What Do Animals Know?
And how do we find out?

(Thanks to Aimee Dunlap for designing this lecture.)

Cognition as a Black Box

Information goes in

Behavior Comes Out

Open the Black Box by Putting the Animal into a Box...

The Behaviorist Approach

- Explain behavior through its consequences: Input → Output
- Look for an orderliness in responses to experience - this is all about the methodology
- Limitations: you ignore anything not directly observable in the box - mental events, "feelings", motivations, consciousness

Things Animals Might “Know”

- How much and how many?
- When?
  - Timing
- What do I know?
  - Metacognition
- What, where and when together?
  - Episodic memory and planning for the future
- What do other animals know?
  - Theory of mind
How Much? How Many?

Lions live in female-dominated prides, and defend a territory.

Game theory: when fighting is costly, assess the ability of your opponent, and run away if your chances of winning are low.

E.g., when you are outnumbered...

- Loudspeaker plays invader roars within a territory of females.
- Two kinds of roars: a) 1 lion roaring or; b) 3 lions roaring.
- Females’ responses to the roars assessed.

Defending lions adjusted their response to the number of intruders and the size of their group.

Chimpanzees defend their territory:
- Go on patrol ('parties' range from 1-20 chimps)
- Will attack and kill chimps from other groups
- Territory boundaries shift as larger groups fight for more land
- Some groups are obliterated

Mike Wilson and colleagues did playback experiments:
- Groups of only females or of 1-2 males quietly leave.
- Groups of ≥3 males quickly approach the speaker.
- Males move faster the more they outnumber the intruders.

A later paper “Chimpanzees and the mathematics of battle” by Wilson et al, used a square-law model to predict that males should be willing to fight a group of foreign males when they outnumber them by 1.5.

Numerical Assessment

- What might be the upper limit of this kind of assessment?
- How many roars can you tell apart?
- Are they actually counting?

What is the difference between how much and how many?
A Basic Test with Peeps

Which group has more?

Weber’s Law

Describes the just noticeable difference (JND) between two stimuli as a function of their magnitude.

The JND is a constant proportion across a wide range of values.

Example: suppose a 10-gram weight has to be increased by .5 gram in order for a person to detect the change.

Then a 20-gram weight would have to be increased by 1 gram, in order for the weight change to be detected.
More on Numerical Competency

Relative Numerousness Discrimination
Judgments of more or less
Rats, monkeys, birds, and small children can all solve these tasks.
When large amounts presented, mistakes follow Weber’s Law.

Absolute Number Discrimination
E.g., always choose 5
Learning to pick food container with specific number of markings; turn in a maze based on the number of whisker touches, learning to peck a fixed number of times.

Concept of Number & Counting
10 is twice as much as 5, but half as much as 20
Chimpanzees and Alex the parrot are able to learn number symbols.
Chimpanzees may even be able to add simple numbers.

Alex’s Sense of Number*

Alex gave English language assignments of number to arrays of objects.
80% accuracy was unaffected by array quantity, or object mass and shape.

* work of Irene Pepperberg

“How many blue?”
“How many block?”

Alex could even assign number in relation to categories (shape, material, color).
Including a concept of zero (“none”).

Assignment of number by Alex was ‘cross-modal’:
1. seeing array of intermixed subsets of four, five, and six objects
2. hearing a question
3. translating phrase into search for a specific object among distractors
4. determining number
5. vocalizing cardinal amount viewed as the label such as “six”
Assignment of Number versus Counting

Counting is a serial operation (1, 2, 3, 4...). Assignment of number makes no presumption about order.

Troubles with Alex

“After responding without error in eight trials … Alex completely balked during testing for approximately 2 weeks.

He would, for example, stare at the ceiling, reply with a color or object label not on the tray, fixate on that label, and repeat it endlessly;

this behavior was interspersed with requests to return to his cage or with requests for water or various foods. …

He might produce labels for each of the four colors not on the tray, that is, carefully avoid any response that could be construed as task related … Occasionally he called out numbers that might or might not be relevant. We tried using what we thought might be more enticing items (e.g., jelly beans) to no avail.”

-- from Pepperberg & Gordon 2005

A More Serious Problem?

Alex was one bird. N=1.

We would like to replicate!

But other birds have not done nearly so well as Alex.

Ordinal Numerosity & Transitive Inference

Learn that: $A > B > C > D > E$

Then test pairings like C and E, or B and D

Prediction: Animals with complex societies should be able to do transitive inference.

Monkeys can do it, pigeons cannot.

But both monkeys and pigeons are social. And very different kinds of animals.
Prediction: Animals with complex societies should be able to do transitive inference.

Pinyon jays can do it, scrub jays cannot.

Pinyon jay
highly social, often forming very large flocks of 250 or more birds

Scrub jay
Forage in pairs, families or small groups

The Function of Transitive Inference?

In a large social group, a single individual cannot observe every possible dominance encounter.

Conflicts are risky: you shouldn't fight everyone to find out.

How do you know where you stand in the hierarchy?

Social Intelligence Hypothesis: complex sociality drives cognitive ability

Can birds use transitive inference to assign relative dominance?

Pinyon jays placed in chambers on either side of a chamber containing a peanut in a box.

Doors opened and birds show either dominance or submission.*

* Submission indicated by 'beak down' position.

Two Groups of Birds: Group 1 (A>B>C) and Group 2 (1>2>3)

Experimental: Observer Jay 3 watches B dominate 2, who 3 is submissive to.

Control: Jay 3 watches B dominate C, who it doesn’t know.
Prediction: If transitivity is inferred, Jay #3 in Experimental treatment should be more submissive to B than to the analogous jay in the Control treatment.

That’s what happened!

More circadian effects on cognition...

Honeybees learn better in the morning!

Explained as an adaptation to pattern of nectar availability of flowers

"The early bee catches the flower."

How generalized is this effect? Work on olfactory learning with cockroaches shows that circadian effects modulate acquisition of memories. They learn better in the early night.

Results imply that learning & memory are costly.

“Mental Time Travel” in Animals?

Remembering the past and being able to plan for the future has been viewed as a solely human feature.

Animals considered “stuck in the present.”

Studies with human suggest retrospective and prospective “travel” are part of the same neuropsychological process.
"Mental Time Travel" in Animals?

Remembering the past: Episodic Memory

Episodic memory = memory of what, where, and when

Experiment:
Scrub Jays given worms and peanuts to cache (what and where)
Then, jays learned that worms go bad (they degrade; when)
Then... (see next slide!)

Planning for the Future as Mental Time Travel

Scrub Jays show evidence of episodic memory
Can they plan for the future?

Only some kinds of behavior ‘count’ as planning for the future
1. Can’t reflect unlearned cues & needs to be a novel action
   Flying south for the winter = not planning
   Storing fat for hibernation = not planning
2. Can’t reflect current motivational state
   Getting food when you’re hungry = not planning

'Planning for Breakfast Experiment'

Jays placed in one of the side rooms for 2 hours every morning
They get to roam around all day; this repeats for 10 days.
On day 11 they are given seeds to cache, and trays for caching.
Jays cached 3x’s more food in the 'no breakfast' room.
'Breakfast Choice Experiment' to control for hunger location

Same set-up, but two types of breakfasts: peanut and dog kibble rooms.

Jays cached peanuts in the kibble-only room and kibble in the peanuts-only room.

Raby et al. 2007

Metacognition: Do You Know What You Know?  
*A form of introspection? "I think therefore I am"*

Make a judgment about the strength of your knowledge and use that to guide behavior.

Why would this knowledge be useful?

Testing metacognition in animals

Make a test with an “opt out” button where the animal can decline a difficult trial.

Give a huge reward for being correct, no reward for being incorrect, and a small reward for taking a pass.

Monkeys, dolphins, and rats all can do this (pigeons, maybe)

Testing metacognition in animals cont’d

Give the animal a test on how confident it was on its prior choice.

“Retrospective gambling paradigm”

Monkeys rate their confidence by wagering either a large or small number of tokens on the accuracy of their test trial right after they completed it (but before they get a reward or not).

Then they can “cash out” once a certain amount has been accumulated.

Monkeys wagered large amounts on the easy tests and small amounts on the difficult tests, as predicted.

Kornell et al. 2007

Theory of Mind

Theory of mind: an animal knows about the mental state of another animal
Theory of Mind cont’d
How might a theory of mind be useful?
- Using others to gain information
- Intentional deception
- Communicating with intent to inform

Theory of Mind:
Idea is that you need a sense of your own mental state for this to happen.
How can you test what an animal knows about the mental state of another animal?

The False Belief Task
The task tests for an understanding that someone else may have a belief different from your own.

- You have to know your state, the other animal’s state, and know the difference.

Well studied in child development:
Children before age 4 don’t perform well.
Autistic children don’t perform as well.

The False Belief Task
Children are told or shown a story involving two characters. The child is shown two dolls, Sally and Anne, who have a basket and a box, respectively. Sally also has a ball, which she places in her basket and then leaves to take a walk. While she is out of the room, Anne takes the ball from the basket, eventually putting it in the box. Sally returns, and the child is then asked where Sally will look for the marble. The child passes the task if she answers that Sally will look in the basket, where she put the marble. The child fails the task if she answers that Sally will look in the box, where the child knows the marble is hidden, even though Sally cannot know, since she did not see it hidden there.

In order to pass the task, the child must be able to understand that another individual’s mental representation of the situation is different from their own, and the child must be able to predict behavior based on that understanding.
Take a few steps back....

Knowing another animal’s state: seeing is knowing

"Knower" (watches when food is placed)  "Guesser" (out of the room when the food is placed)

Chimpanzees do well but must learn the task- what else are they learning that doesn’t require theory of mind?

Inferring another animal’s state from your own

I want that banana, therefore Trixie also wants that banana

Useful information in the wild...

A way to test this?
• 2 visors, one you can see through and one you can’t
• The subject learns this through experience
• Then the visors are given to a new animal
• Does the subject act appropriately as to whether the new animal can see food location?

Toddlers can do this, not sure about chimps

The Lessons of Clever Hans and Morgan’s Canon

Clever Hans could presumably understand German, count, and do arithmetic. Answered by varying the number of hoof touches to the ground.

Oskar Pfungst found that as long as someone present knew the answer, Hans could use subtle cues to give his answer.

C. L. Morgan, 1894

“In no case may we interpret an action as the outcome of the exercise of a higher psychical faculty, if it can be interpreted as the outcome of the exercise of one which stands lower in the psychological scale.”

(What is this scale? What seems simple often is not.)
"The Cognitive Revolution": Inferring what is in the ‘black box’
Comparing performance of animals to that of humans, who we can talk to
New methods mean it is less of a ‘black box’
An important component is natural history: what is it used for in the wild

New Caledonian crows show astounding abilities to use tools, abilities that rival what primates do.

But why them?

The ecological perspective suggests that an animal’s cognition
...should be tuned to the species’ ecology.