ANIMAL COGNITION

IPAM Tutorials

Erica Cartmill
Cognitive Science, Animal Behavior, Anthropology, Psychology
Indiana University

ericac@iu.edu
comparelab.org

TUTORIAL OUTLINES

How people study animals	Different solutions to common problems	Complex (human-like?) cognition

• Why study animal cognition?
• Historical overview
• Human bias
• Methods for studying animals
• *What* animals learn
• *How* animals learn
	• Space
	  • (Navigation)
	• Number
	  • (Approx vs. Exact)
	• Objects
	  • (Tool use)
	• Other animals
		• Communication
		• Theory of mind
		• Episodic memory
		• Flexibility
		• Metacognition
		• Animals vs. AI

"The best known pattern recognition system is the human brain"

Jacob Foster
IPAM 2024 MOIOD

OUTLINE

- **Why study animal cognition?**
- Historical overview
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- *What* animals learn
- *How* animals learn

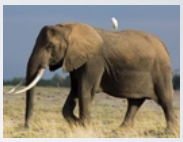
GREATER DIVERSITY OF…

- **Substrates** (bodies & brains)
- **Problems** (behaviors & environments)
- **Solutions** (computations & learning)

GREATER DIVERSITY OF…

- **Substrates**
  (bodies & brains)

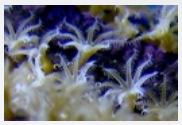
C. elegans
(302 neurons)



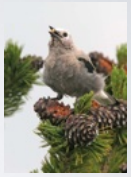
Elephas africana
(257,000,000,000 neurons)

GREATER DIVERSITY OF…

- **Problems**
  (behaviors & environments)



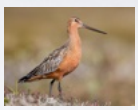
Coral polyps



Clark's nutcracker

GREATER DIVERSITY OF…

- **Solutions**
  (computations & learning)



Bar-tailed godwit

Desert ant

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CLEVER HANS

- German horse at turn of 20th Century
- Answered questions about mathematics, time, and language, often by pawing ground
- Investigation found that when owner didn't know the right answer, Hans failed
- Concluded Hans was responding to human (unconscious) cues

IS A BEHAVIOR "INTELLIGENT"?

Reptile eggs develop into male or female embryos based on temperature

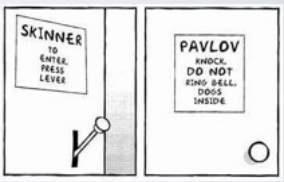
Male sticklebacks fan eggs more quickly as oxygen levels drop

Predators can learn to search for turtle eggs where humans have marked nests

BEHAVIORISM

Very American debate!
Ethological perspectives began in Europe in 19th century

- Focus on behavior of *individuals*
- Believes sources of behavior are *external*
- Behavior can & should be explained without reference to mental states



CONDITIONING

CONDITIONING

- **Associative learning**: linking events, actions, or stimuli together through conditioning
- **Classical conditioning** - links a stimulus to anticipation of an event (e.g., dog starting to salivate at sound of a bell, anticipating food)
- **Conditioning**: repeated exposure to co-ocurrence of a natural stimulus (e.g., food) with a normally neutral stimulus (e.g., a ringing bell)

Ivan Pavlov
1849 - 1904
Institute of Experimental Medicine

OPERANT CONDITIONING

OPERANT CONDITIONING

- **Operant conditioning**: increase or decrease of a behavior over time due to reinforcement
- **Positive reinforcement** increases likelihood of the behavior (e.g., dog gets a treat for doing a trick)
- **Negative reinforcement** decreases likelihood of behavior (e.g., dog gets punished for barking)

Reinforcement learning (RL)

B.F. Skinner
1904 - 1990
Harvard

OPERANT CONDITIONING

"[Behaviorism] disposed of many of the problems raised by mentalism and freed itself to work on its own projects without philosophical digressions. By directing attention to genetic and environmental antecedents, it offset an unwarranted concentration on an inner life.

It freed us to study the behavior of lower species, where introspection *(then regarded as exclusively human) was not feasible,* and to explore similarities and differences between man and other species."

Skinner, B. F. (1974) *About behaviorism.*

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1904 - 1990
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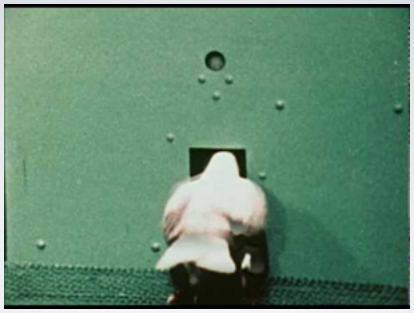
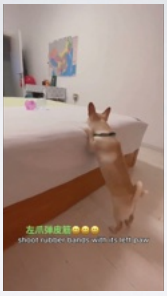


https://www.youtube.com/watch?v=TtfQIkGwE2U&list=PPSV

Even complex behaviors can be trained through simple reinforcement…



But can everything be reduced to a history of rewards?

https://youtube.com/shorts/GSyKcgsRc2E

COGNITIVE REVOLUTION

- Behaviorism introduced rigorous experimentation to study of behavior
  - emphasized role of environment on behavior
  - but couldn't fully explain complex systems like language
- 1930s-50s cognitive psychologists pushed back against behaviorism
  - interested in mental imagery, phenomenology, semantic memory, language, and questions of representation, simulation, and projection

BEYOND STIMULUS-RESPONSE SEQUENCES

- When placed in a maze, rats will learn shortest route to food
- What do they do when this route is disrupted?
- Do they learn through a series of stimulus-response sequences, or do they learn a "cognitive map"?

Edward Tolman
1886 - 1959
Berkeley

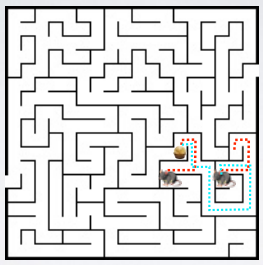
Tolman, E. C., & Honzik, C. H. (1930). " Insight" in rats. *University of California Publications in Psychology.*

BEYOND STIMULUS-RESPONSE SEQUENCES

1. Rat explores maze

2. Rat learns location of food starting from point A

3. Put rat in maze at new starting point



prediction if stimulus-response

prediction if cognitive map

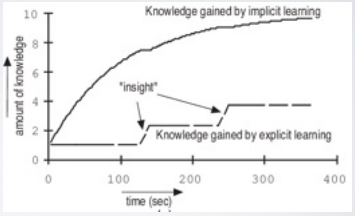
Tolman, E. C., & Honzik, C. H. (1930). " Insight" in rats. *University of California Publications in Psychology.*

EARLY HINTS OF COGNITION BEYOND CONDITIONING

- Cognitive maps (can infer shortcuts or alternate routes)
- Learning biases (certain types of stimuli easier to link than others)
  - e.g., food with nausea, but not flashing lights or sound with nausea

(SOME) CURRENT TOPICS WITH COGNITIVE APPROACHES

- Intentionality
- Behavioral flexibility
- Insight in learning
- Hypothesis-testing
- Deception
- Teaching
- Theory of mind
- Cultural norms



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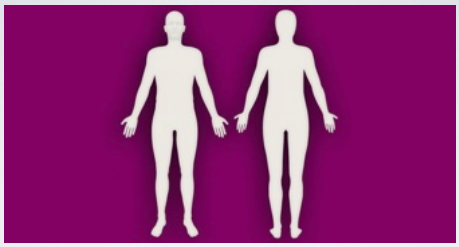
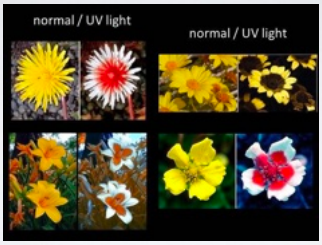
WE HAVE A HARD TIME THINKING "BEYOND THE HUMAN"

HUMANS…

- Have big brains
- Rely on vision
- Are highly social
- Are good with tools
- Make artifacts
- Manipulate our environments
- Use language & other symbols
- Communicate mainly through sound and vision
- Have long developmental periods
- Teach one another



WE HAVE A HARD TIME THINKING BEYOND THE HUMAN … **IN SENSORIA**

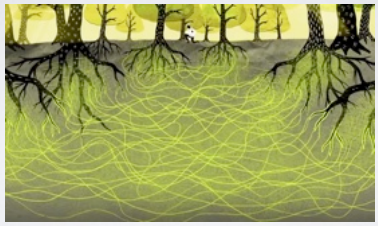


Kevan, P., Giurfa, M., & Chittka, L. (1996). Why are there so many and so few white flowers?. *Trends in Plant Science, 1*(8), 252.

WE HAVE A HARD TIME THINKING BEYOND THE HUMAN … **IN BODY PLAN**

WE HAVE A HARD TIME THINKING BEYOND THE HUMAN … **IN TIME SCALE**

WE HAVE A HARD TIME THINKING BEYOND THE HUMAN … **IN INDIVIDUATION**



HUMAN BIASES LEAD TO SKEWED CONCLUSIONS

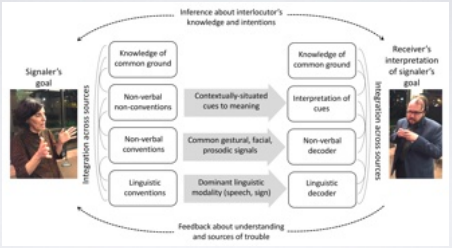
Not great at imagining ways of being that differ from our own

We're (relatively) good at looking for human-shaped things and tend to over-attribute them

- "Clever Hans"
- "ELIZA effect" in AI

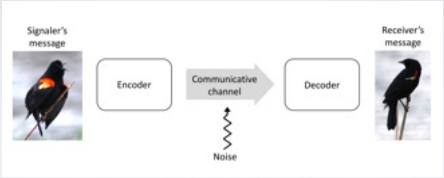
Though sometimes we also assume our way of doing things is unique!

SIMPLIFIED MODEL OF HUMAN LANGUAGE



Cartmill, E.A. (2023) Overcoming bias in the comparison of human language and animal communication. *PNAS*, 120 (47), e2218799120

MODEL UNDERLYING (MOST) ANIMAL COMMUNICATION RESEARCH



Cartmill, E.A. (2023) Overcoming bias in the comparison of human language and animal communication. Proceedings of the National Academy of Sciences, 120 (47), e2218799120

Shannon, C. E. (1948). A mathematical theory of communication. The Bell system technical journal, 27(3), 379-423.

Reddy, M. (1979). The conduit metaphor. Metaphor and thought, 2, 285-324.

HUMAN BIASES LEAD TO SKEWED CONCLUSIONS

This can result in both over and under-attribution of abilities in other species

CASE STUDY: COOPERATIVE COMMUNICATION

- e.g., man with the hat