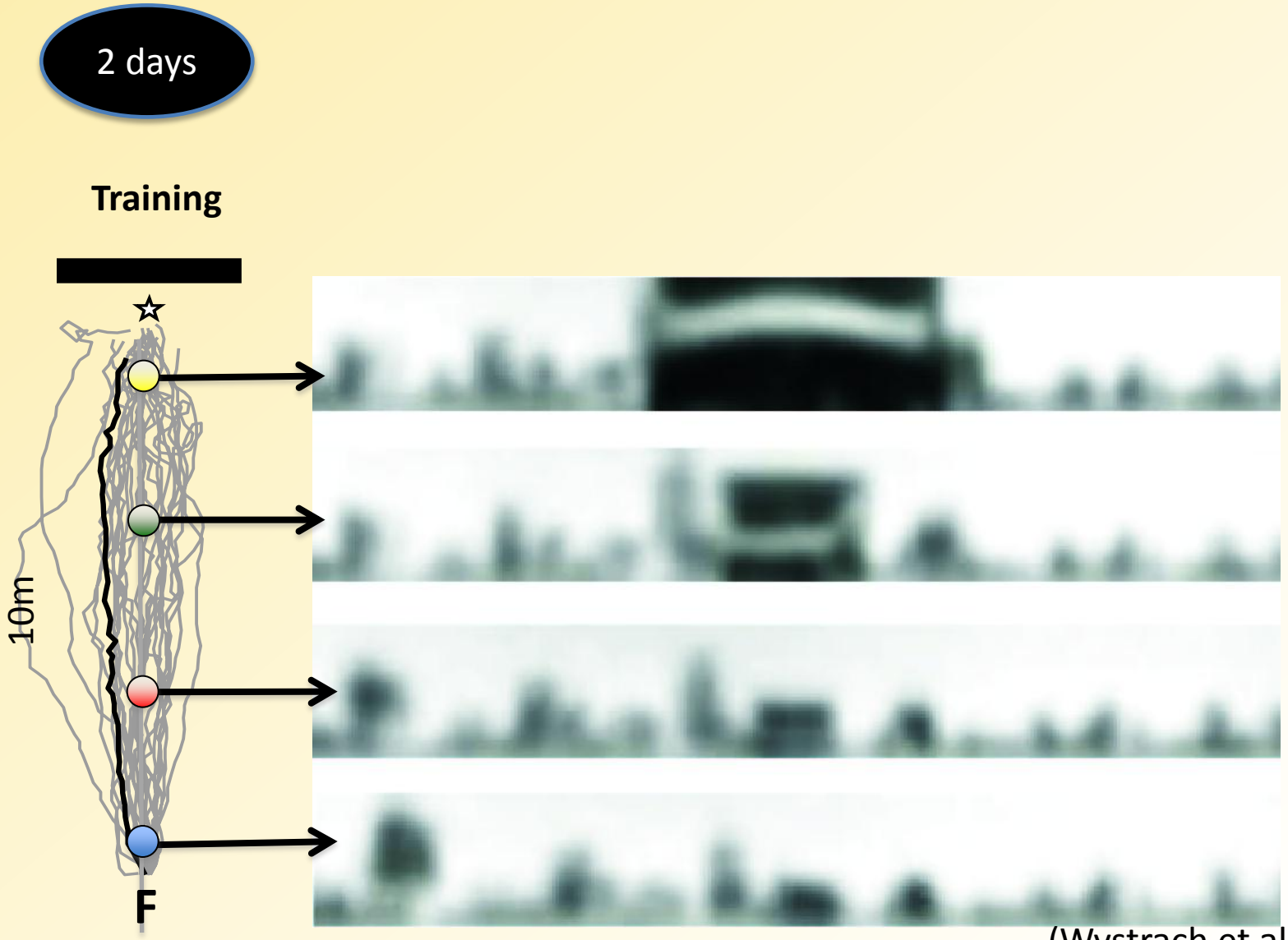
A little bit more objective…

A little bit more objective…

Do insect segregate landmarks and panorama?

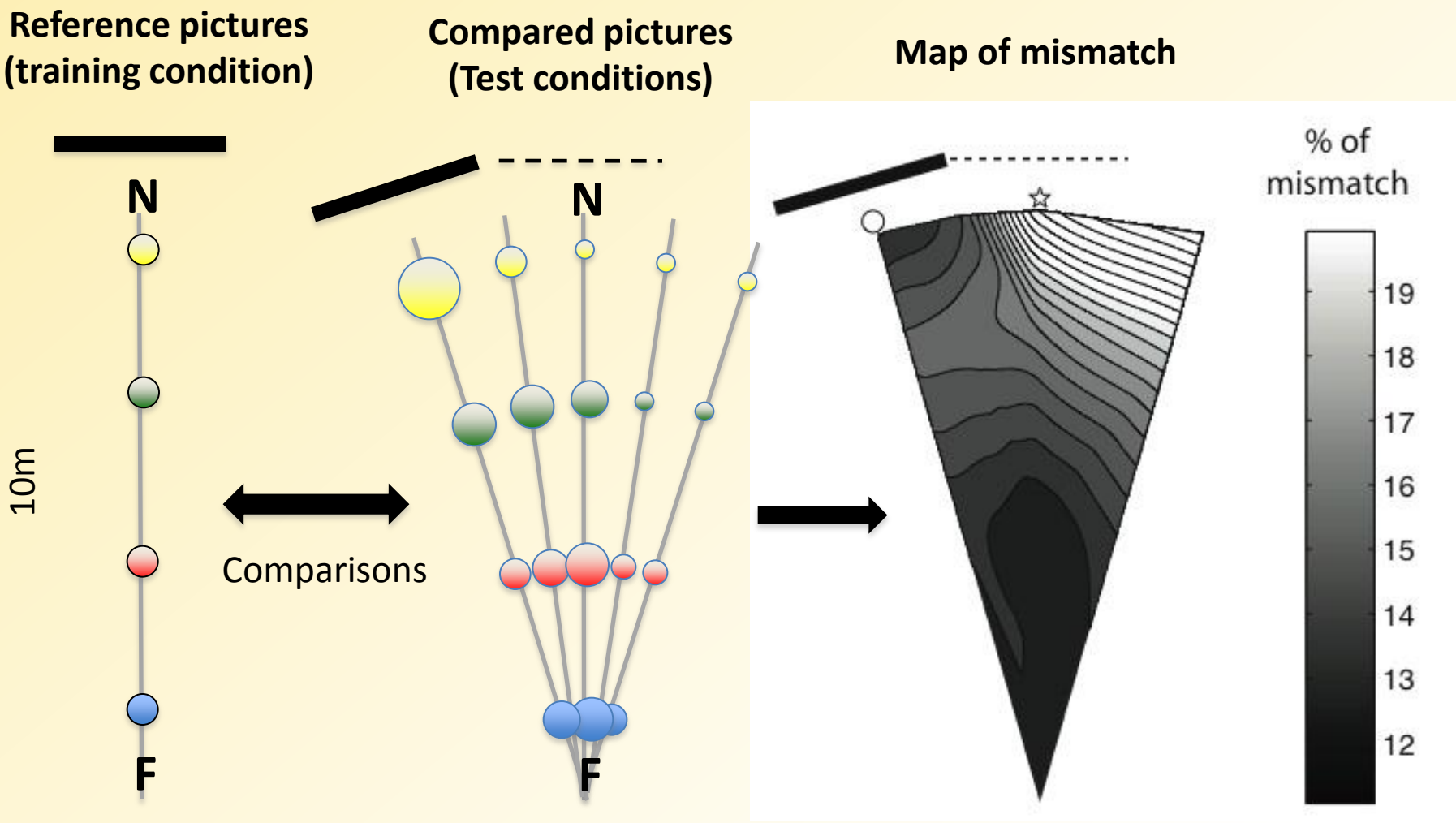
(Wystrach and Graham 2012)

Quantify the modification of the scenery…

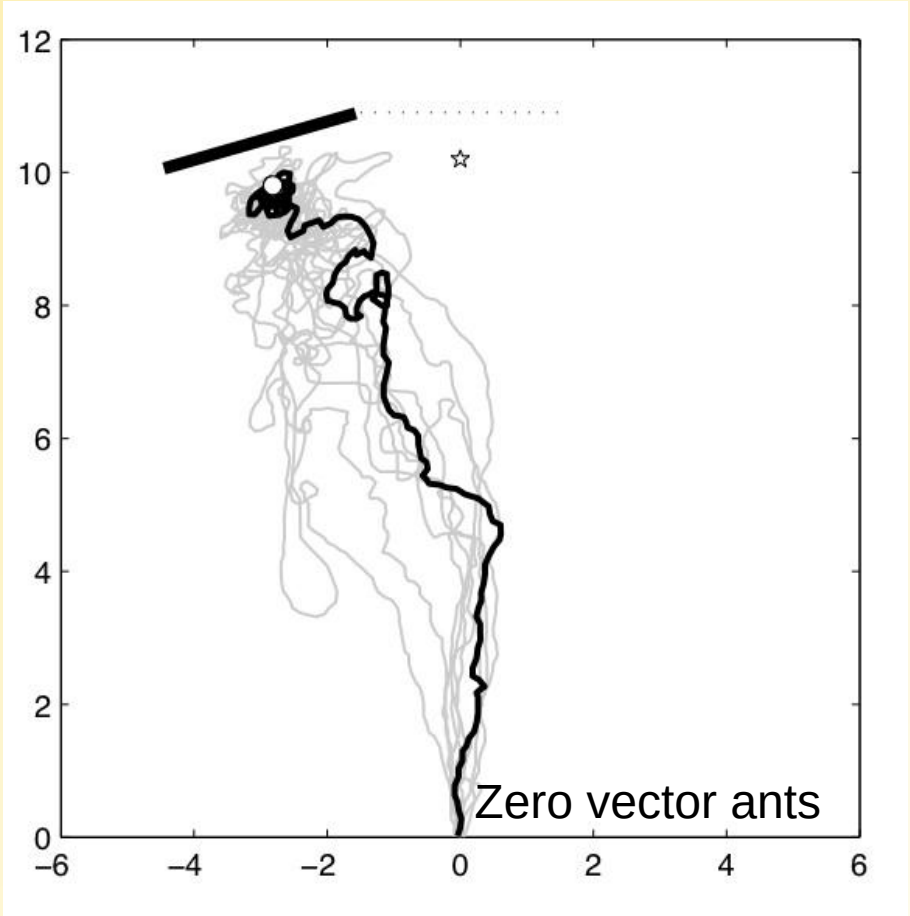


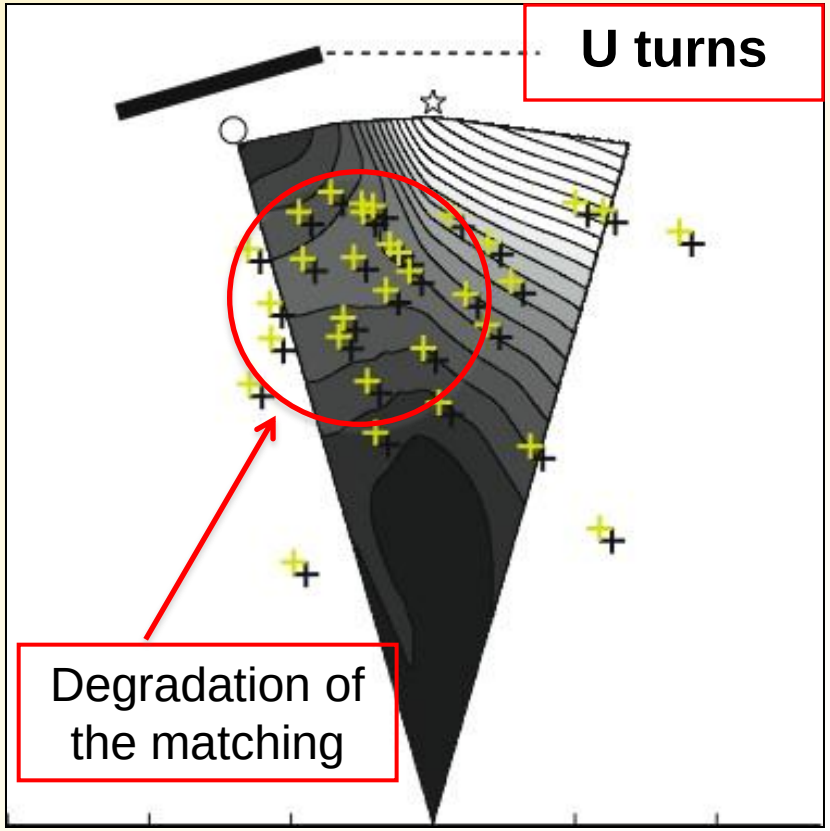
(Wystrach et al., 2011)

Quantify the modification of the scenery…



Relate image difference / ant behaviour…





(Wystrach et al., 2011)

Information available to the animal

Cues widespread on their panoramic view

Landmark navigation

Information available to the animal

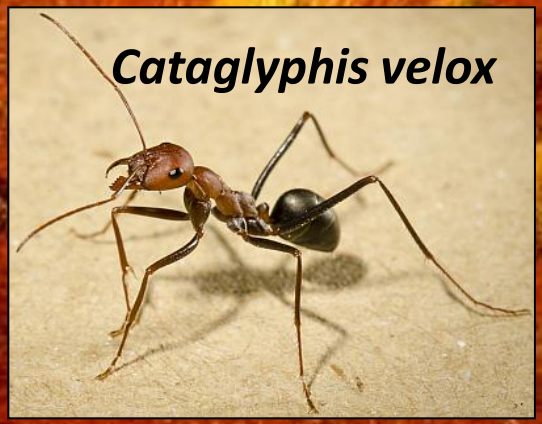
Cues widespread on their panoramic view

Visual scene navigation

Identify the problem in natural environment

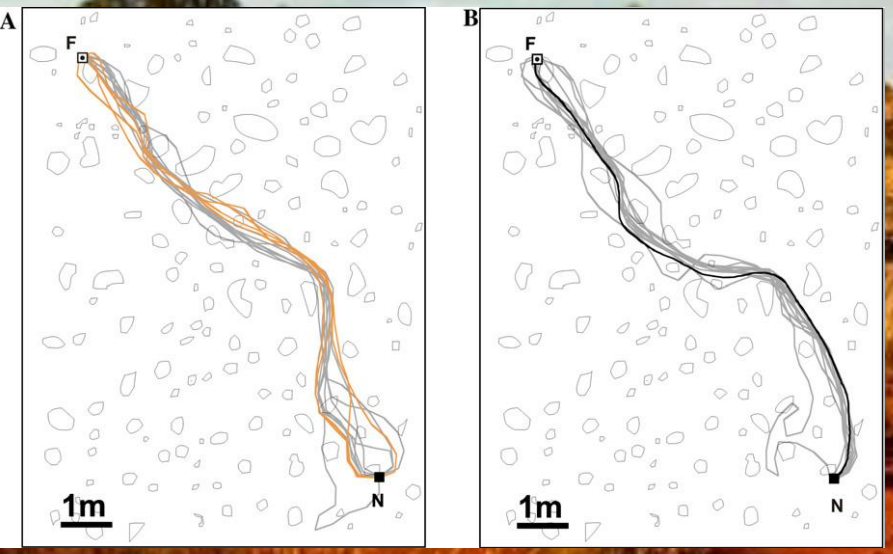
Visual scene navigation

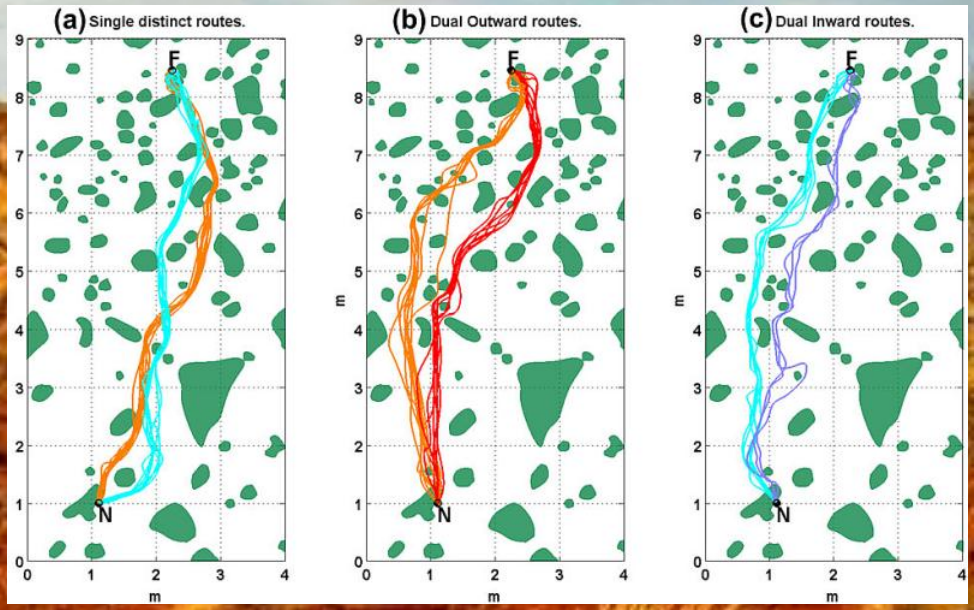
Melophorus bagoti

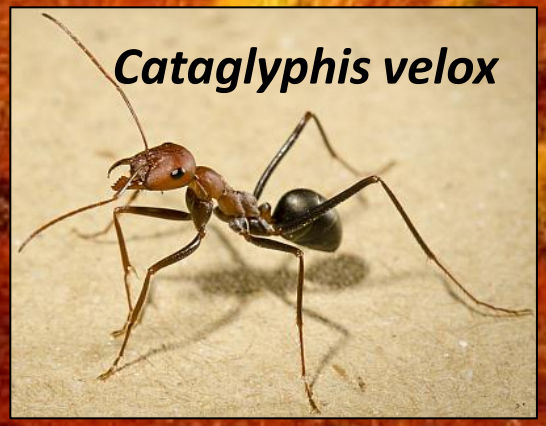


Cataglyphis velox

Route following

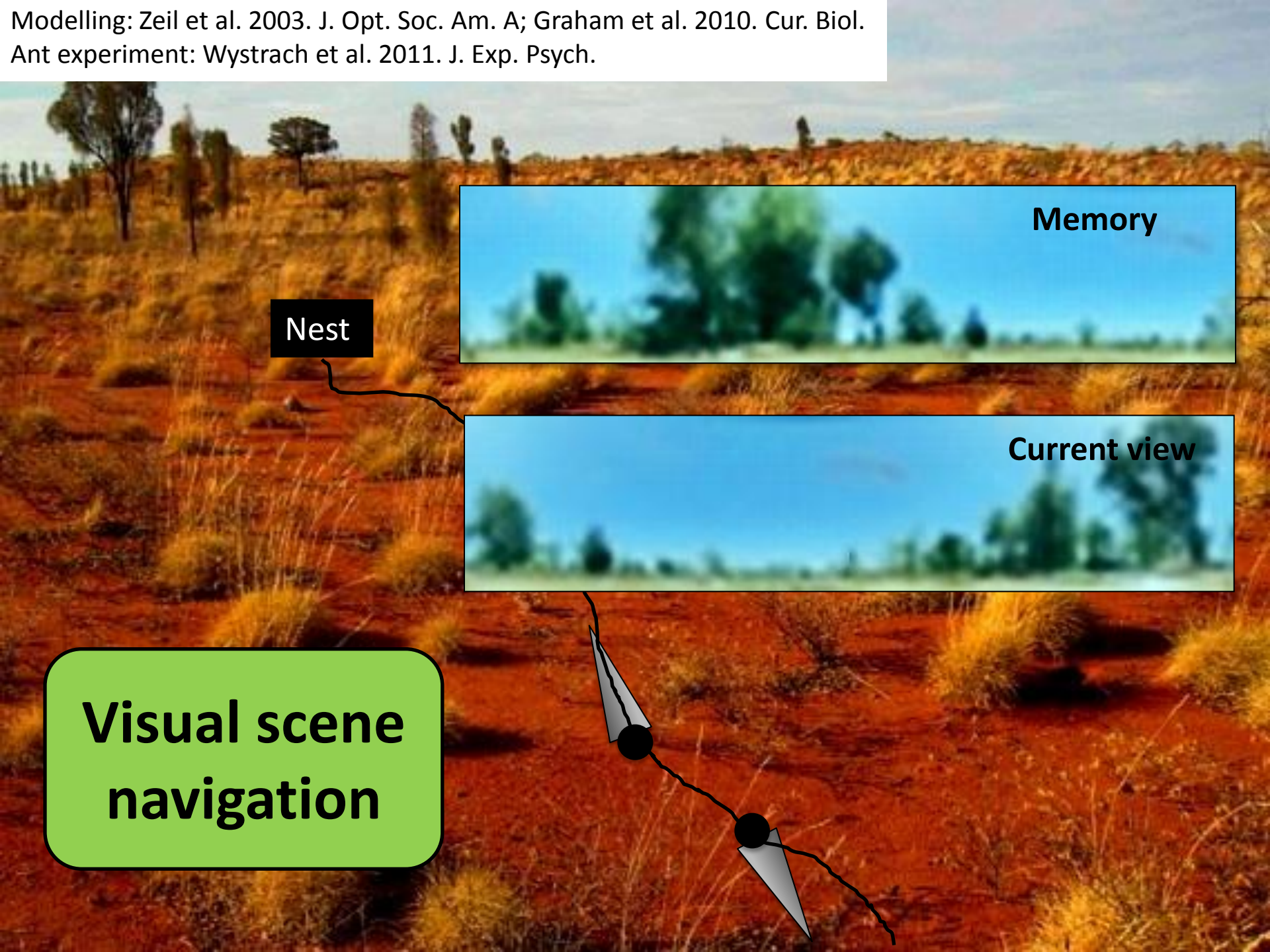






Mangan and Webb 2012. Behav. Ecol.
Kohler and Wehner 2005, Neurobiol. of Learn. and Mem.

Modelling: Zeil et al. 2003. J. Opt. Soc. Am. A; Graham et al. 2010. Cur. Biol.
Ant experiment: Wystrach et al. 2011. J. Exp. Psych.



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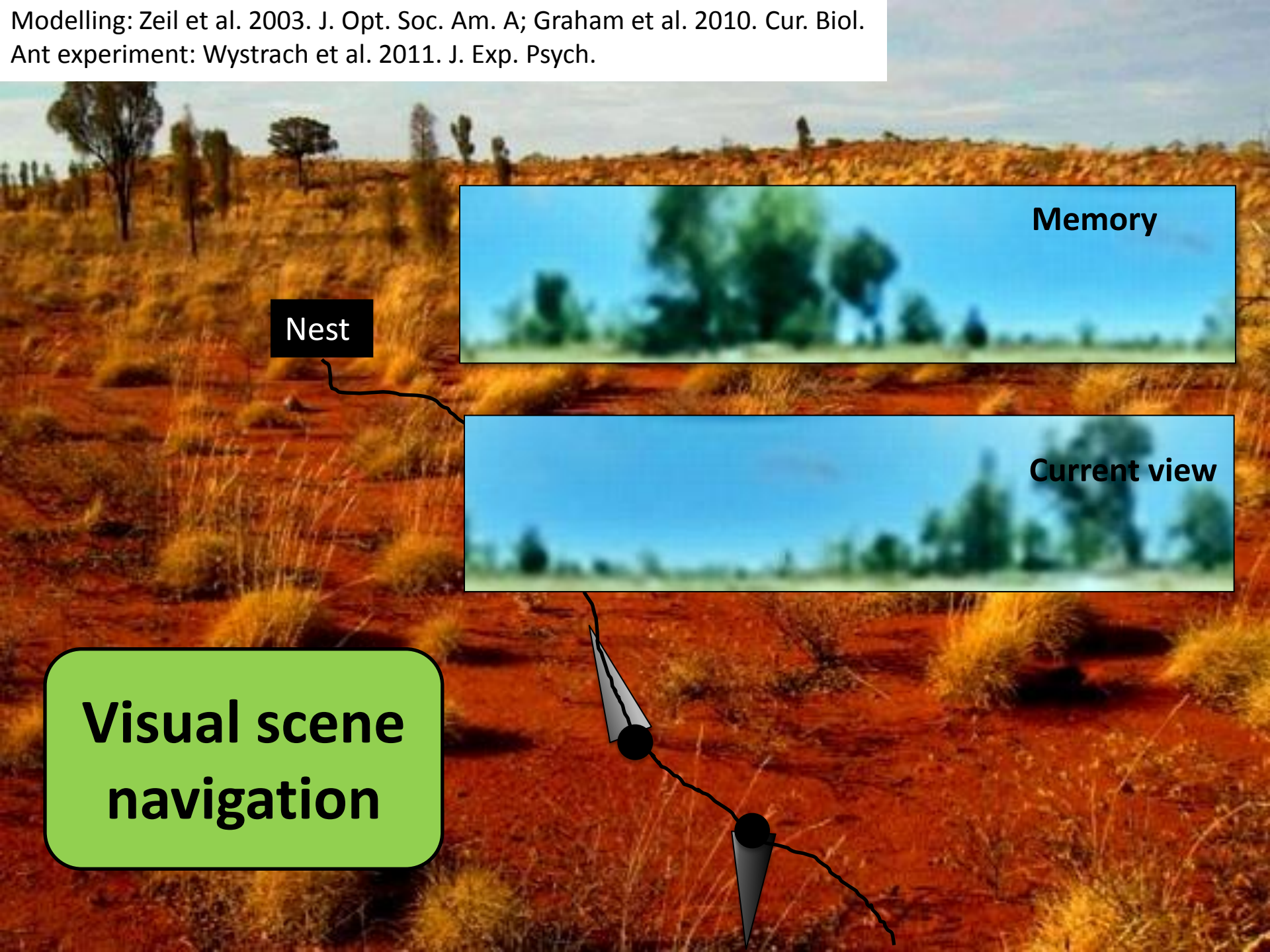

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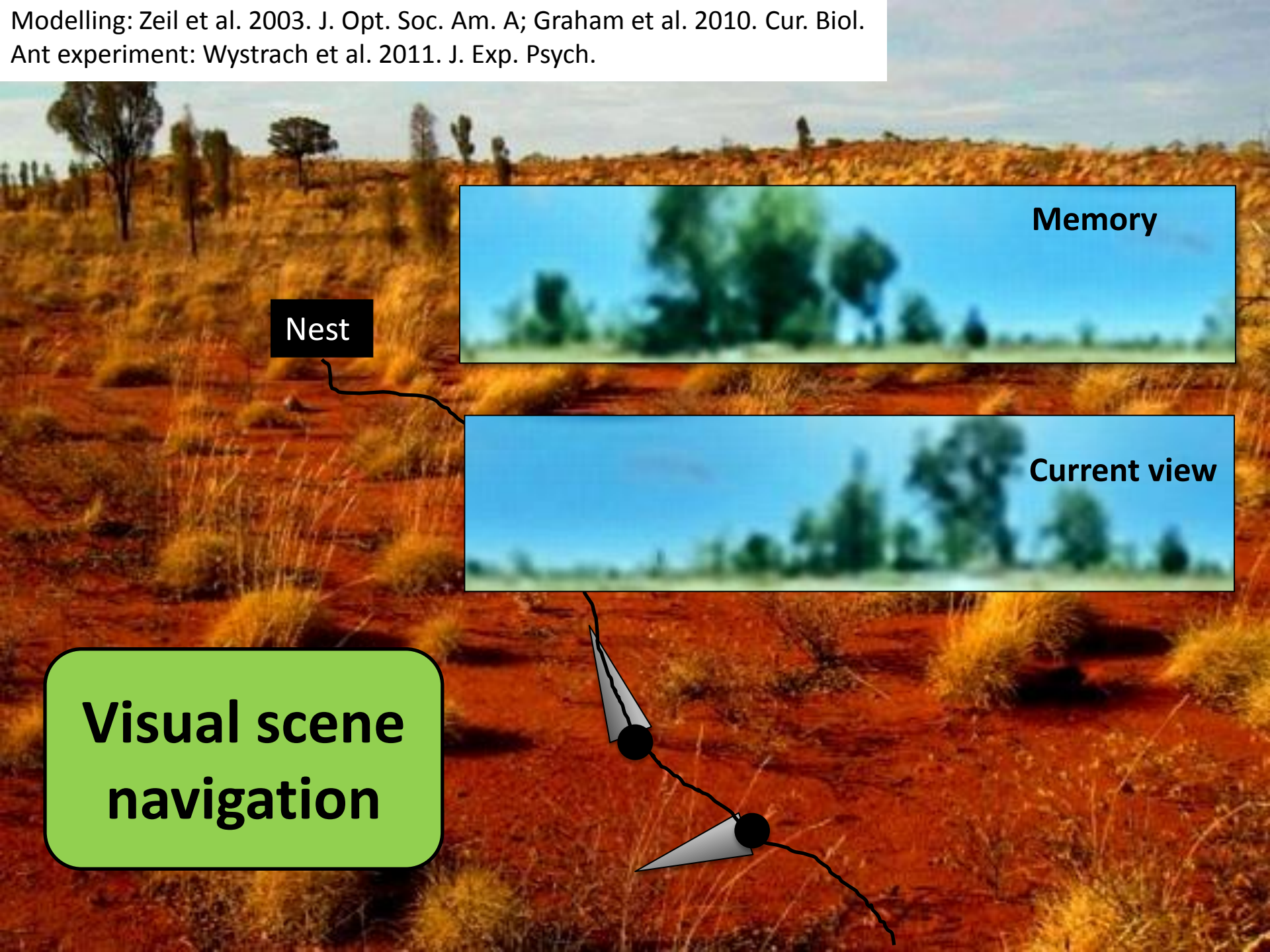

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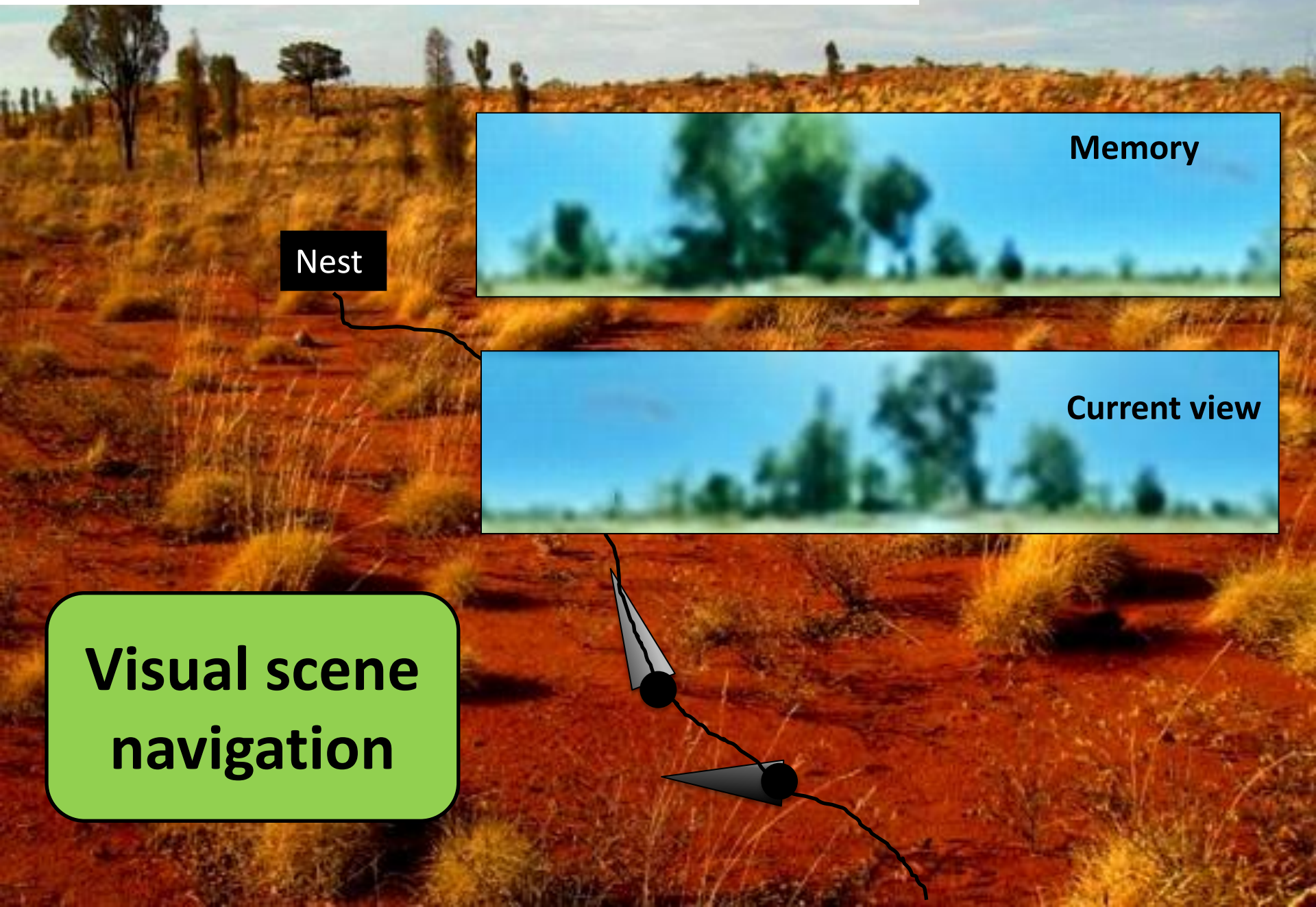

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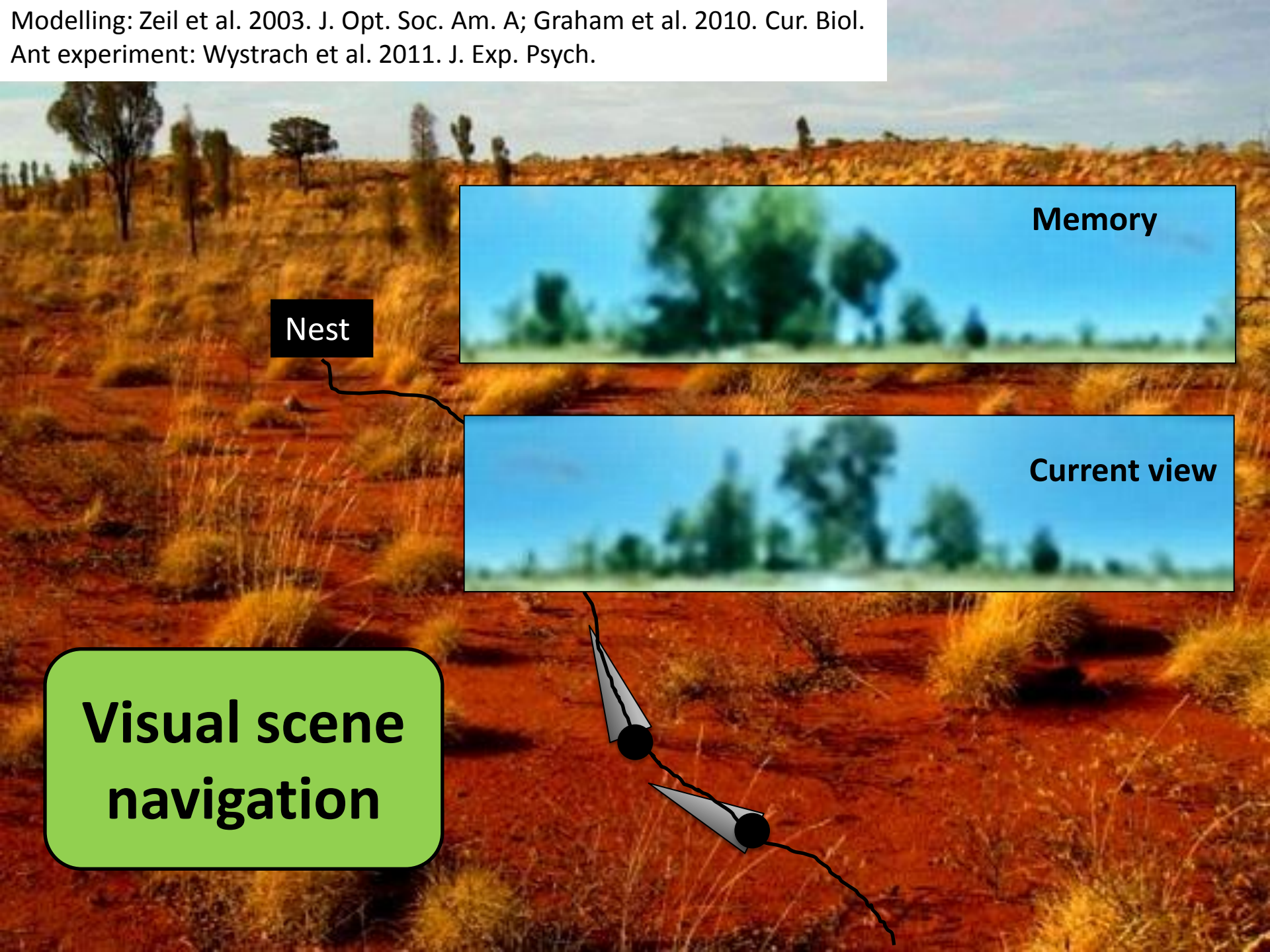

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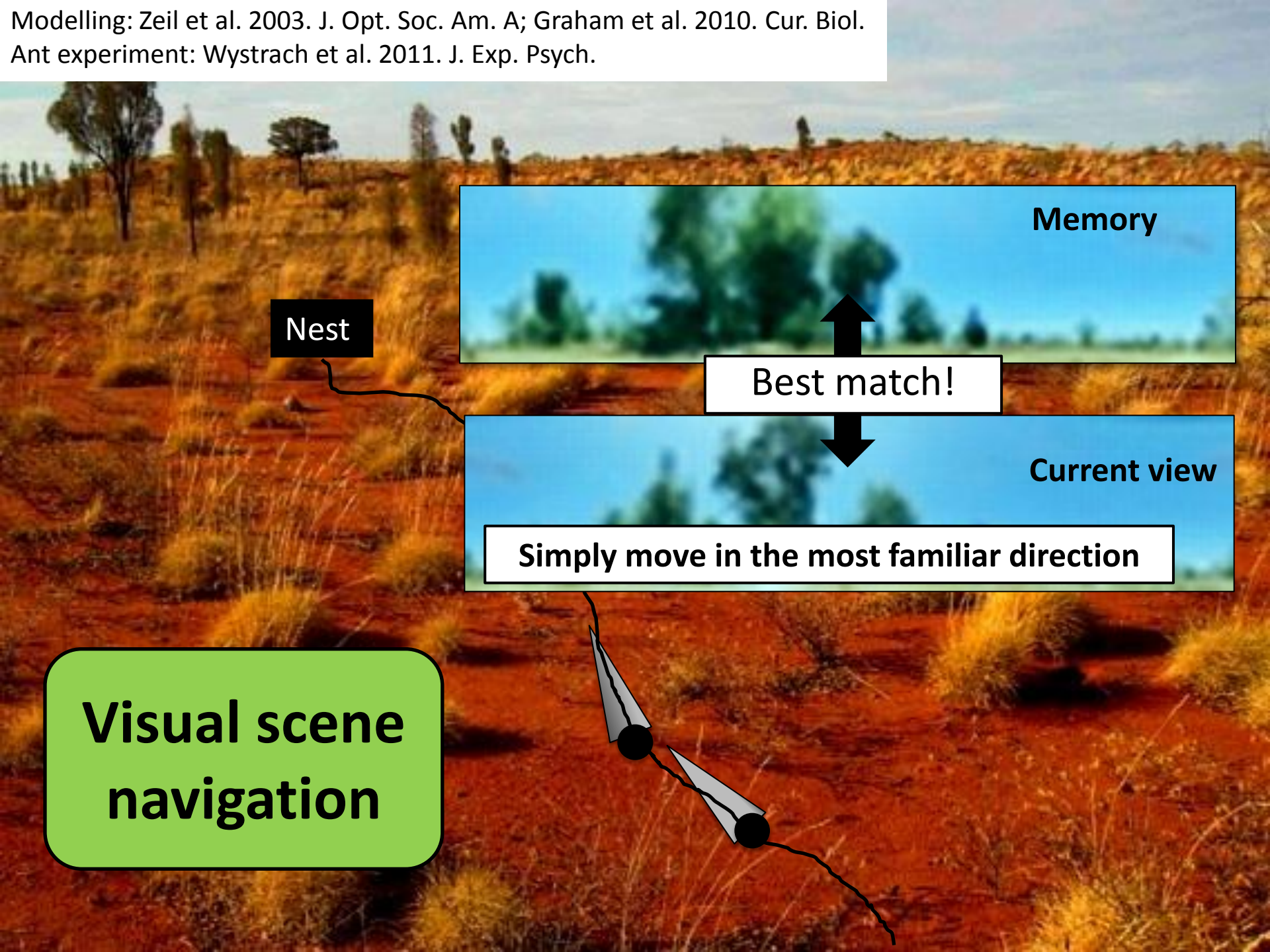
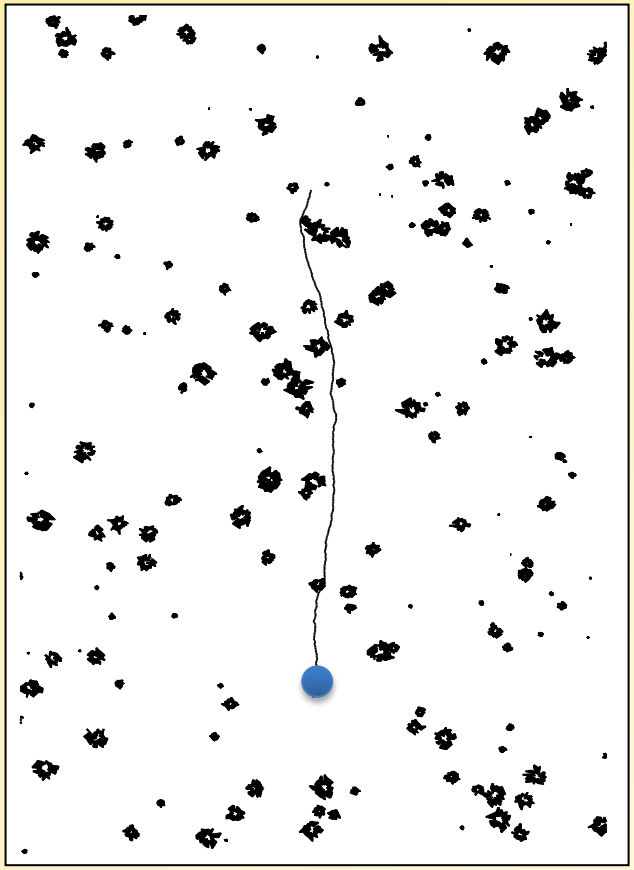


Route following model
(Baddeley et al., 2012)

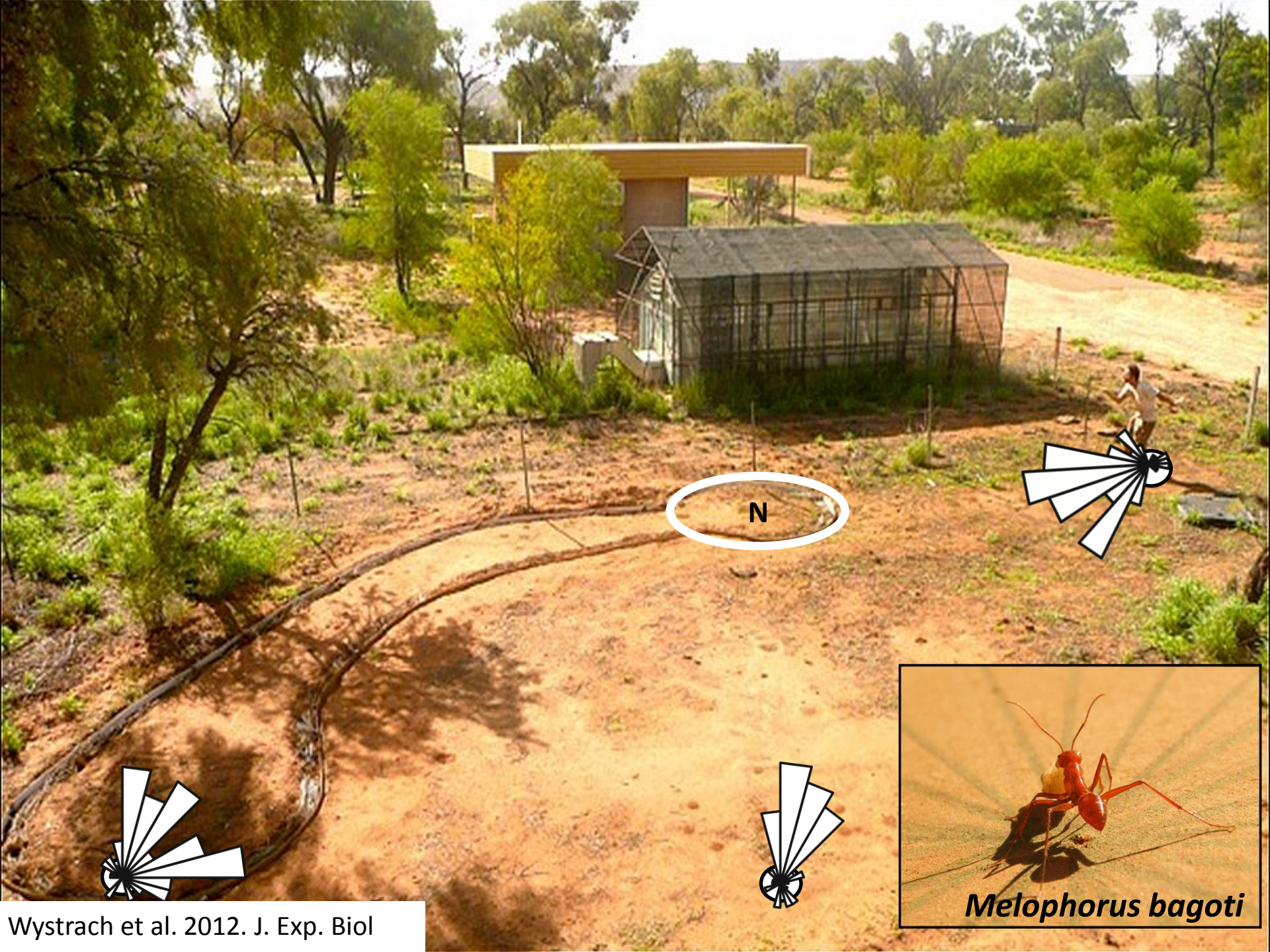


Route following

No positional knowledge

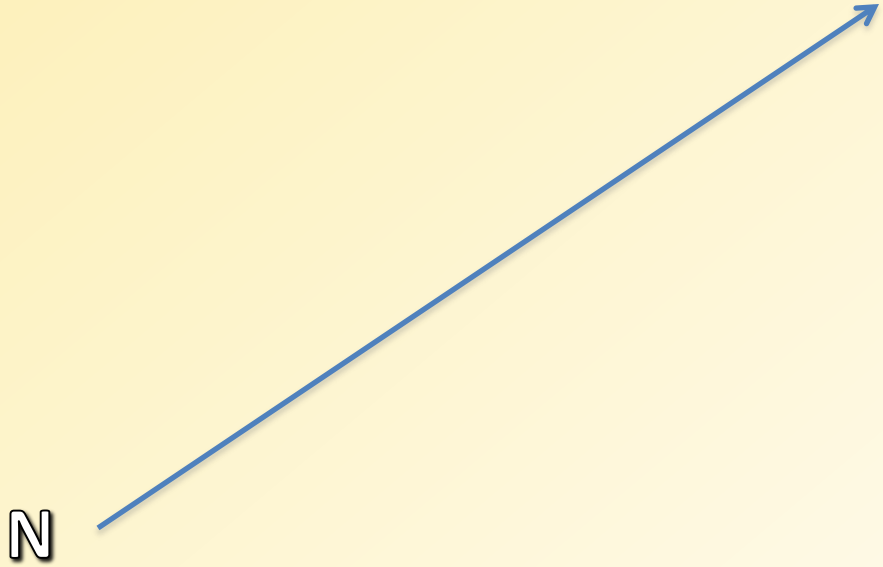
Simply move in the most familiar direction

Homing from novel locations



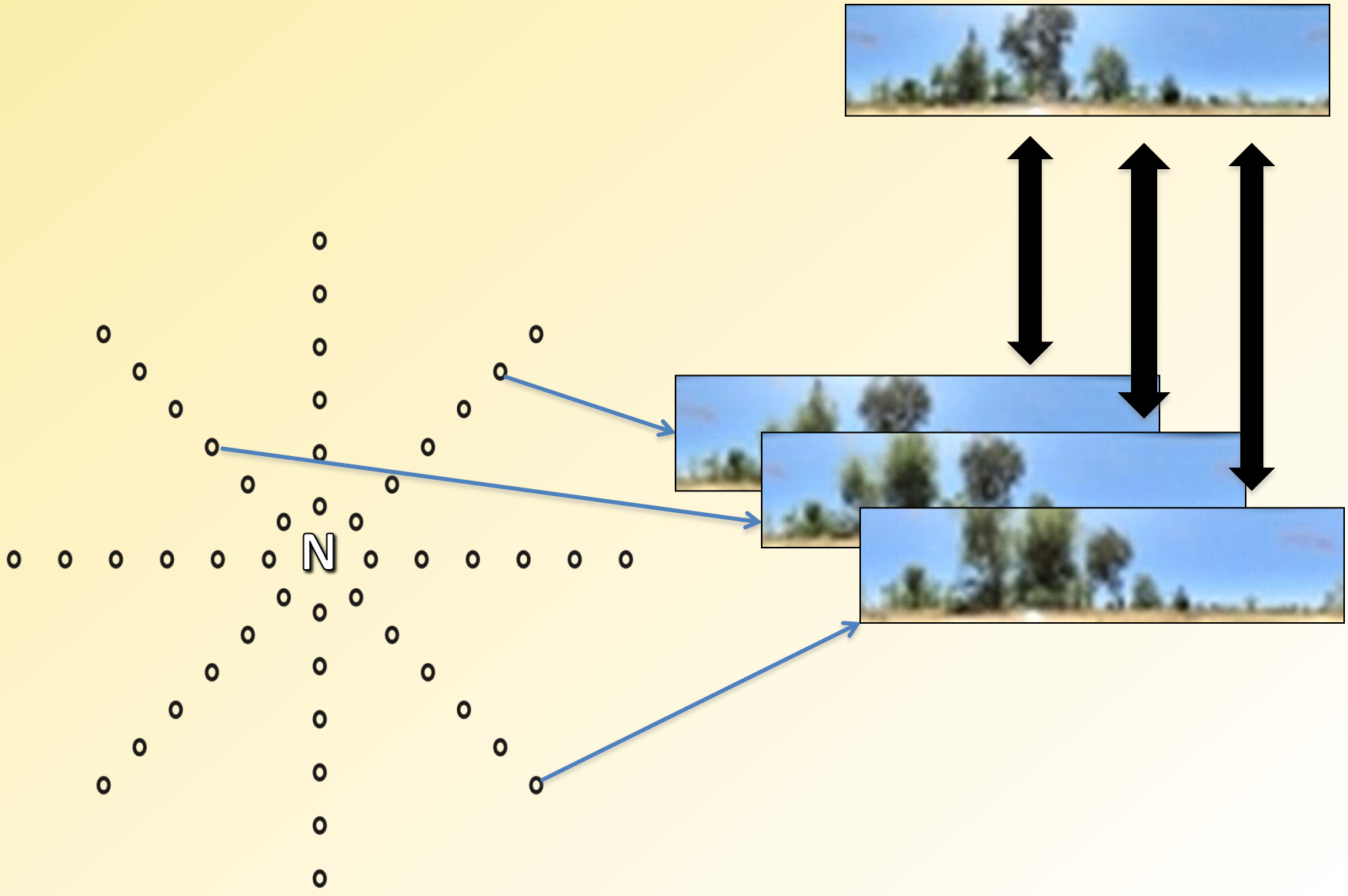
Wystrach et al. 2012. J. Exp. Biol

Homing from novel locations



(Cartwright and Collett, 1983; Zeil et al., 2003)

Homing from novel locations



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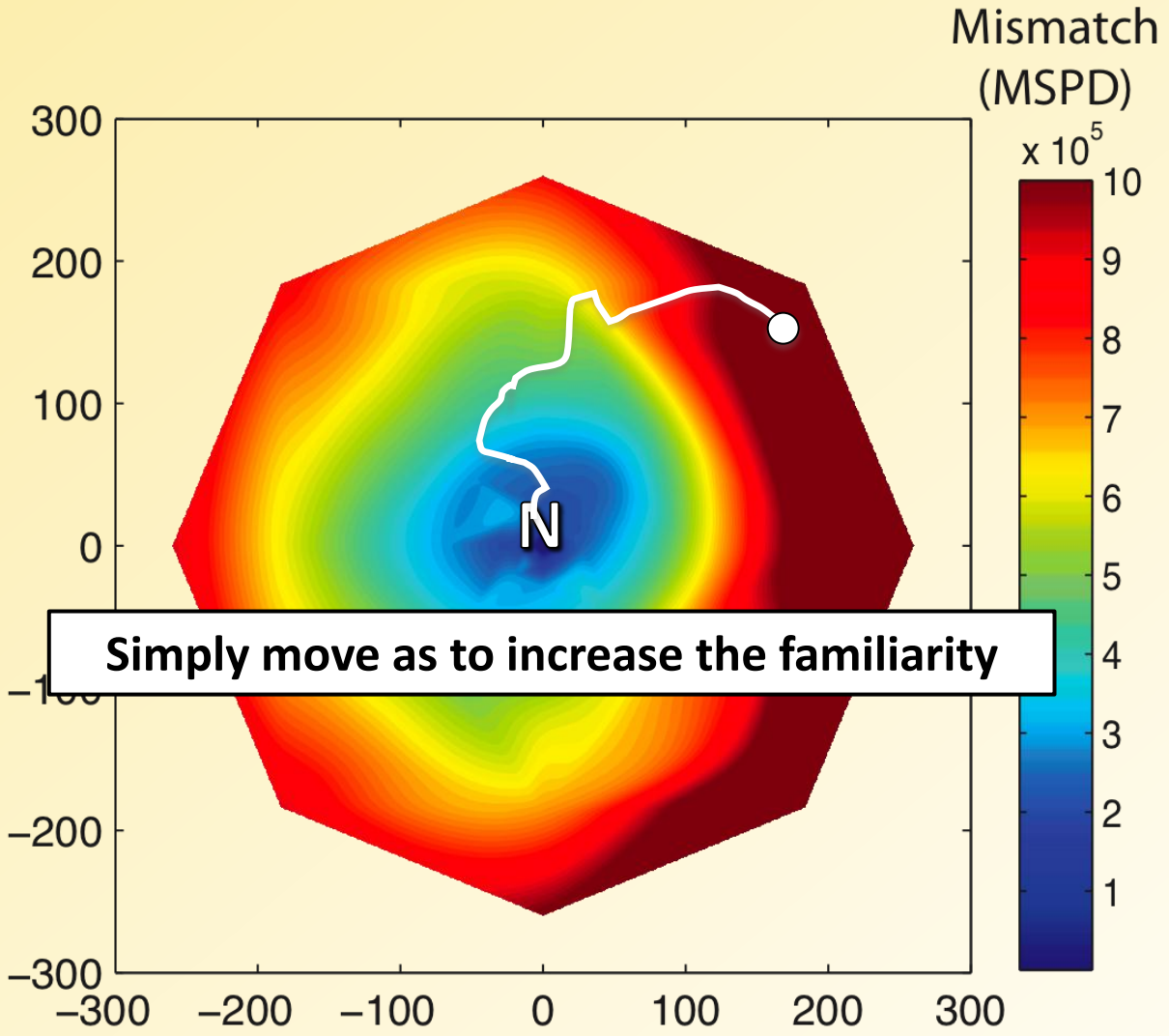
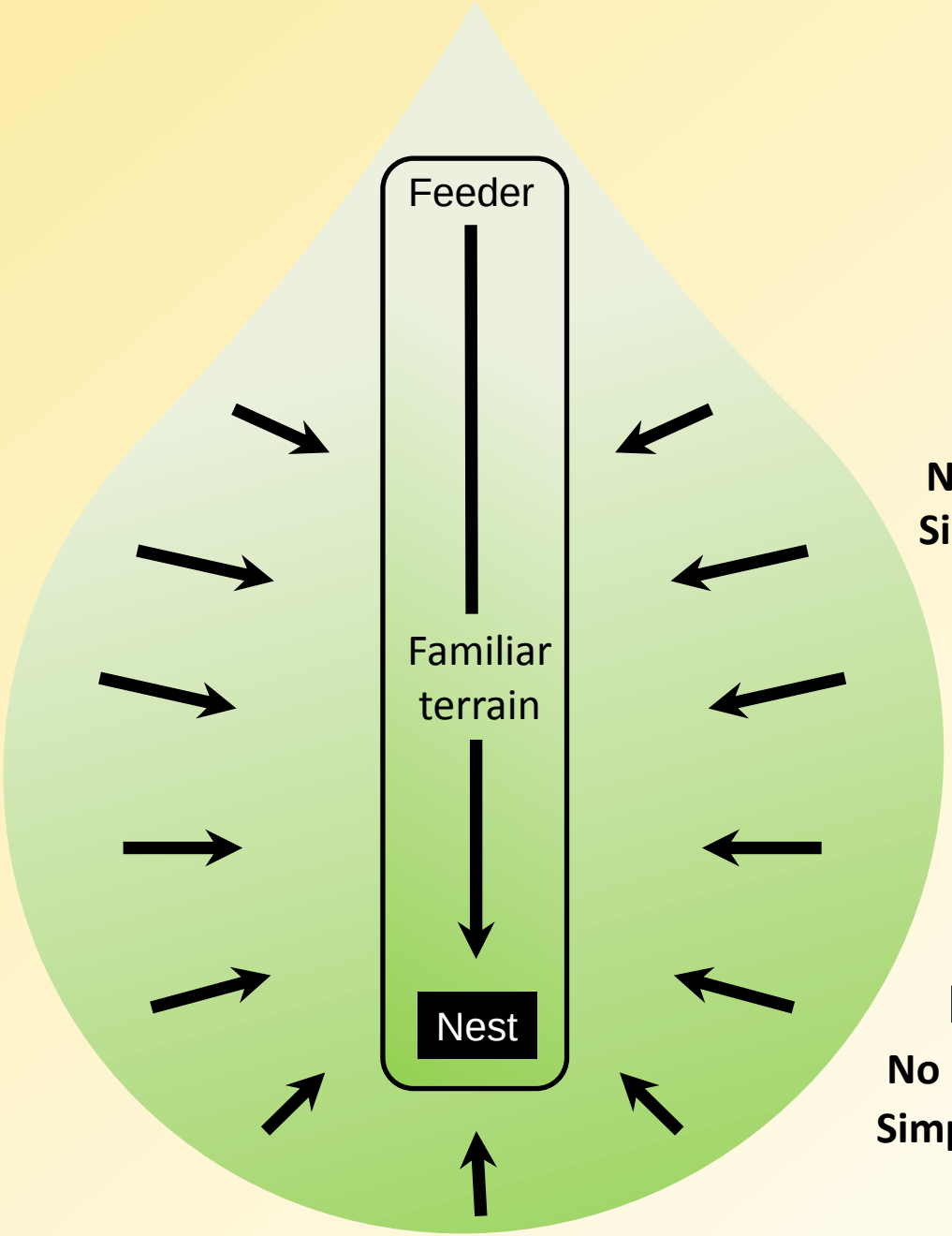
Homing from novel locations



Simply move as to increase the familiarity

(Cartwright and Collett, 1983; Zeil et al., 2003)

Visual scene navigation



Route following

No positional knowledge

Simply going in the most familiar direction

Homing from novel locations

No positional knowledge

Simply moving so as the familiarity increase

The ants' navigational toolkit

Path Integration

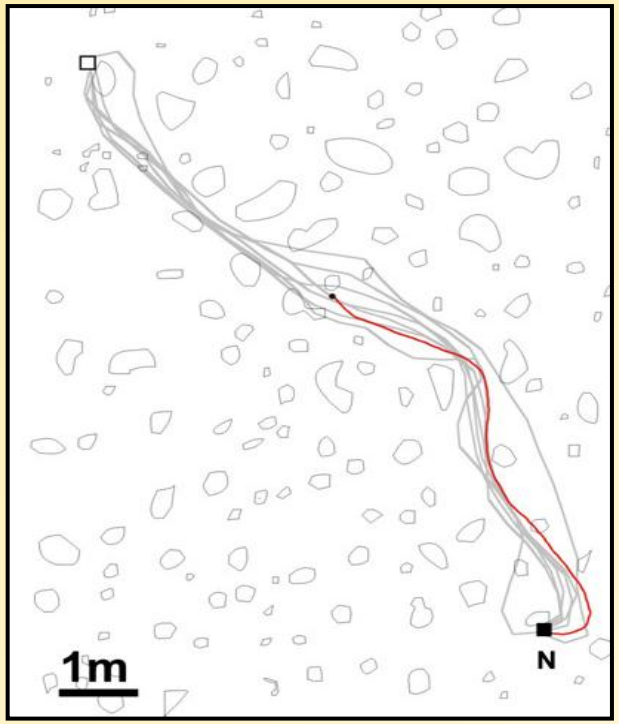
Visual scene navigation

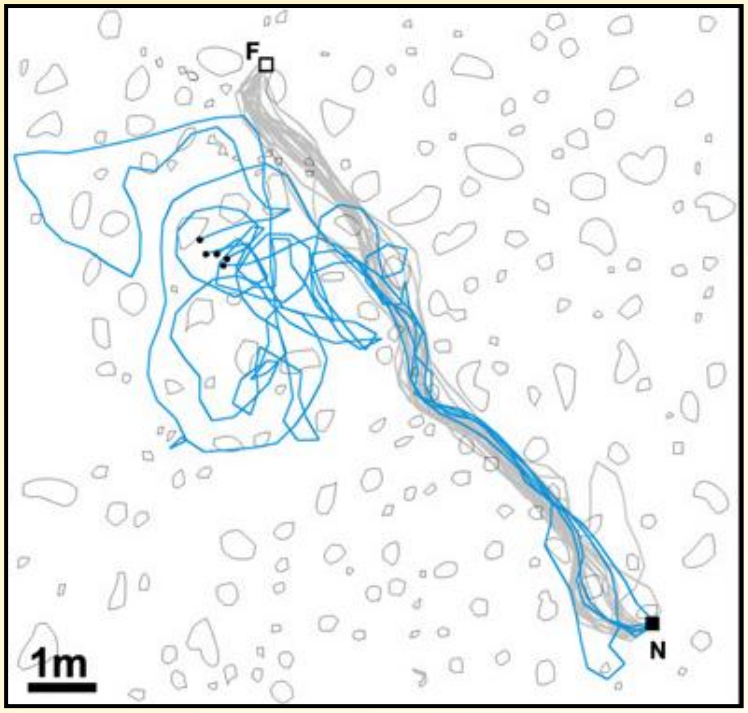
Systematic Search

Quite simple …

How can it be so robust ?

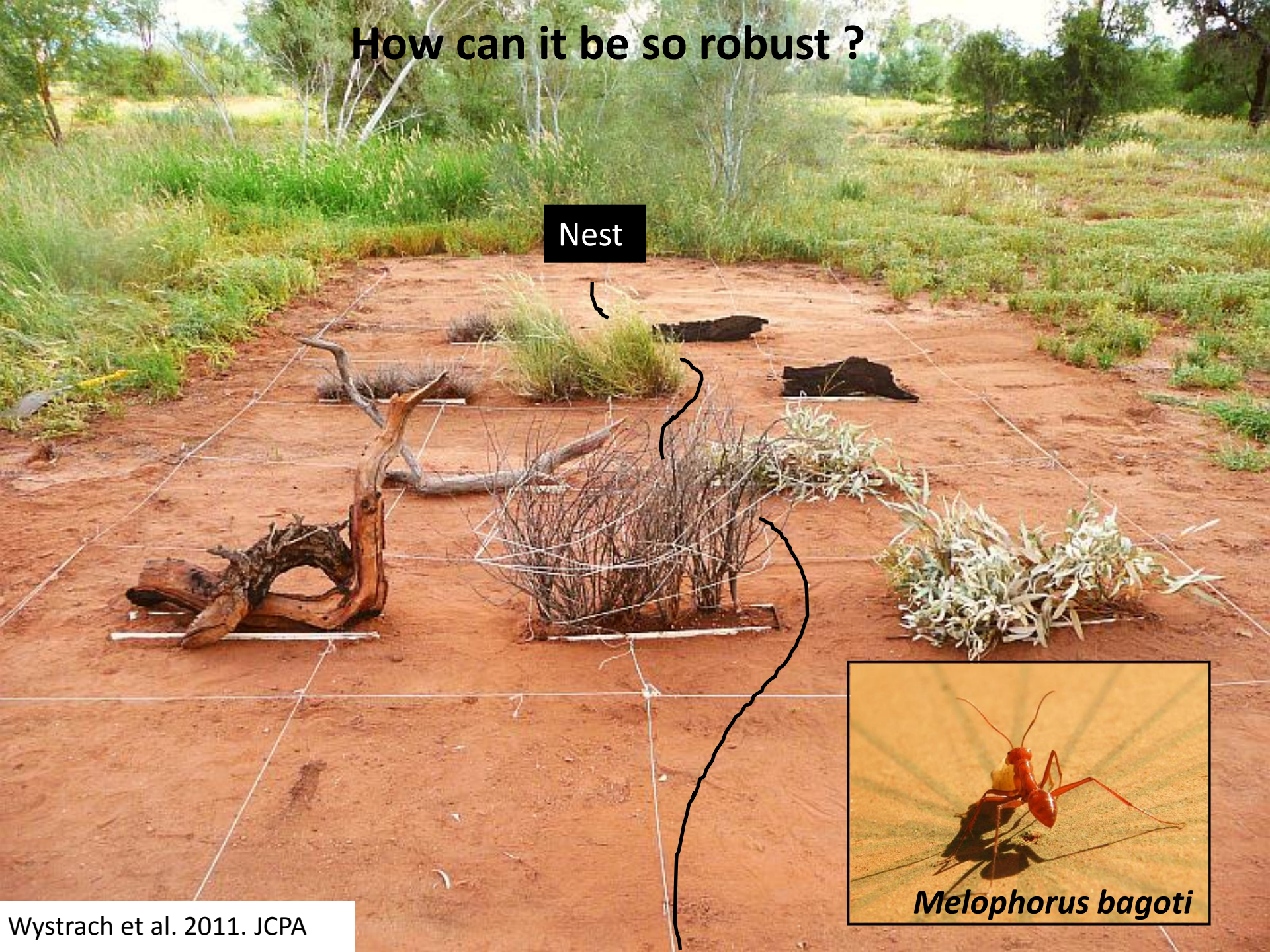
How can it be so robust ?





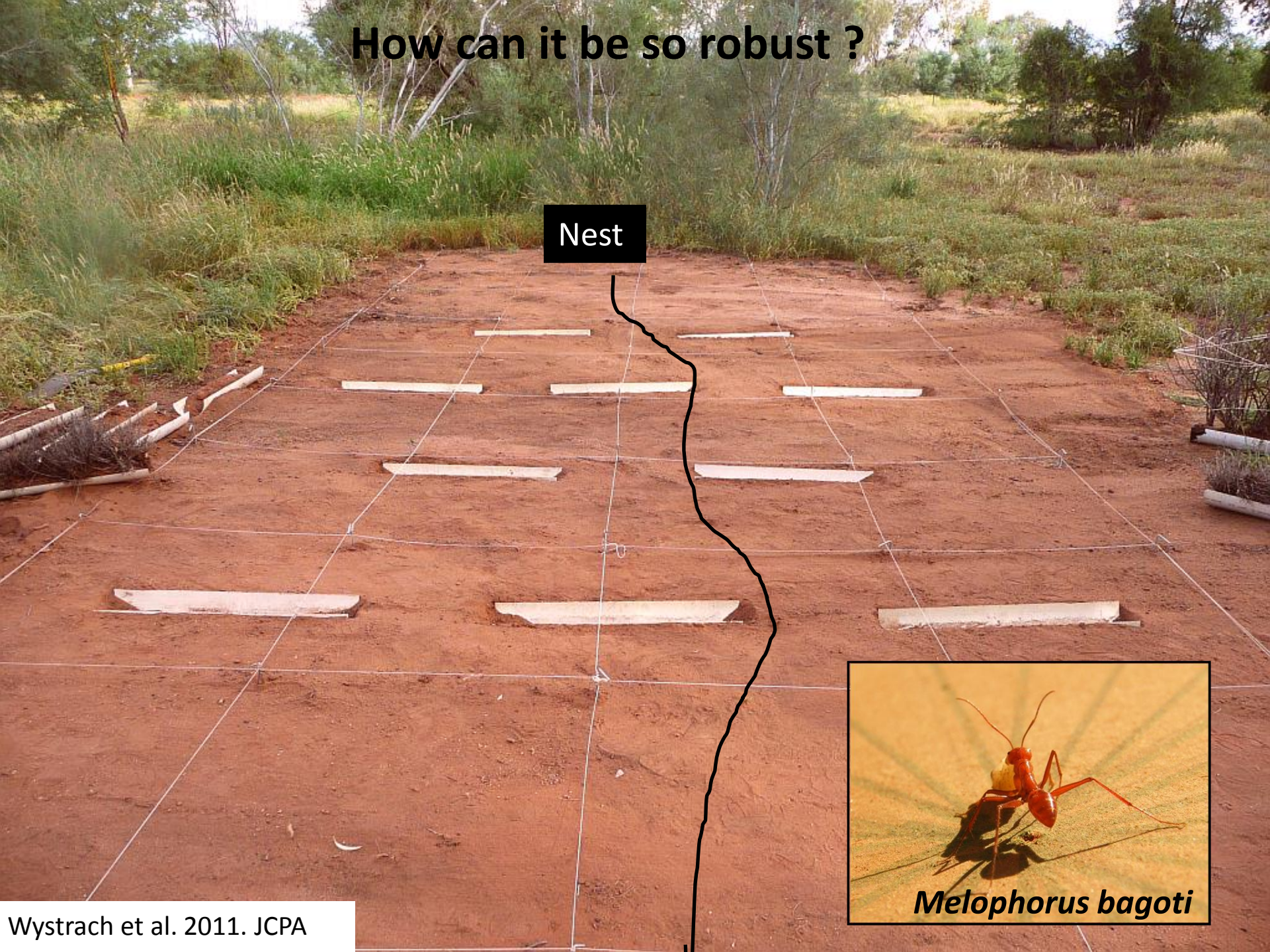
Kohler and Wehner 2005. Neurobiol. Learn. Mem.

How can it be so robust ?



Wystrach et al. 2011. JCPA

How can it be so robust ?



Wystrach et al. 2011. JCPA

How can it be so robust ?

Sensory level: using multiple cues

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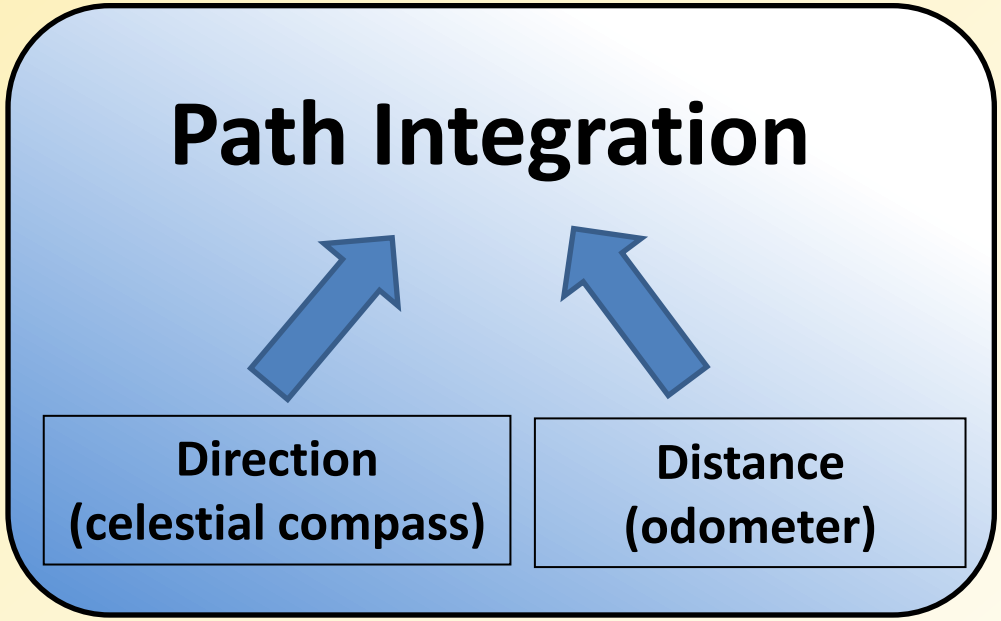
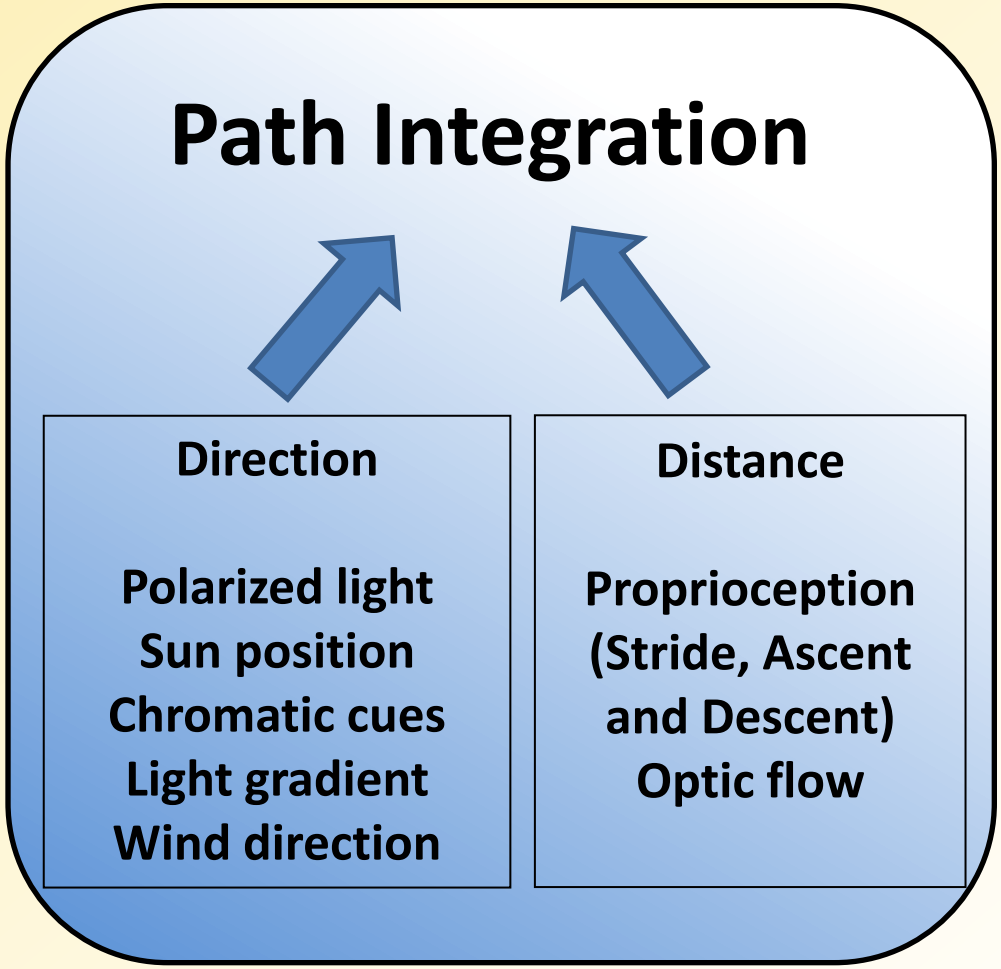
Sensory level: using multiple cues



How can it be so robust ?

Sensory level: using multiple cues



Wehner 2008. Myrmec. news
Wystrach and Schwarz, in prep

Wittlinger et al., 2006. Science
Ronacher 2008. Myrmec. News

How can it be so robust ?

Sensory level: using multiple cues

Visual scene navigation

Wystrach et al., 2011. Front. in Zool.

How can it be so robust ?

Sensory level: using multiple cues

Visual scene navigation

Panoramic views
Wystrach et al., 2011. Front. in Zool.

Motor routines
Knaden et al. 2006. Curr. biol

Odor cues
Steck et al., 2009. Front. in Zool.

Magnetic cue
Buehlmann et al., 2012. Plos one

Vibratory cue
Buehlmann et al., 2012. Plos one

credit: Max Planck Institute for Chemical Ecology/Badeke

How can it be so robust ?

Sensory level: using multiple cues

Learnt information

Panoramic views
Wystrach et al., 2011. Front. in Zool.

Motor routines
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Odor cues
Steck et al., 2009. Front. in Zool.

Magnetic cue
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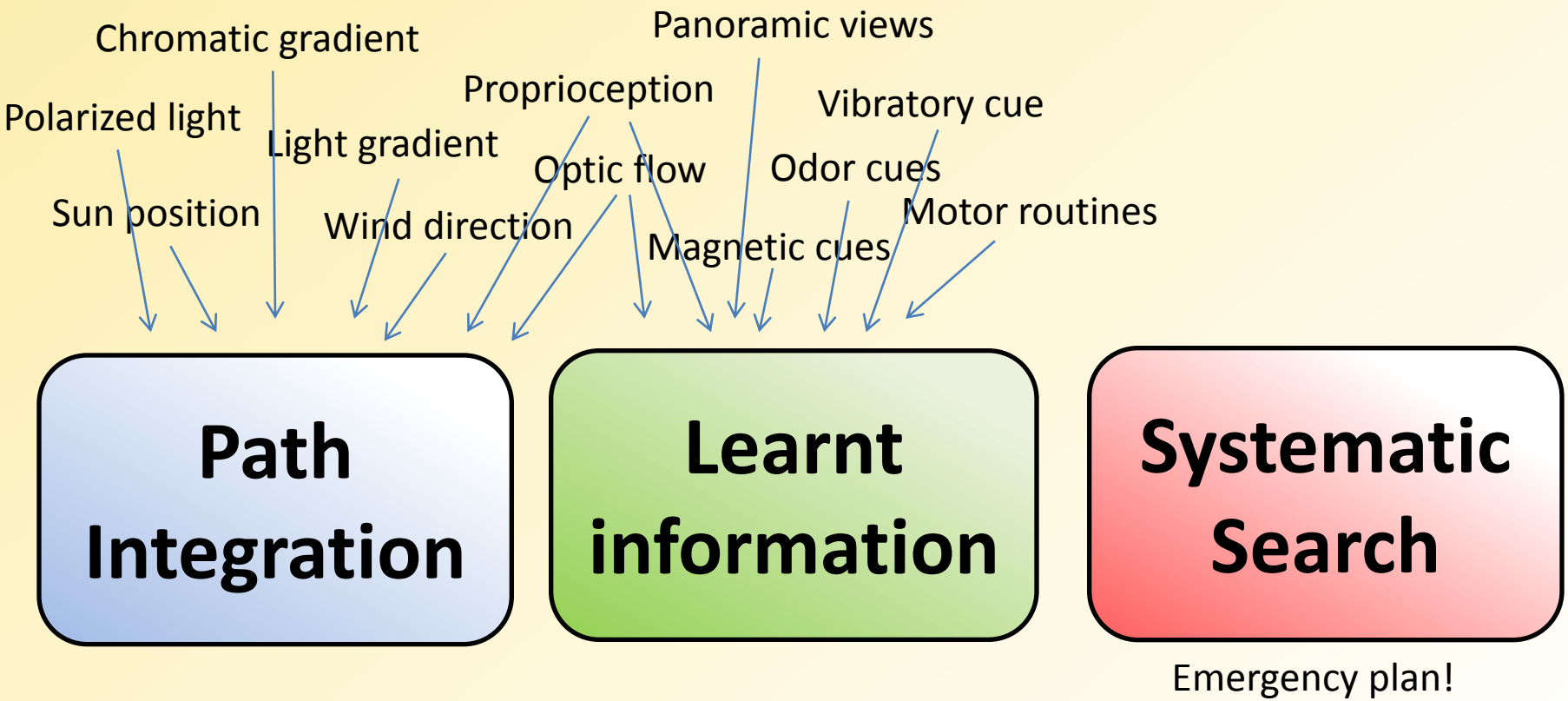
credit: Max Planck Institute for Chemical Ecology/Badeke

How can it be so robust ?

Sensory level: using multiple cues



How can it be so robust ?

Output level: combining strategies

Path Integration

Learnt information

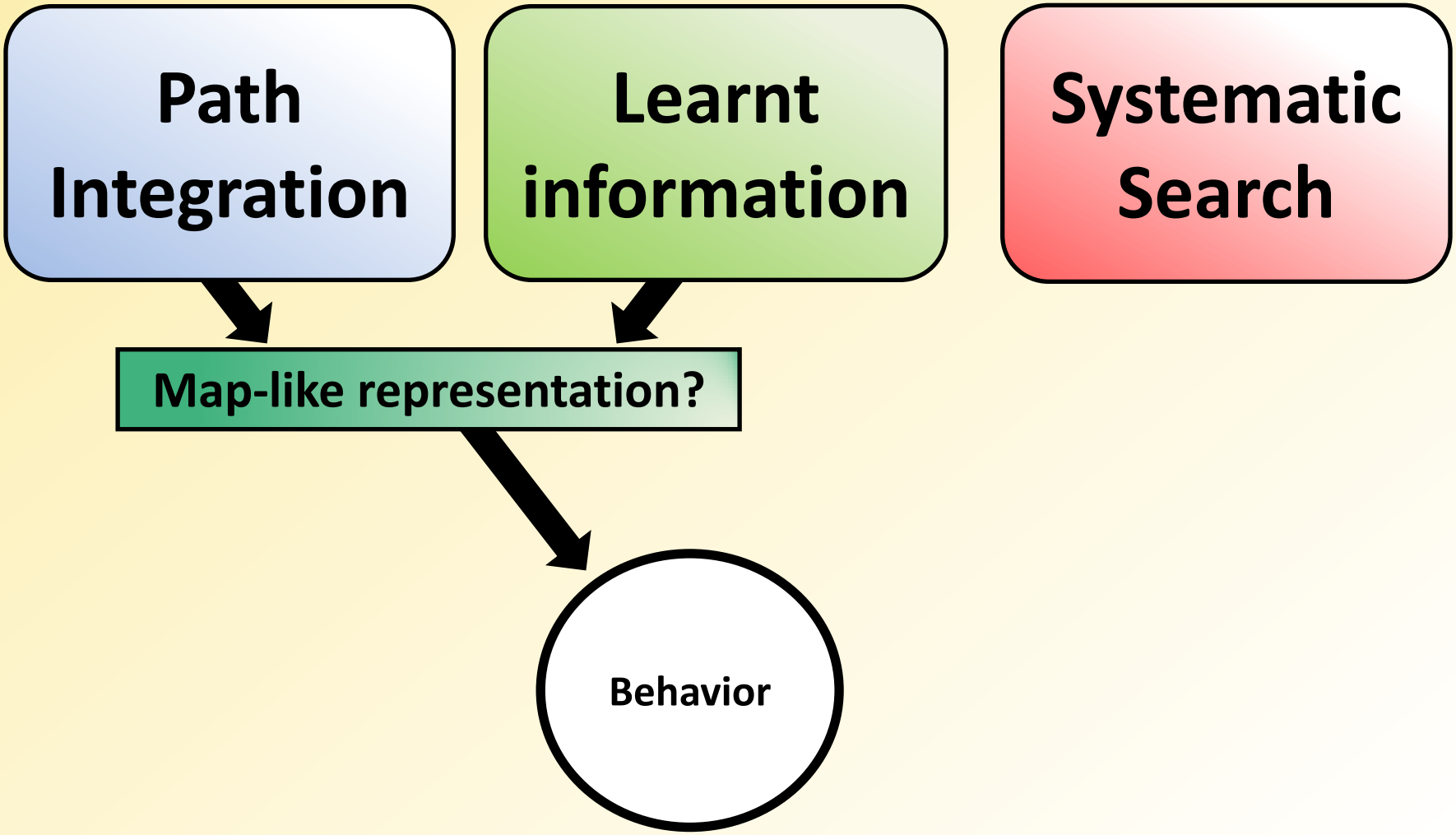
Systematic Search

?

Behavior

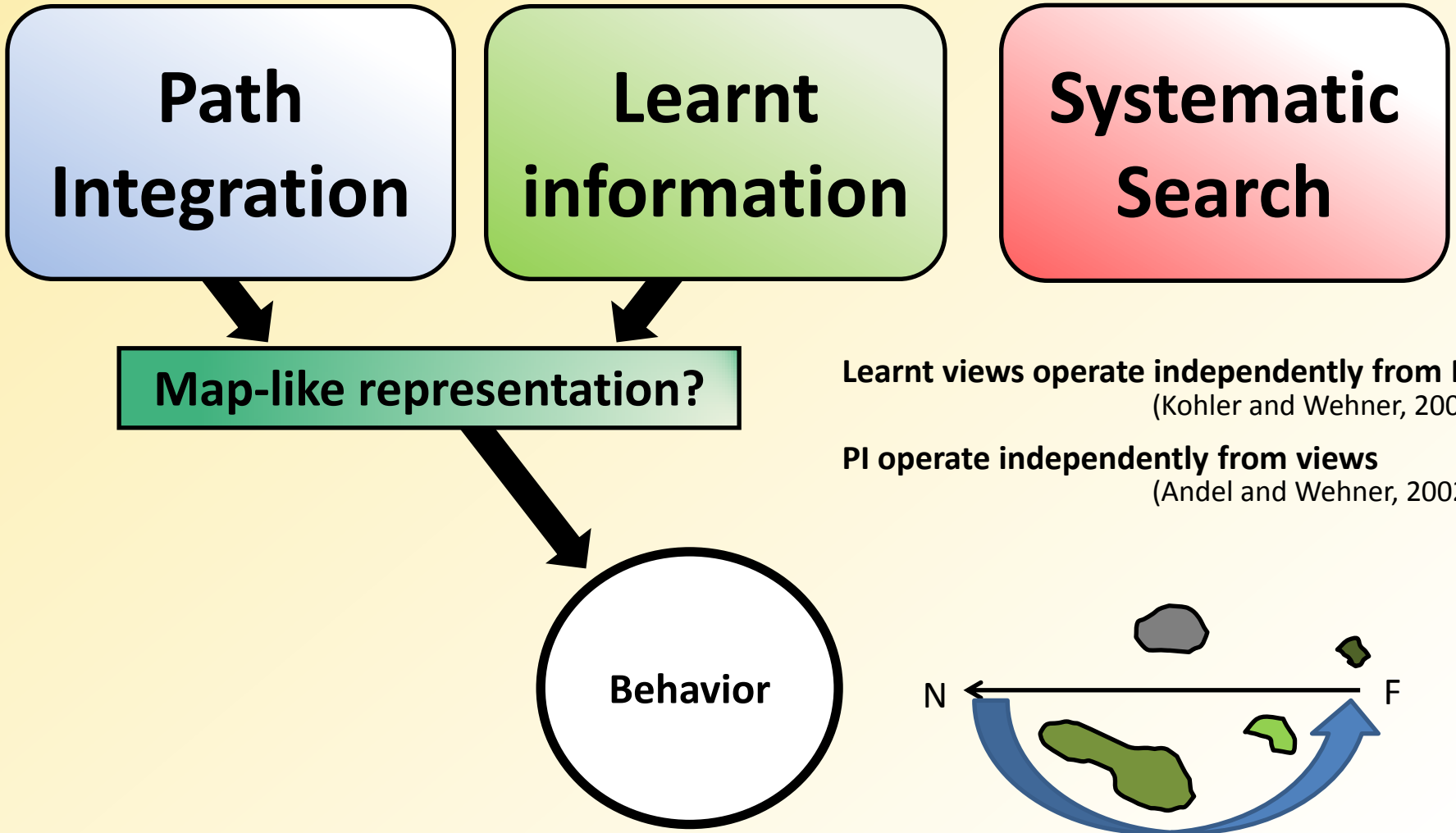
How can it be so robust ?

Output level: combining strategies



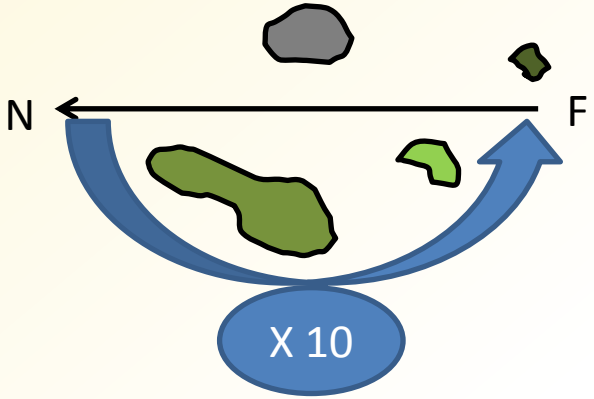
How can it be so robust ?

Output level: combining strategies



Learnt views operate independently from PI
(Kohler and Wehner, 2005)

PI operate independently from views
(Andel and Wehner, 2002)



How can it be so robust ?

Output level: combining strategies

Path Integration

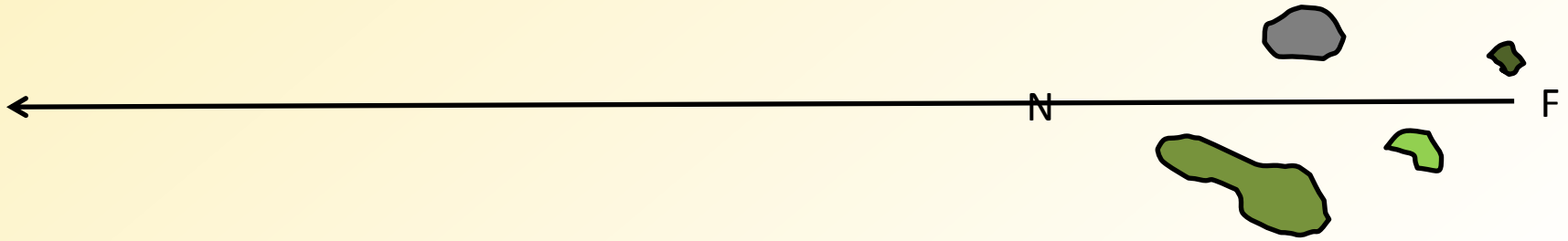
Learnt information

Systematic Search

Map-like representation?

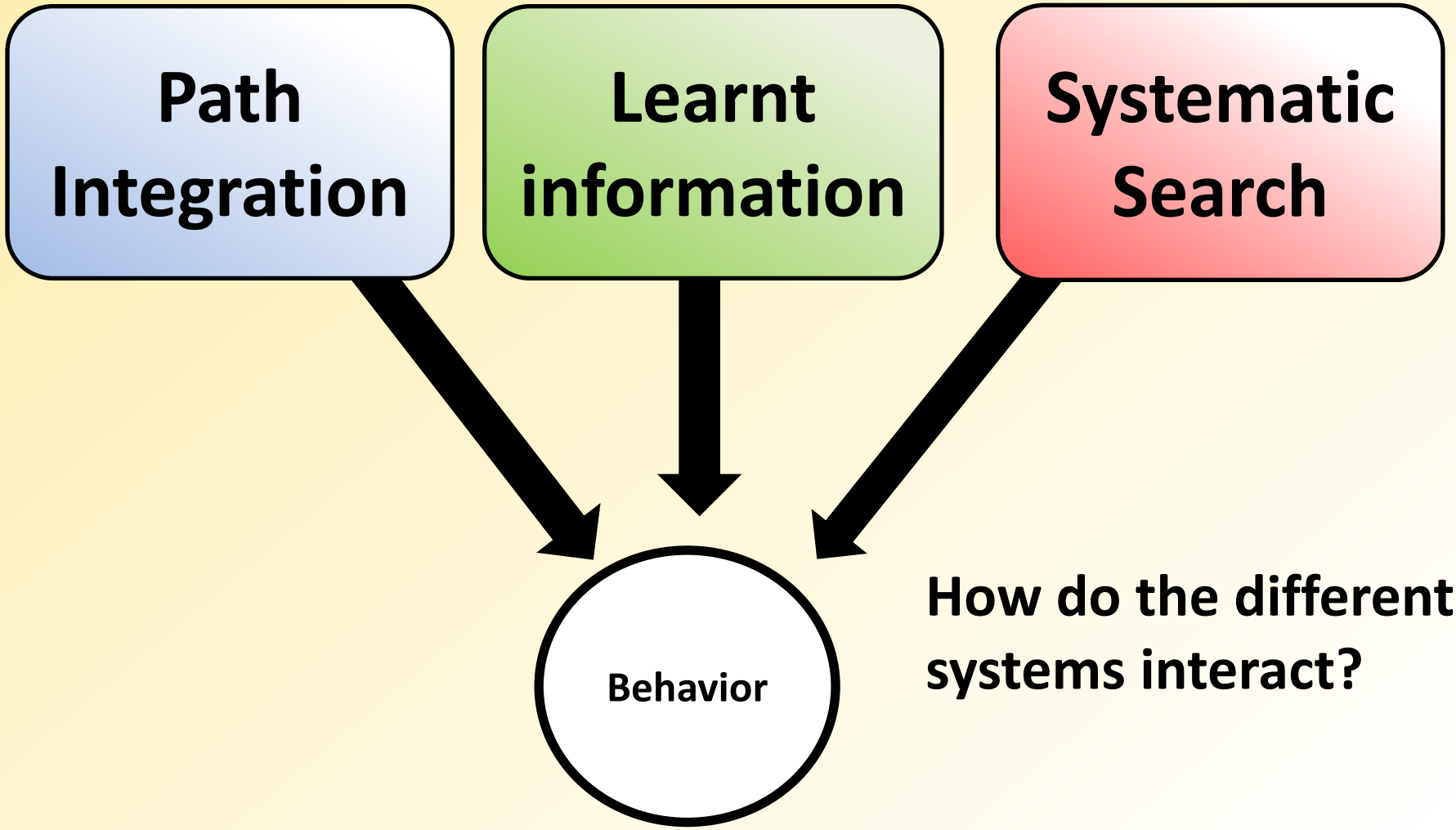
Learnt views operate independently from PI
(Kohler and Wehner, 2005)

PI operate independently from views
(Andel and Wehner, 2002)



How can it be so robust ?

Output level: combining strategies



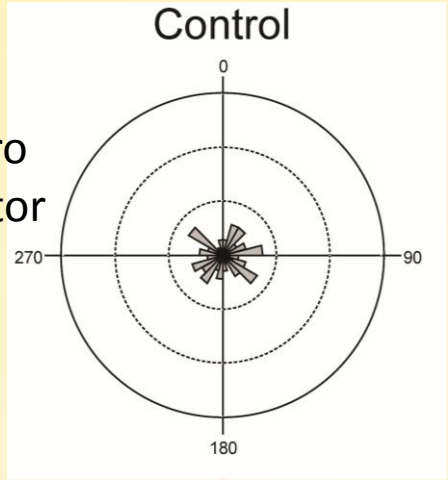
How do the different systems interact?

Wehner 2008, Myrmec. News.

How can it be so robust ?

Output level: combining strategies

~~PI~~ ~~Views~~

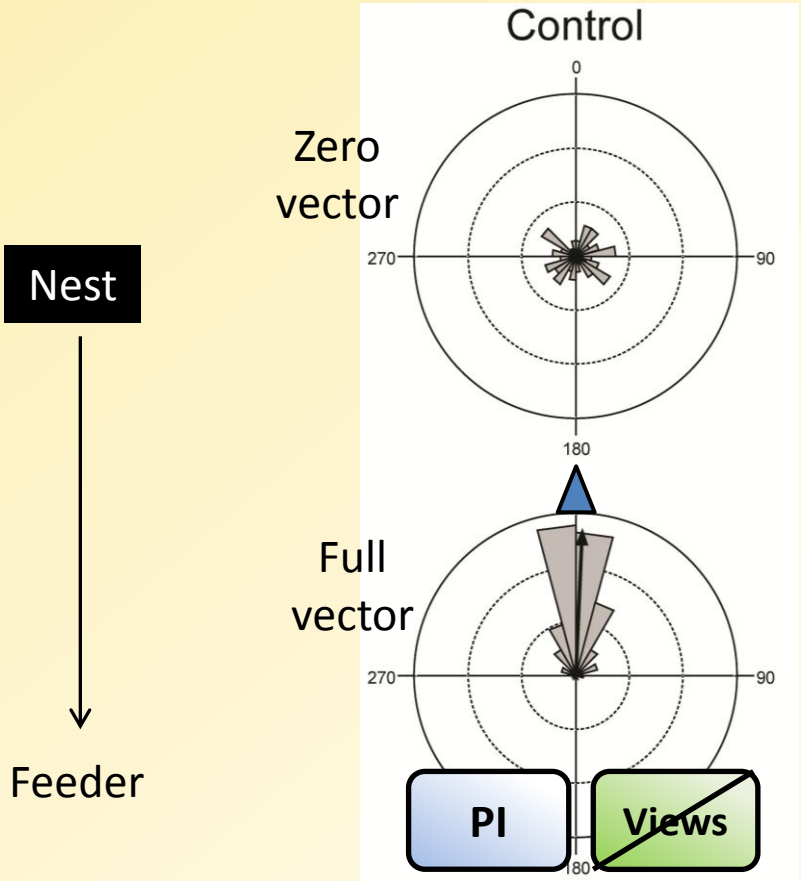


Nest

Wystrach and Legge, in prep

How can it be so robust ?

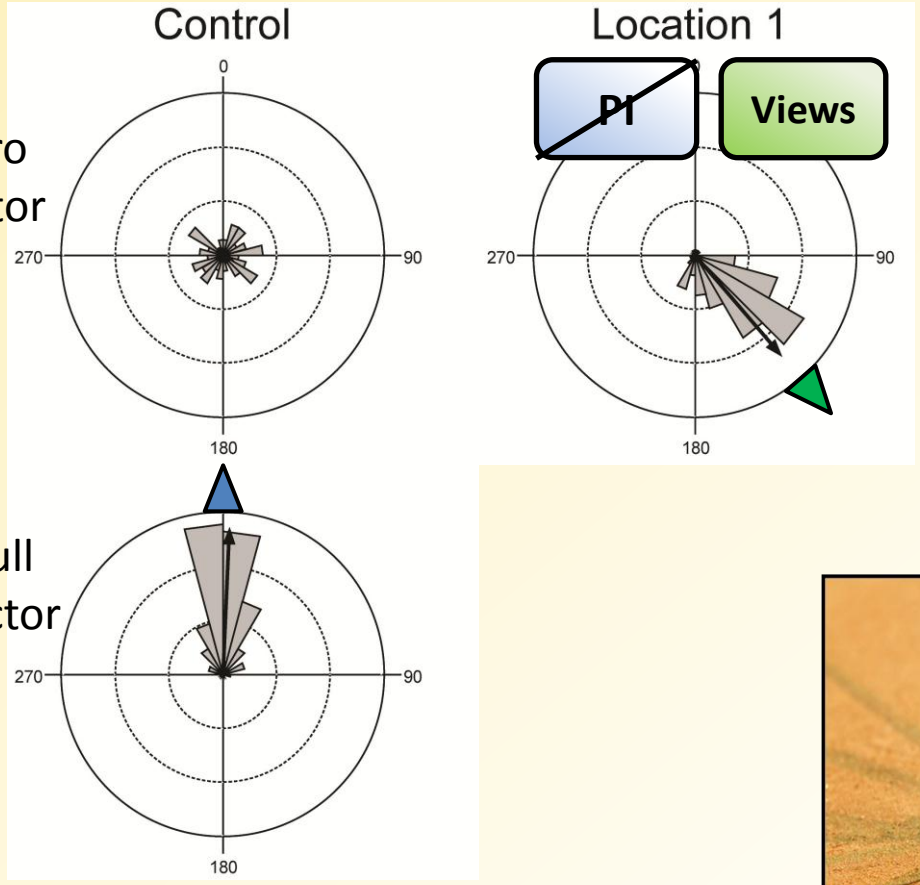
Output level: combining strategies



Wystrach and Legge, in prep

How can it be so robust ?

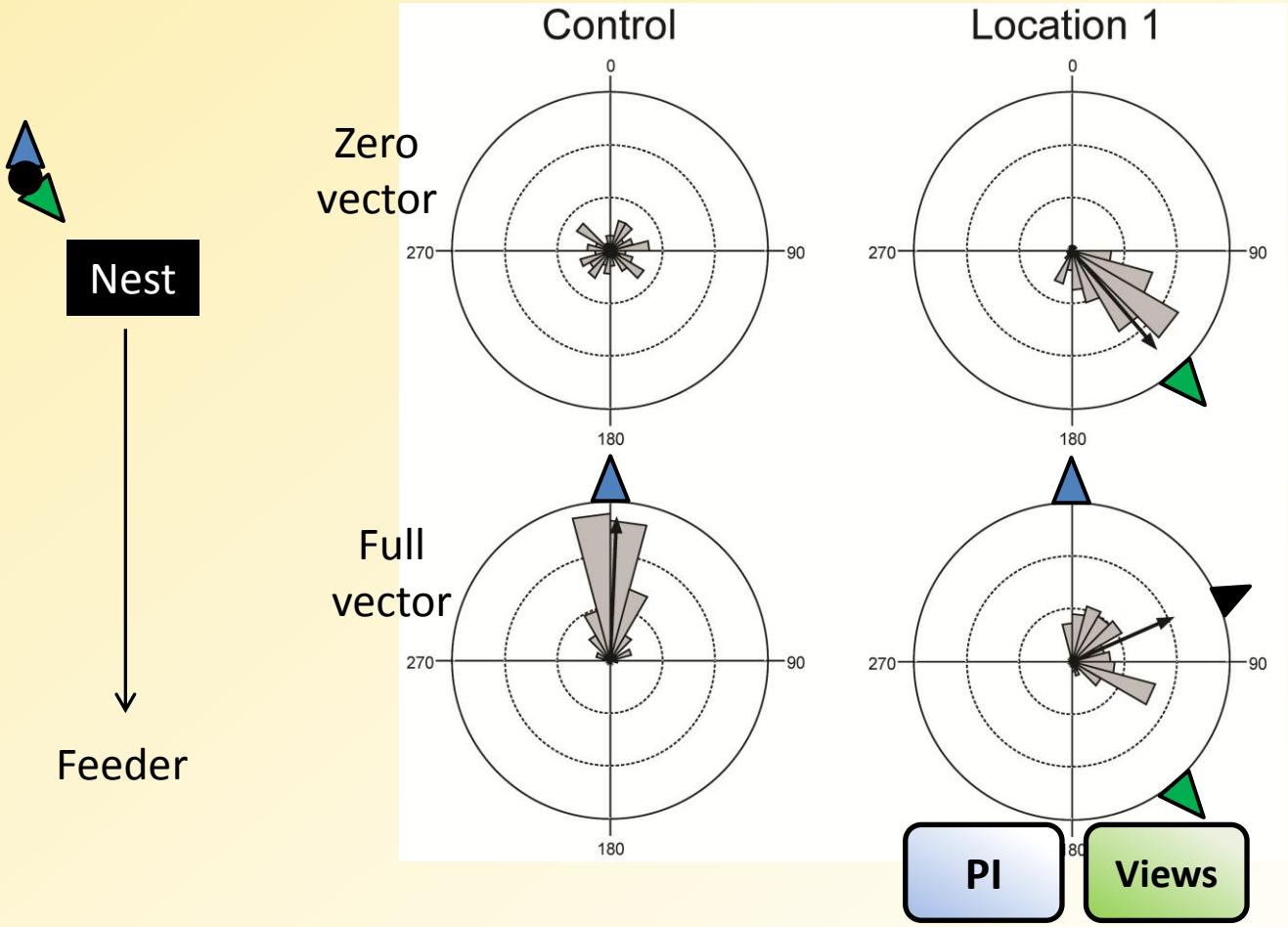
Output level: combining strategies



Wystrach and Legge, in prep

How can it be so robust ?

Output level: combining strategies

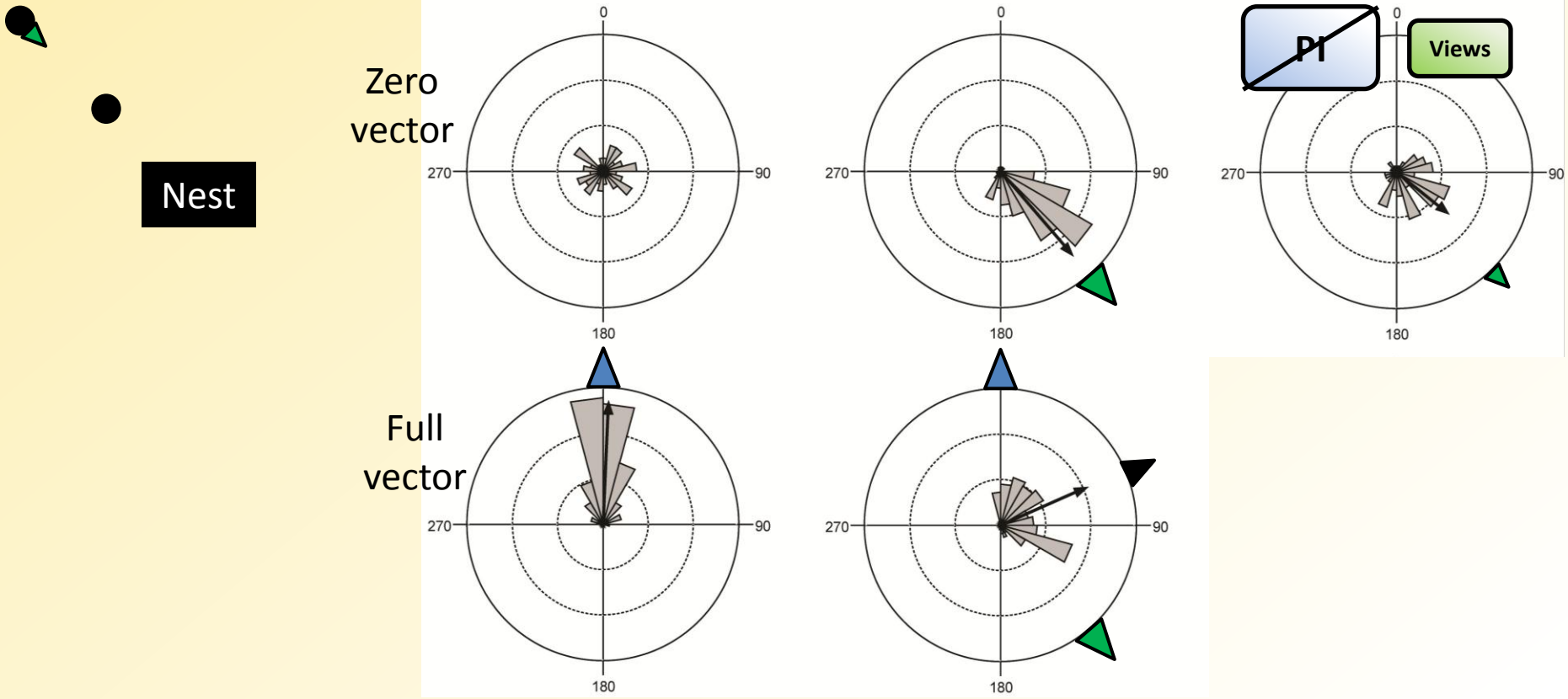


Wystrach and Legge, in prep

See also Collett 2012. Curr. biol.

How can it be so robust ?

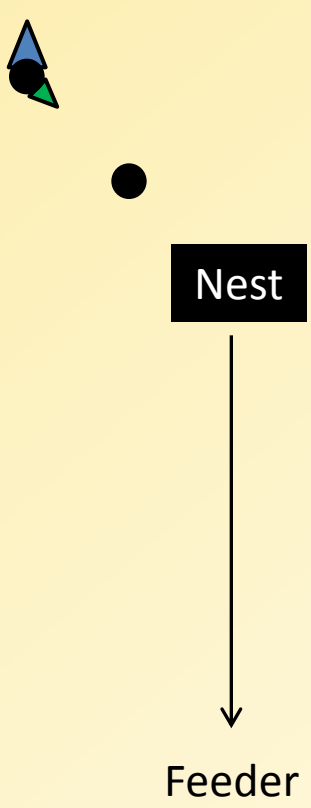
Output level: combining strategies

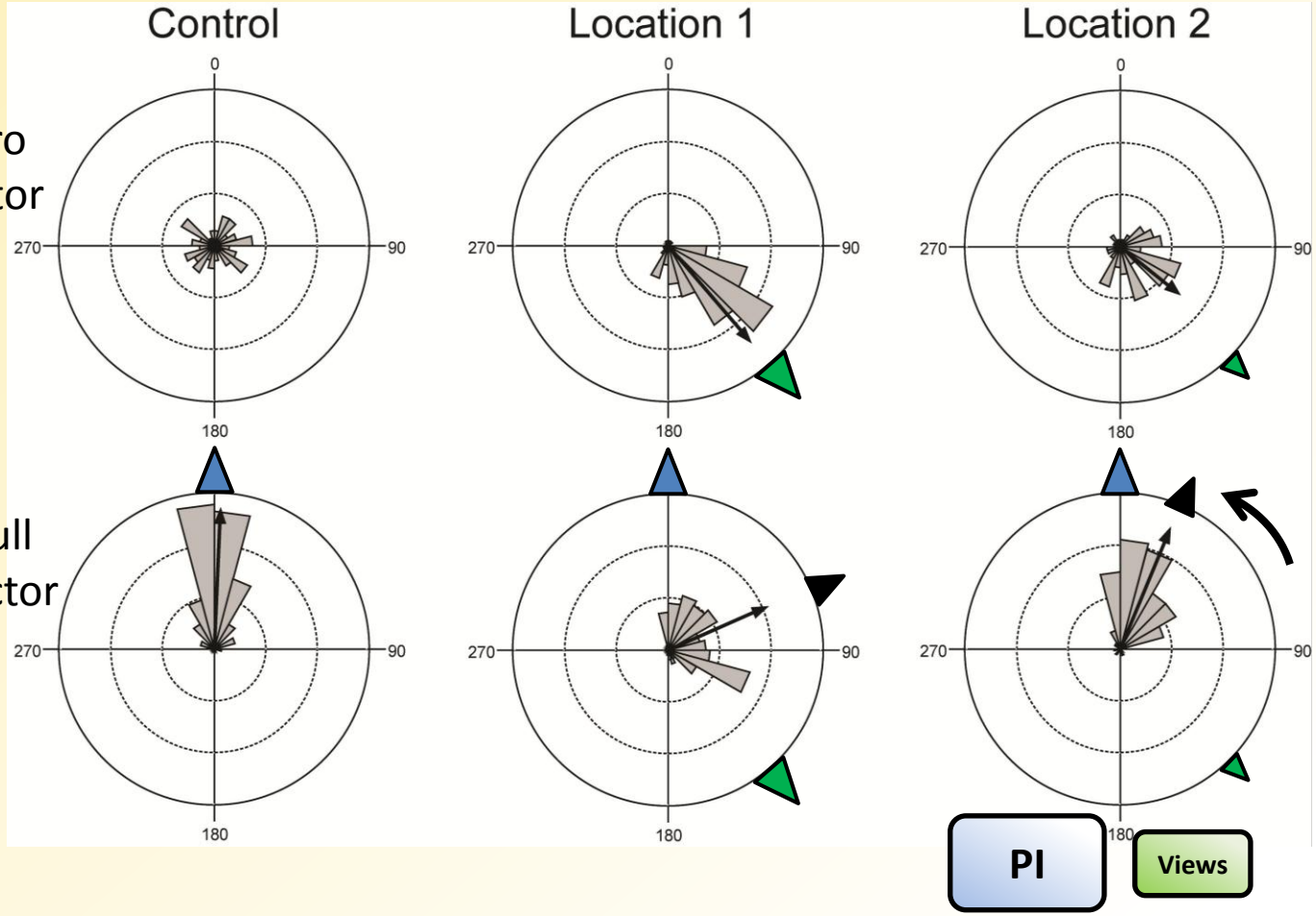


Wystrach and Legge, in prep

How can it be so robust ?

Output level: combining strategies

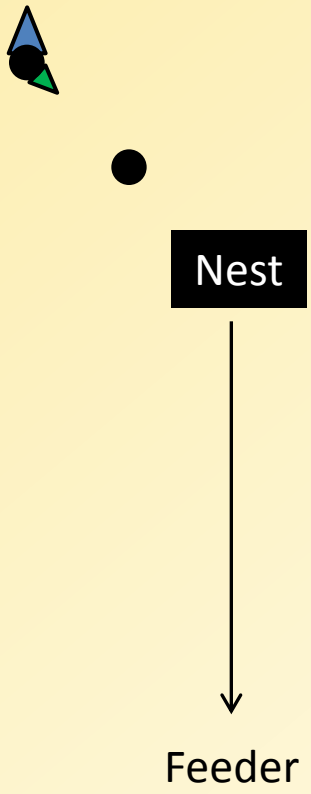


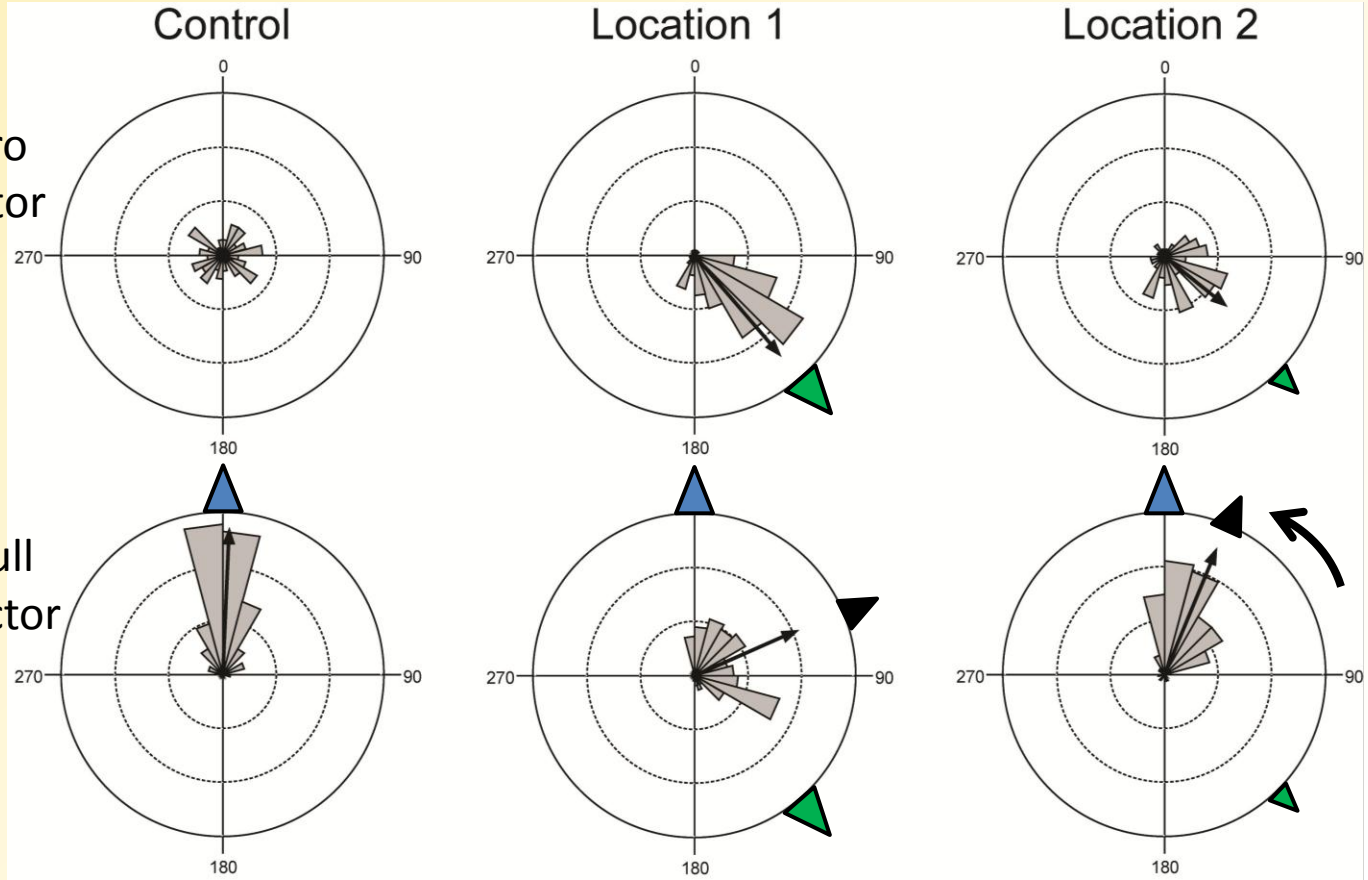


Wystrach and Legge, in prep

How can it be so robust ?

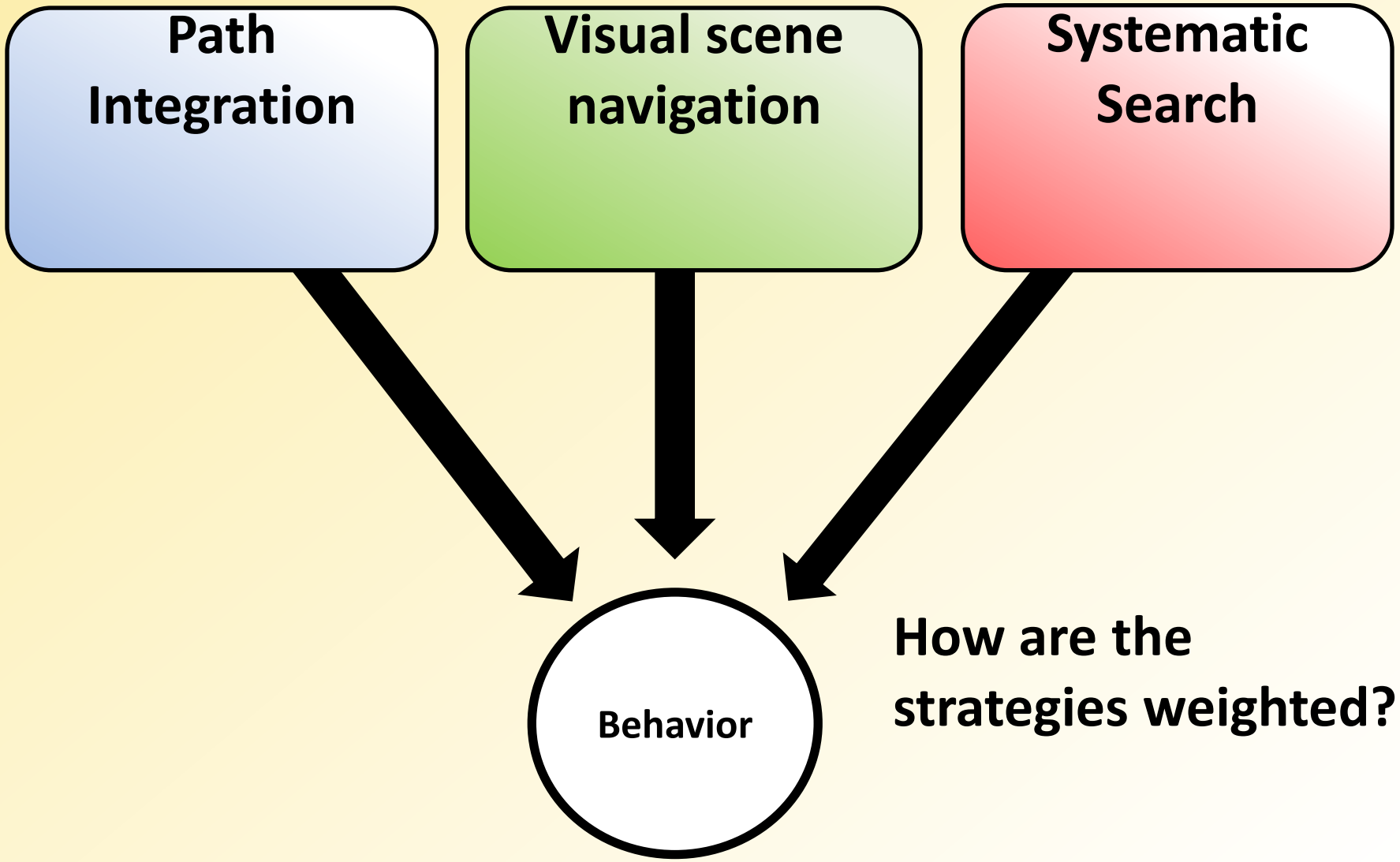
Output level: weighting strategies





Wystrach and Legge, in prep

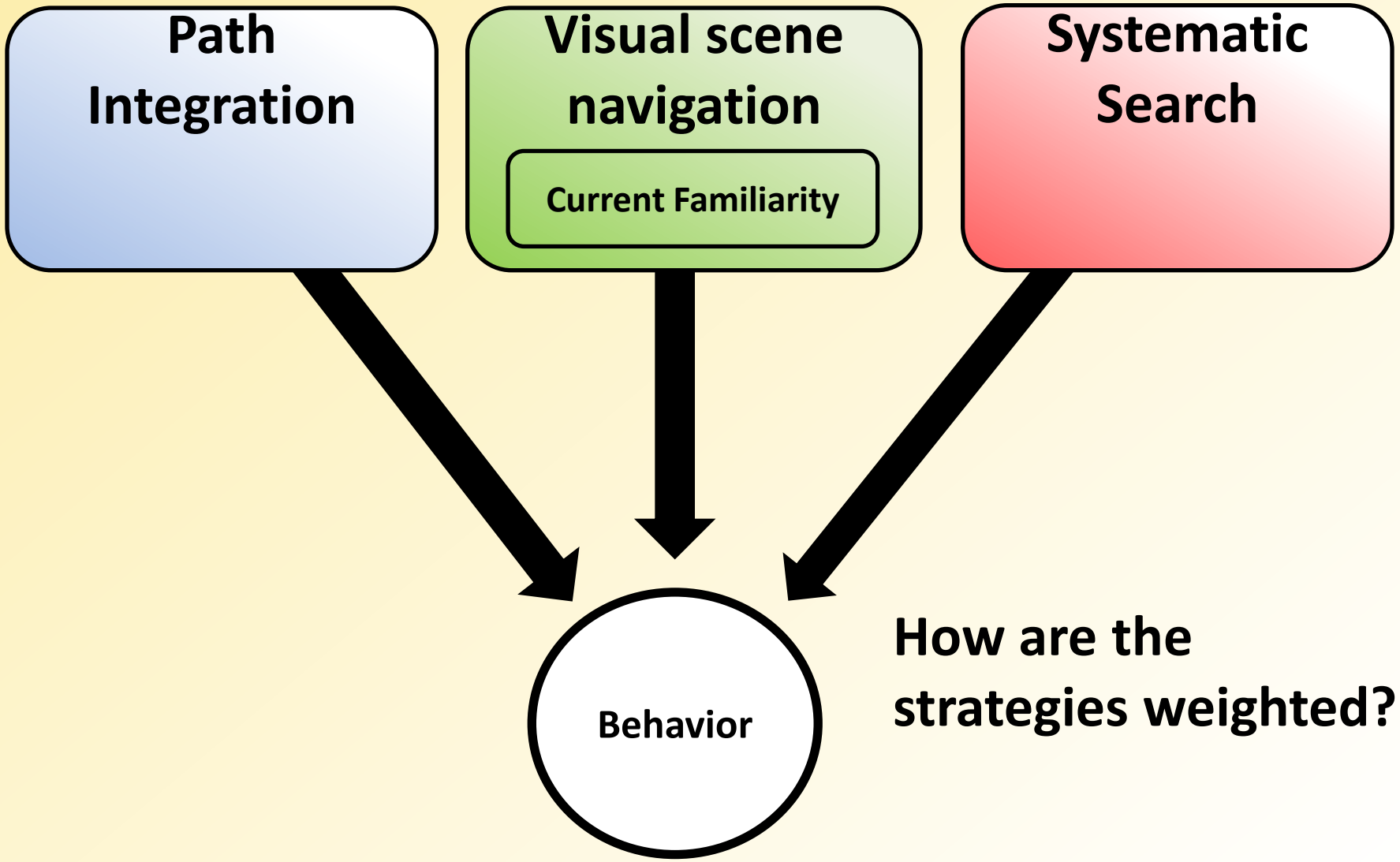
Weighting the different systems



How are the strategies weighted?

Wystrach et al. in prep

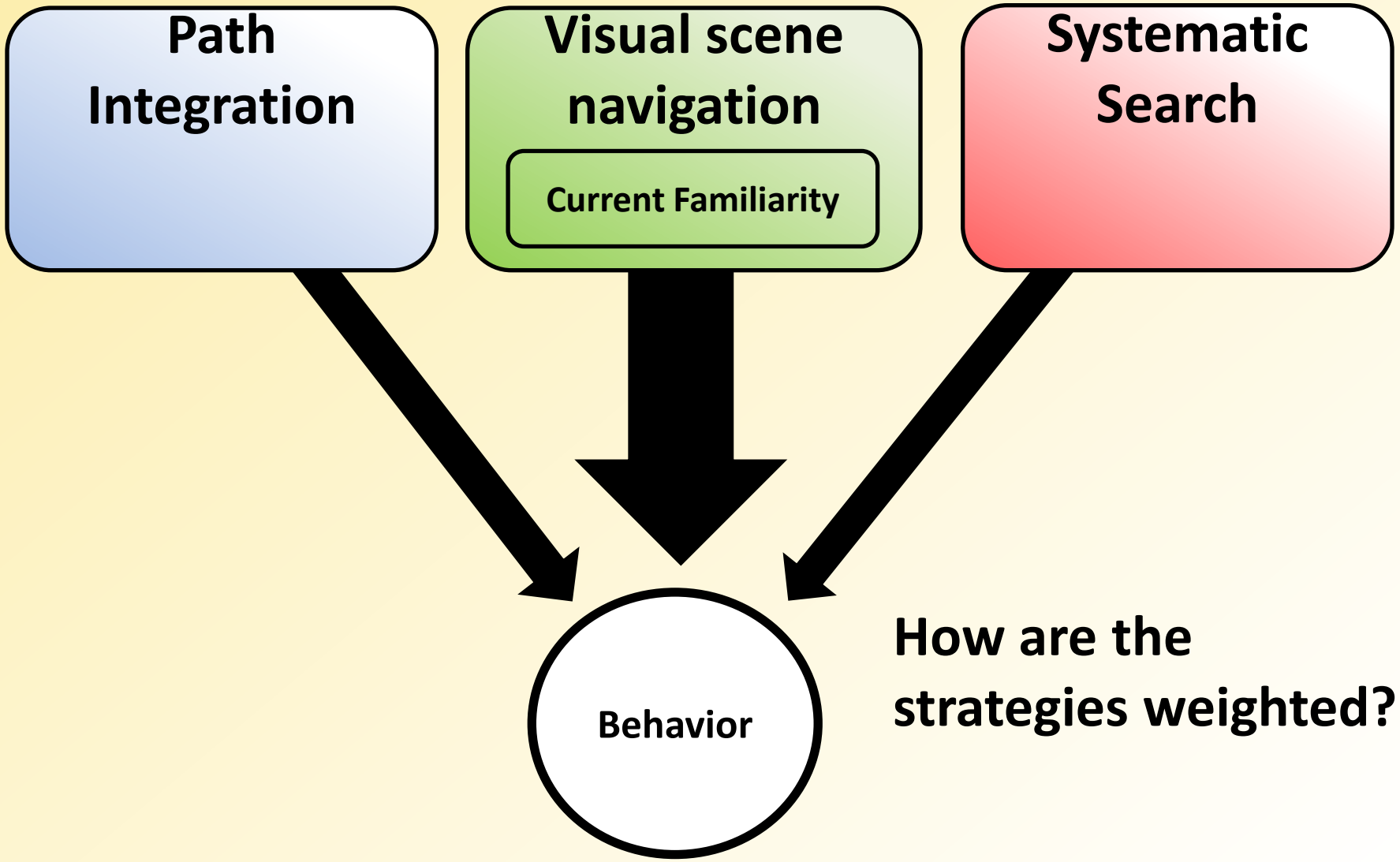
Weighting the different systems



How are the strategies weighted?

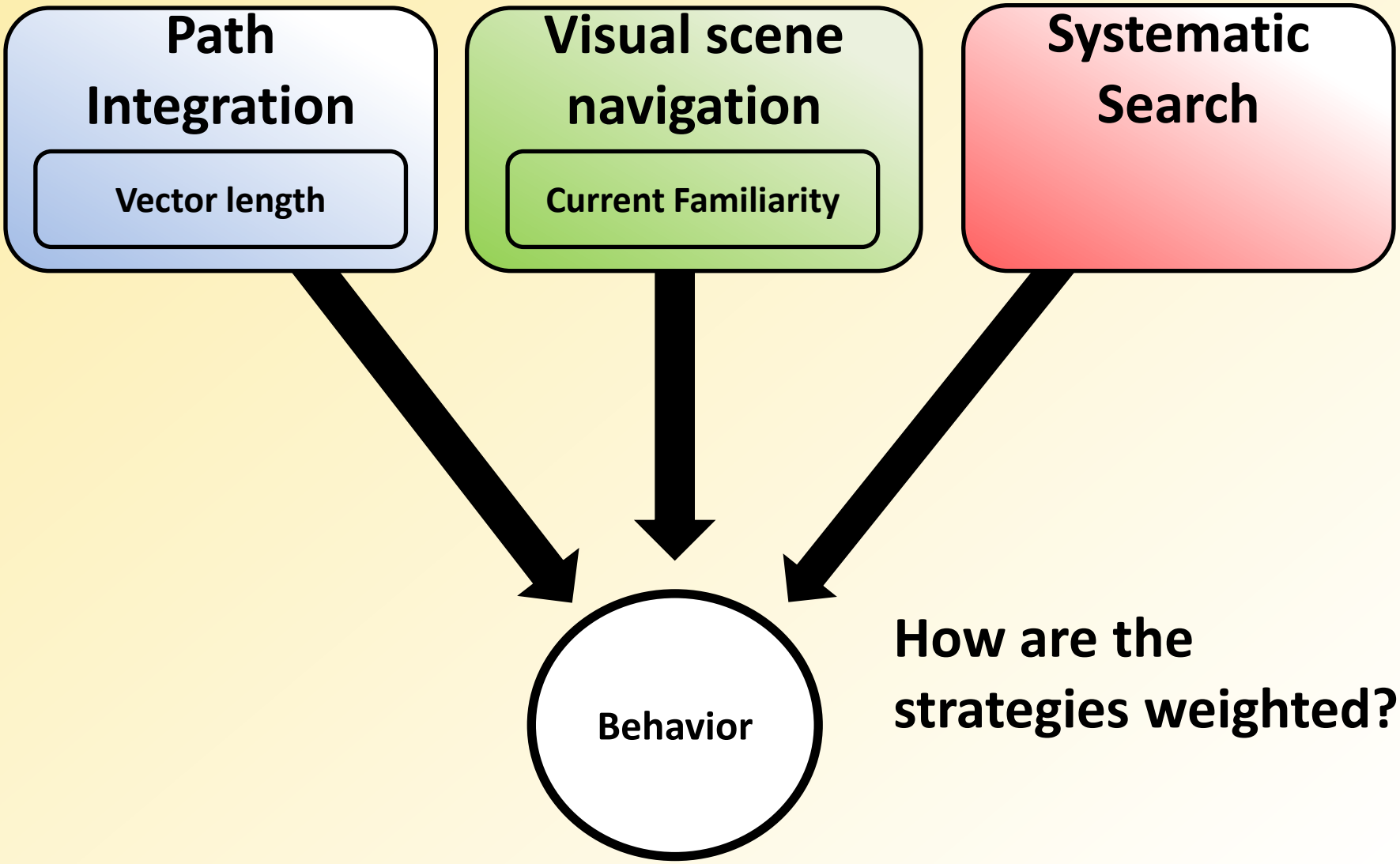
Wystrach et al. in prep

Weighting the different systems



Wystrach et al. in prep

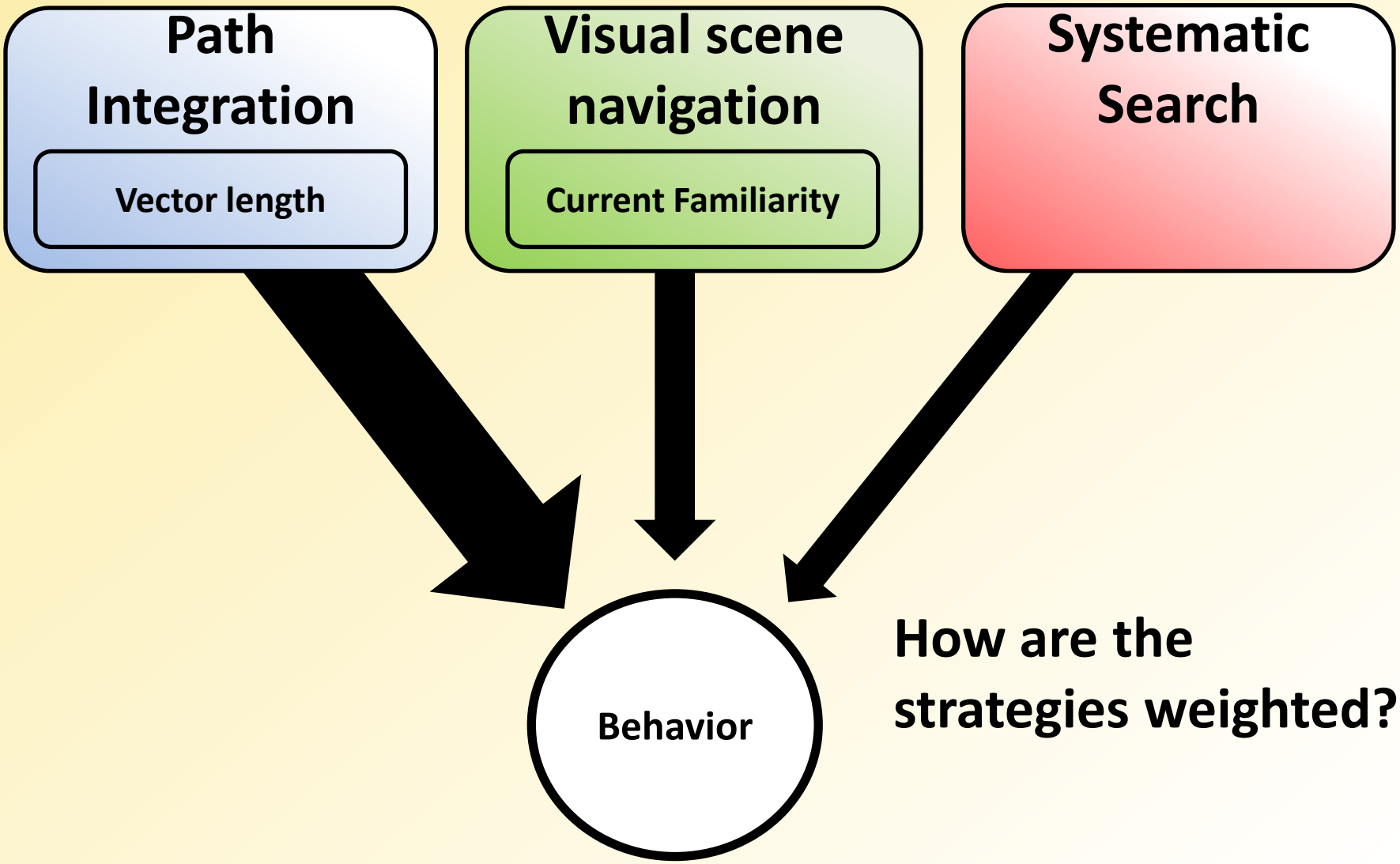
Weighting the different systems



How are the strategies weighted?

Wystrach et al. in prep

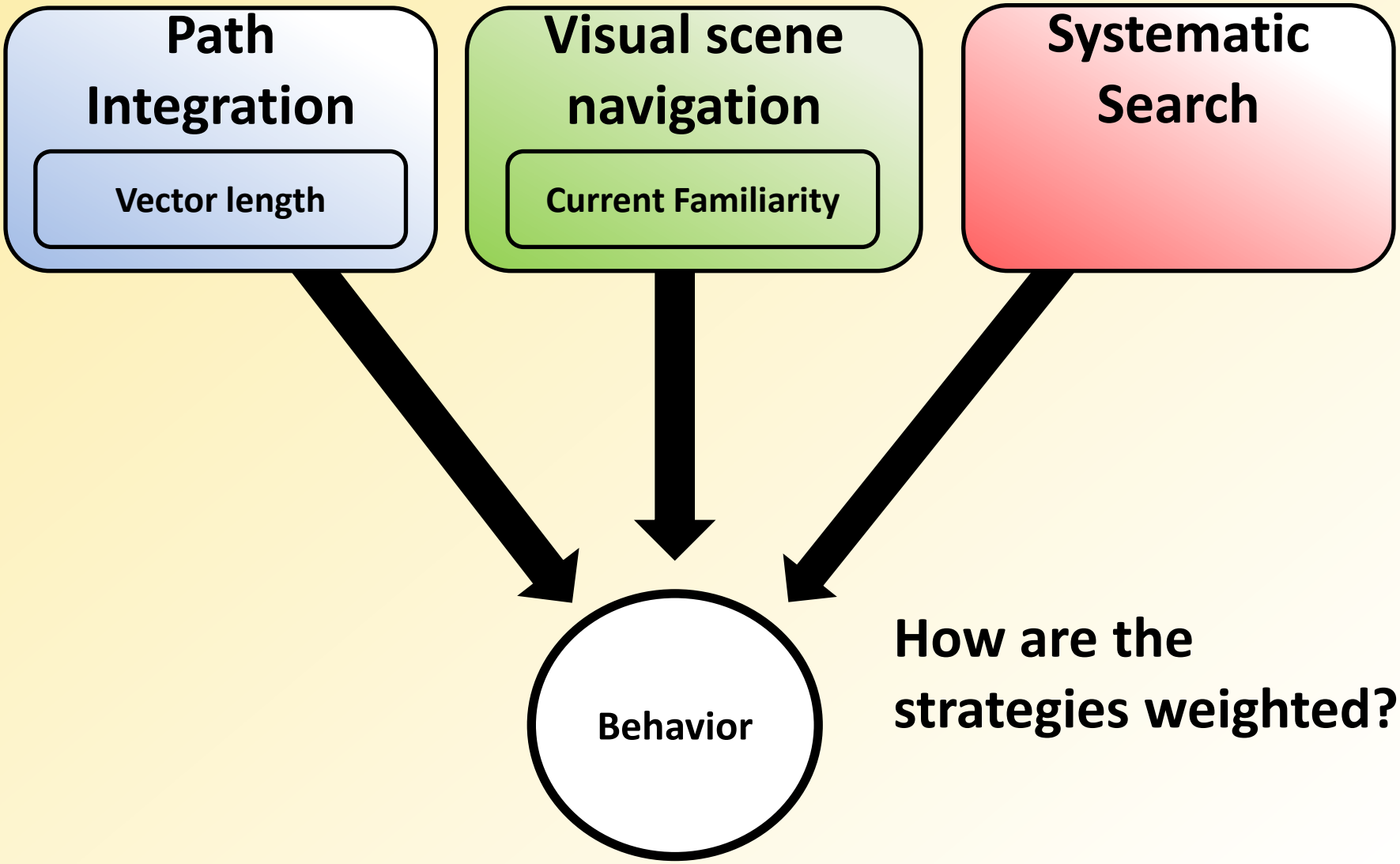
Weighting the different systems



How are the strategies weighted?

Wystrach et al. in prep

Weighting the different systems



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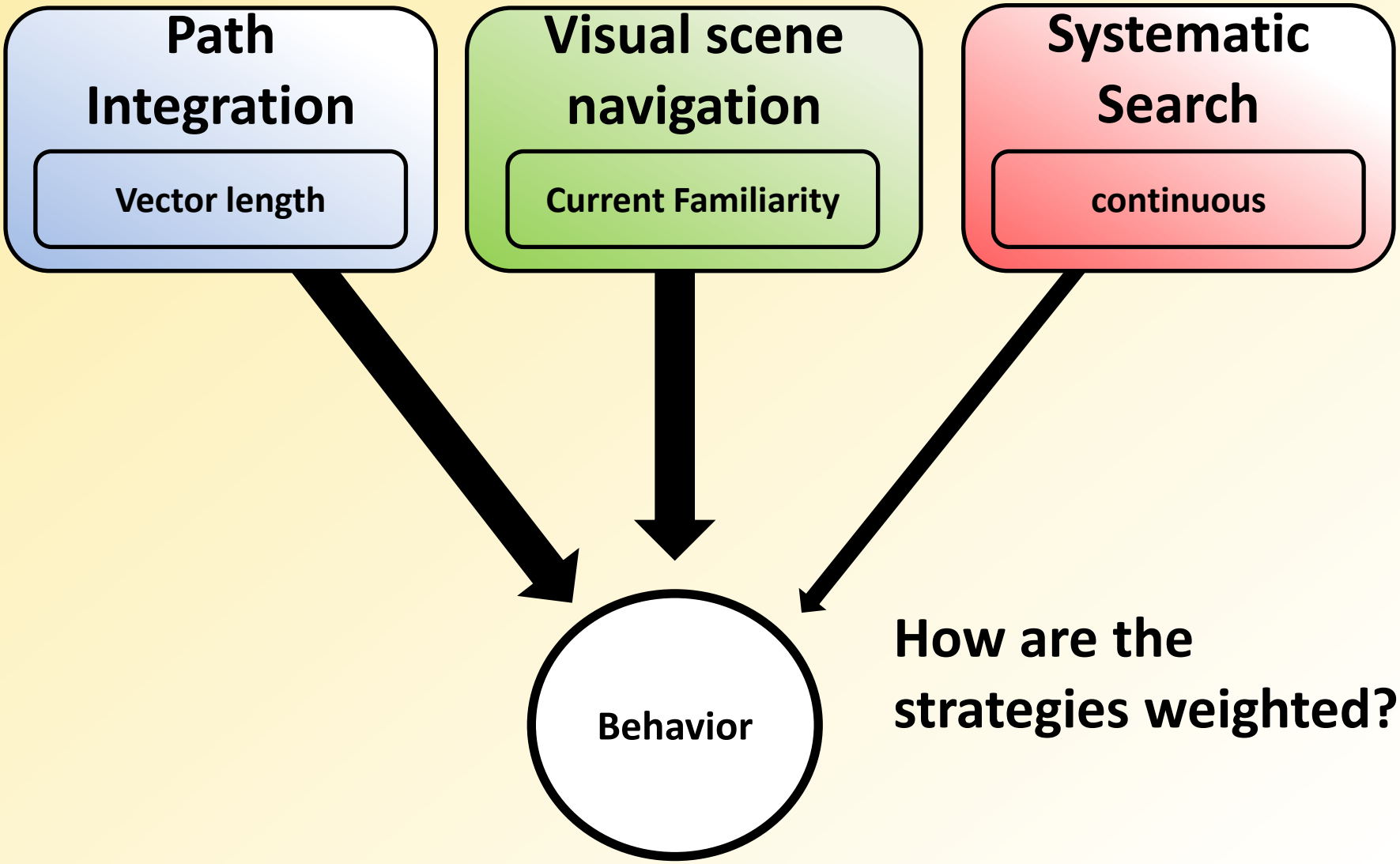
Weighting the different systems



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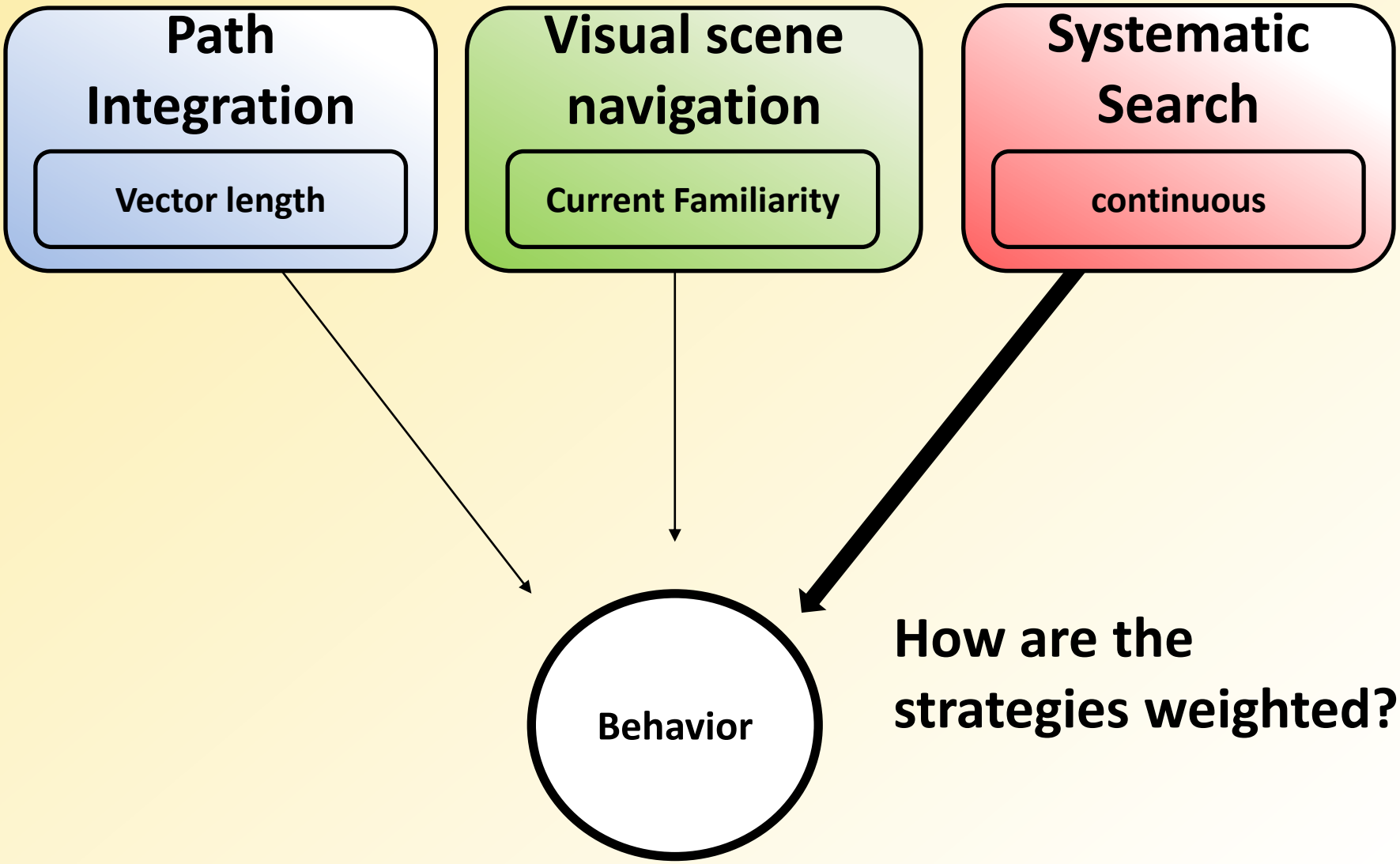
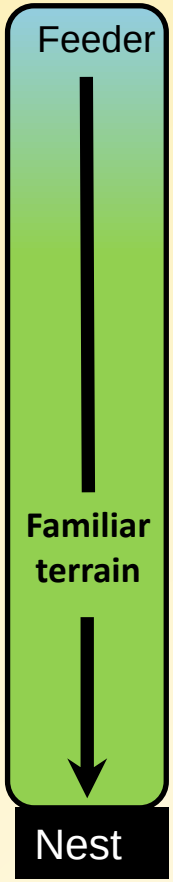
Wystrach et al. in prep

Weighting the different systems



Wystrach et al. in prep



Path Integration

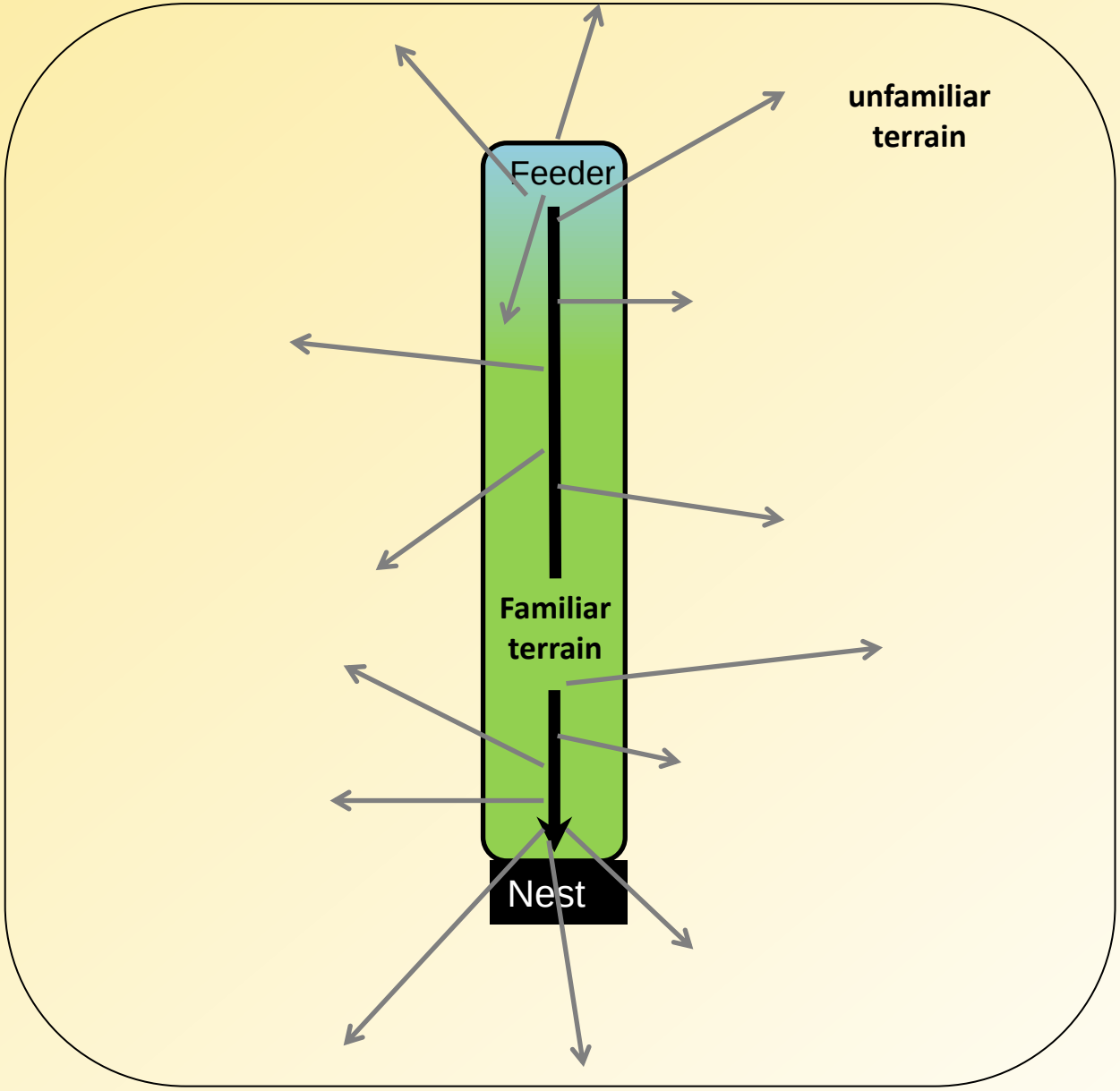
Vector length

Visual scene navigation

Current Familiarity

Systematic Search

continuous



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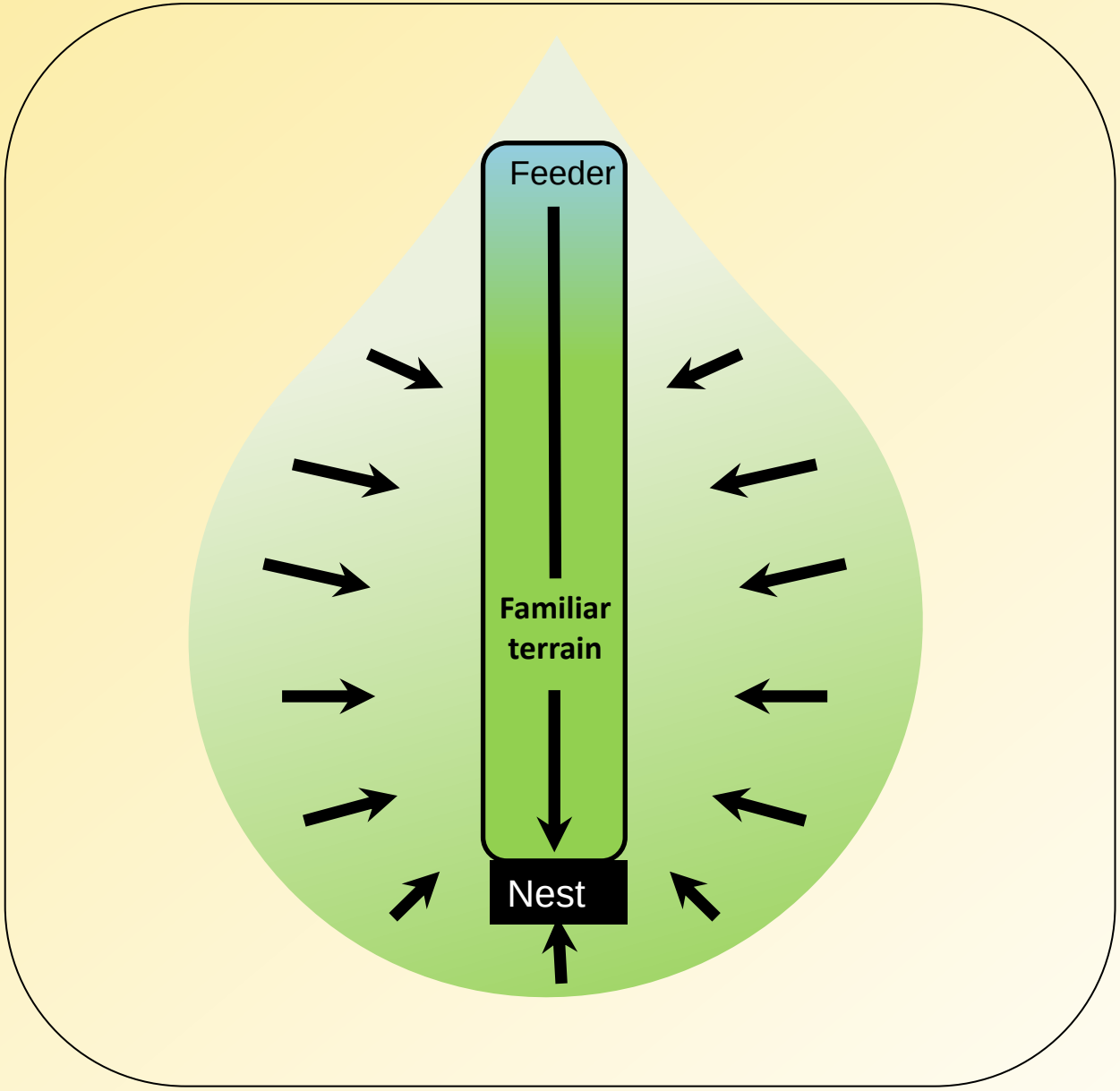

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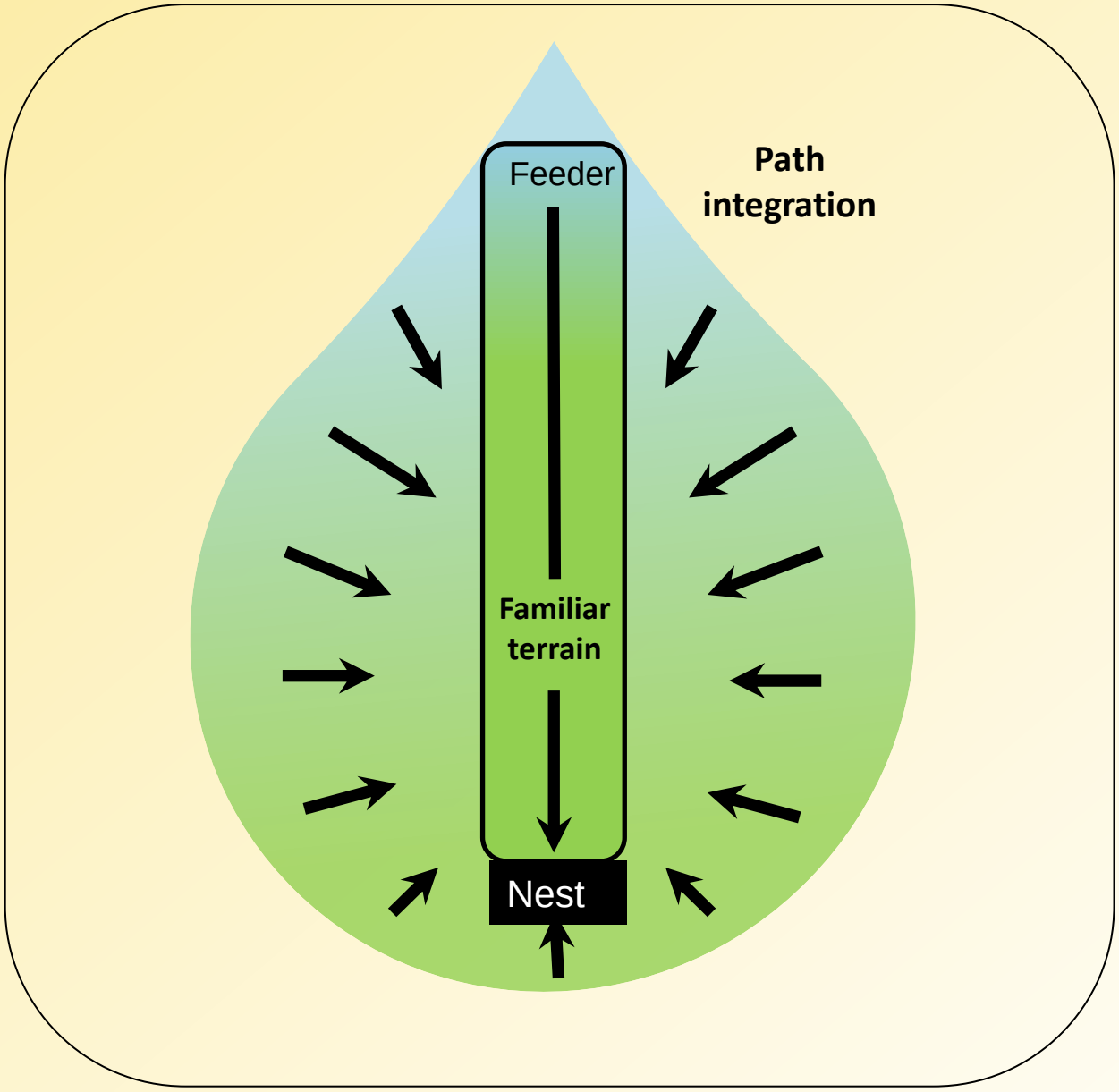

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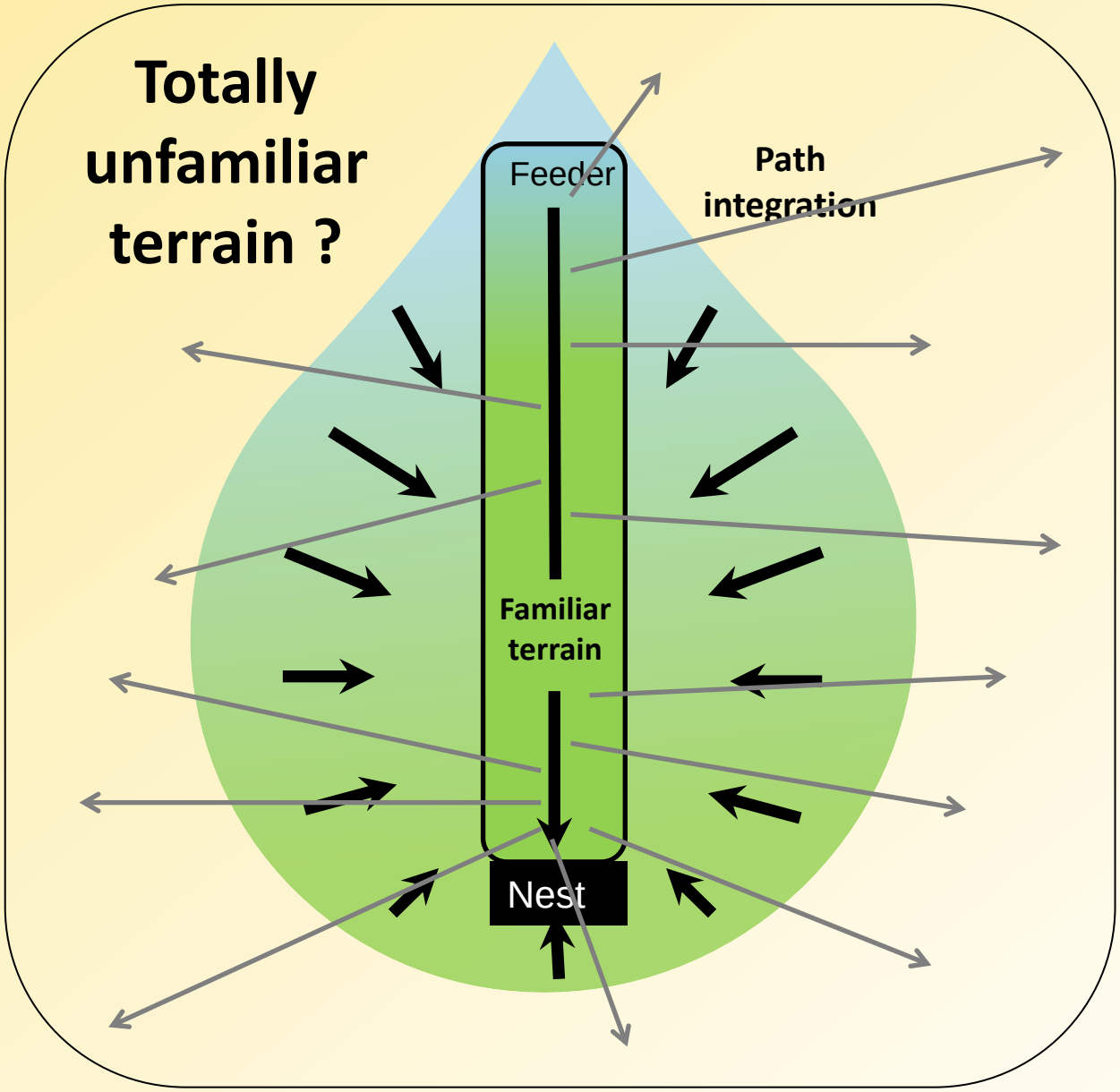

Path Integration

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Visual scene navigation

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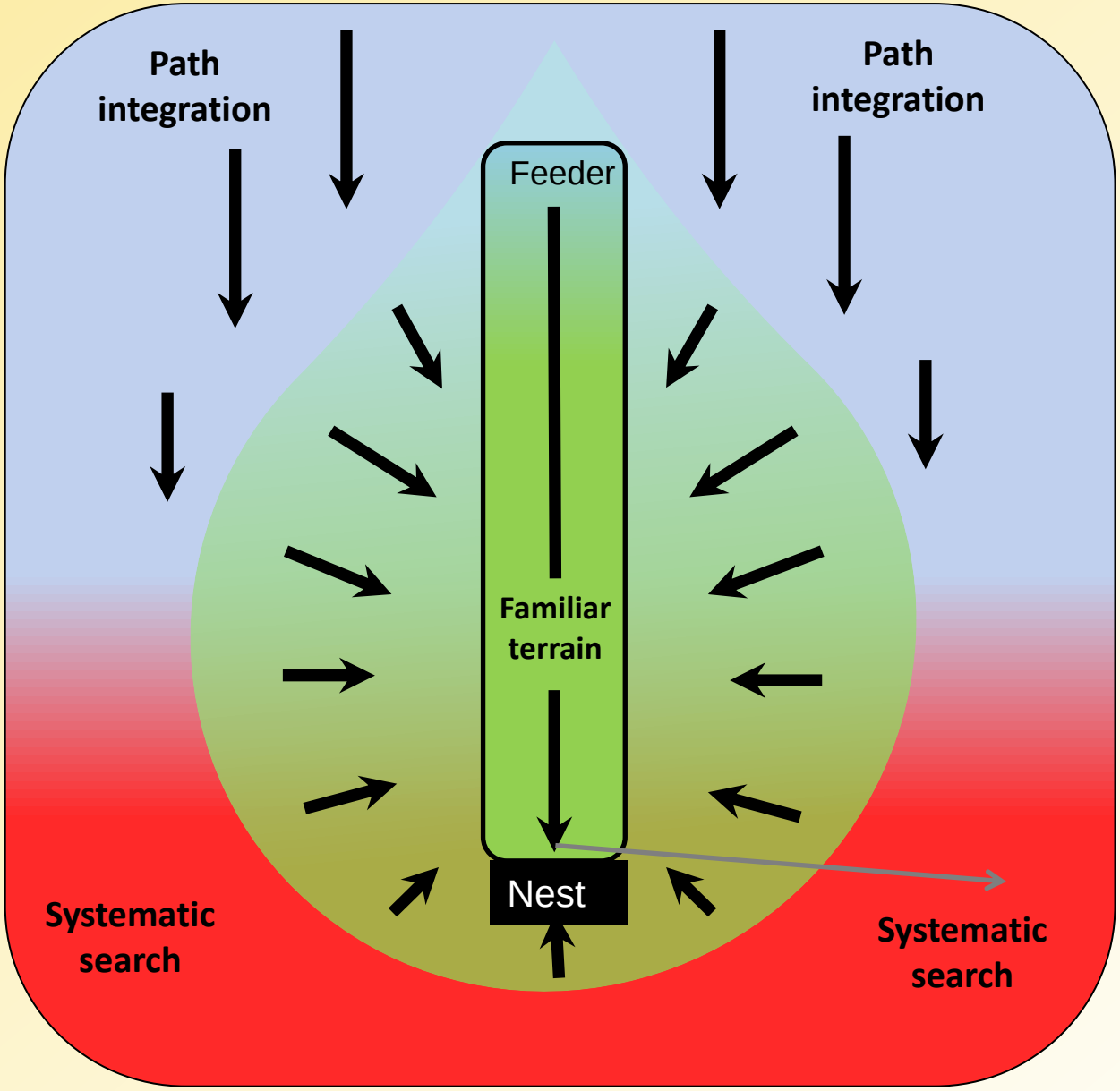
continuous



Path Integration

Vector length

Visual scene navigation

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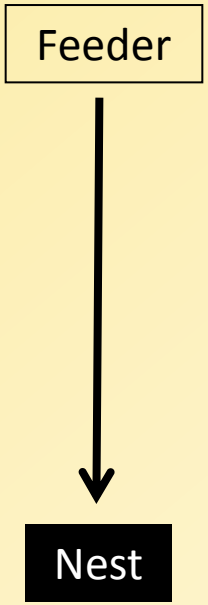
continuous

What ants do when they are lost ?



Wystrach et al. in prep

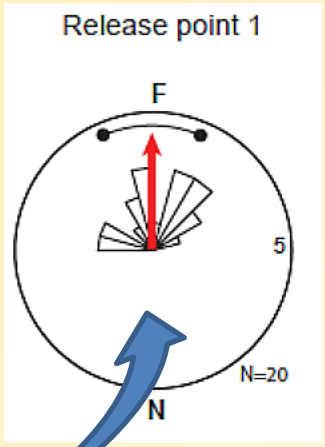
What ants do when they are lost ?

Distant release points: unfamiliar environment

Feeder

Nest

Zero vector



?

Path Integration
Vector length

Visual scene navigation
Current Familiarity

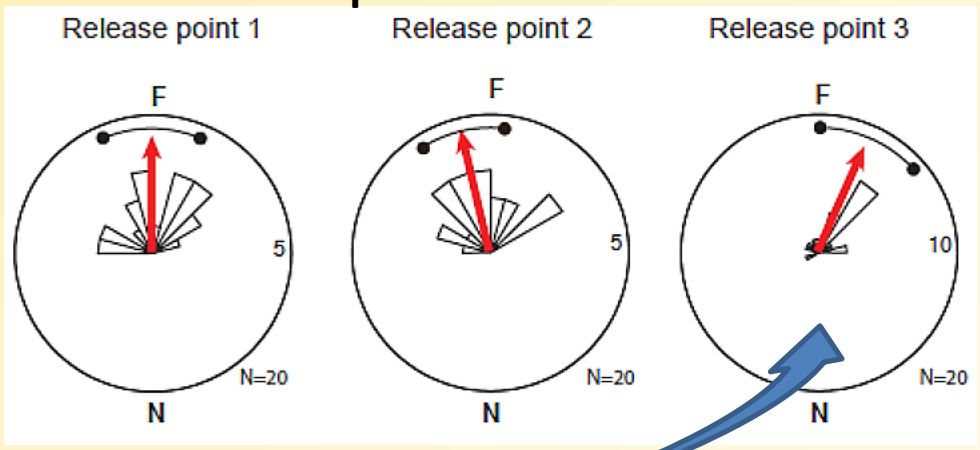
Systematic Search
continuous

Behavior

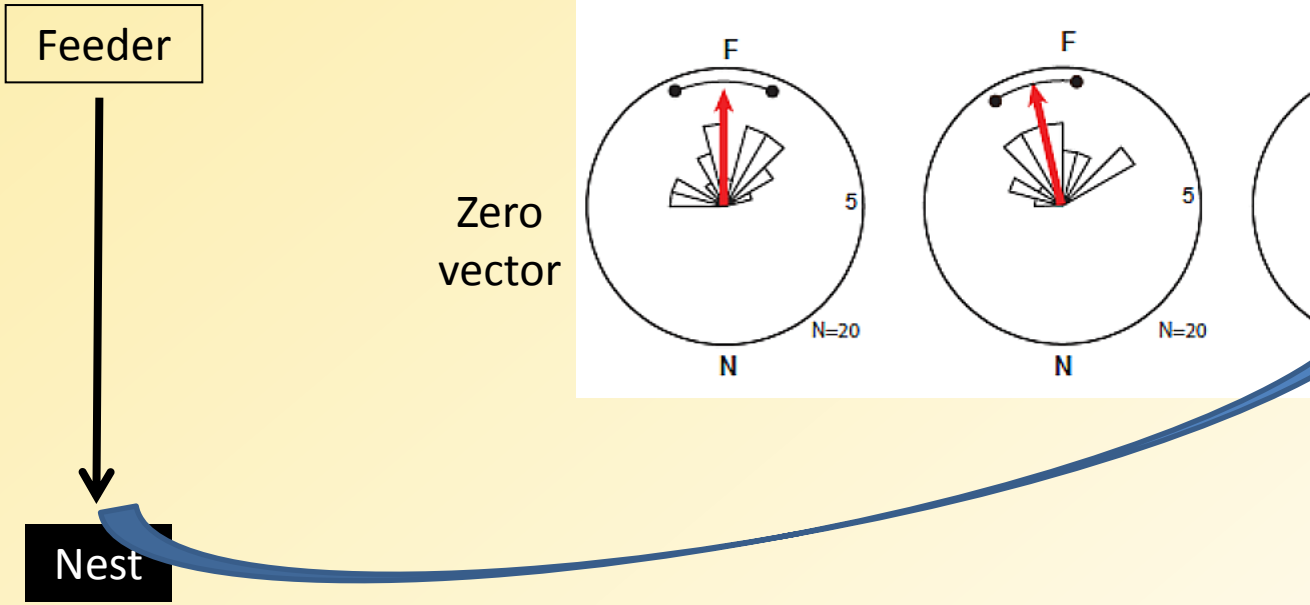
Wystrach et al. in prep

What ants do when they are lost ?

Distant release points: unfamiliar environment

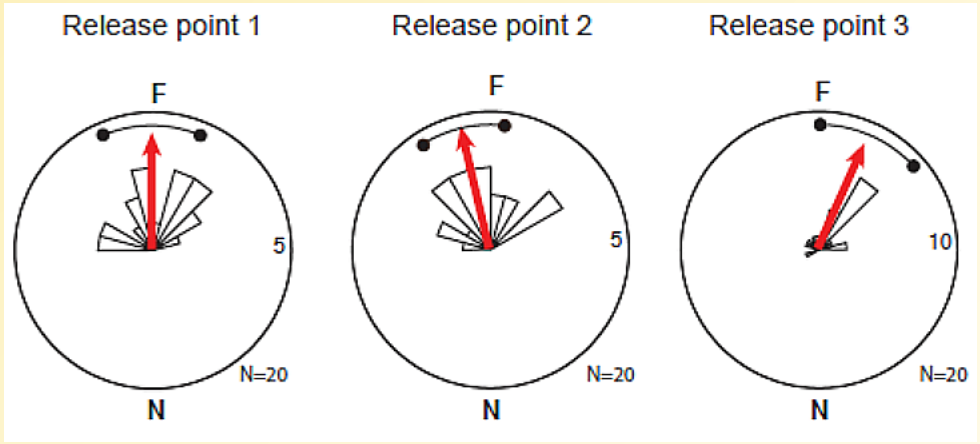


Zero vector

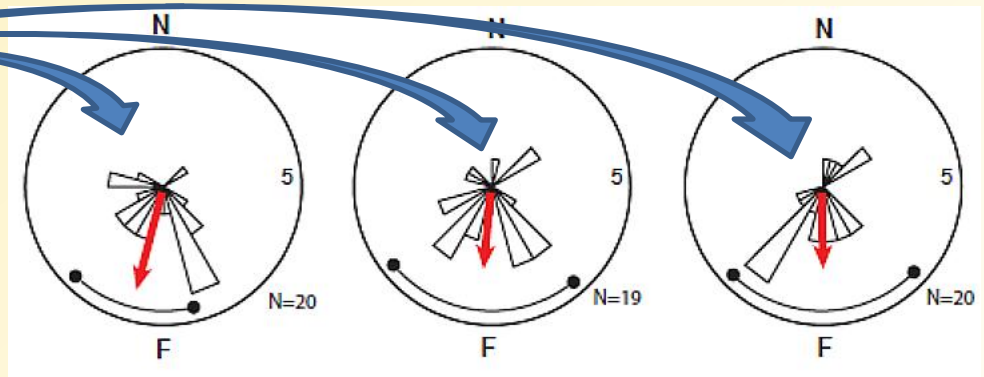


Wystrach et al. in prep

Distant release points: unfamiliar environment



Zero vector



Zero vector

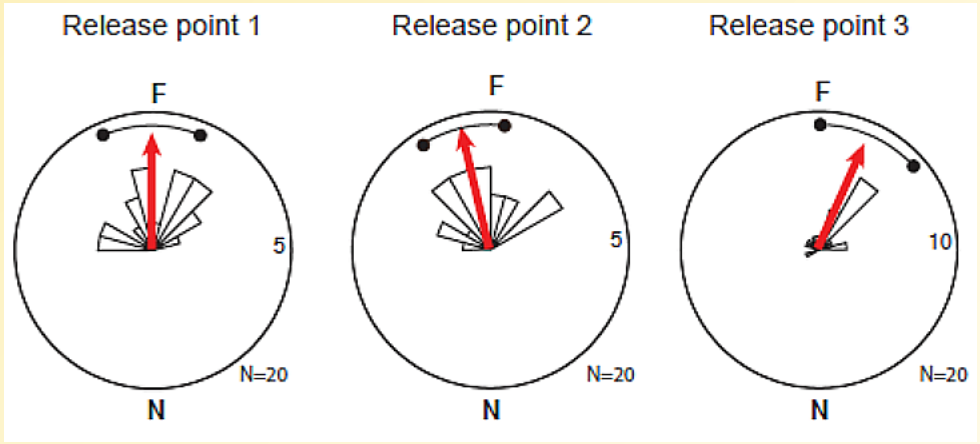
Nest

Feeder

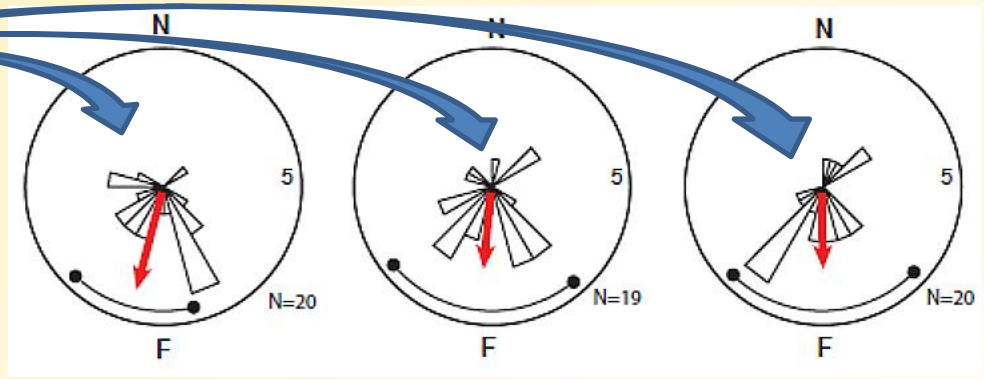
Wystrach et al. in prep

Backtracking

Distant release points: unfamiliar environment



Zero vector



Zero vector

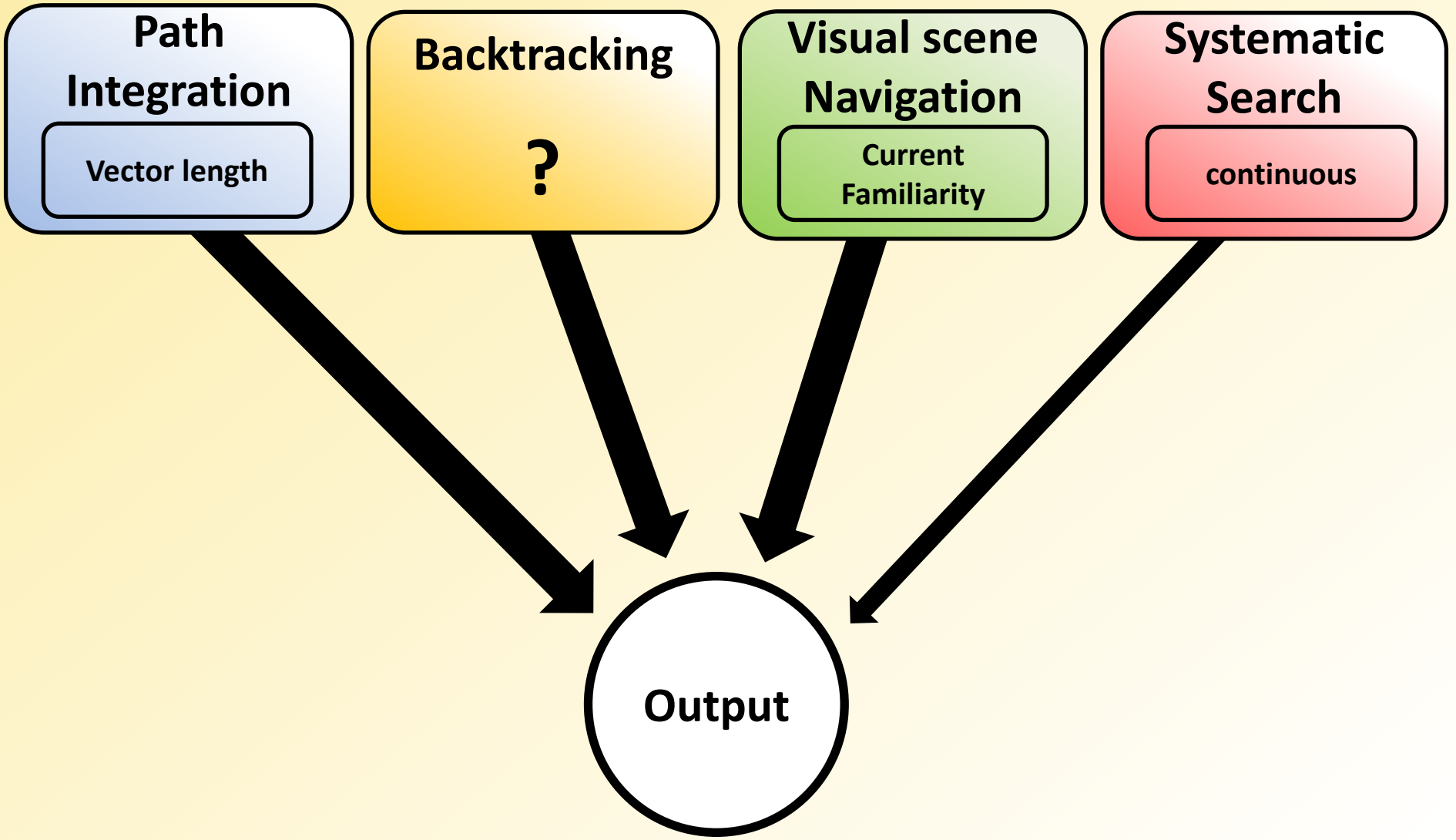
Nest

Feeder

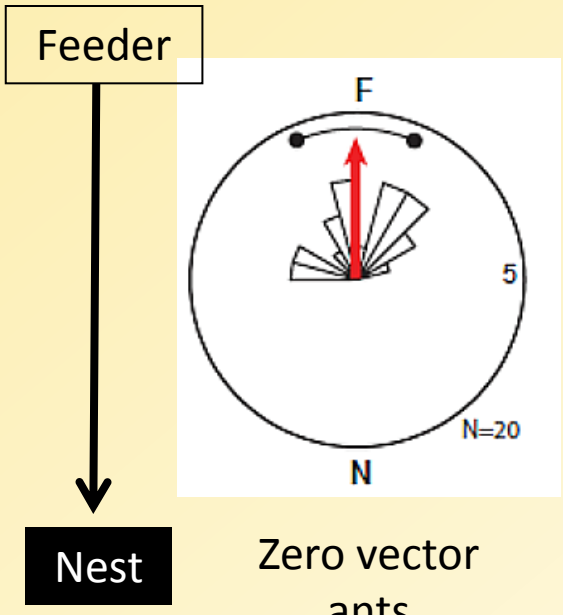
Zero-vector ants backtrack towards the feeder

Wystrach et al. in prep

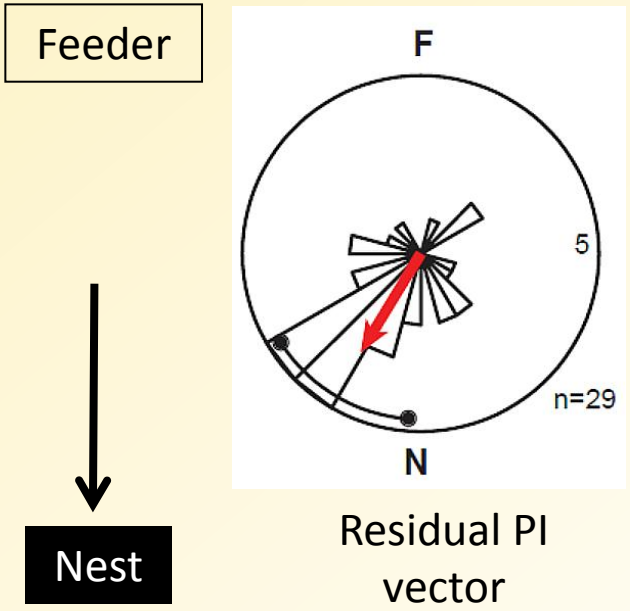
When do ants backtrack ?



When do ants backtrack ?



Zero vector ants



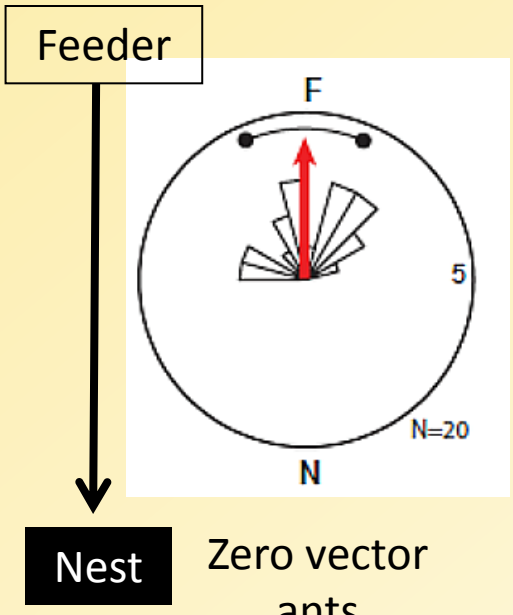
Residual PI vector

- On unfamiliar terrain…

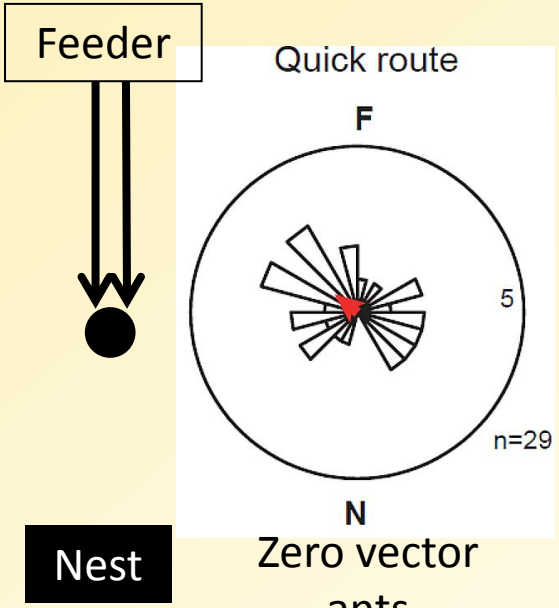
- When PI vector is small…

Wystrach et al. in prep

When do ants backtrack ?

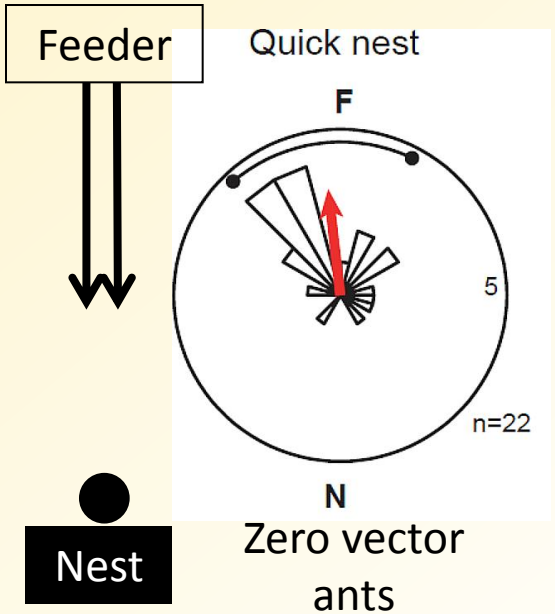


Zero vector ants



Zero vector ants

Recent view of the nest vicinity!

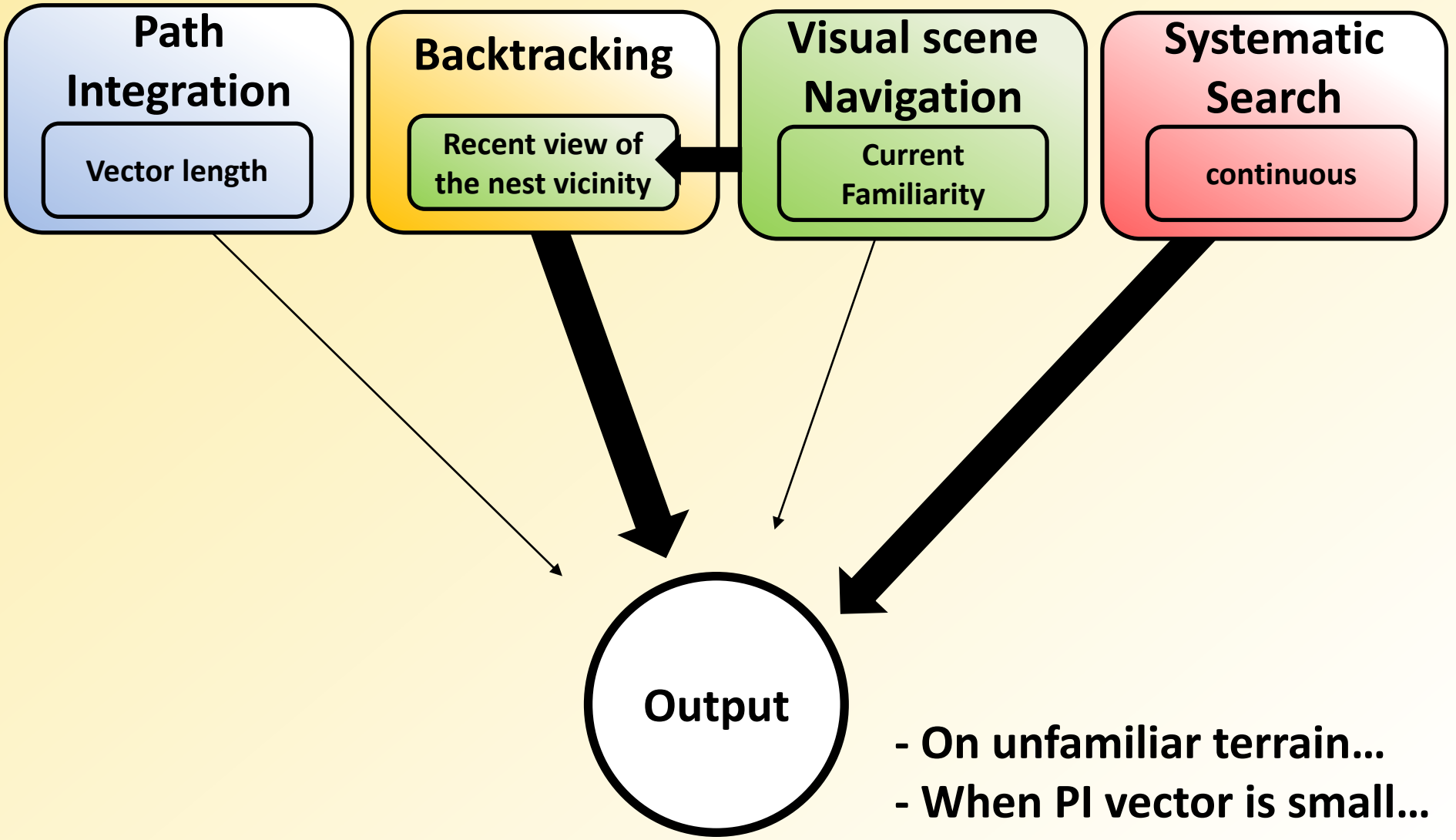


Zero vector ants

- On unfamiliar terrain…
- When PI vector is small…
- Recent view of the nest vicinity

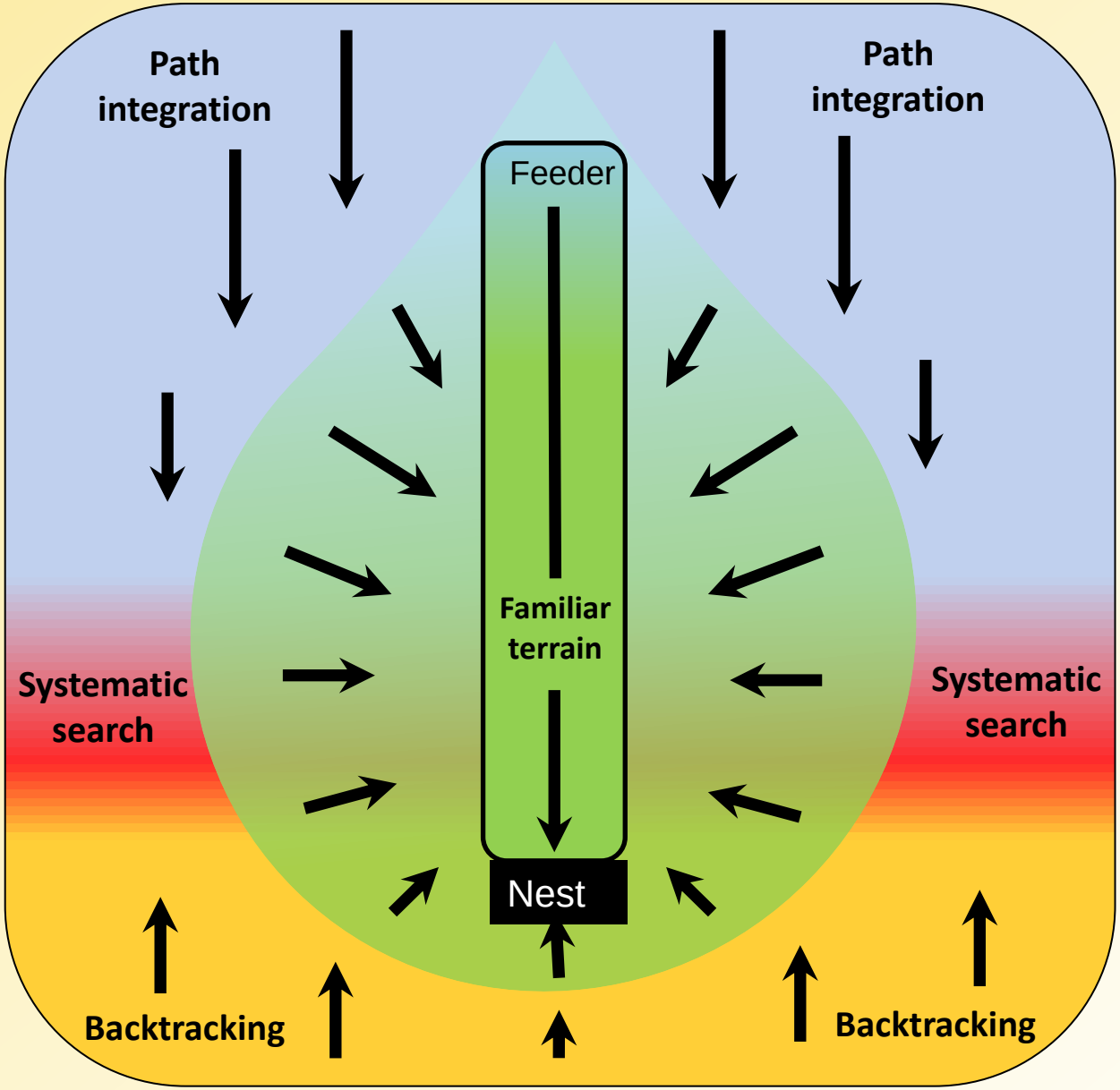
Wystrach et al. in prep

When do ants backtrack ?



- On unfamiliar terrain…
- When PI vector is small…
- Recent view of the nest vicinity

Robust !



Path Integration

Vector length

Visual scene navigation

Current Familiarity

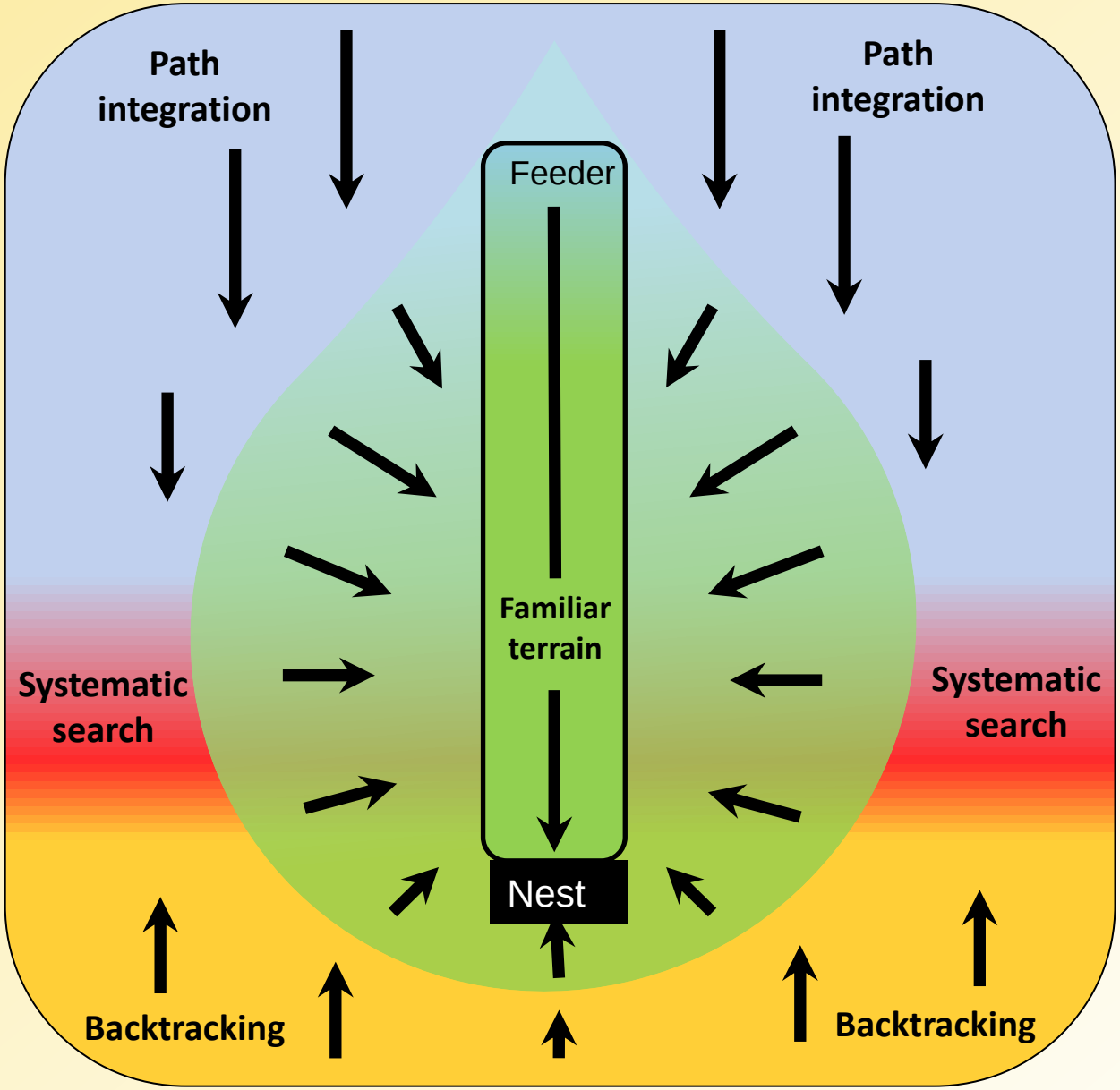
Systematic Search

continuous

Backtracking

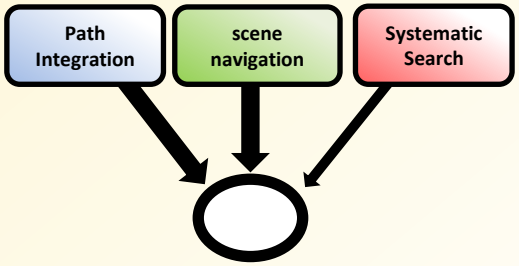
Recent view of the nest vicinity

Robust !



Complex Decision making ?

A distributed system with simple interactions

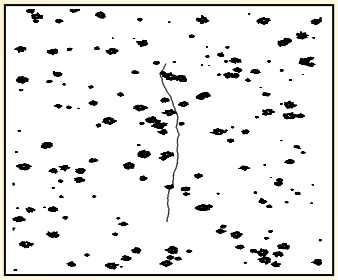


No need of a higher representation

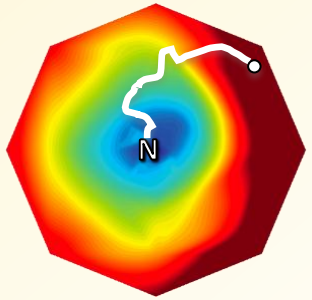
Simple solutions behind apparently complex behaviour

Exploit complex visual information without landmark recognition

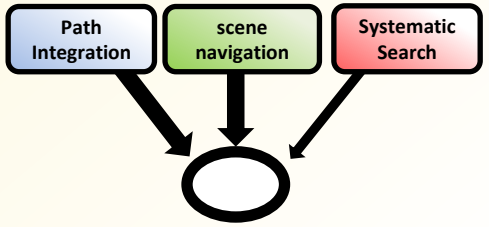
Follow complex routes without positional knowledge



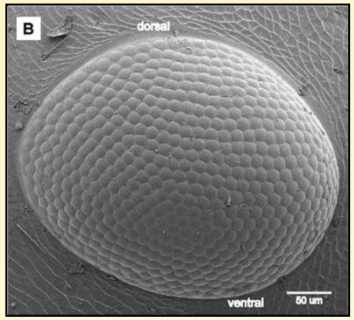
Home from novel locations without cognitive map



Complex decision making without higher representations



What is their ecological problem ?
How do they solve it?



Animal's Umwelt

Bottom-up

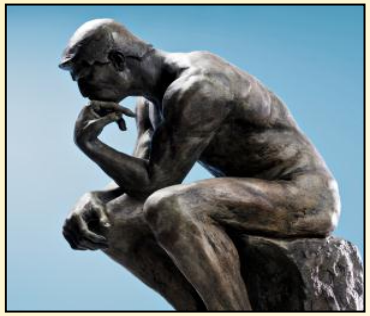
Chittka et al., 2012

Wystrach and Graham, 2012

CONCLUSION

Top-Down

Human way of seeing the world



(Landmarks)

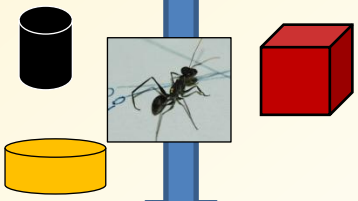
(Cognitive map)

Hypotheses

Literature

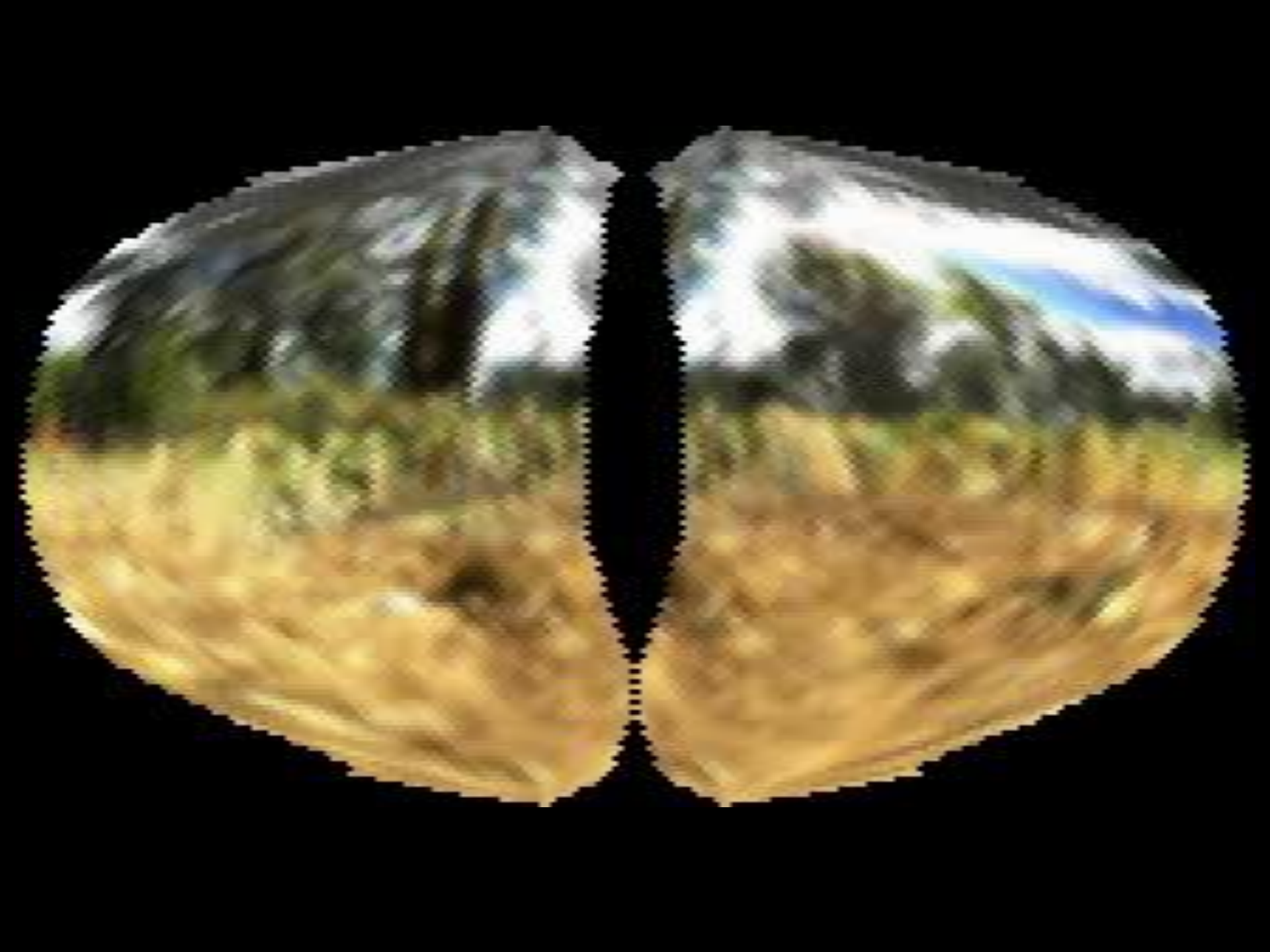
Insects use landmarks!

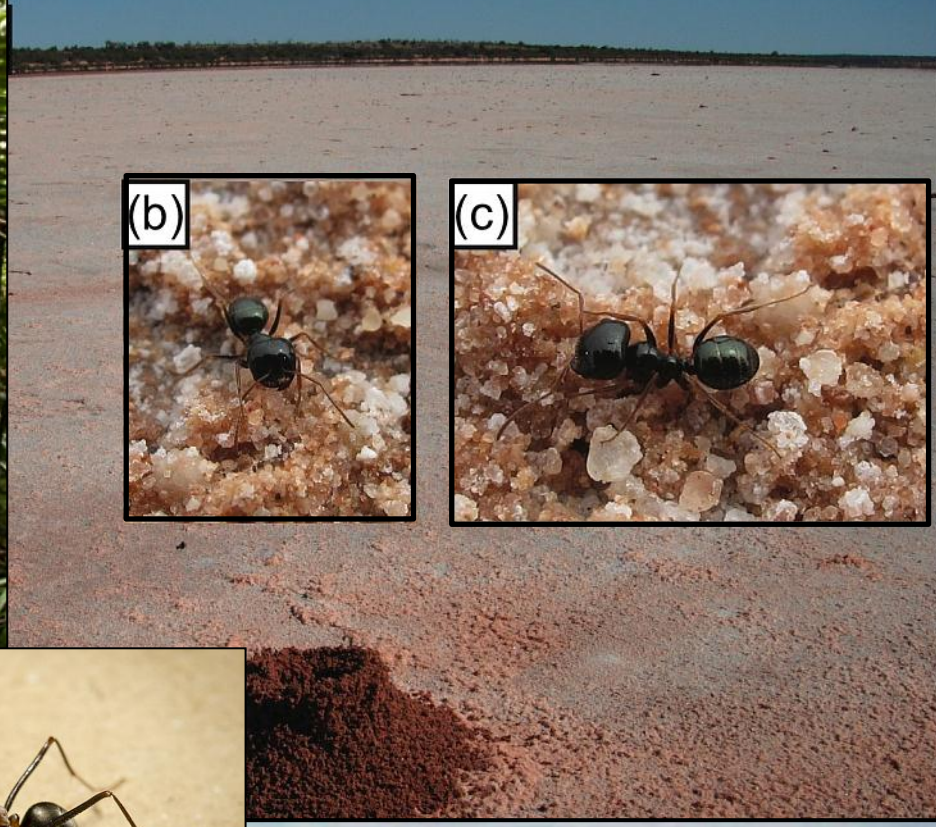
Behavioural criterion



Result

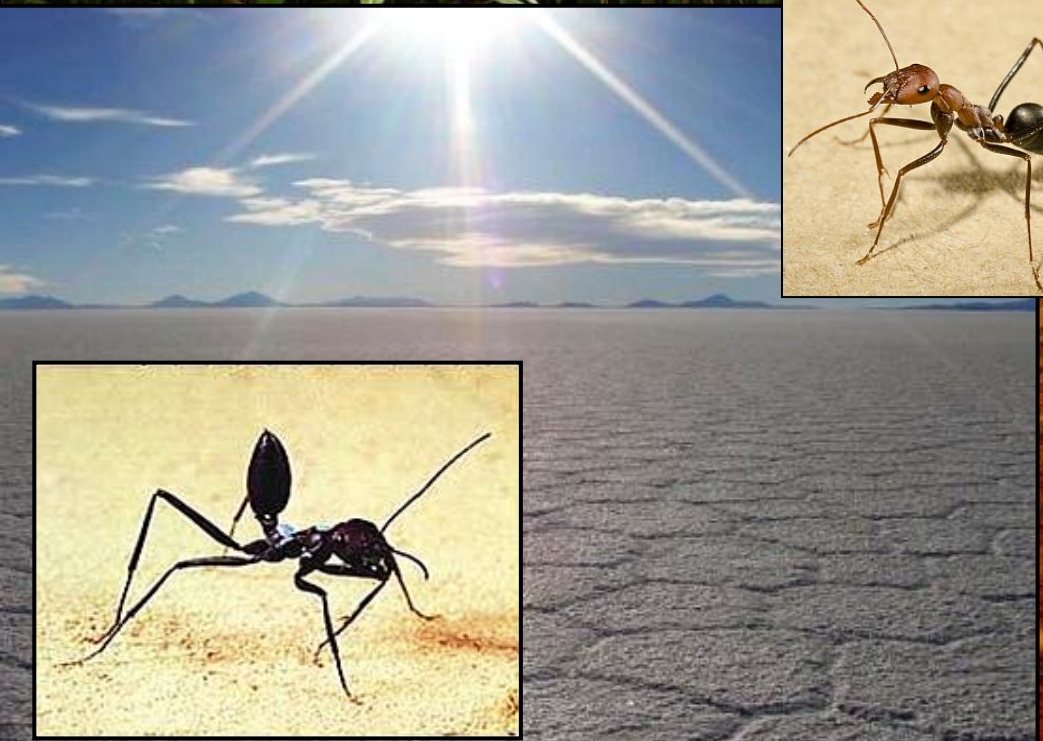
Insects use landmarks!





(b)

(c)



Thanks

Sebastian Schwarz

Patrick Schultheiss

Alice Baniel

Ken Cheng

Paul Graham

The ants

you

Michael Mangan

Bart Baddeley

Andy Philippides