PS452
Intelligent Behaviour

Lecture 8: Tools, Puzzles, Beliefs, and Intentions

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Part 3: Intelligent Behaviour in Animals

- **Lecture 7: Animal Intelligence Tests**
  Measuring animal cognitive capacity
  - Learning and logic between species
  - The ubiquitous *g* factor

- **Lecture 8: Tools, Puzzles, Beliefs, and Intentions**
  Complex interactions with objects
  - Natural tool use
  - Understanding the properties of objects

Lecture 8: Tools, Puzzles, Beliefs & Intentions

- **8.1 The Problem of Explanational Indeterminacy**

- **8.2 Animal Tool Use**
  - Highlights from nature
  - Underpinnings of natural tool use

Lecture 8: Tools, Puzzles, Beliefs & Intentions

- **8.3 Problem Solving in the Laboratory**
  - Early work: trial & error versus insight
  - Asking the right questions
  - Modern work: animal causal reasoning
  - Evaluation of laboratory studies
  - Precocious tool users are special

- **8.4 Beliefs, Desires, Intentions**
  - Detecting intentional states
  - Dennett’s *Intentional Systems Theory*

8.1 Explanational Indeterminacy

- Kuczaj & Walker (2006)
  - Dolphins taught to gather weights to obtain fish, four weights necessary
  - Leant by imitation to carry individual weights
  - Some dolphins spontaneously learnt to carry multiple weights simultaneously
  - ➡ Planning/foresight to obtain food with fewer journeys?

8.1 Explanational Indeterminacy

- Kuczaj & Walker (2006) *cont.*
    - Or is there a simpler explanation?
        - Weights and food became more and more associated
        - As weights became associated with food, more carried
    - ➡ Results explicable by learnt associations
    - ➡ Not a demonstration of intelligent behaviour

➡ Avoid invoking human-equivalent cognitive processes unless absolutely necessary

➡ Simple explanation preferred to anthropomorphic one

8.2 Animal Tool Use

- Tool use is interesting from multiple perspectives
  - Animal capabilities can exceed genetic physical endowment
  - Widens environmental niche
  - ➡ Increases adaptation

  - A key stage in human evolution
  - Associated with development of language
  - ➡ Precursor to massive, rapid development

8.2 Animal Tool Use

- Tool use is interesting from multiple perspectives *cont.*
  - Might imply understanding of properties of objects?
  - ➡ Intelligent behaviour = selecting correct tool for task, modifying tools to improve function
  - ➡ What does tool use reveal about planning, causal reasoning, intent?

  - Kacelnik et al. (2006), Pearce (2008), Reznikova (2007), Visalberghi & Fragaszy (2006)

Highlights From Nature

- Rare in the animal world
  - Woodpecker finches remove/shape cactus spines, probe for insects in tree bark
  - Egyptian vultures drop stones on eggs to break them, have preferred stone sizes
  - Sea otters dive for shellfish, use stones to break shells
- Non-primate multiple tool use almost non-existent
  - Elephants throw logs, strip branches to swat flies, use grass to clean/close wounds

➡ Most usage limited: animals only ever use one object for just one specific purpose

Highlights From Nature

- More versatility [dexterity?] from primates
  - Most versatility from Chimpanzees, then orangutans, then gorillas, etc.
  - Food extraction
    - Chimpanzees strip sticks, probe termite mounds
    - Orangutans use sticks to assist eating *puwin* fruit
    - Leaf sponges used by chimpanzees, vervet monkeys
    - Stones used to break nuts by chimpanzees and capuchins
  - Defence/aggression
    - Objects (e.g. stones) thrown by many species
    - Chimpanzees use objects to make noises, e.g. oil drums

Highlights From Nature

- More versatility [dexterity?] from primates *cont.*
  - Intuitive physics
    - Gorillas use sticks to test water depth
    - Gorillas use logs to cross water

- Equal versatility from corvids (crows etc.)
    - Strip twigs, feathers to probe for insects in bark and holes
    - Reshape implements to improve function

Highlights From Nature

- Kacelnik et al. (2006)
    - Chimpanzees and New Caledonian crows are unique
        - Frequency: universal between populations
        - Diversity: different tools/different function
        - Complexity: tools may be manufactured

- Too much versatility for direct genetic programming?

➡ Why are these animals different?

➡ What are the cognitive origins of versatility?

Underpinnings of Natural Tool Use

- What might lead to animals using tools?
    - ***Innate mechanisms:*** genetic programming to use certain objects in certain ways
    - ***Trial & error:*** unprincipled manipulation of nearby objects reveals solution by chance
    - ***Imitation:*** tool use observed, repeated
    - ***Insight:*** understanding the causal properties of objects and identifying their potential role in attaining goals

Underpinnings of Natural Tool Use

- Natural tool use appears ingenious, but observational evidence has limitations
    - No control over upbringing/experience
    - No control over opportunities/needs

➡ Cannot give insights into origins, ability or understanding

➡ Laboratory studies needed for deeper insights

8.3 Problem Solving in the Laboratory

- Innate tool use: easy to rule this out for primates and corvids, especially when artificial objects are used
- Imitation: can attempt to restrict opportunities for this

➡ Early research sought to resolve whether tool use resulted from to ***trial & error*** versus ***insight***

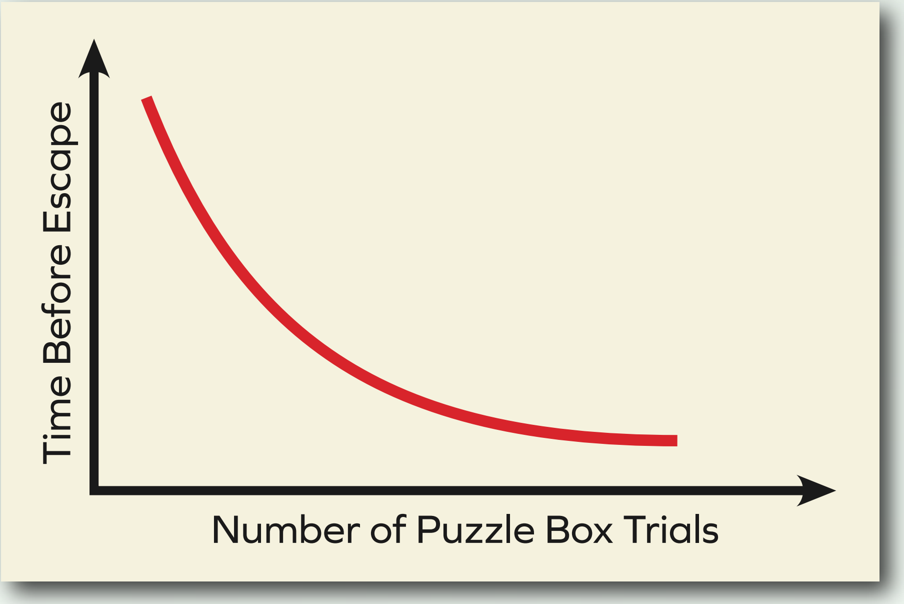
8.3 Problem Solving in the Laboratory

- Problem: any manipulation of a potential tool during problem solving can invoke ***trial & error*** explanation
  - Reznikova (2007)
    - Use of object must be sudden
    - No relevant past experience
  - Researchers seek to demonstrate
    - Periods of inactivity (= reflection?)
    - Objects used in novel ways, not previously observed

➡ Onus of proof for *insight* advocates becomes extraordinary

Early work: Trial & Error versus Insight

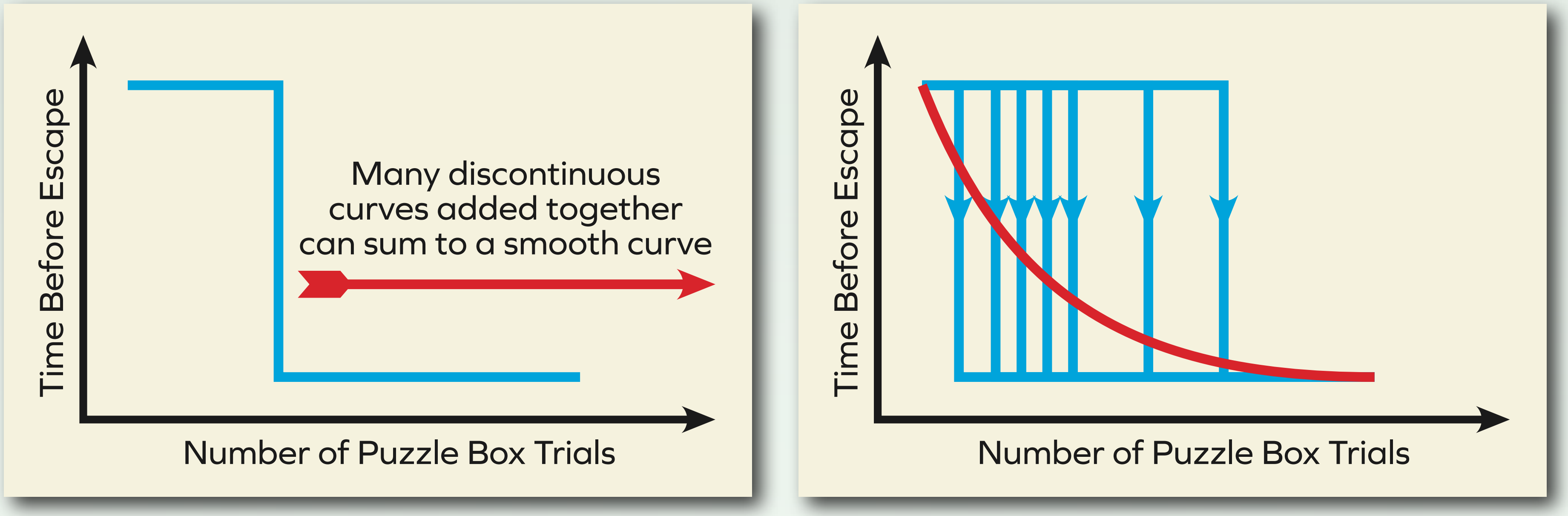
- Thorndike (1911)
  - Problem solving = random trial & error behaviour
    - Accidental success reinforced, response strengthened,
    - More likely to emit response in same situation in the future
  - Animals escaping from puzzle boxes
  - Gradual improvements, smooth learning curves



➡ Zero insight/inference/understanding

Early work: Trial & Error versus Insight

- Approach by Thorndike often criticised
  - Puzzle boxes gave little opportunity for insight
  - ➡ Impoverished situation → impoverished behaviour
  - Woodworth (1938)
    - Considerable individual differences between animals
    - Discontinuities (sudden solutions) often observed



➡ Cleaning noise from data or a misleading summary?

Early work: Trial & Error versus Insight

- Köhler (1920s)
  - Series of studies of problem solving by young chimpanzees caught in wild
  - Various situations, with a variety of objects in cage

(1) Food high up, out of reach

- Initial attempts at jumping failed
- After pause, single ape pushed box to food and stood on it

(2) Food outside of cage, slightly out of reach

- Initial attempts at stretching through bars failed
- Failed attempts included reaching with food dish
- After pause, single ape used stick to reach for food

Early work: Trial & Error versus Insight

- Köhler (1920s) *cont.*

  (3) Food outside of cage, far out of reach of single stick

    - Initial attempts at using single stick failed
    - Likewise throw stick outside and push with another stick
    - Later, playing with sticks, accidentally joined two together, immediately went to food and successfully reached for it

  - Across all studies
    - Not random behaviour
    - Mixture of lucky discoveries, and failure-retreat-solution
    - Awareness of concepts such as distance/reach
    - ➡ Not entirely compatible with Thorndike's conclusions

Early work: Trial & Error versus Insight

- Observations on Köhler's (1920s) work
    - Considerable individual differences
        - Best apes: repeated attempts at novel (creative?) solutions
        - Worst apes: complete failure, e.g. push box containing heavy stones
    - ➡ Indicates reaching upper limits of chimpanzee ability?
    - ➡ Compatible with Chabris (2007): universal *g factor*

Early work: Trial & Error versus Insight

- Observations on Köhler's (1920s) work *cont.*
  - Previous history of apes unknown
  - Able to play in laboratory
  - Birch (1945)
    - Chimpanzees bred in captivity only retrieve food with sticks after experience playing with them

    ➡ Successful use requires past reinforcement?

  ➡ Problem solving behaviour comprises trial & error, memory, understanding?

Asking the Right Questions

- *Trial & error* versus *insight?*
  - Trial & error so wide-ranging that criteria for insight make its demonstration almost an impossibility

  ➡ Could humans demonstrate insight by the criteria

  - Can humans use tools/objects successfully without manipulating/exploring them beforehand?

  ➡ Insight requires knowledge/experience?

  - Pearce (2008): false dichotomy

  ➡ Elements of knowledge and inference in almost all use of novel objects in novel situations

Asking the Right Questions

- *Is insight about object properties the only criterion for intelligent behaviour?*
  - Epstein, Kirshnit, Lanza & Rubin (1984)
    - Trained pigeons to push a box towards a spot randomly placed on a wall
    - Trained same pigeons to climb on a static box to peck at a plastic banana
    - Fully trained pigeons now placed in novel situation: no spot on wall, box not under banana
    - ▸ Pigeons pushed box under the banana and climbed upon box to peck at it
    - ▸ Fastest performance better than apes
    - ➡ Learning necessary, but no trial & error

Asking the Right Questions

- *Is insight about object properties the only criterion for intelligent behaviour? cont.*
  - Pearce (2008): Pigeons learned to push box towards food association (spots/bananas)?
  - Reznikova (2007): Apes often gathered inappropriate tools! Associated with food?
  - ➡ Primate problem solving is mere activation of learned associations between objects/actions and food?

Asking the Right Questions

- *Is insight about object properties the only criterion for intelligent behaviour? cont.*
  - Pigeon behaviour interesting because it is goal directed
    - Applied novel ***sequence*** of learnt behaviours to attain goal
    - ➡ Not insight but still important
  - Many interesting/relevant unanswered questions
    - Can all species create sequences equally well?
    - If pigeons had three step problems, would they omit steps or mis-sequence them?
    - If pigeons taught several behaviours, including irrelevant ones, would they be able to select the correct behaviours?
    - What are the control processes to select and co-ordinate individual components of sequences of behaviour?

Asking the Right Questions

- *Is insight about object properties the only criterion for intelligent behaviour? cont.*
  - In humans
    - Stenning & Van Lambalgan (2007): Sequencing of complex actions requires planning, a precursor to language in humans, a marker for advanced cognition
    - Intelligence = sophisticated goal management
    - Highest intelligence = the most effective goal management
  - Goal-directed sequencing of behaviour in animals is worthy of attention

Modern Work: Animal Causal Reasoning

- Problem solving tasks where solution is ‘visible’
  - What can animals infer from visible environment?
  - Understanding of causal properties of objects if …
    - Rapid solution
    - Objects are modified in order to perform the task
    - Appropriate behaviour if task is modified
  - Can easily modify tasks systematically

  ➡ Can animals show insight = obsolete question

  ➡ What are the limits of animal understanding?

Modern Work: Animal Causal Reasoning

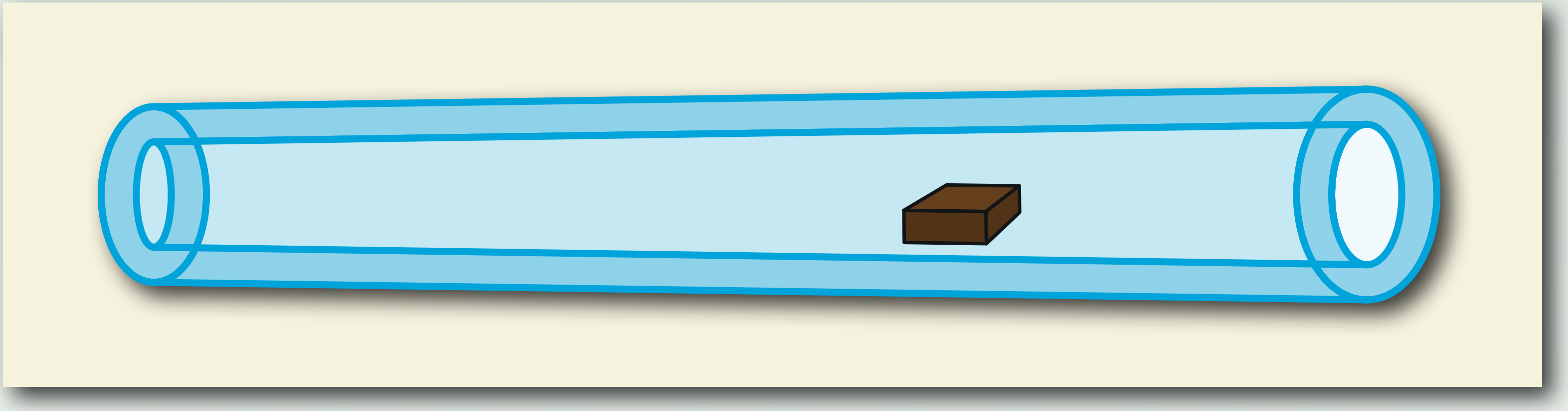
- ***Pulling string tasks*** *(zero order complexity)*
  - Pull string or cloth to obtain food
    Do not pull string if food not visibly linked
    - Success:
      - Most apes/monkeys (not all individuals)
      - One-year-old children
      - Many birds (individual and species differences)
      - Kea (parrot): correct string even if crossed
    - Failures:
      - Digger wasps (on prey)
      - Elephants (despite widespread tool use)
    - Difficult to train:
      - Cats, rats
    - Attempt to cue experimenter:
      - Socialised animals (dogs, talking parrots)

Modern Work: Animal Causal Reasoning

- ***Stick tasks*** *(first order complexity)*
  - Use stick or similar to draw in food
    May need to choose appropriate stick
    - Success (requires good dexterity)
      - Apes and monkeys
      - Certain corvids
      - New Caledonian Crow (Kacelnik *et al.* 2006)
        - Can select appropriate length even when tool/reward not simultaneously visible
        - Can select appropriate rigidity
        - Can create hooks from wire without trial & error

Modern Work: Animal Causal Reasoning

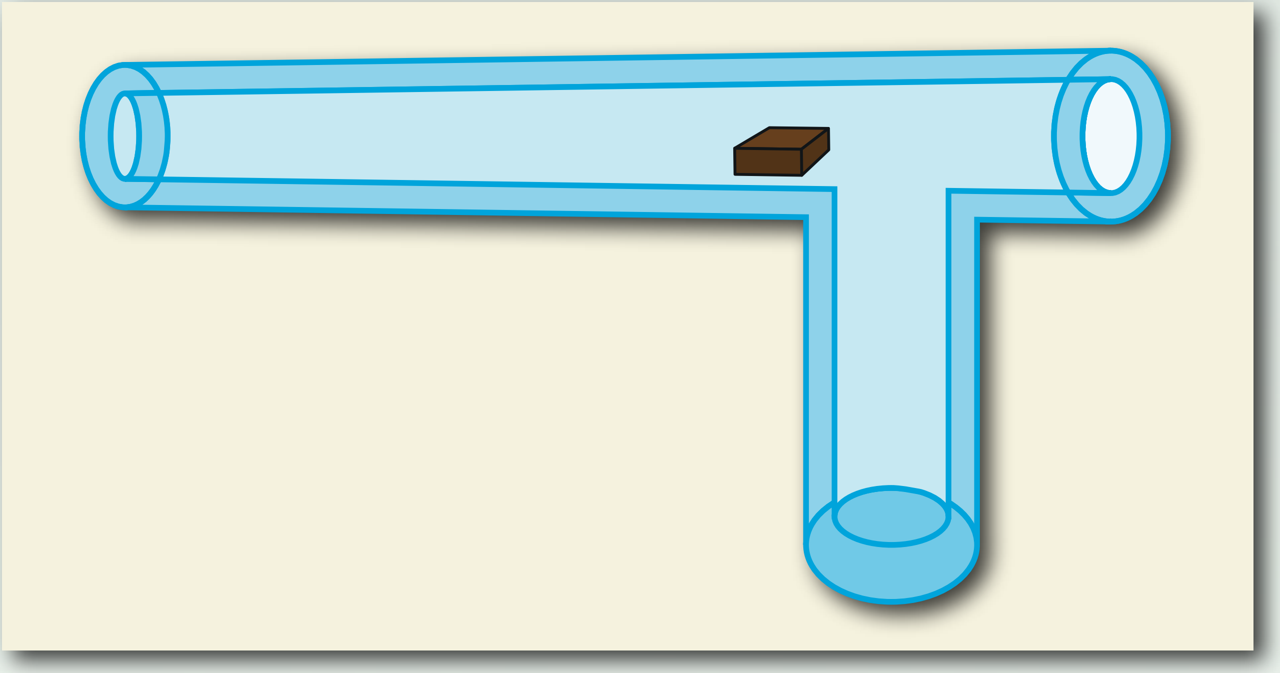
- ***Tube tasks*** *(first order complexity)*
  - Use stick to push food out of tube
    May need to modify sticks

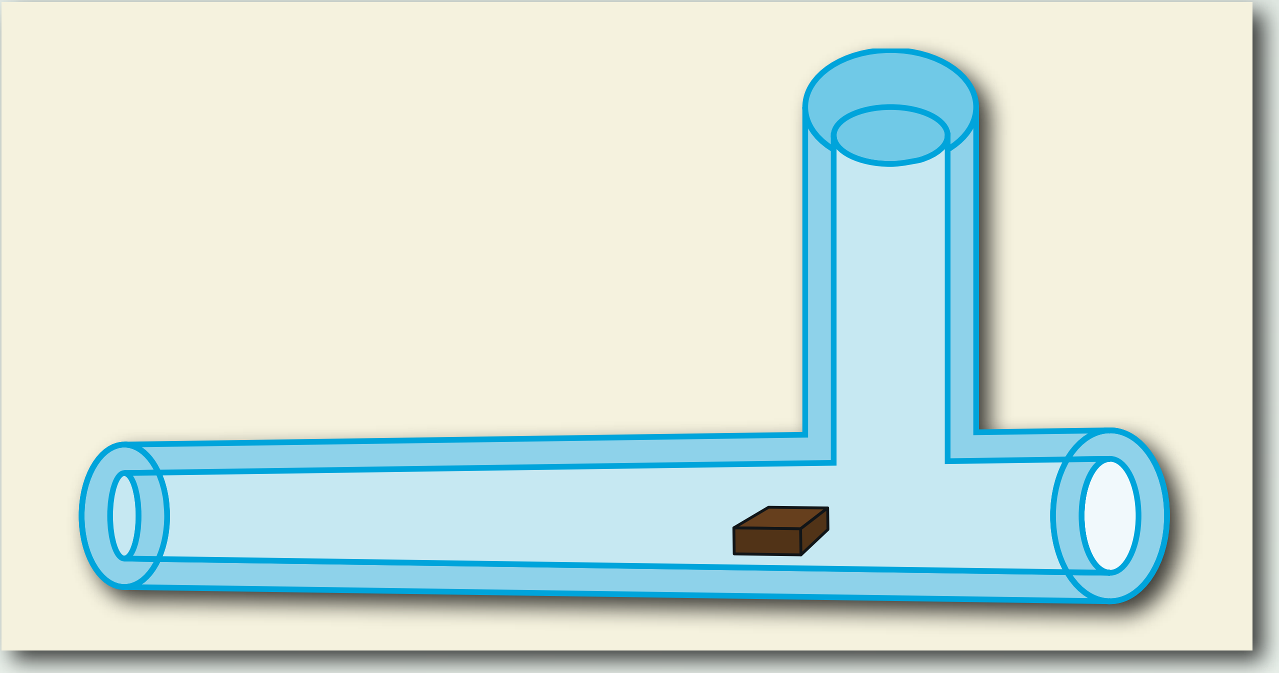


- Success (requires good dexterity)
  - Chimpanzees/other apes
    - Can reshape, unbundle, without trial & error
  - Capuchins
    - Poor at reshaping, unbundling
  - Corvids
    - Can choose diameter, unbundle, reshape

Modern Work: Animal Causal Reasoning

- ***Tube tasks with trap*** *(second order complexity)*
  - Use stick to push food out of tube, avoiding trap
    Learn that *inverted trap* presents no obstacle





Modern Work: Animal Causal Reasoning

- ***Tube tasks with trap*** *(second order complexity) cont.*
  - Use stick to push food out of tube, avoiding trap
    Learn that *inverted trap* presents no obstacle
    - Partial success (requires good dexterity)
      - Chimpanzees/other apes
        - Can learn 'nearest opening' strategy loses food
        - Cannot react to trap inversion
      - Capuchins
        - Can learn 'nearest opening' strategy loses food
        - Cannot react to trap inversion
      - Corvids
        - Can learn 'nearest opening' strategy loses food
        - Cannot react to trap inversion

Evaluation of Laboratory Studies

- Individual differences important
  - Small number of studies with small sample sizes
  - ➡ Species failure could be sampling failure

  - Poor performance is revealing
    - Köhler: Bad mistakes

      Pulling down on stick hanging from loop
      Failure to refine solutions
      Negative transfer/set effects
  - ➡ Success/flexibility = exception, not the rule

Evaluation of Laboratory Studies

- Modern work
  - Causal reasoning can be demonstrated, and its limits
  - ➡ With dexterity caveats, exactly same species pattern as for learning (Lecture 7) and natural tool use

    Apes

    Monkeys = Corvids

    Other mammals = Other birds

    Reptiles, amphibians, fish???

Precocious Tool Users are Special

- Kacelnik et al. (2006)
  - Corvids are outstanding tool users amongst birds
    - Chose rigid rake over flexible one, exposed to rakes before, but not used for dragging
    - Spontaneously created hook from wire, never encountered wire, or similar, before
  - As good as monkeys and even chimpanzees, sometimes better
- Cognitive capacity out of the ordinary?
  - Good rule learning (Lecture 7)
  - Good problem solving/causal reasoning (Lecture 8)

➡ ***Anything else?***

Precocious Tool Users are Special

- Visalberghi & Fragaszy (2006)
  - Capuchin monkeys
    - In the wild: destructive foragers, seek hidden food, little tool use
    - In the laboratory: considerable tool use

    - In the wild: tree-living limits ***both*** availability ***and*** manipulability of objects (plus prolific food)
    - In the laboratory: considerable cognitive focus on objects: explore, manipulate

➡ ***Focused cognitive capacity is crucially important***

Precocious Tool Users are Special

- The best learners/tool users/problem solvers/ causal reasoners are different
  - Best manipulation skills (beaks, arms)?

    Physical opportunities limited for most animals
  - Innate interest in objects (twigs, containers)

    Potential tools must feature 'on the radar'
  - Few predators, so attentional priorities differ

    Exploring objects and deliberation = luxury

➡ ***All of the above are true for humans too***

Precocious Tool Users are Special

- Three possibilities

  (1) ***Tool users have innate predispositions to use certain objects in certain ways***, other animals have other skills

  Unsatisfactory explanation for the most versatile users

  (2) ***Tool users have superior cognitive capacity*** giving them the induction skills and goal management necessary for learning, tool use, problem solving, causal reasoning

  Enough by itself? How much capacity is needed?

  (3) ***Tool users have innate predisposition to explore objects*** leading to superior understanding of their properties

  Interest and knowledge gained enhances performance compared with less focused animals of similar capacity

8.4 Beliefs, Desires, Intentions

- McFarland (2008)
  - Humans appear to have plans, goals, beliefs, desires, intentions
  - ➡ These may guide behaviour
- Searle (1980)
  - ➡ Computers have the wrong hardware, can never be intentional
- Animals have the right hardware, can their brains be intentional?

➡ When a chimpanzee chooses a stick, does it believe that it will solve the problem?!

➡ Is appearance of surprise/distress on failure enough?

Detecting Intentional States

- Avoid ***anthropomorphism*** whenever possible

➡ Are intentional concepts needed to understand behaviour?

- Are ***assumptions*** warranted

➡ Are human intentions really behaviourally causal, or are they part of narratives constructed after events?

- Beware ***architectureism***
  - A pet waits at a food bowl, does it desire food and believe this will be provided?
  - A computer plays chess, does it desire my defeat and believe that it can win?

➡ What would animals have to (fail to) do, in order not to have intentions ascribed to them?

Detecting Intentional States

- Heyes and Dickinson (1993)
  - Causal accounts of intentions assume rationality
  - ➡ Cannot predict that beliefs/desires will affect behaviour for irrational entities

  - Testable predictions needed
  - Enormously difficult to identify
    - Thermostat: goals and control, but not intentions
    - Computer: chess, civilization game, likewise
  - ➡ Do things with intentions behave differently from things without them?

Detecting Intentional States

- Heyes and Dickinson (1993) *cont.*
  - Do beliefs *cause* behaviour?
    - Put animal in a world where expressing its beliefs prevents it from attaining goals
    - ➡ Does it change its behaviour?

    - When chicks approach food bowl, do they believe that this will enable them to obtain food?
      - Food bowls raced away when approached
      - Approached the chicks when they walked away
    - ▸ No change in behaviour, chicks chased away food
    - ▸ Many animals (e.g. rats) have difficulty learning that approach may cause failed goal attainment

Detecting Intentional States

- Heyes and Dickinson (1993) *cont.*
  - Do beliefs *cause* behaviour?
    - ***Either*** no beliefs about approach, automatically attempt to obtain food
    - ***Or*** possess beliefs, no causal properties, could not prevent physical response
    - ***Or*** defective beliefs about approach insufficiently flexible to change
    - ➡ Approach behaviour may be non-intentional in some cases

- ***But*** many human beliefs very resistant to change also?

Detecting Intentional States

- Heyes and Dickinson (1993) *cont.*
  - Do desires *cause* behaviour?
    - Difficult to manipulate desires
    - Difficult to separate desire from motivation
    - Put animal in a situation where satisfying desires is no longer fulfilling
    - ➡ Does it change its behaviour?

    - Rats taught to obtain saccharine solution, then drug given to induce nausea, taste now associated with illness
    - ▸ No difference in drinking *initiation* compared with controls
    - ▸ Reduced drinking *after* solution tasted

Detecting Intentional States

- Heyes and Dickinson (1993) *cont.*
  - Do desires cause behaviour?
    - Rats expected solution to quench thirst?
    - ➡ Reminded of nausea when tasting so that desire reduced?

- McFarland (2008)
  - Behaviour can easily be simulated by a 'robot rat'
  - ➡ Differences between intentional versus non-intentional behaviour too subtle to test empirically

Dennett's *Intentional Systems Theory*

- Simple animal behaviour too likely to be too automated to be subject to reveal intentionality
- Communication and social behaviour sufficiently complex?
- All-or-nothing ***intentional*** versus ***non-intentional*** unlikely

➡ ***Intentional Systems Theory*** provides a graded framework for interpreting behaviour

Dennett's *Intentional Systems Theory*

- Dennett (1983)
  - Some animals may be treated as intentional systems
  - Intentional stance: behaviour of a system can have an intentionality level ascribed to it
    - Classify behaviour by intentionality level
    - Determine highest degree of intentionality that an organism can display by observing its behaviour
    - Predict complexity of behaviour in future?

  ➡ Need not be real, a convenience with predictive power

  ➡ More predictive than behaviourist stance?
- E.g. vervet monkeys give different alarm calls according to which predator is seen, such as a lion …

Dennett's *Intentional Systems Theory*

0 ***Zero order:***
Reflexes/associations

Lion call automatically triggered by lion
"AAAGH"

1 ***First order:***
Agent desires to change behaviour of target, not beliefs

"A first order intentional system has beliefs and desires (…) but no beliefs and desires about beliefs and desires."

Monkey desires others to climb to safety
"CLIMB"

Dennett's *Intentional Systems Theory*

2 ***Second order:***

Agent desires to change the beliefs of target, *now knows about beliefs and desires of target*

Monkey desires others to believe that there is a lion (and hence to climb trees)

"LION"

3 ***Third order:***

Agent desires to change the target's belief about agent's beliefs/desires

Monkey wishes others to believe that it wishes them to climb trees

"?????"

Dennett's *Intentional Systems Theory*

- Dennett (1983)
  - Human limit around 5th/6th order?

➡ Vervet monkey lifestyle and vocalisations can't do this justice …

Dennett's *Intentional Systems Theory*

0 **No intentionality:** an automatic response

"!@$", "ouch", "fire"*

1 Change **TARGET behaviour,** e.g. an order

"Get out of this building"

2 Change **TARGET beliefs,** e.g. a warning

"This building is on fire"

Dennett's *Intentional Systems Theory*

3 Change **TARGET beliefs about AGENT beliefs,** e.g. an excuse

"I left the lecture early yesterday because I thought that the building was on fire"

4 Change **TARGET beliefs about AGENT beliefs about TARGET beliefs,** e.g. an accusation

"I don't think you really thought that the building was on fire yesterday, I think that you were looking for an excuse to leave early"

Dennett's *Intentional Systems Theory*

5 **Change TARGET beliefs about AGENT beliefs about TARGET beliefs about AGENT beliefs,** e.g. a revelation

"I want you to know that I am fully aware of just how gullible you think I am for being fooled by the fire alarm prank yesterday"

6 **Change TARGET beliefs about AGENT beliefs about TARGET beliefs about AGENT beliefs about TARGET beliefs,** e.g. a denouement

"I never realised that you knew I had evidence to show that you didn't really believe that the building was on fire yesterday"

Dennett's *Intentional Systems Theory*

- Dennett (1983)
  - How intentional are Vervet Monkey alarm calls?
    - Always given even when no others nearby
    - ➡ Definitely zero order
    - Only given when others present
    - ➡ At least first order intentionality?
  - ➡ Intentionality level = empirical question

Dennett's *Intentional Systems Theory*

- Cheney & Seyfarth (1985, 1991)
  - Varied vervet monkey company and its (visible) status
  - ▸ More likely to give alarm calls when own offspring present than only others present
  - ➡ Not an automatic response, otherwise no target effects
  - ▸ Calls NOT altered by the known knowledge (gaze direction) of targets
  - ➡ Unlikely that vervet communication is more than first order?

Dennett's *Intentional Systems Theory*

- Is this a potential animal intelligence test?

➡ Only if classification is genuinely possible

- What sorts of complex social behaviour might ascend the intentionality scale?

➡ Communication (Lecture 9), deception (Lecture 10)?

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