



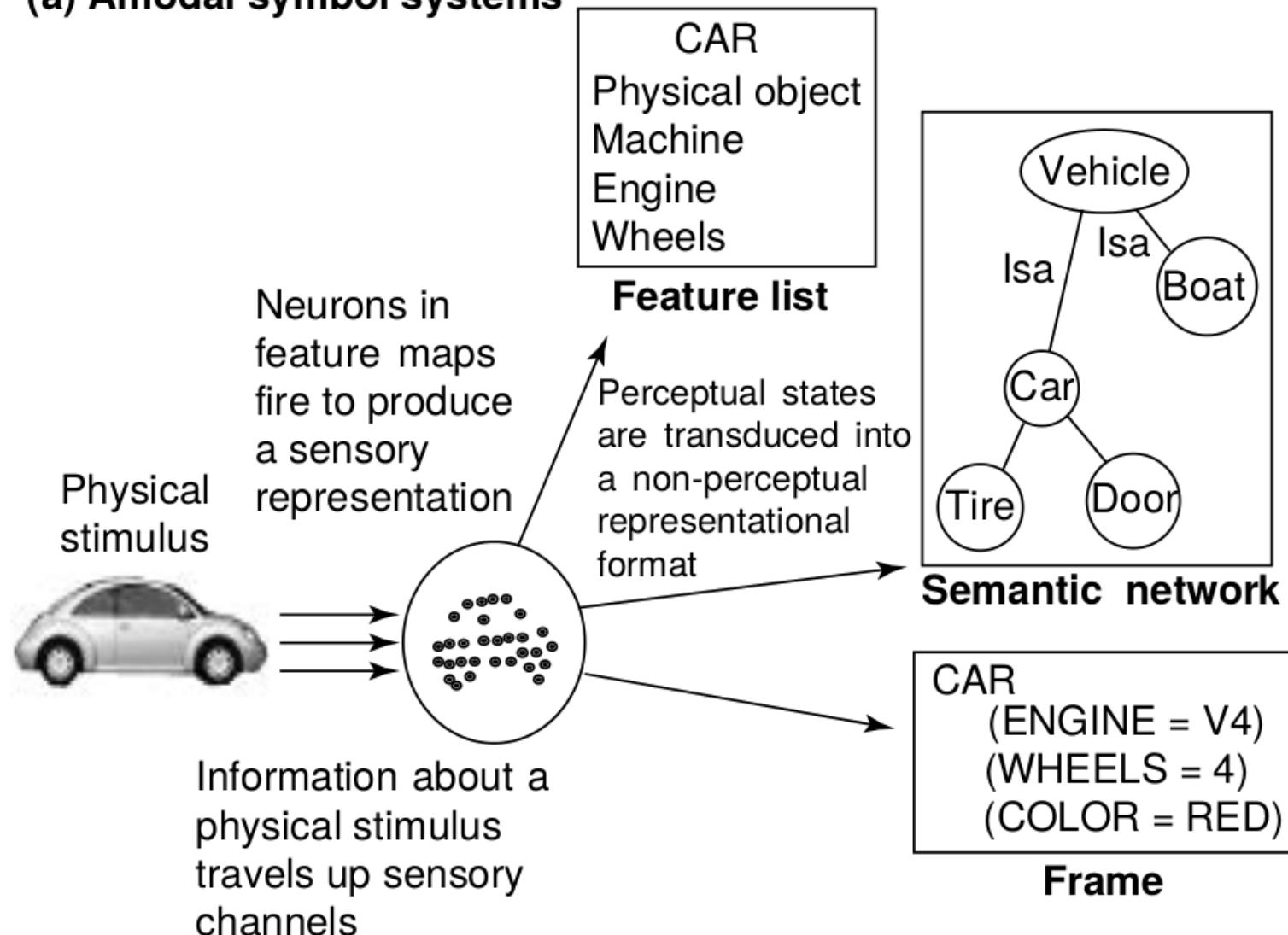
# Mental imagery and simulation

BCS 153, Spring 2018



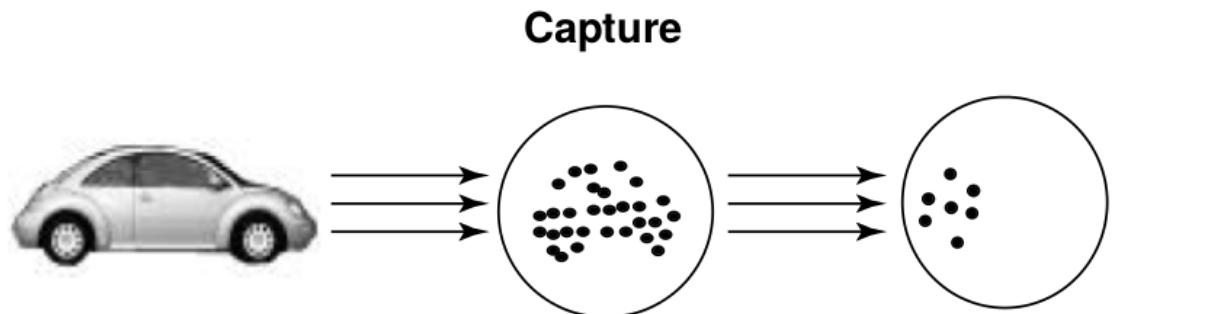
# Amodal symbol systems

(a) Amodal symbol systems



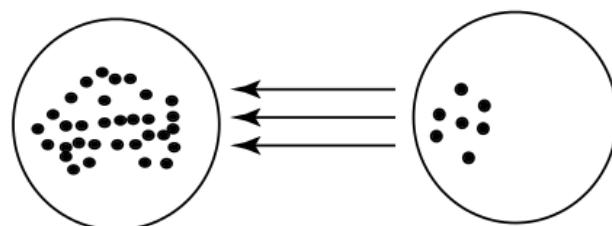
# Perceptual symbol system

## (b) Perceptual symbol systems



Physical stimulus	Information travels up sensory channels	Neurons in feature maps fire to produce a sensory representation	Conjunctive neurons in an association area capture the sensory representation
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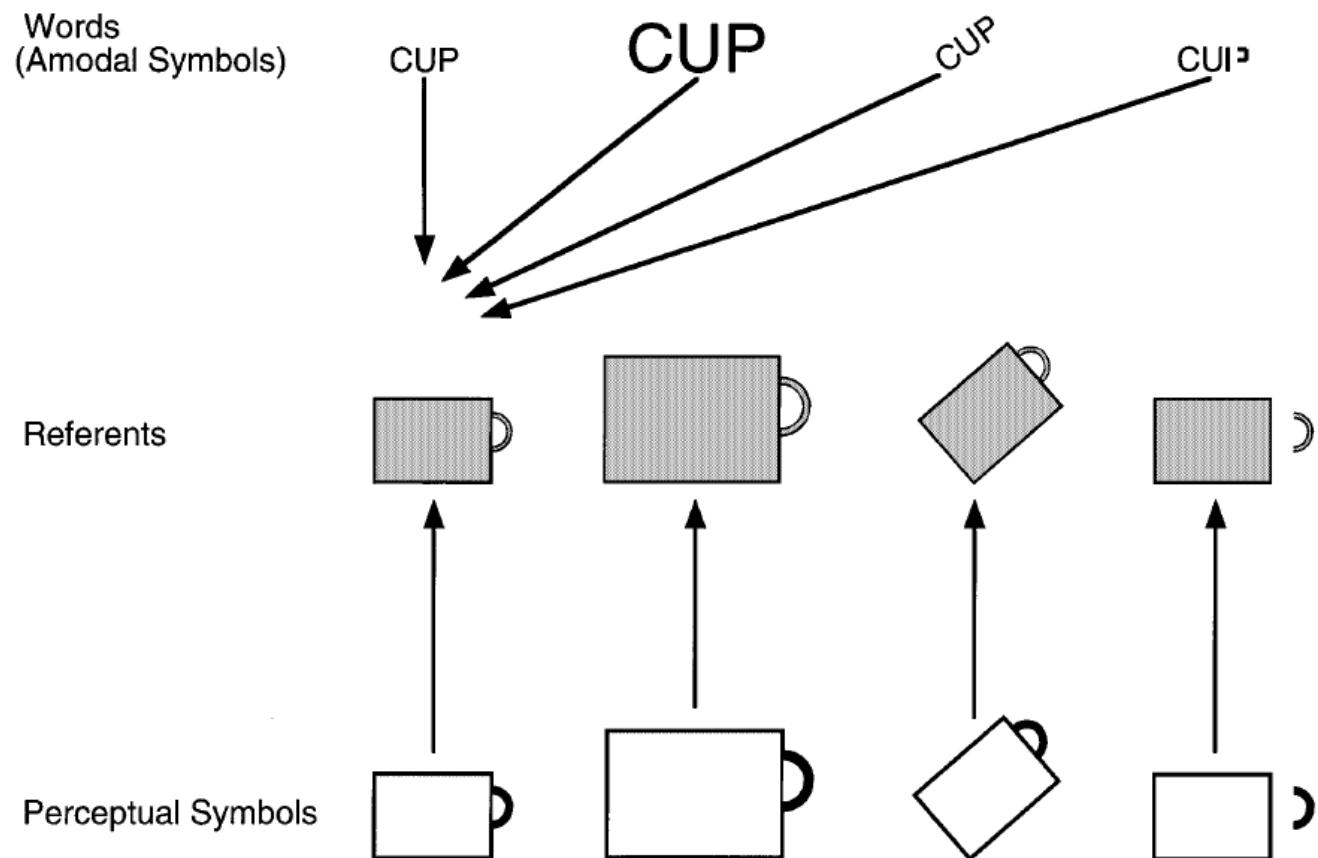
## Re-enactment / simulation



Neurons in feature maps fire to reenact the earlier sensory representation	Conjunctive neurons in the association area fire to partially reactivate the earlier sensory representation
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# **Perceptual symbol system**

- A highly-interactive representation where concepts require (partial) re-activation of sensory and motor representations.



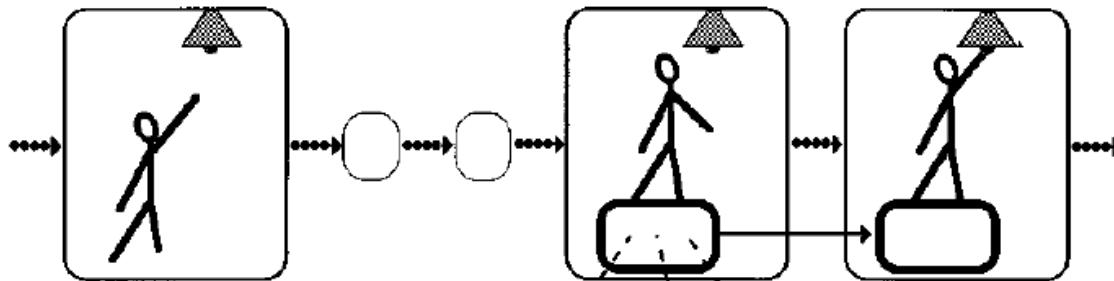
# **Perceptual symbol system**

- **A highly-interactive representation where concepts require (partial) re-activation of sensory and motor representations.**
  - Concepts can involve simulation, highly context-dependent

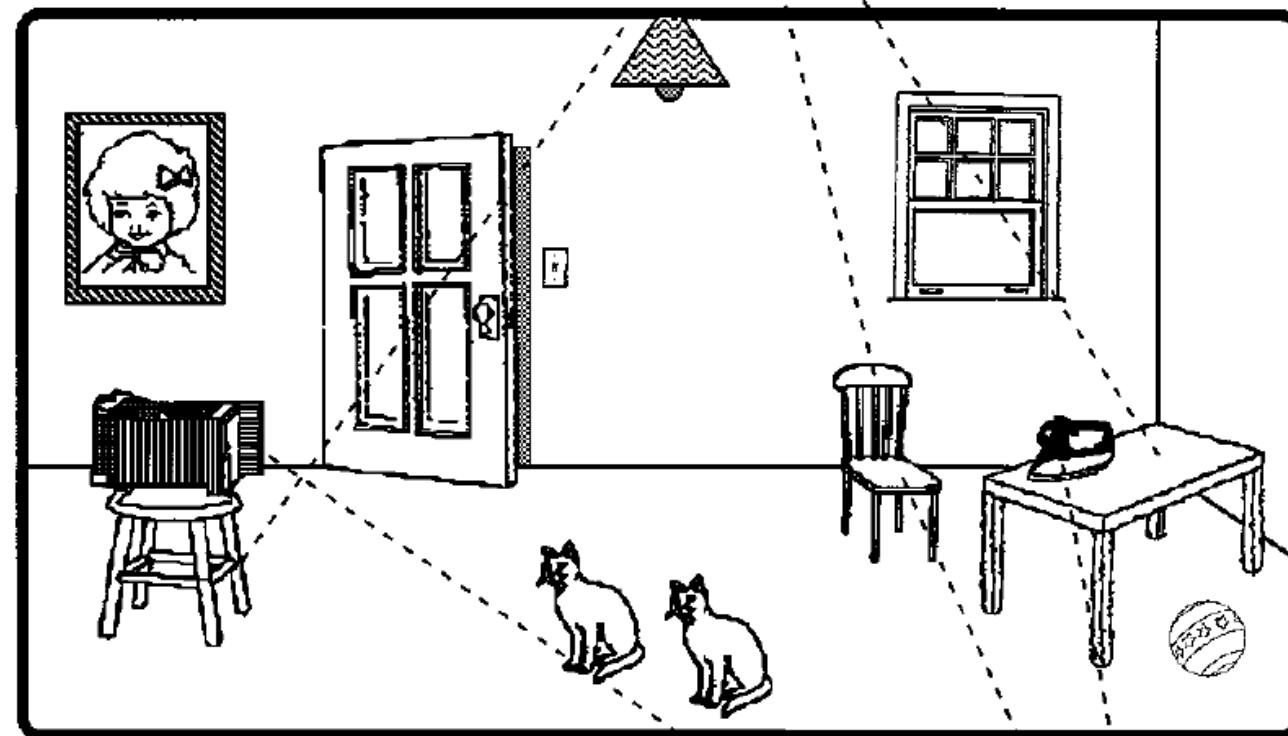
# **Think about ad hoc categories...**

- Consider the category of things you could stand on to change a lightbulb...**

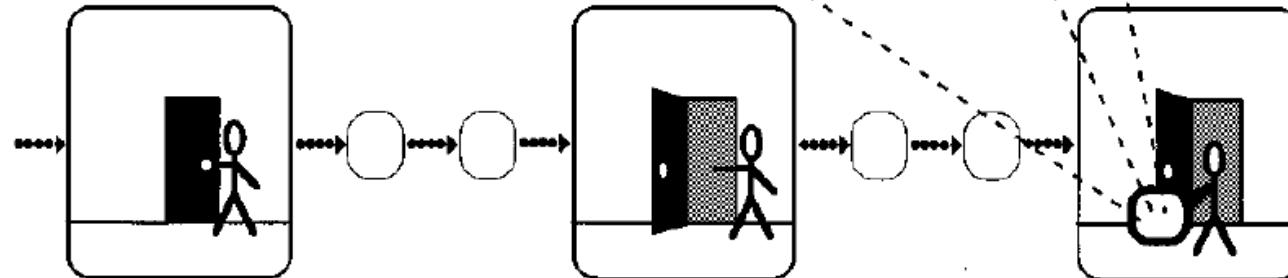
A



B



C



# So...

- **Simulation-based concepts could address the puzzle of ad-hoc concepts**
  - They require us to simulate the world, rather than recall some stored conceptual knowledge.

# **Some experiments**

# Vallee-Tourangeau et al. (1998)

- Asked people to generate instances of a category (e.g. fruit) and answer *how they came up with them*.
  - Analyze the responses:
    - Experiential – memories of specific personal experiences
    - Semantic – abstract conceptual characteristics
    - Unmediated – you just do it
  - Experiential outnumbers semantic, 4-to-1, even for ad-hoc categories.
    - Evidence against abstraction in conceptual knowledge.

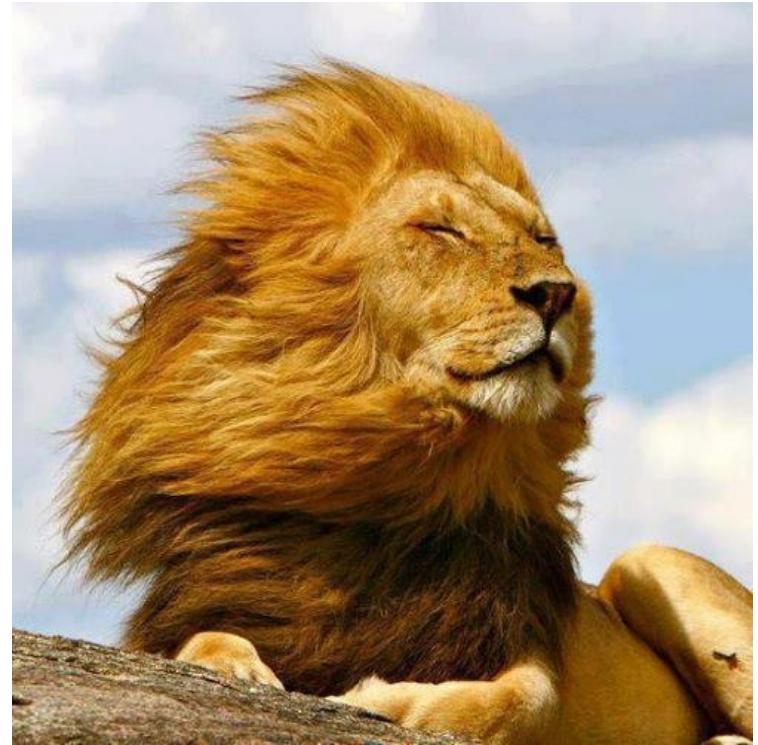
# **Wu (1995)**

- **Subjects asked to describe concepts (e.g. watermelon, lawn, face, etc.) with either**
  - “construct an image for this concept and describe it...”
  - “list the characteristics typically true of a concept...”

→ **Similar features are described**
- **Asked subjects to describe features either for nouns (e.g. watermelon), or noun phrases (e.g. half watermelon) that make the internal features salient.**
  - These noun phrases changed the listed features to highlight internally-available information (e.g. black seeds)

# Solomon & Barsalou (1996)

- **Feature-verification task:** “Does a pony have a mane?”
- Prediction:
  - **Fast:** mane-for-horse → mane-for-pony
  - **Slow:** mane-for-lion → mane-for-pony
  - Why?
    - Mane-for-horse activates the right perceptual category – pony and horse manes are similar
    - Mane-for-lion activates the right abstract feature, but the wrong perceptual category since lion and pony manes look different.



# Solomon & Barsalou (1996)

Condition	Example of a sequence		RT (errors)
Similar parts	PONY-mane	HORSE-mane	725 (2%)
Dissimilar parts	LION-mane	HORSE-mane	778 (5%)

# Solomon & Barsalou (1996)

Condition	Example of a sequence		RT (errors)
Similar parts	PONY-mane	HORSE-mane	725 (2%)
Dissimilar parts	LION-mane	HORSE-mane	778 (5%)
Similar categories	PONY-back	HORSE-back	691 (4%)
Dissimilar categories	LION-back	HORSE-back	695 (2%)

# Lesion studies

- **Lesions in sensory/motor areas can lead to apparent conceptual deficits (see Barsalou 2010).**

Area → Concept

- Visual area → LIVING THING
- Motor areas → MANIPULABLE ARTIFACT, TOOLS
- Color → Color knowledge
- Spatial processing → location knowledge

# Arguments against

- It seems like concepts can't be picture-like because that would require determinate visual features (e.g. the number of stripes on a tiger) (Dennett 1969)

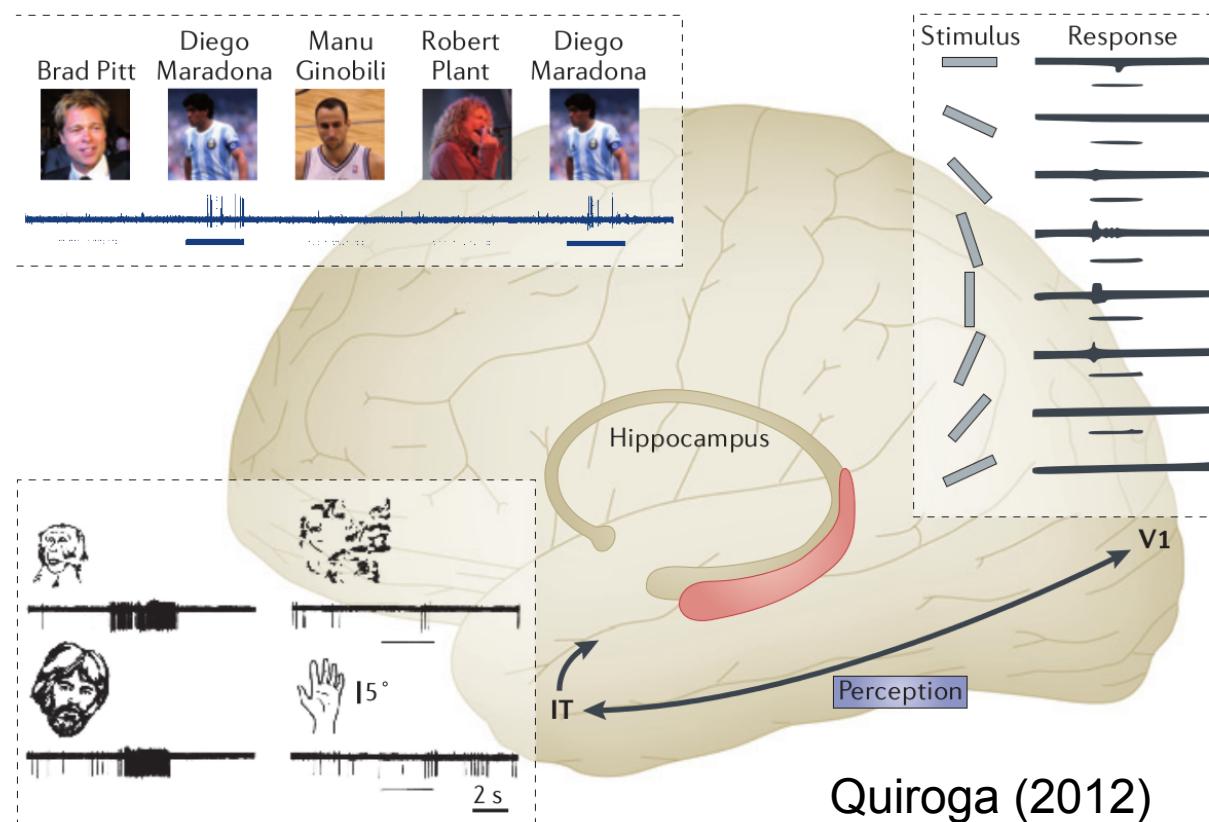


# Arguments against

- It seems like concepts can't be picture-like because that would require determinate visual features (e.g. the number of stripes on a tiger) (Dennett 1969)
- How do you represent the necessary abstractness? There is no perceptual analog of “all triangles have 3 sides”
- Don't you still need a language/formalism for expressing the simulations and relations between elements?
- Existence of high-level, amodal response cells.

# Quiroga et al. (2009)

- Multimodal responses of neurons in medial temporal lobe.



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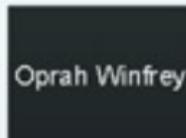
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11



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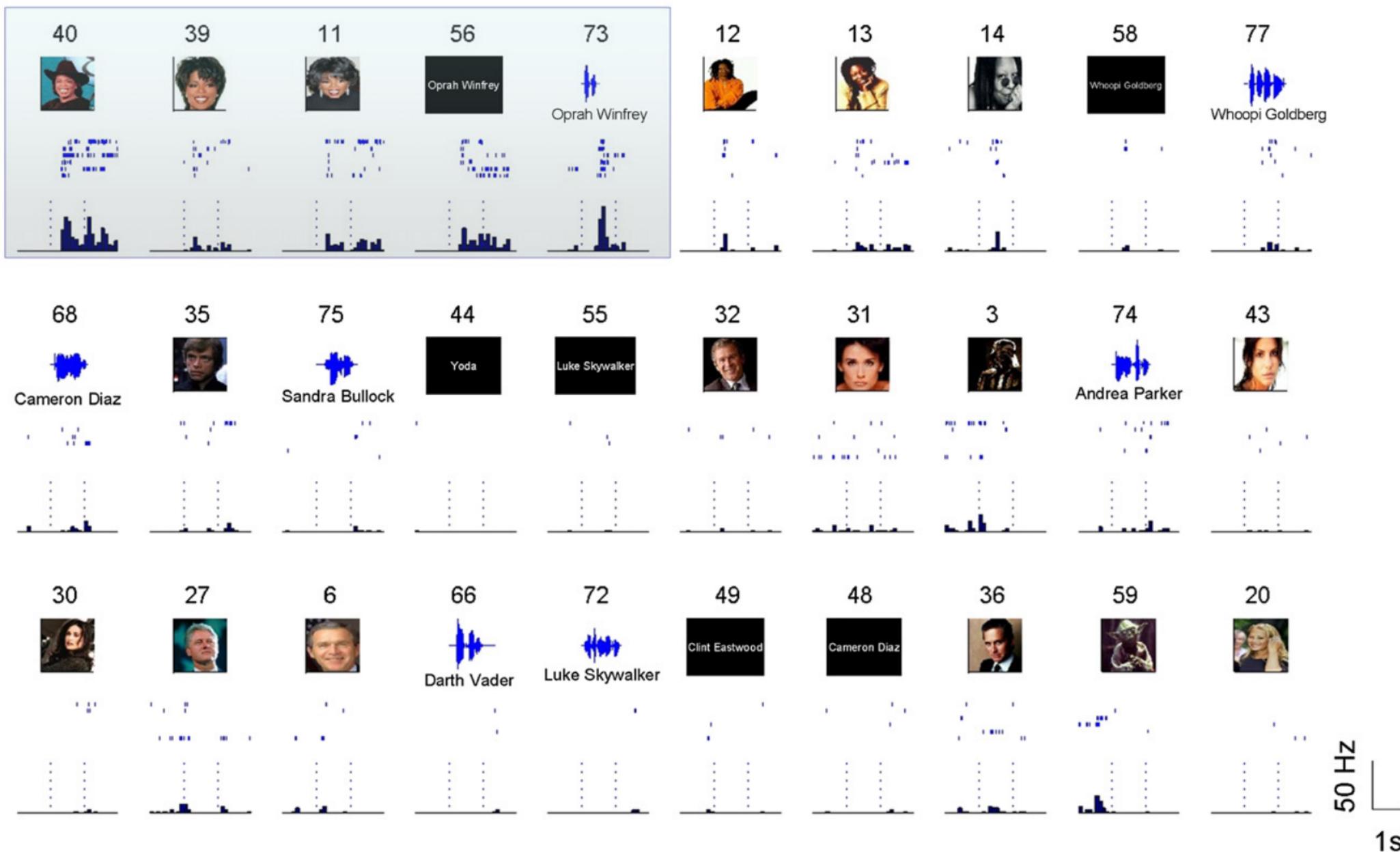


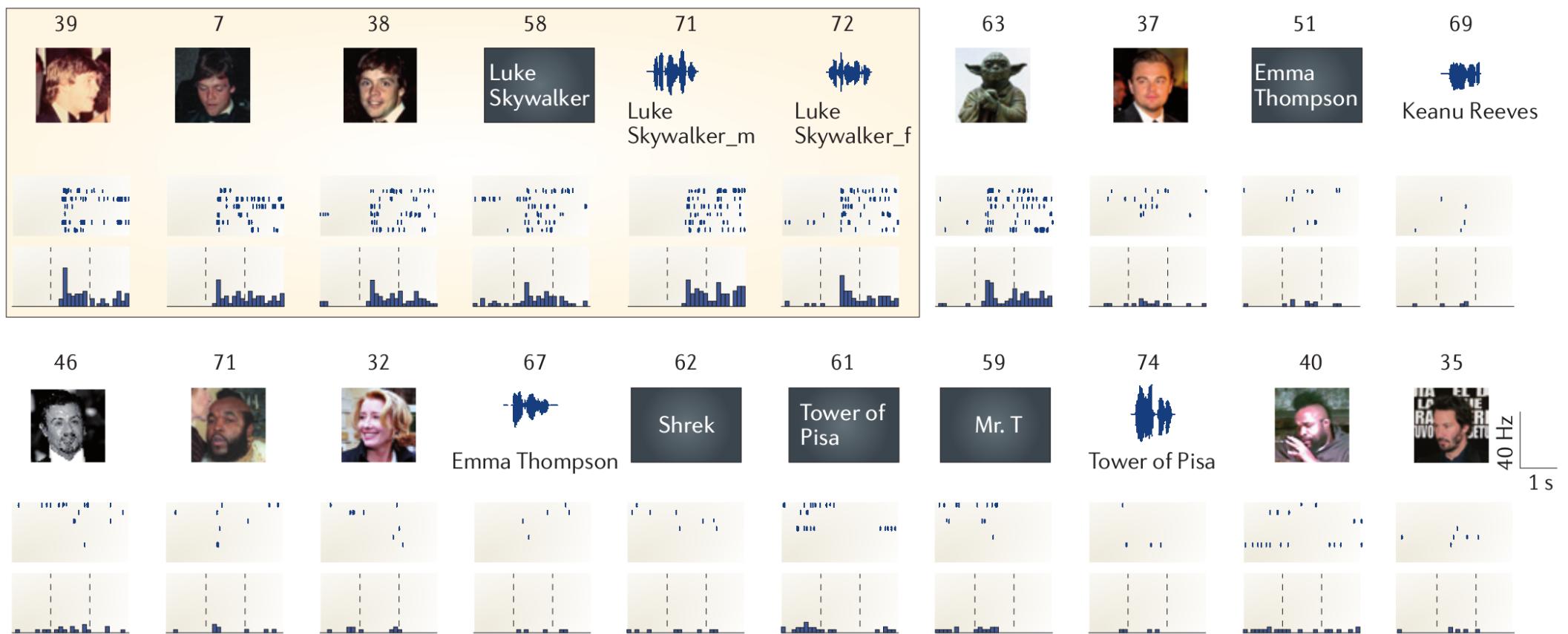
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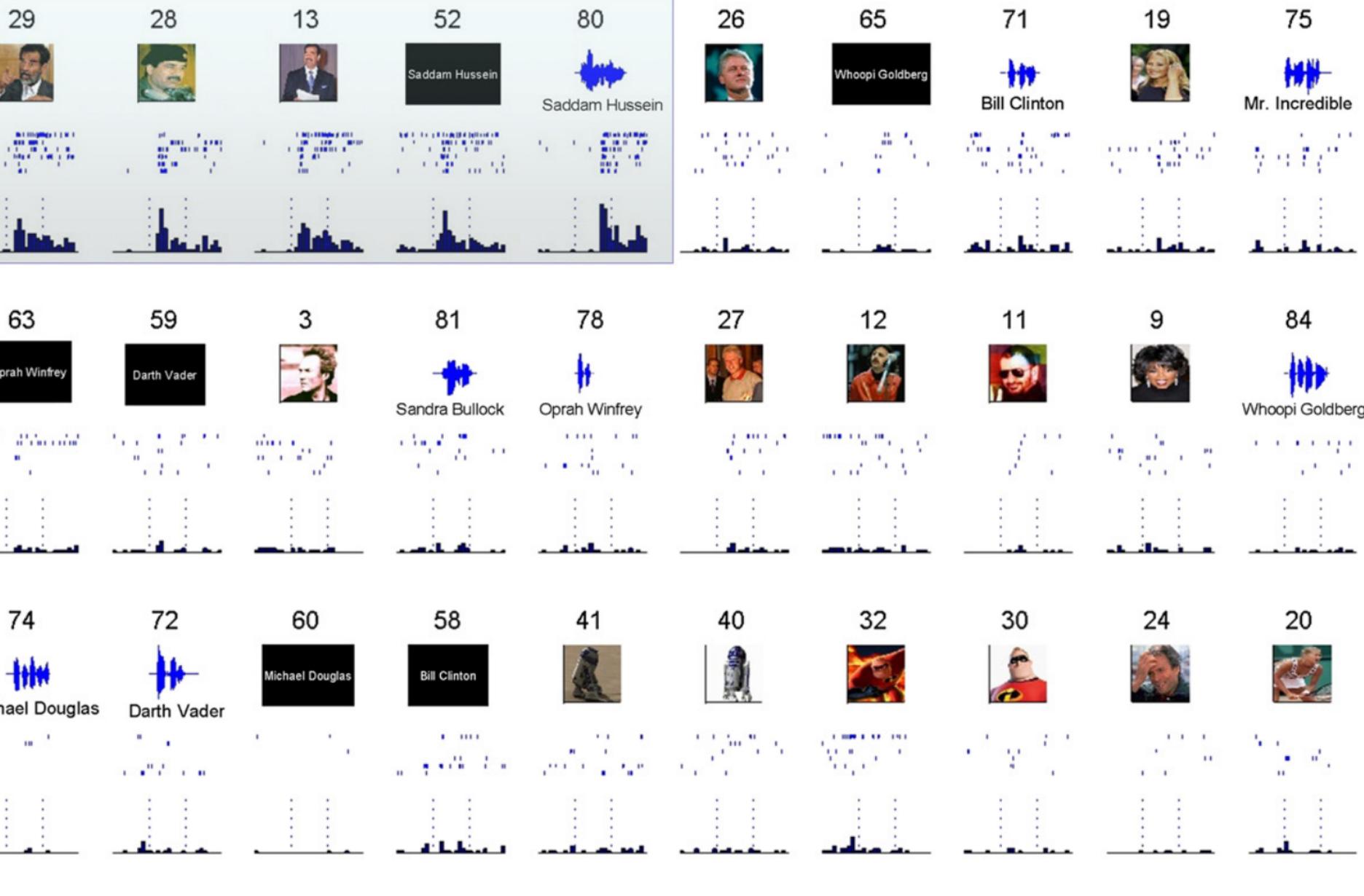


Oprah Winfrey

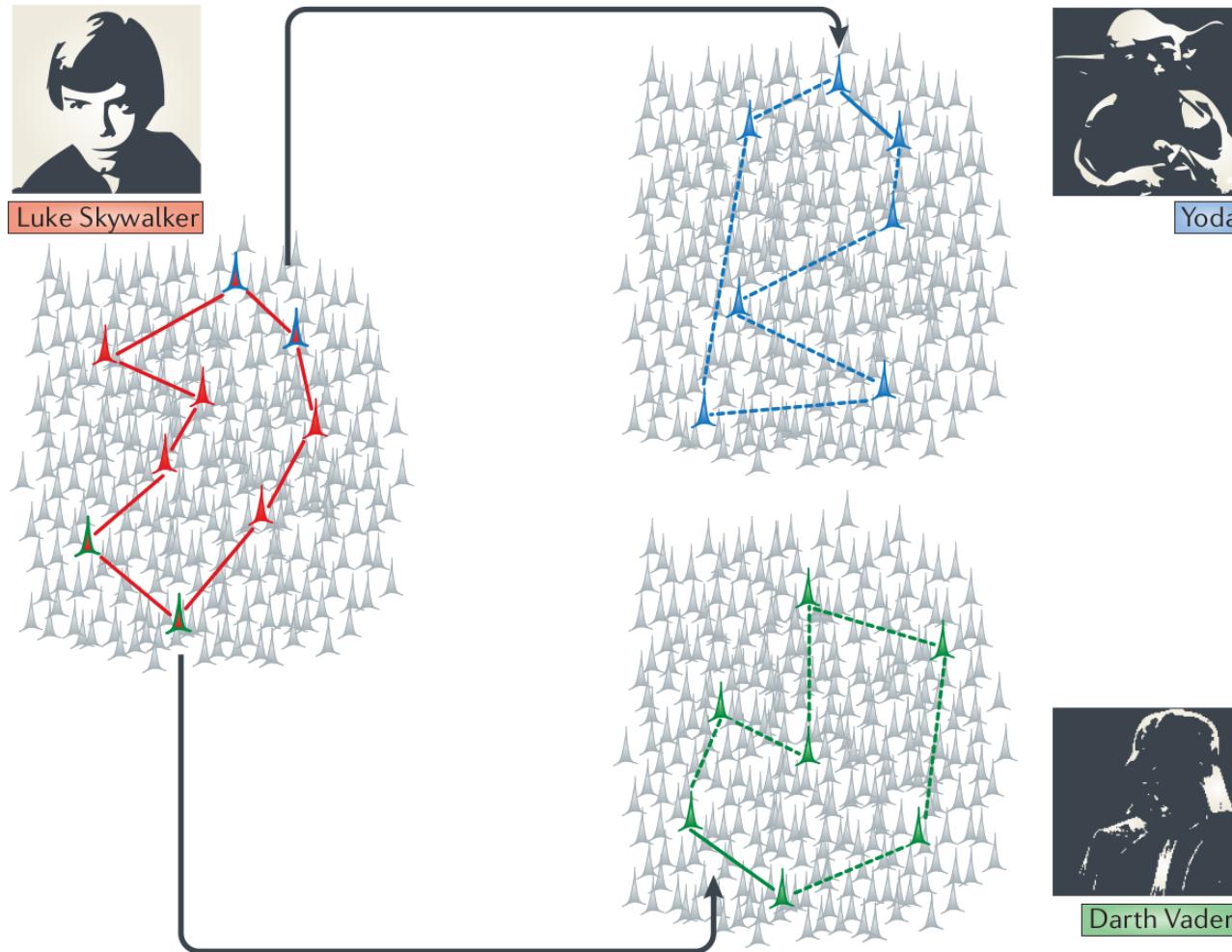








# Sparse coding of concepts



Quiroga (2012)



# The mental imagery debate

- **Kosslyn** – the brain works with picture-like representations
- **Plyshyn** – propositional (logical) representations can get the same thing



*Figure 2.* The fictional map used in Experiment 2.

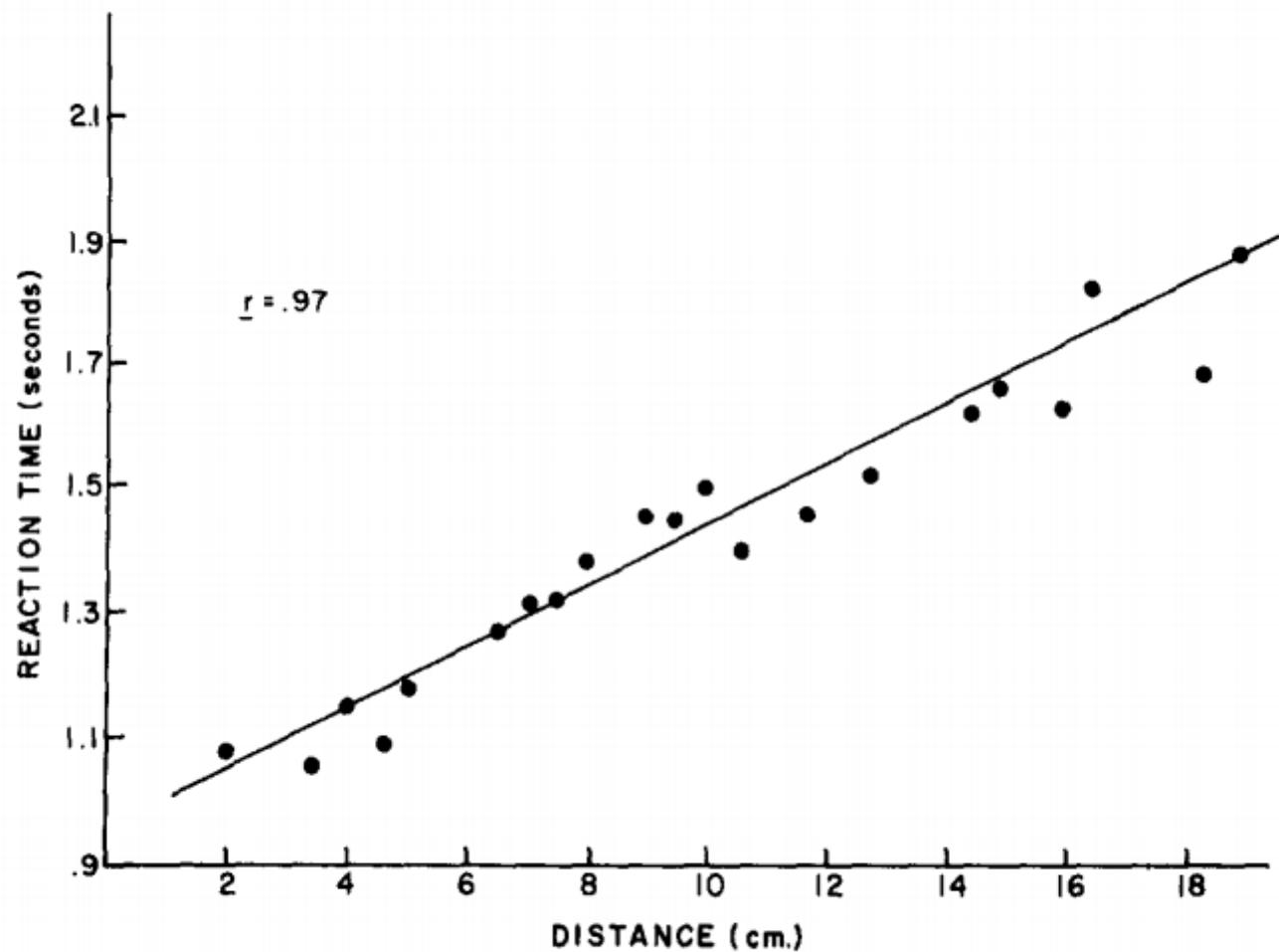


Figure 3. The results of Experiment 2: Time to scan between all pairs of locations on the imaged map.

# Alternatives?

- **What about a propositional representation?**

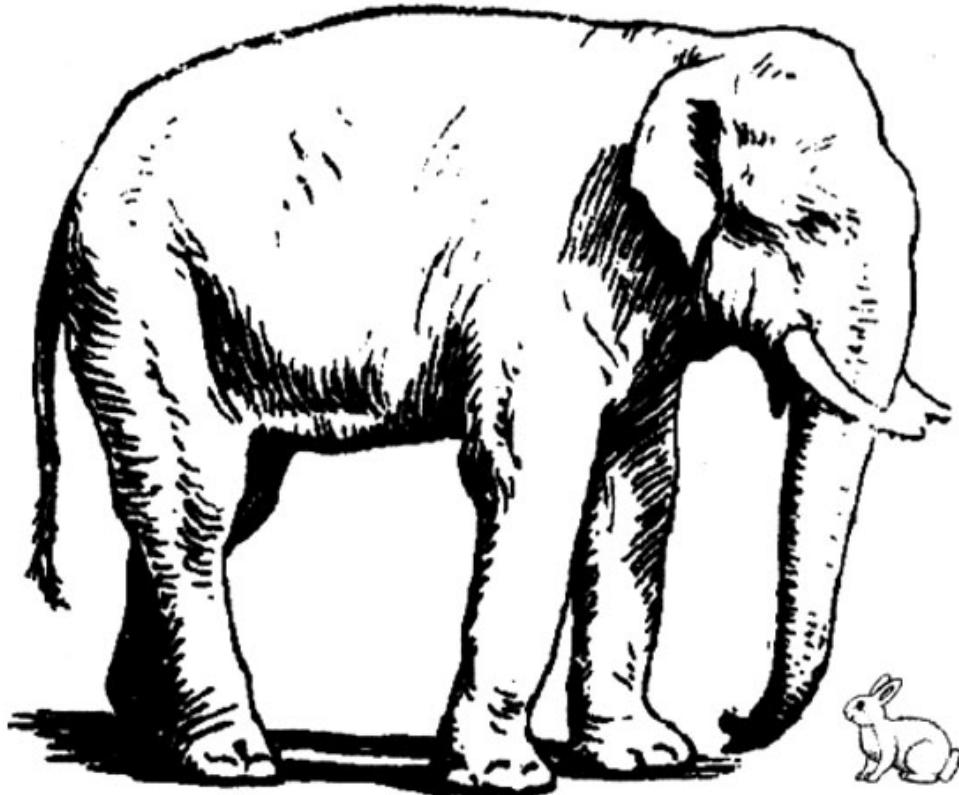
ADJACENT(A,B)

ADJACENT(B,C)

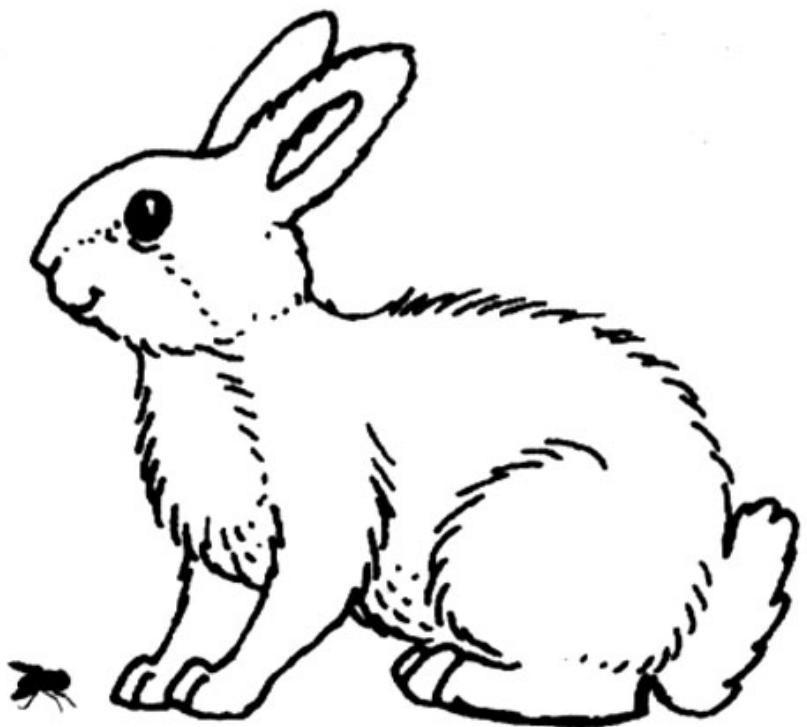
ADJACENT(C,D)

Could yield slower times in  $A \rightarrow D$  than  $A \rightarrow C$

Rabbit beside an elephant

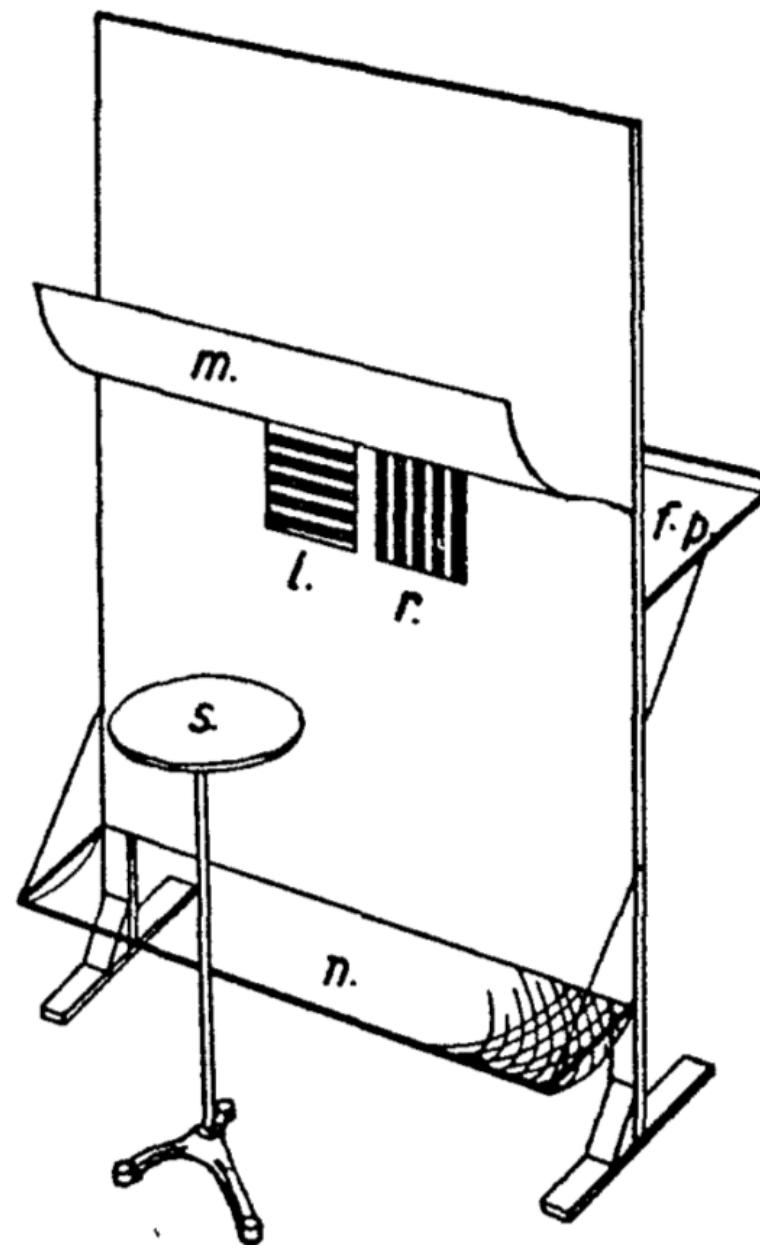


Rabbit beside a fly



# **Related concept: mental simulation**

# Tolman (1948)



# Possible explanations?

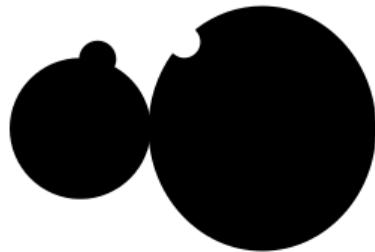
# Mental simulation in humans

- **Some primary debates:**
  - What, if anything, do we solve using mental simulation?
  - If we do mental simulation, do we use a model of physics?

# Mechanical reasoning by mental simulation

(see Hegarty 2004)

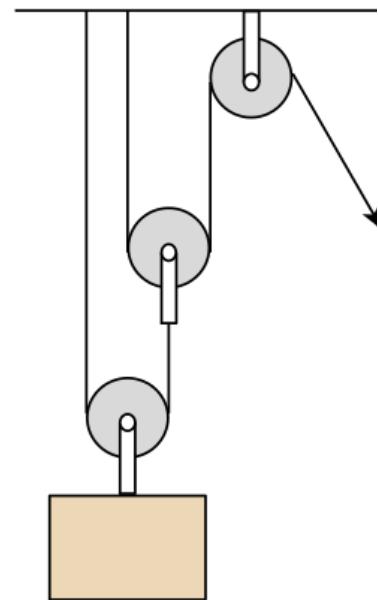
(a) Gear rotation problem



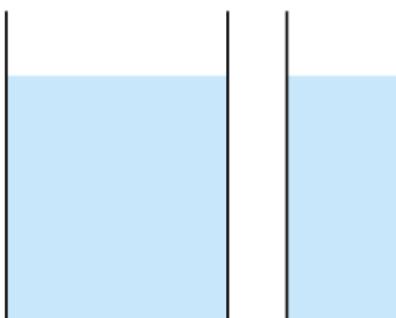
The diagram shows two interlocking gears. Will the knob on the leftmost gear mesh with the groove on the right gear if the gears are rotated inward?

(b) Pulley problem

The diagram depicts a pulley system. When the free end of the rope is pulled, will the lower pulley turn clockwise?



(c) Water pouring problem



The diagram shows two glasses of water. The glasses are the same height and filled to the same water level. If the glasses are tilted, will the water pour out of the two glasses at the same or different angles of tilt? If they are tilted at the same rate, which will pour first?

# Battaglia, Hamrick, & Tenenbaum (2013)



# Battaglia, Hamrick, & Tenenbaum (2013)



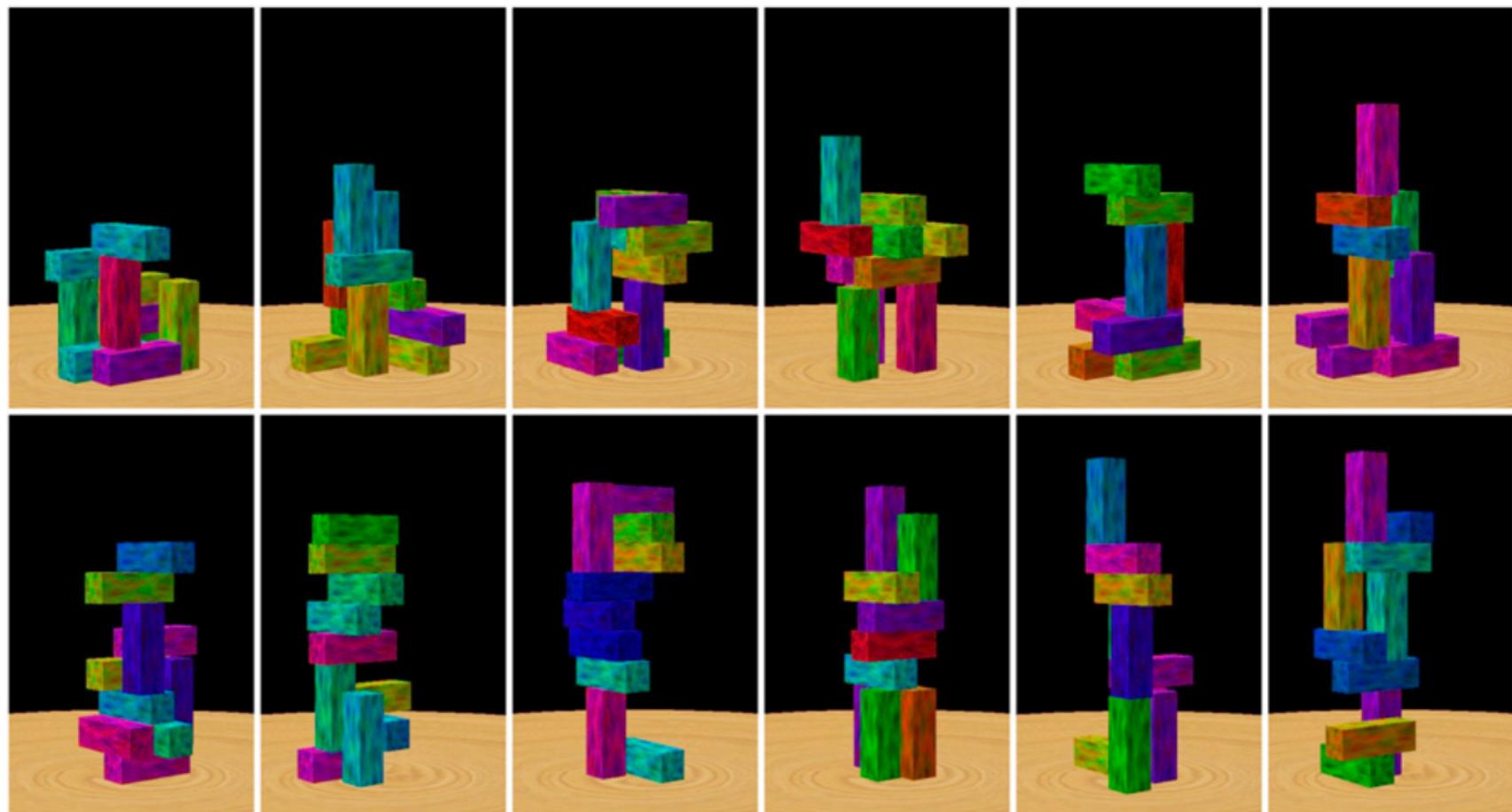
# Battaglia, Hamrick, & Tenenbaum (2013)



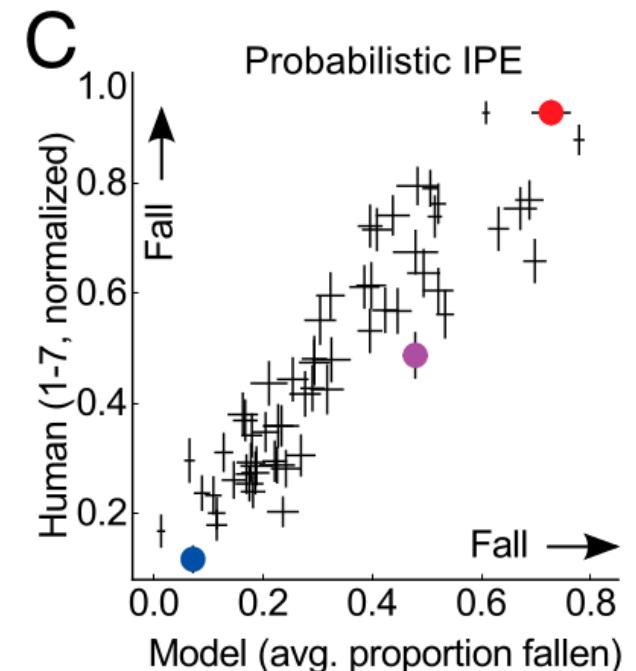
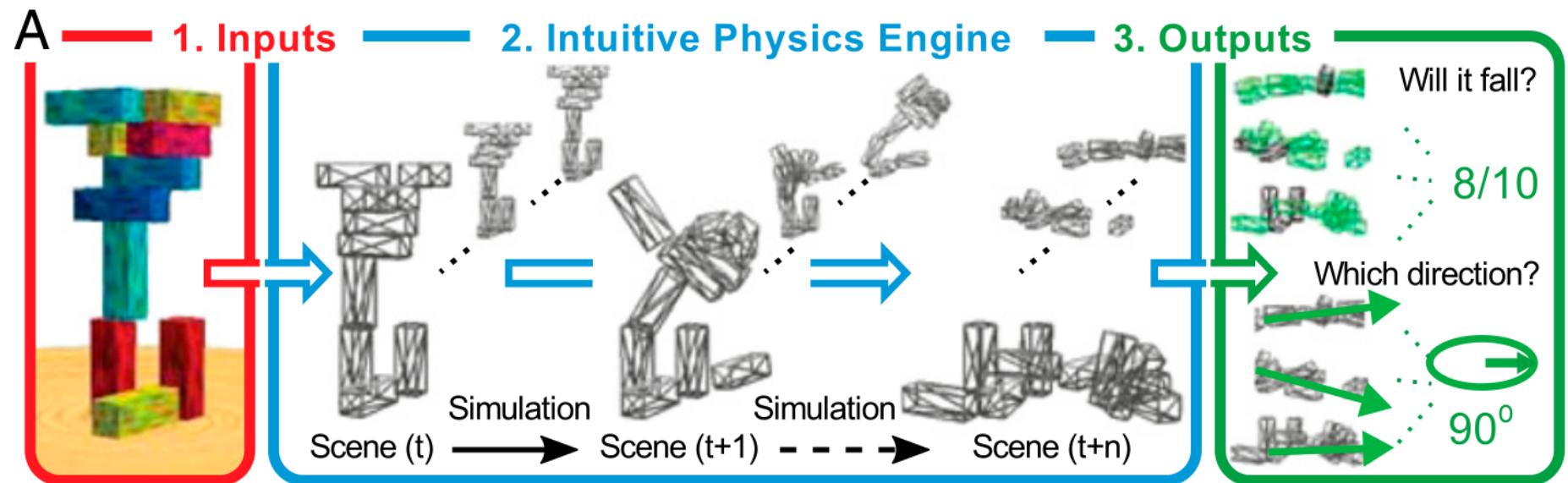


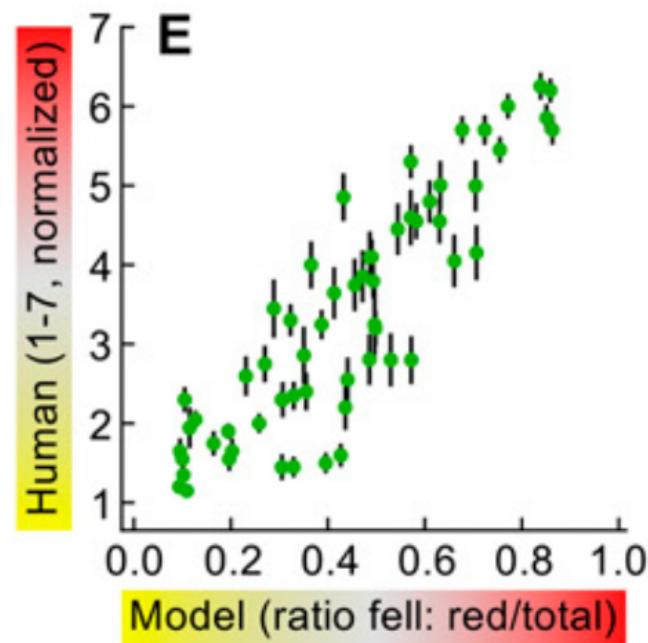
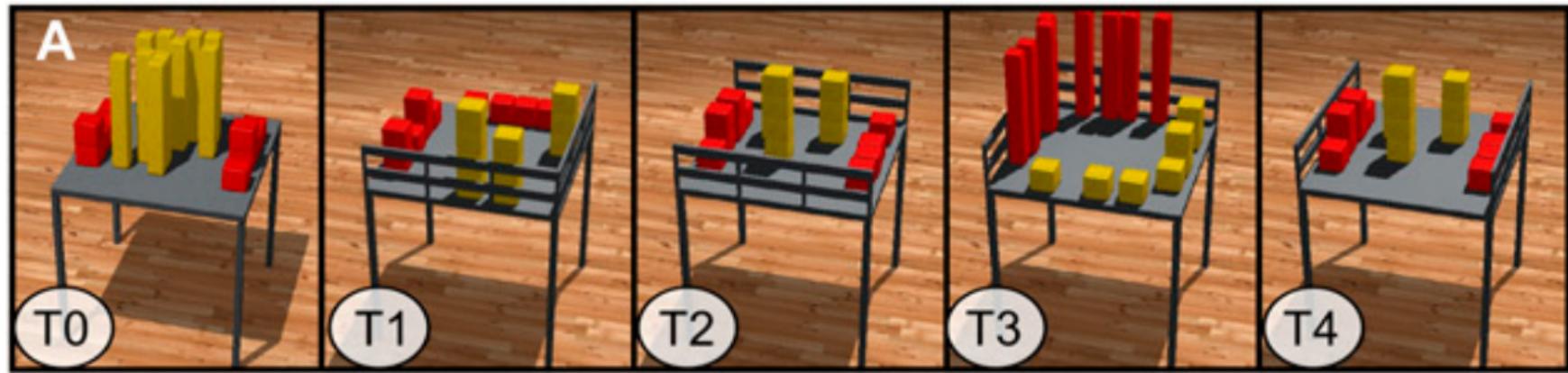


# Battaglia, Hamrick, & Tenenbaum (2013)



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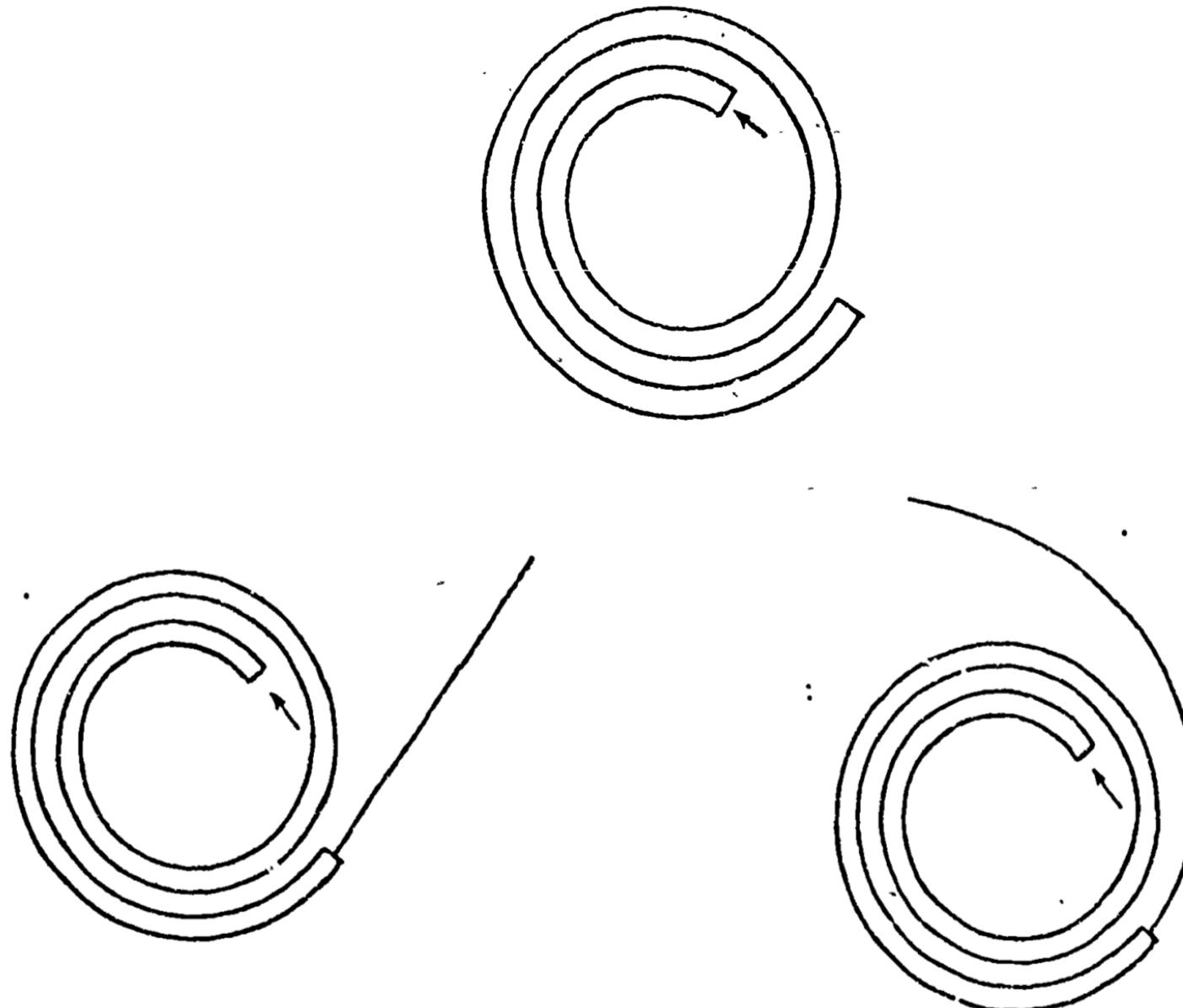


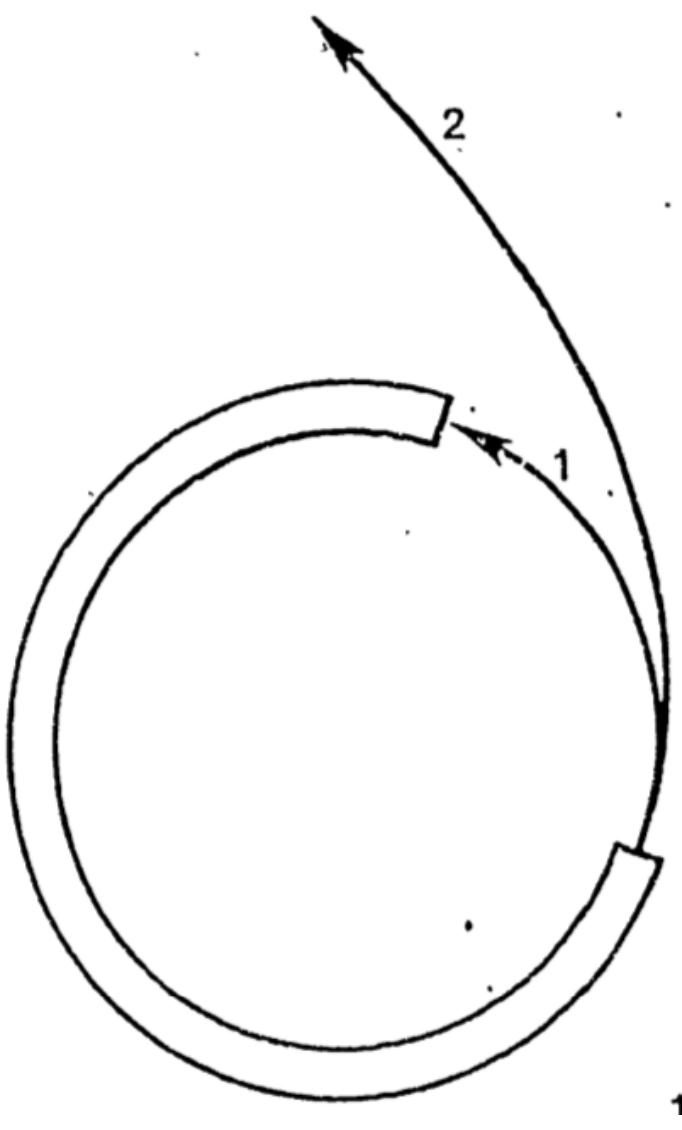




# Naive theories of motion

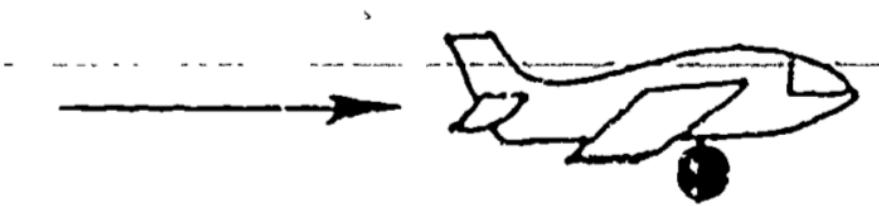
(McCloskey 1983)

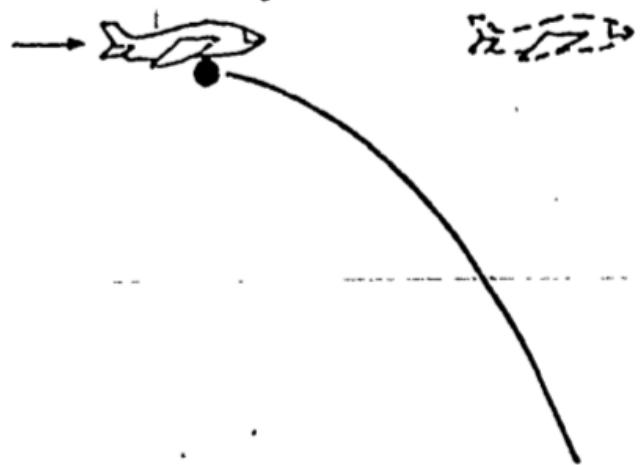




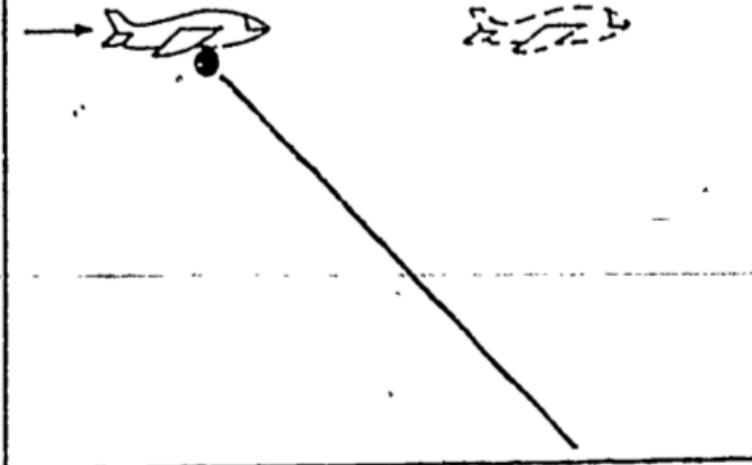
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(McCloskey 1983)

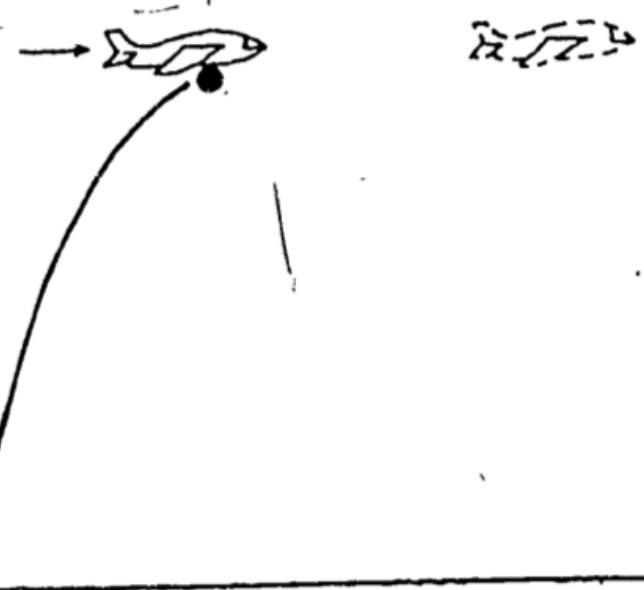




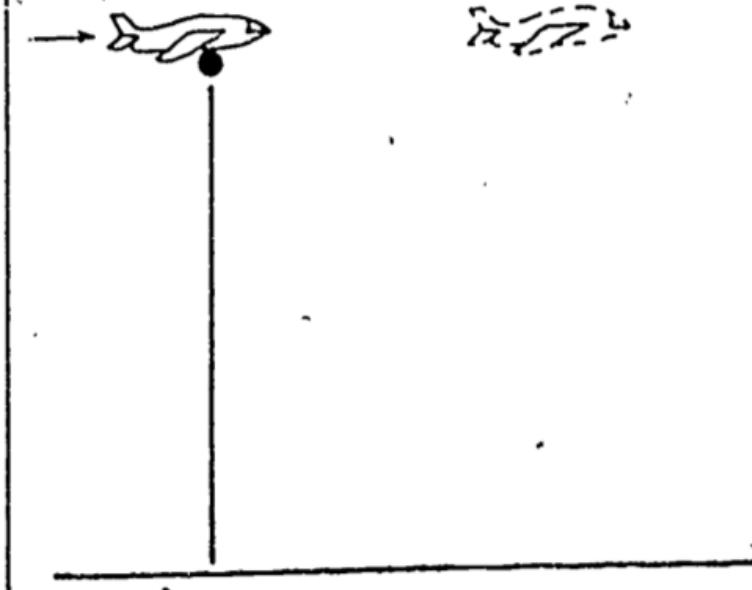
A



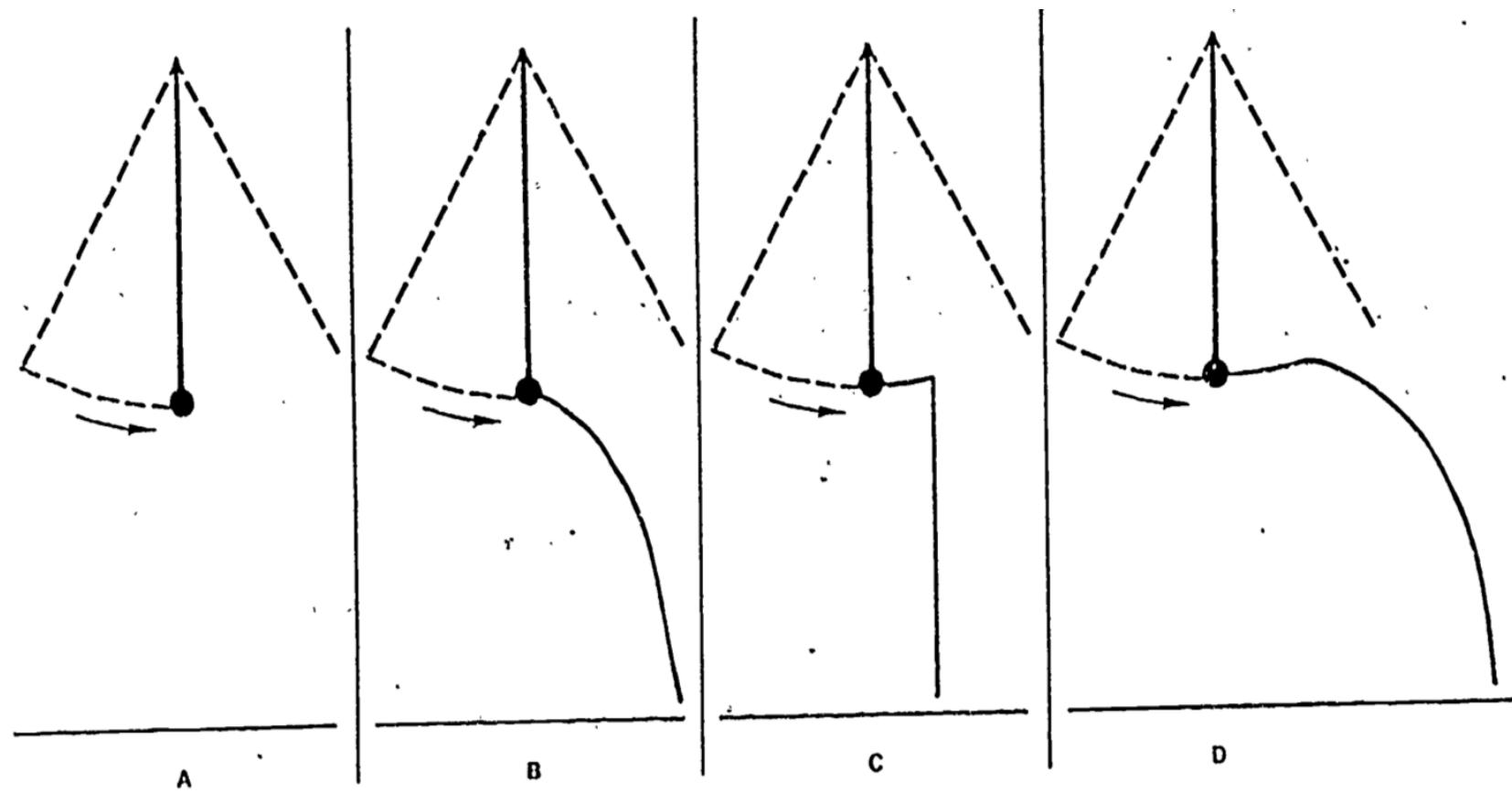
B



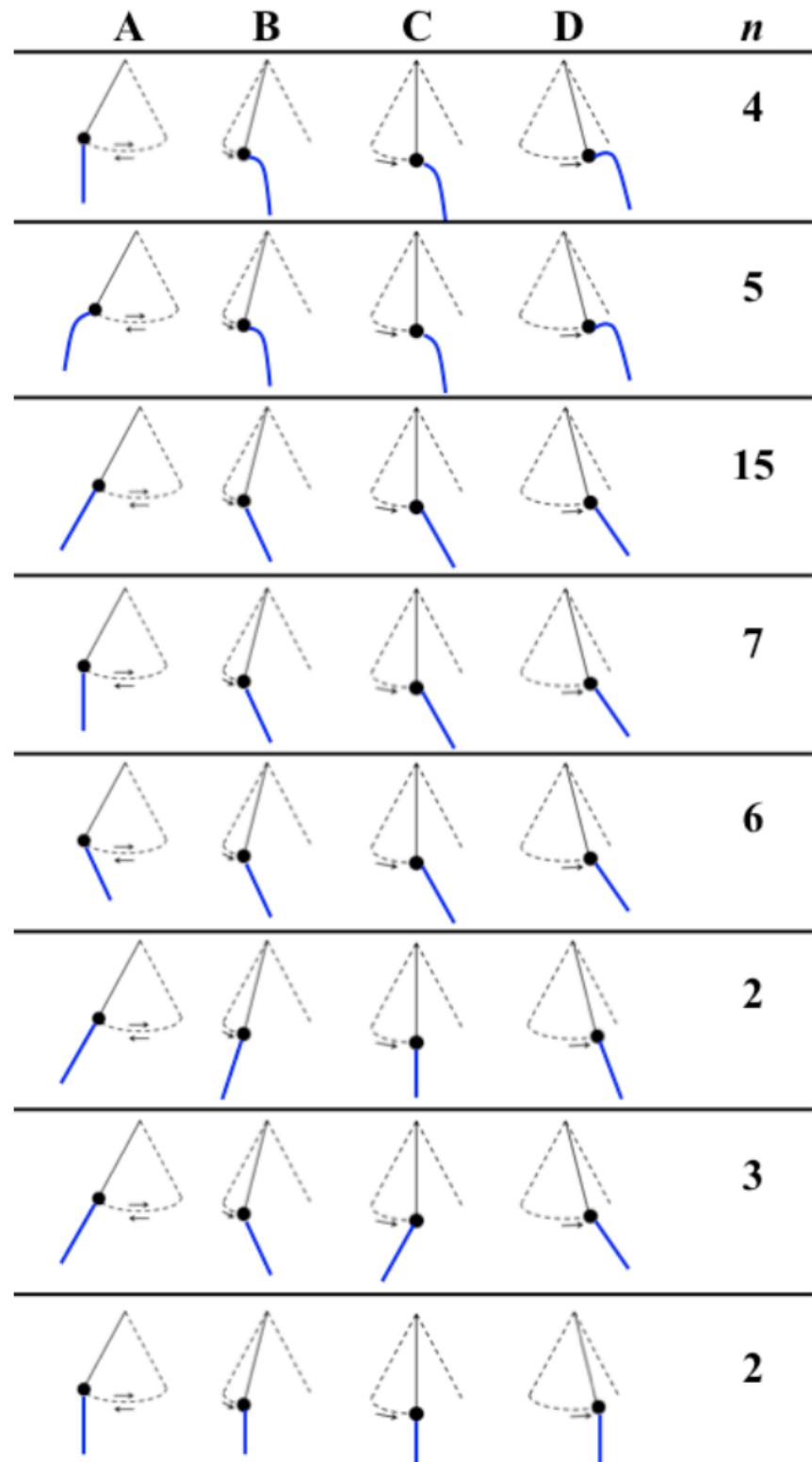
C



D

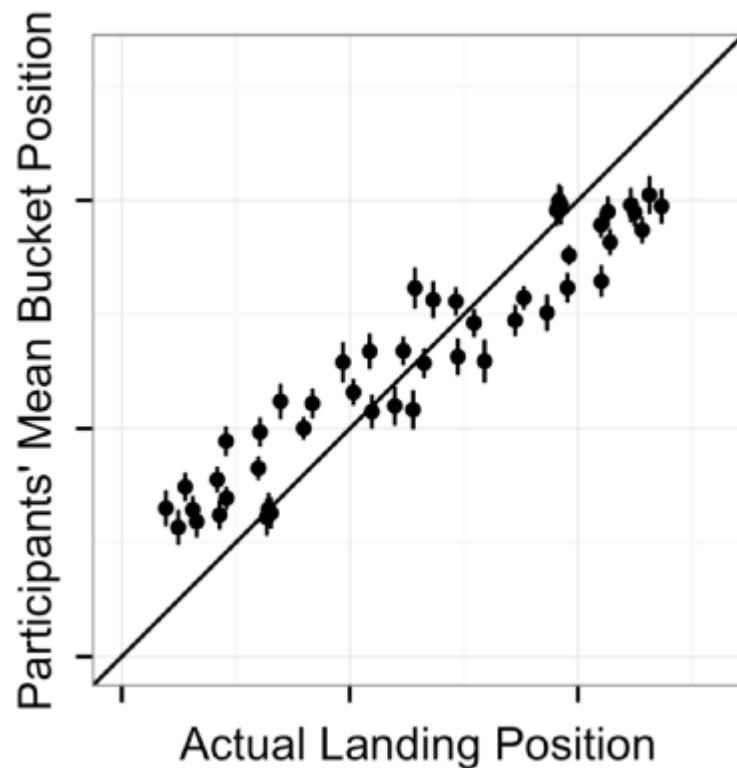


# Smith, Battaglia, & Vul (2013)

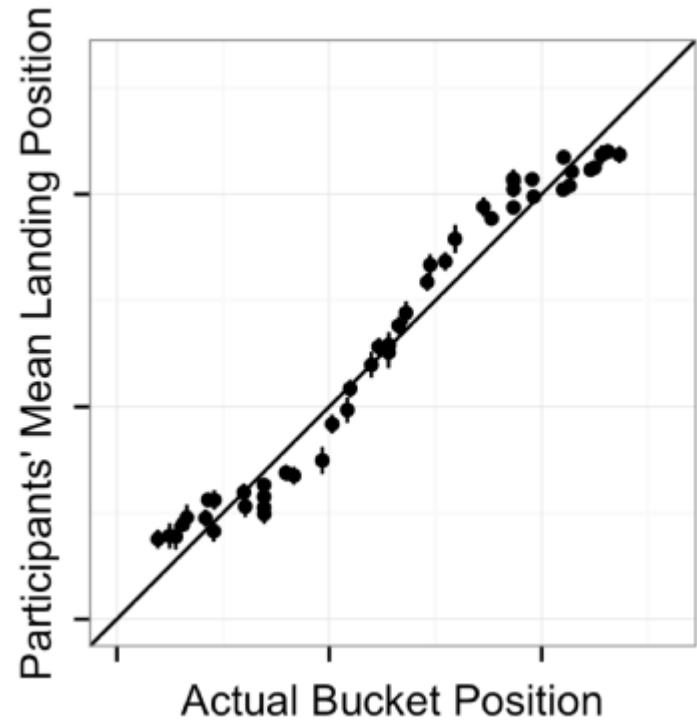


# Smith, Battaglia, & Vul (2013)

Catching task

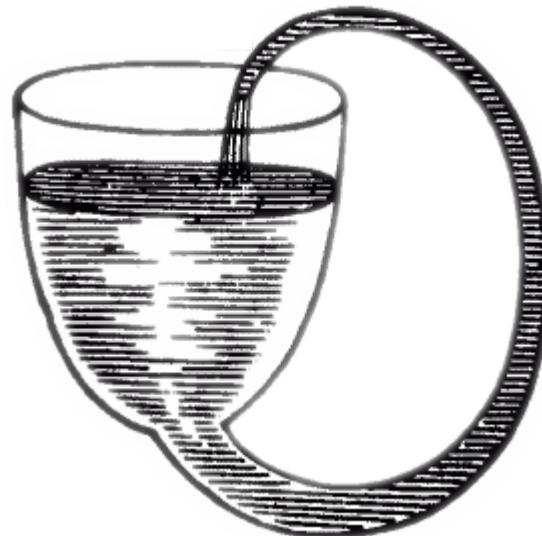


Cutting task



# Perpetual motion

- Provides some really neat failures of intuitive physics

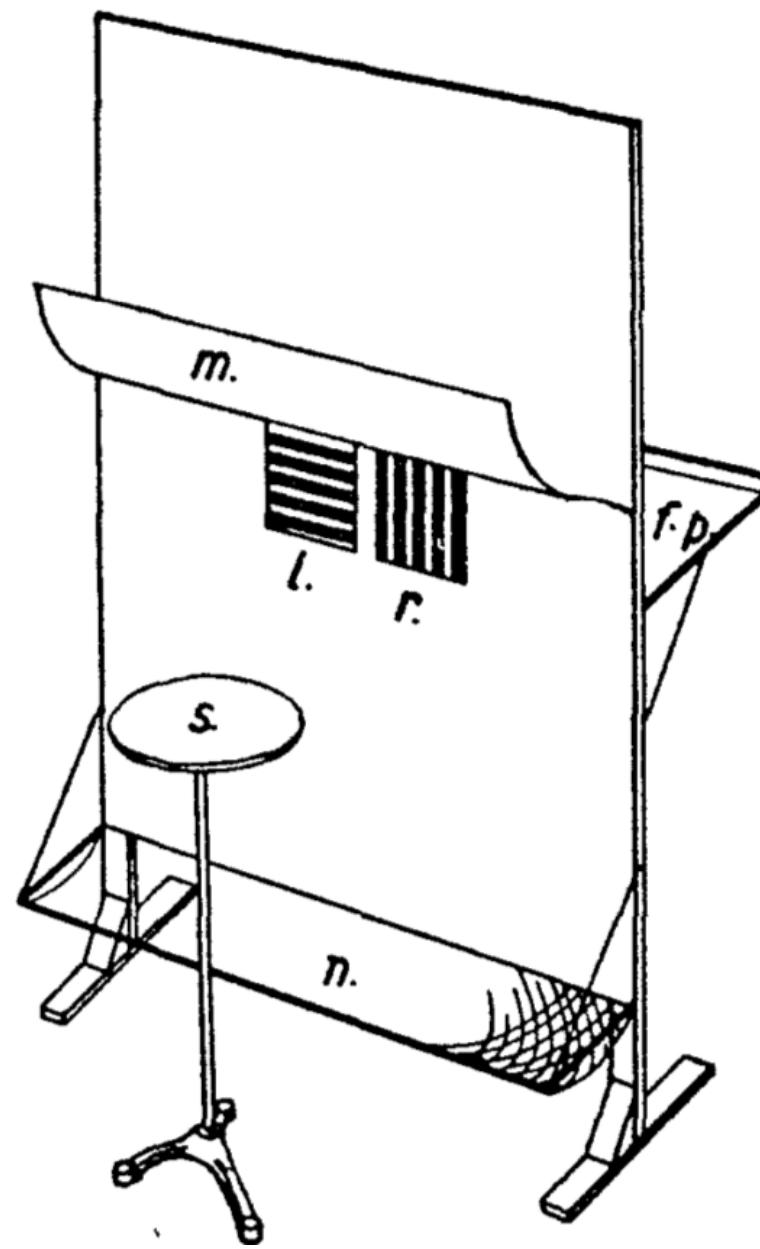


# Perpetual motion



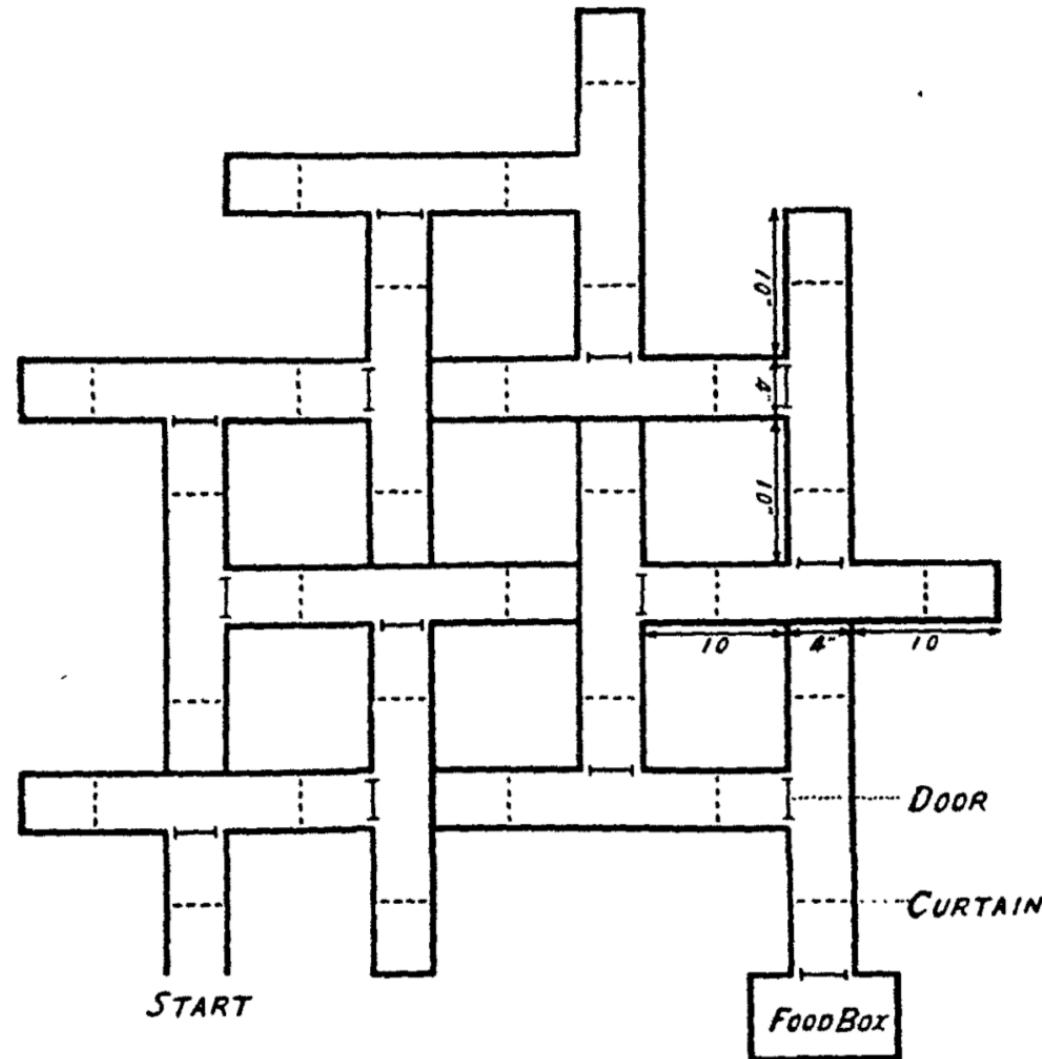


# Tolman (1948)



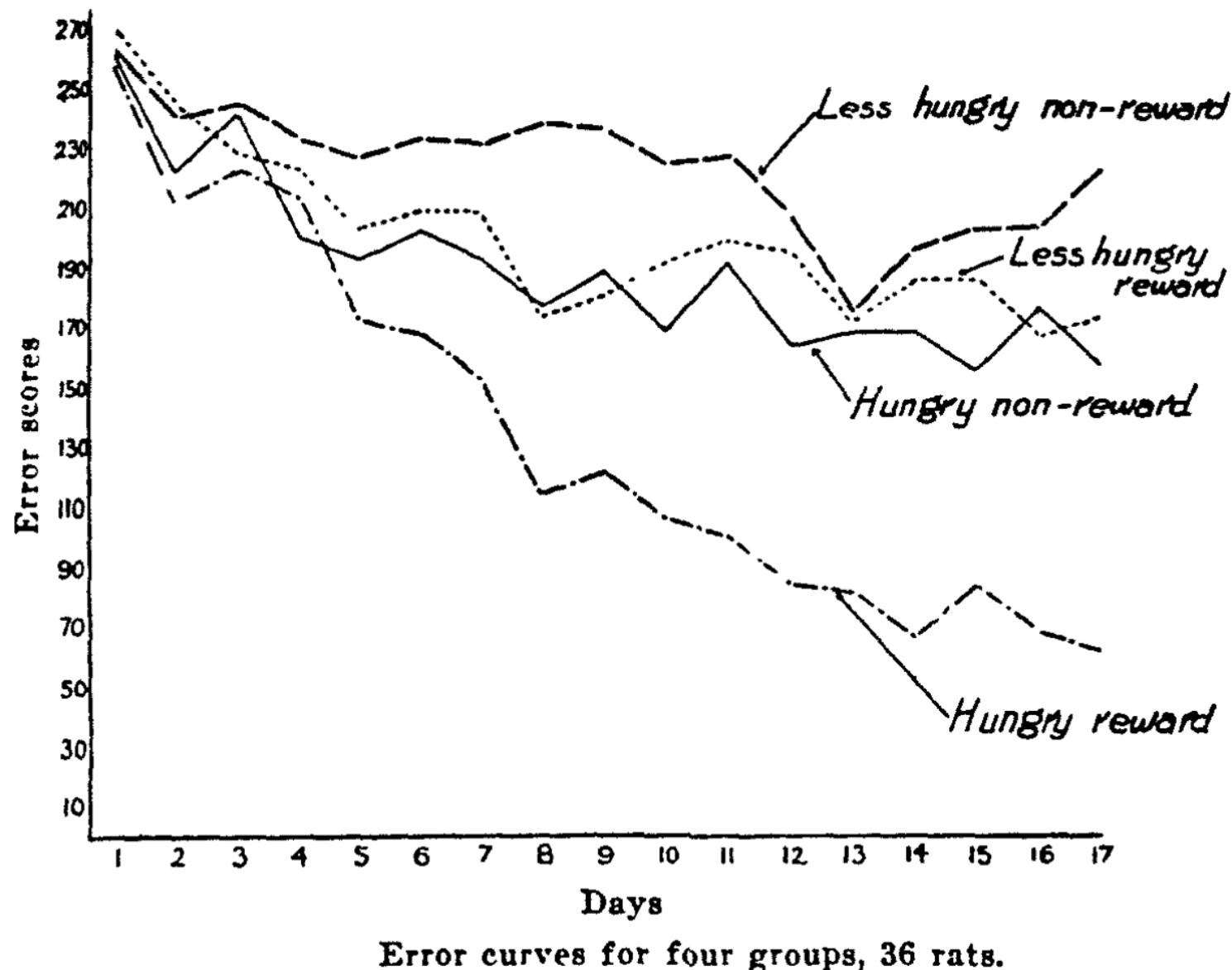
# Tolman (1948)

## Cognitive maps in rats and men



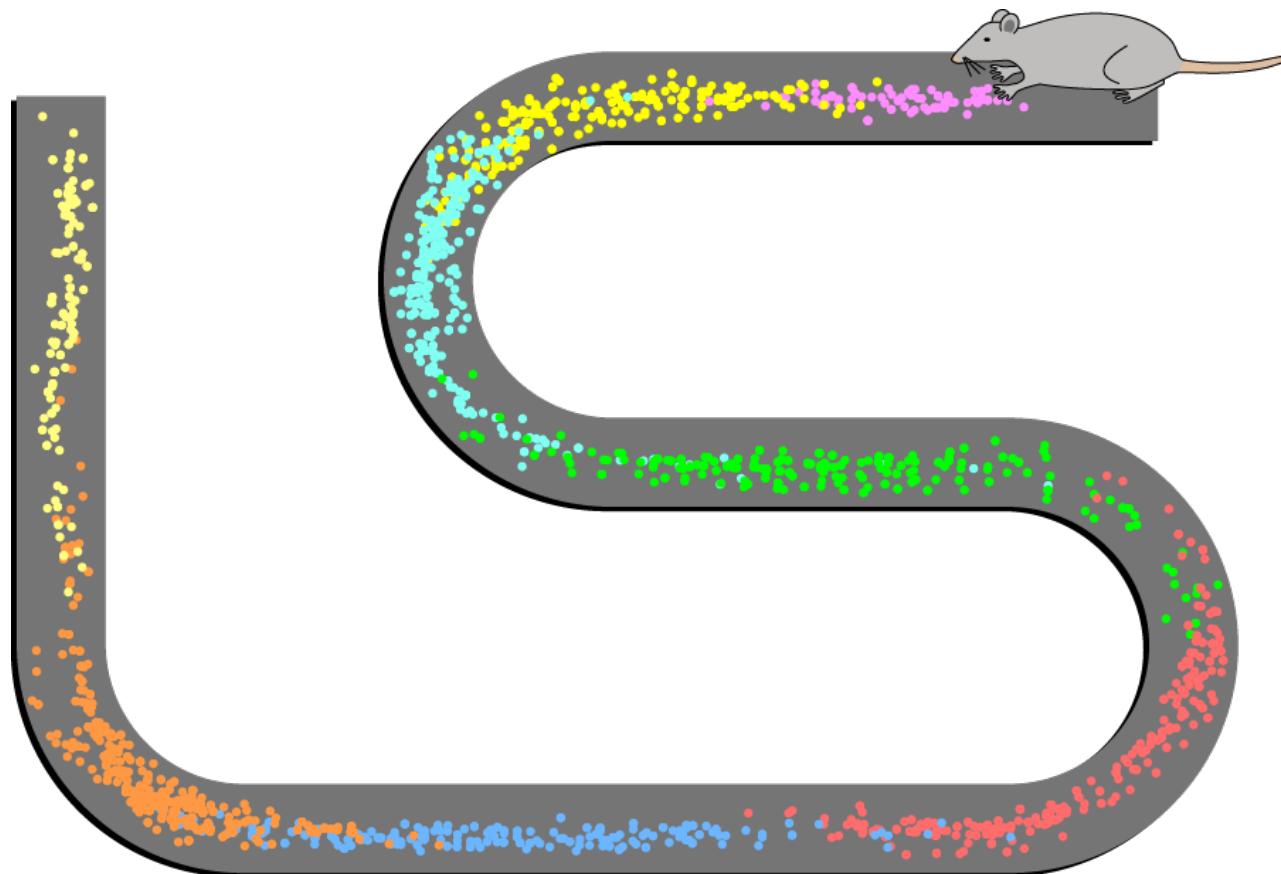
Plan of maze  
14-Unit T-Alley Maze

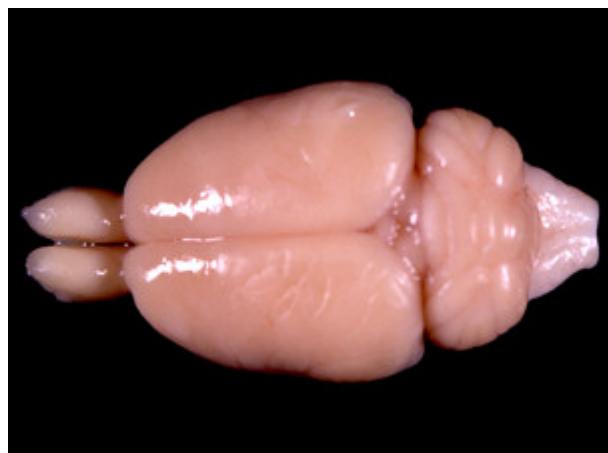
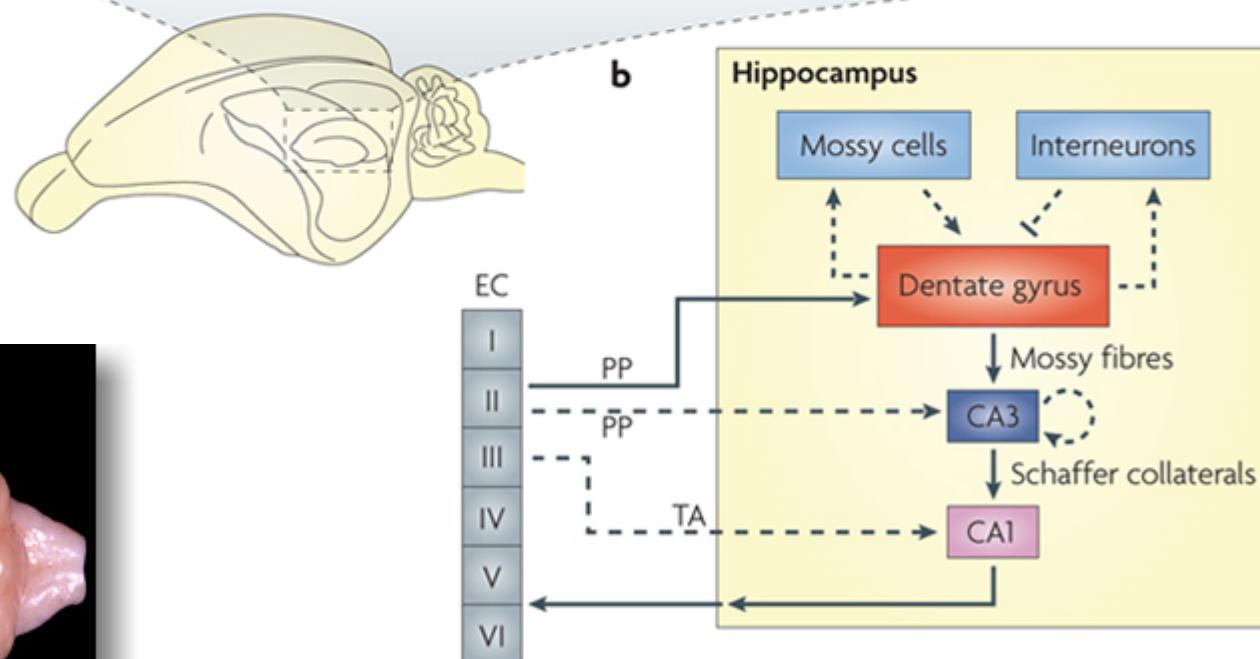
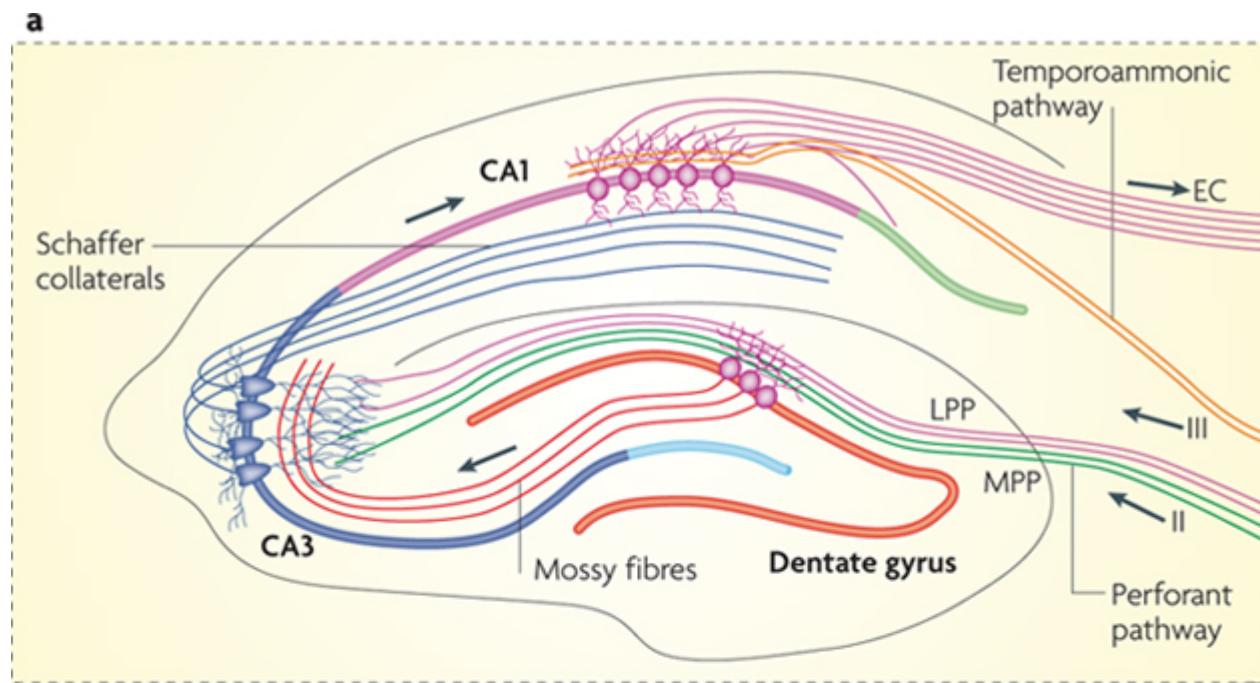
# Tolman (1948)



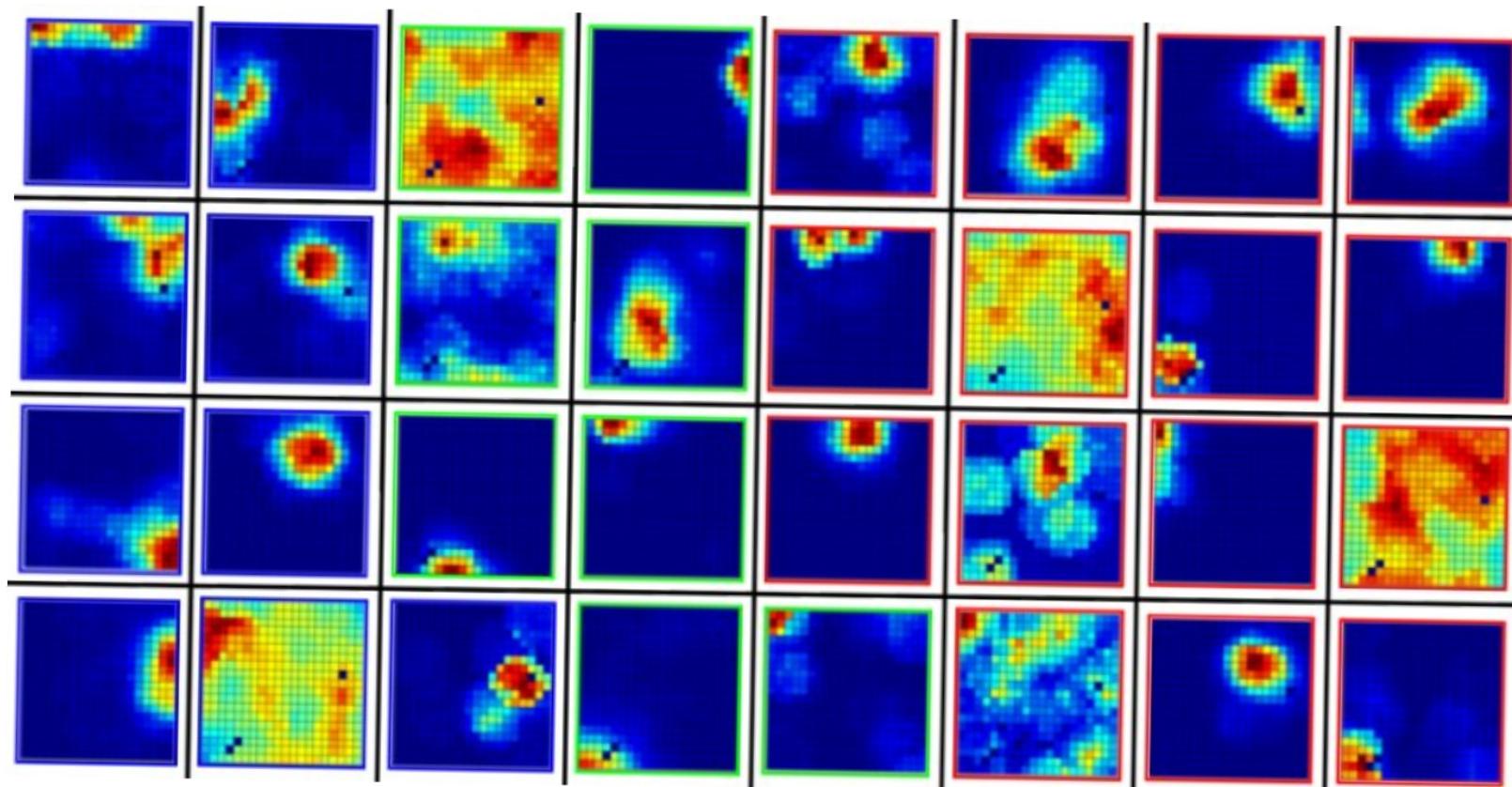
# The hippocampus as a cognitive map

(O'Keefe & Nadel 1978)

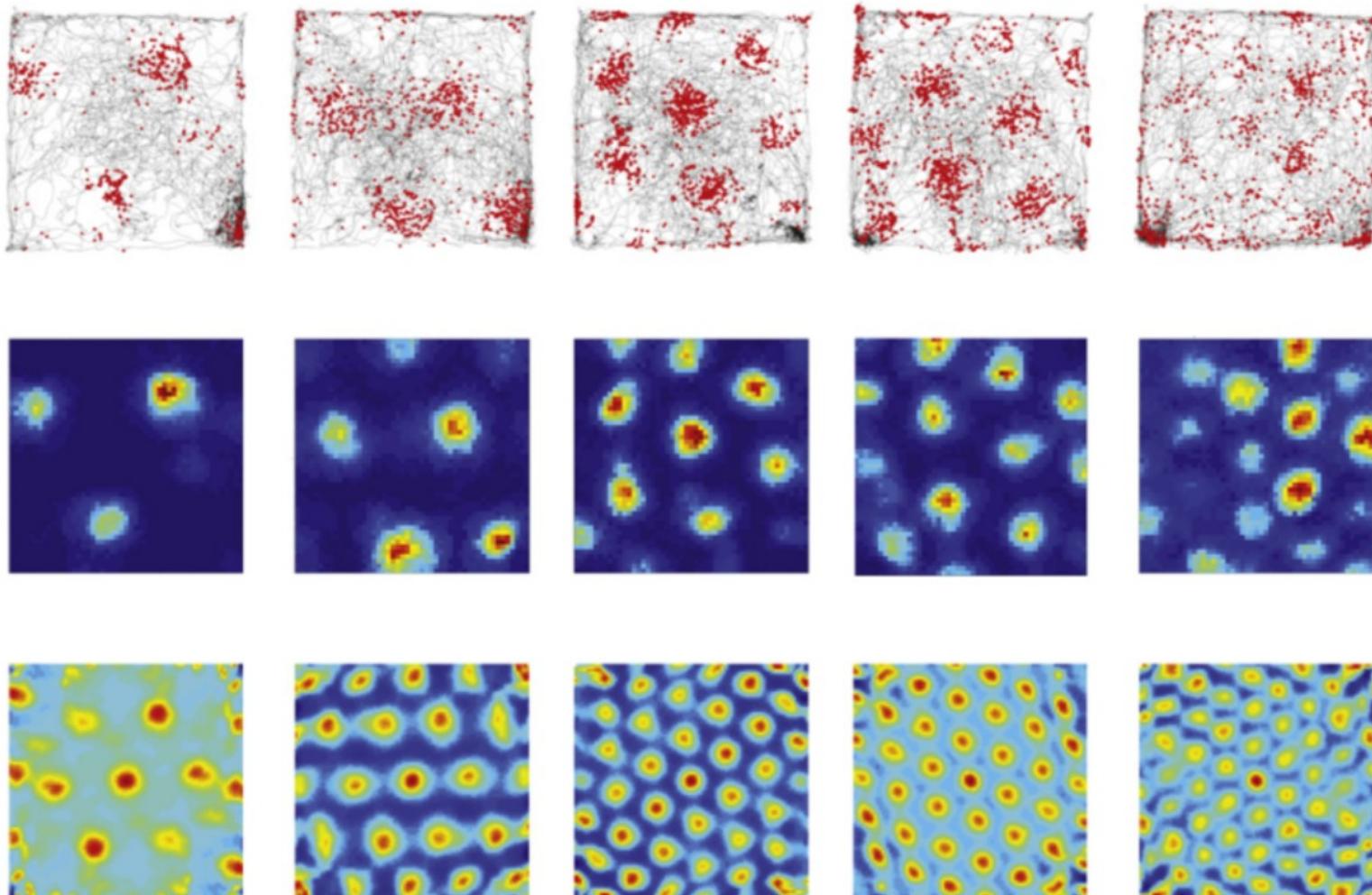




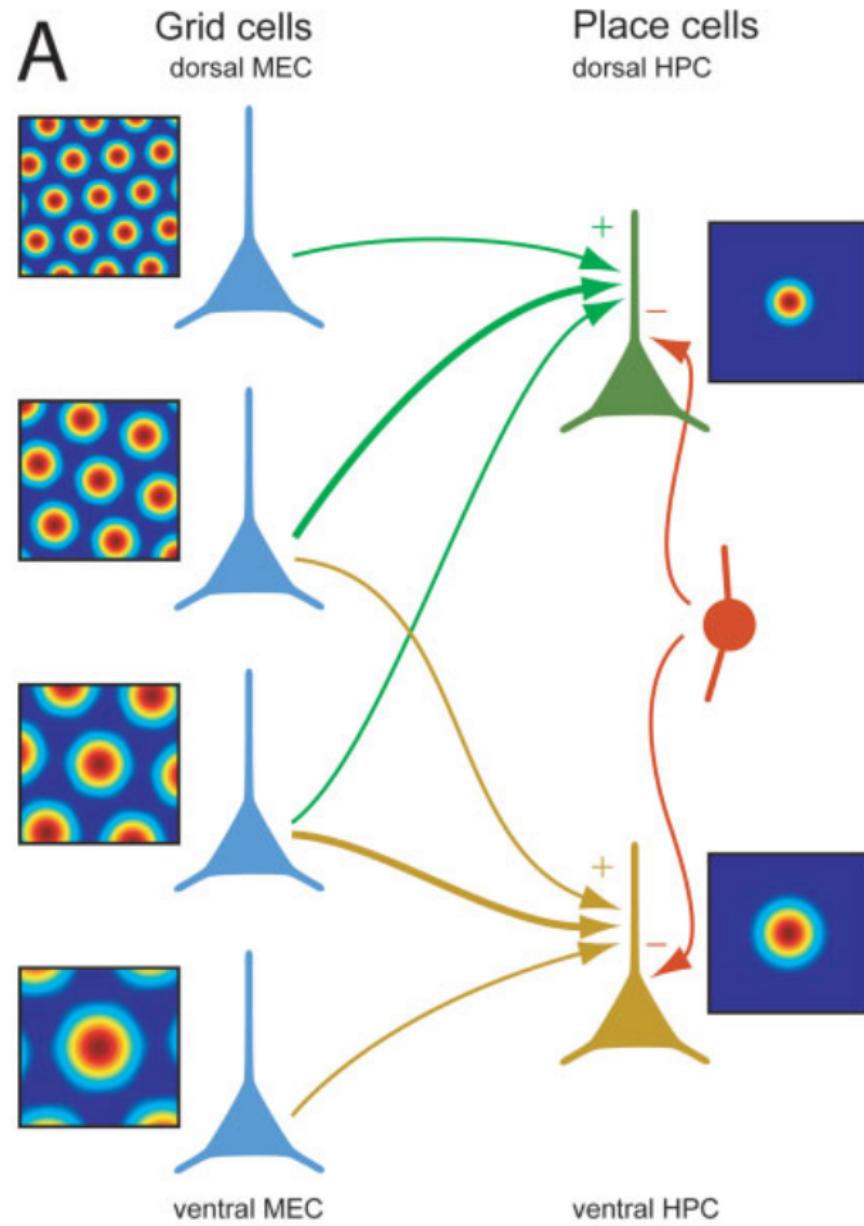
# Place cells



# Grid cells

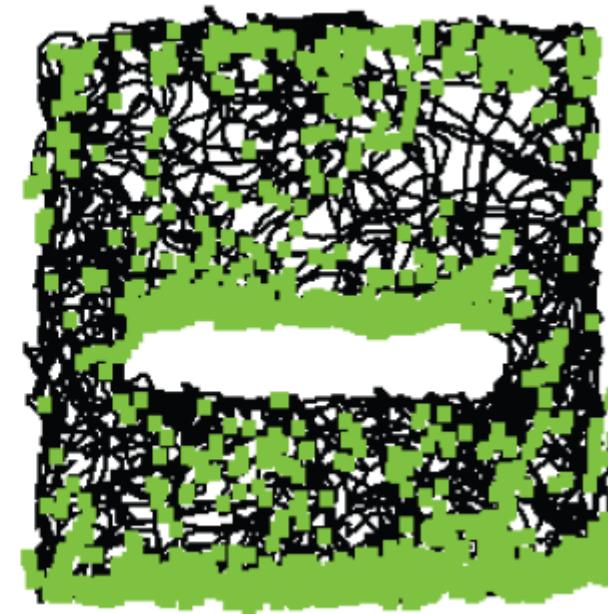
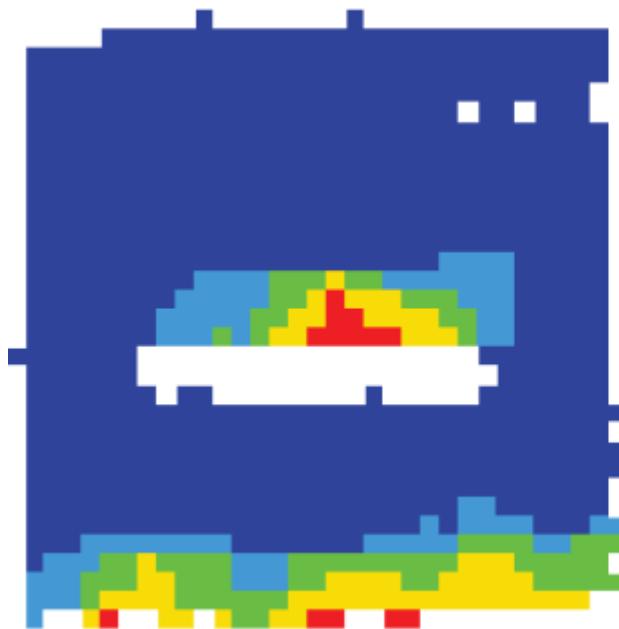


Solstad, Moser, & Einevoll (2006)



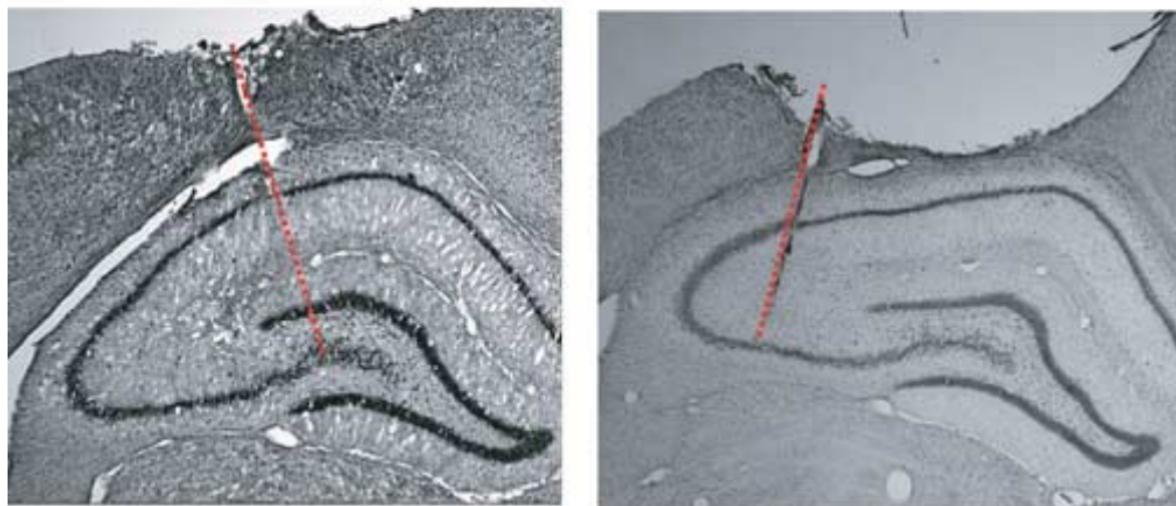
Solstad, Moser, & Einevoll (2006)

# Border cell

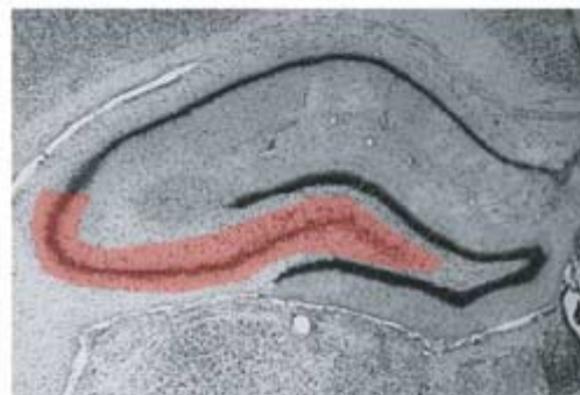


# Johnson & Redish (2007)

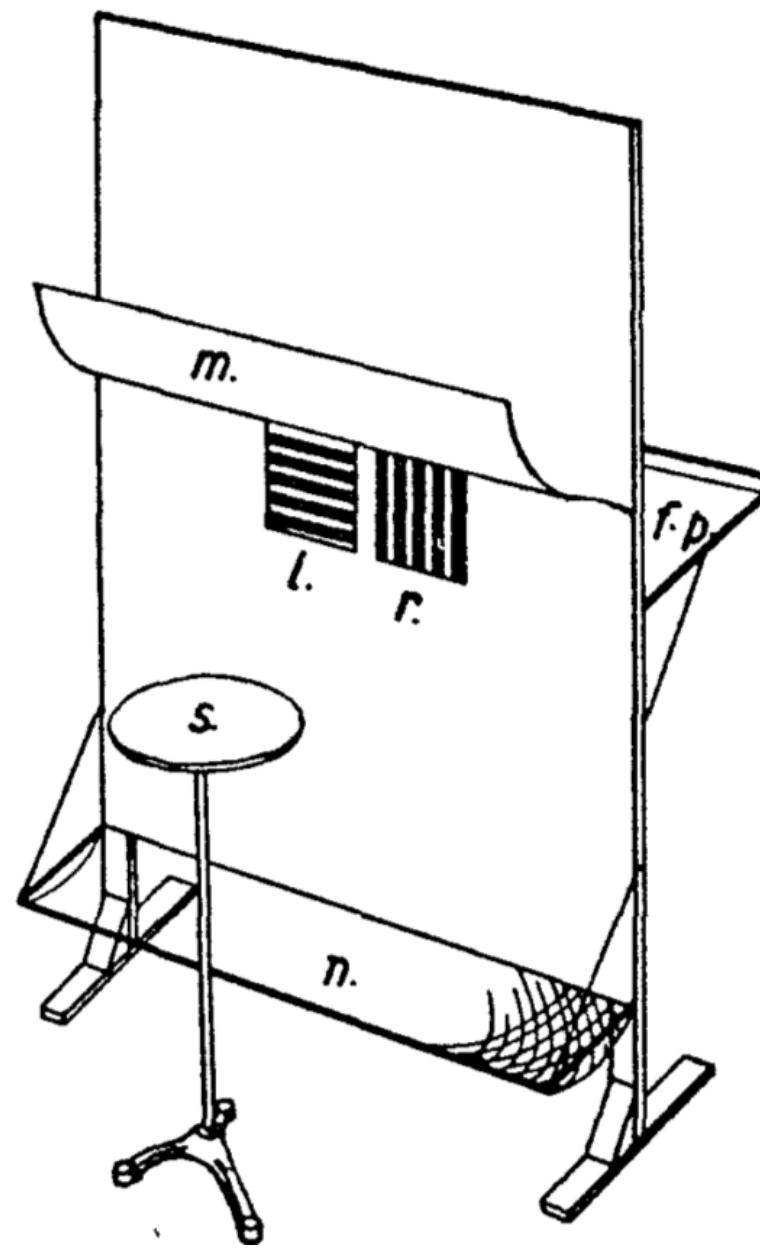
*Sample electrode tracks*



*Recording zone*



# Tolman (1948)



# Johnson & Redish (2007)

