PS452 Intelligent Behaviour

Course Overview

Lectures 1 to 2

- Intelligent behaviour in humans

Lectures 3 to 6

- Intelligent behaviour in machines

Lectures 7 to 10

- Intelligent behaviour in animals

Part 3: Intelligent Behaviour in Animals

1) Animal Intelligence Tests

➲ *Can we measure animal cognitive power?*

- Between species: difficult?
- Within species: easy?

2) Planning, Tools, and Puzzles

➲ *What is learnt from complex behaviour?*

- Natural tool use
- Understanding the properties of objects

3) Animal Communication

➲ *Deliberate acts or mindless signals?*

- Natural communication
- Taught language

4) Mind Reading and Deception

➲ *The most complex behaviour of all?*

- Predicting the behaviour of others

Lecture 7:
Animal Intelligence Tests?

1) Animal Behaviour Research

- Potential pitfalls
- Potential insights

2) Searching for Intelligent Behaviour

- Origins of behaviour

3) Intelligence Tests for Animals?

- Futile debates
- Learning tasks
- Evaluation

4) The Ubiquitous *g* Factor

5) Overview

1) Animal Behaviour Research

Potential Pitfalls

❶ *Wrong conceptualisation of evolution*

- Evolution not the ascent of a grand staircase to a higher existence [Hodos & Campbell, 1969; Pinker, 1994]

➔ Chimpanzees are not defective humans

➲ Evolution = adaptation to environment

➲ If environmental changes make human intelligence a hindrance, it will decline

❷ *Wrong conceptualisation of intelligence*

➔ Spatial, navigation, and memory skills of many animals superior to humans

➲ Is a single intelligence ladder appropriate?

❸ *Anecdotal evidence*

- Individual impressive acts = accidents, not intelligence?

➲ Experiments / statistical analysis needed

❹ *Observational evidence*

- Without manipulating surroundings, errors of interpretation can result

➔ Disruption of hunting wasp behaviour (see Copeland, 1993) gives endless loop:

Wasp drags food to mouth of burrow
Wasp checks larva in burrow
Experimenter moves food
Wasp leaves burrow
Wasp drags food to mouth of burrow

➲ Complex behaviour = *fixed action pattern*

➲ Failure to test leads to misunderstanding

❺ *Unwarranted assumptions*

- E.g. *consciousness*
- Griffin (1992):
  Intelligent thought = conscious thought
- Velmans (1991): Narrow range of focal attention-related cognitive phenomena
- Johnson-Laird (1982), Humphrey (1983):
  A specific process for a specific purpose

➲ Widespread in this field

➲ Apply *Occam's Razor:* minimal complexity

❻ *Anthropomorphism*

- Interpret in a human frame of reference

➔ McFarland (1993): Experiment to induce frustration in pigeons

One (aggressive) bird managed to escape

Pulled wiring apart on apparatus

➲ Later, realised that he had seen courtship and nest building

❼ *Speciesism*

- Some species benefit much more from ❻
- Human research focuses on these species

➔ In the right circumstances:

Pigeons/parrots perform as well as apes

Octopuses perform as well as vertebrates (Wells, 1987)

➲ Important findings neglected, misdirects understanding of intelligence

❽ *Architectureism*

- Computers judged much more harshly?

➲ Empathy with animals overrides logic?

❾ *Futile Questions*

- *Can X do Y?* leads to futile debates throughout psychology

➲ Quantitative differences are just as illuminating

Potential Insights

❶ Theories of Intelligence

- Jensen (1980): evidence for single scale for animals = evidence likewise for humans

❷ Human Cognition

- How do species (including humans) differ?
- What processes are necessary for animals and humans? (Byrne & Whiten, 1995)

➲ Symbols, goals, representations, imagery, mental models, schemas, intentions, awareness, or consciousness required?

- Qualitative or quantitative differences?

  Control processes
  Cognitive capacity
  Modules
  Attentional focus (*virtual modules*)

➲ Do humans have more capacity, faster, or different processes to animals?

❸ Wider Issues: Computers versus animals

- Brooks (1991): representations are computationally expensive
- McFarland (1993): rule following is no different from behaviour of a machine

➲ Some animals no more than computers?

- Strong Symbol System Hypothesis: Only computers can be minds

➲ If true for humans, must also be true for animals (Boden, 1989)

- What is needed for thinking?
  computer = symbol system (and syntactic)
- STRONGSSH: computer: **NEC** and **SUFF**
  WEAKSSH: computer: **SUFF**, not **NEC**
  CHINESE-ROOMSSH: computer: **THINKING IMPOSSIBLE**

➲ Where do animals fit in relation to this?

➲ Symbols, intention, meaning, Searle?

2) Searching for Intelligent Behaviour

- Human intelligence: effective …

❶ Reasoning and problem solving strategies

❷ WM capacity and control processes

➲ Adaptive behaviour when seeking goals

- Computer intelligence: in contrast …

❶ Brute force/well defined problems

❷ Lacks inference skills and grounding

➲ Some success but mainly brittle

➲ Needs intelligent programmer

Origins of Animal Behaviour

❶ Genetically programmed/natural selection (innate, instinctive, species specific)

❷ Learned by individual animals

❸ Combination (a): genes supply a general blueprint, fine tuned by learning

❹ Combination (b): genes supply attentional focus, learning is directed

➲ ❶ analogous to computer program

➲ ❷ ❸ ❹ imply intelligence

Spotting Innate Behaviour

- Automatic, no learning requirement
- Inflexible, relies on constant environment

➲ Hard to alter if environment changes

Characteristics of Innate Behaviour

❶ *Innate Releasing Mechanism:* stimulus always triggers the same behaviour

➔ E.g. sea slugs react to starfish

➲ No learning needed if reliable predictors

❷ *Fixed Action Pattern:* behaviour sequence completed even if stimulus is removed

➔ E.g. sea slug's response to starfish

➲ No leeway needed if sequence is successful, and benefits outweigh costs

❸ *Species Specific Behaviour:* all perform in the same stereotyped way (e.g. coughs)

➲ Similarity: genetic component likely

➲ Especially if reliable environment and also performs a survival need

CAUTION: All species members have similar learning opportunities

❹ *Develops despite raised in isolation*

- Is behaviour observed the first time appropriate stimuli encountered?

➔ Sea slugs react to starfish extract

Problem: have all possible sources of learning been eliminated?

➔ Wood ducks react to recorded assembly call of mother …

… but only if eggs are incubated together [calls in eggs similar to assembly call]

➔ Squirrel nut burying behaviour innate?

Can still practise motor skills in isolation

- Much behaviour has a clear genetic basis

➲ Recurring problems solved by evolution

➲ Avoids the pitfalls of learning

➲ Simple animals prosper with low ability, and limited information (Wells, 1987)

Learned Behaviour

- Dangerous if errors are rapid and fatal

➔ Motmot bird must avoid deadly food (programmed, red/yellow coral snakes)

➔ Toad must avoid unpalatable food (learning)

➲ Learning evolves if it improves survival

- Learning useful in an environment which natural selection cannot fully anticipate

➲ Learning capacity develops alongside environmental niche instability/variety

Behaviouristic Learning = Not Intelligent?

- Basic learning principles well known:

  Classical conditioning
  Operant conditioning

➲ Much animal behaviour can be explained by the learning of associations

- Inadequate for human behaviour?
- Inadequate for some animal behaviour (c.f. Tolman)

➔ How much can behaviourism account for?

➲ Beyond this: intelligent behaviour?

2) Intelligence Tests for Animals

- Intelligence and learning synonymous:

➔ Jensen (1980): intelligence =
Speed and complexity of learning
Transfer of learning
Acquisition abstract concepts

➲ Better ability to learn = more intelligent

- Animals: inductions/deductions important for survival
- The most interesting learning tasks: *Transfer* or *Learning to learn*

➲ Looking for abstract rule learning

- Main variables:

Complexity of relationships
Quantity of information
Speed of learning

➲ Similar principles to human IQ tests?

A Bad Research Question

- Are differences between animal species and humans *qualitative* or *quantitative*?

① Are all (most?) animals able to learn anything, differing only in speed?

② Are there some classes of learning task which some (all?) animals cannot do?

➲ A simplistic distinction

➲ Too much focus on *can species do X*

➲ Like other branches of psychology, misdirects research towards futile debates

➲ Leads to *null hypothesis* (see later)

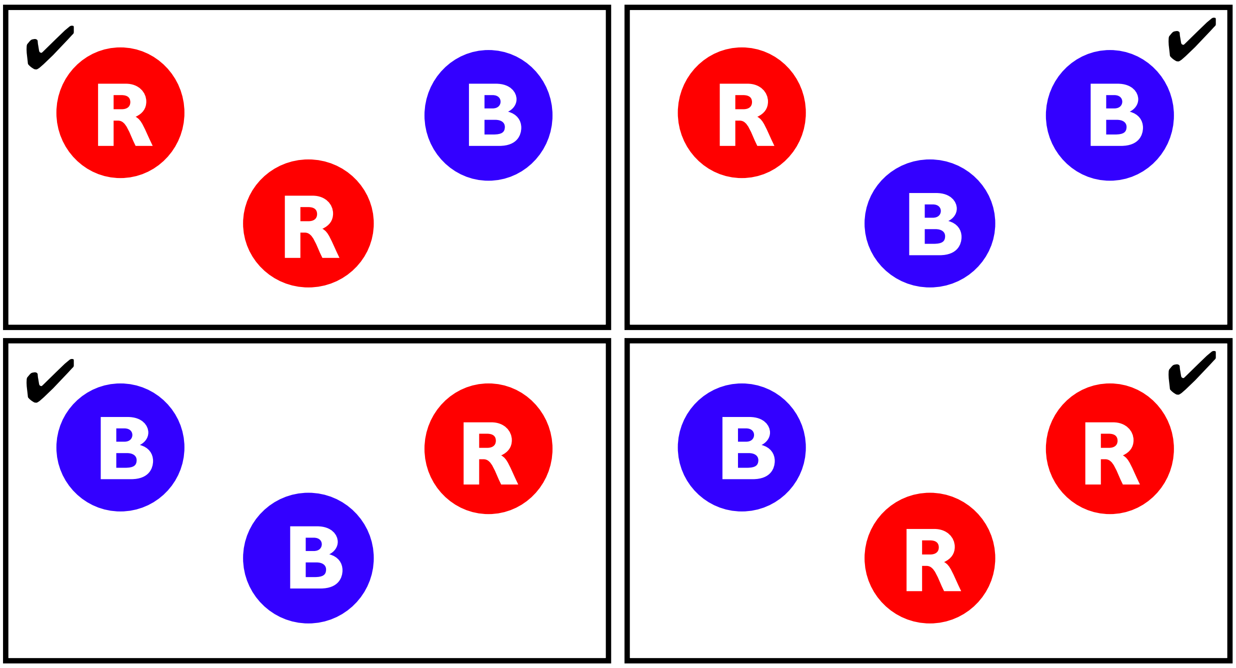
➲ Qualitative framework gives just as much, or more insight

- Reviews from:
  Delius & Delius (2006)
  Mackintosh (1988)
  Pearce (2008)
  Reznikova (2007)

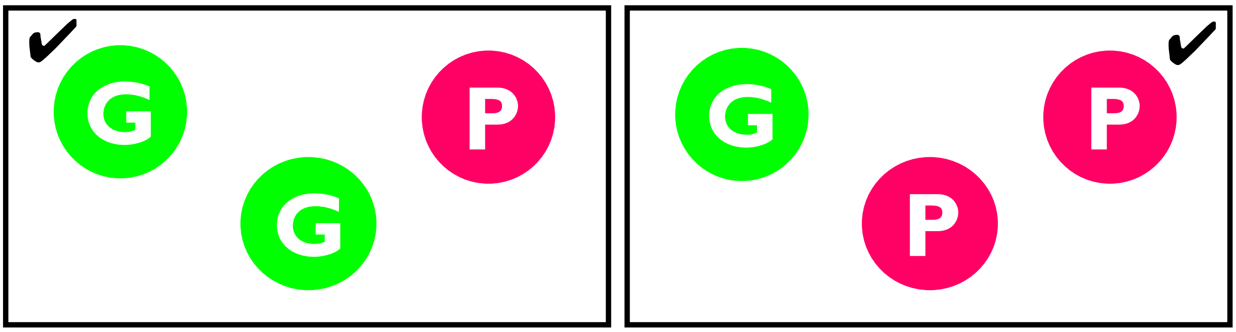
❶ Matching and Oddity

Matching Task

① Teach animal to ‘select’ stimulus that matches target



② Change the stimulus but continue to reward matching



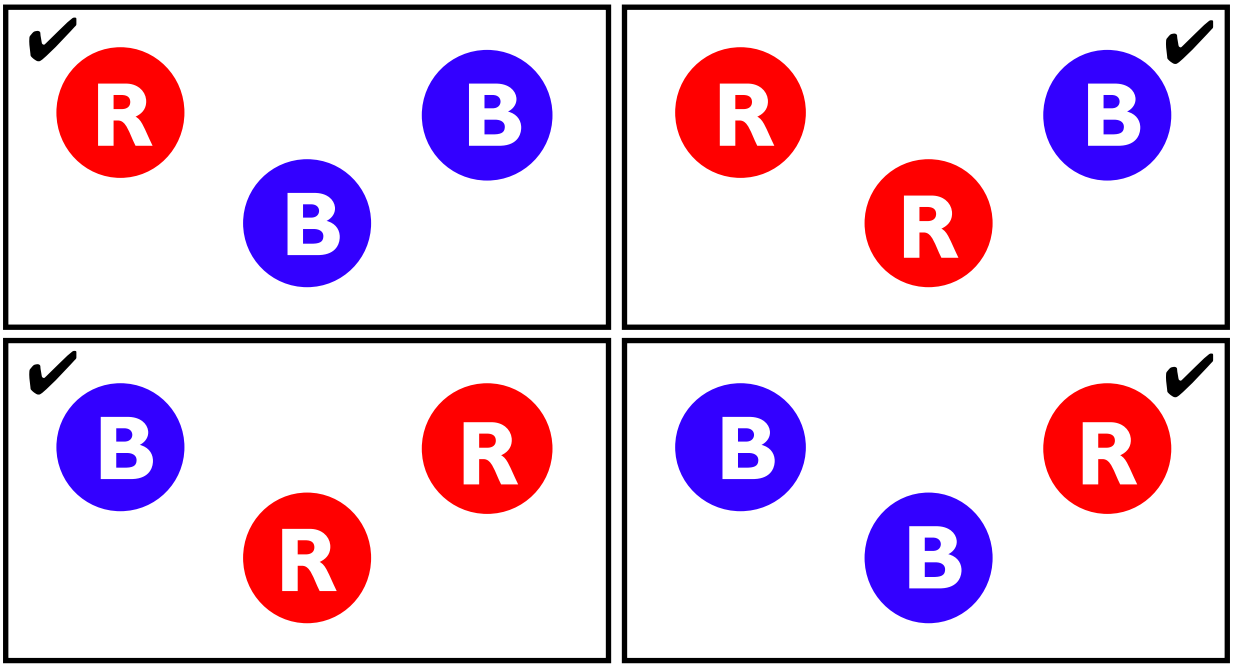
- Rule: select stimulus similar to target

➲ Start from scratch: learnt exemplars

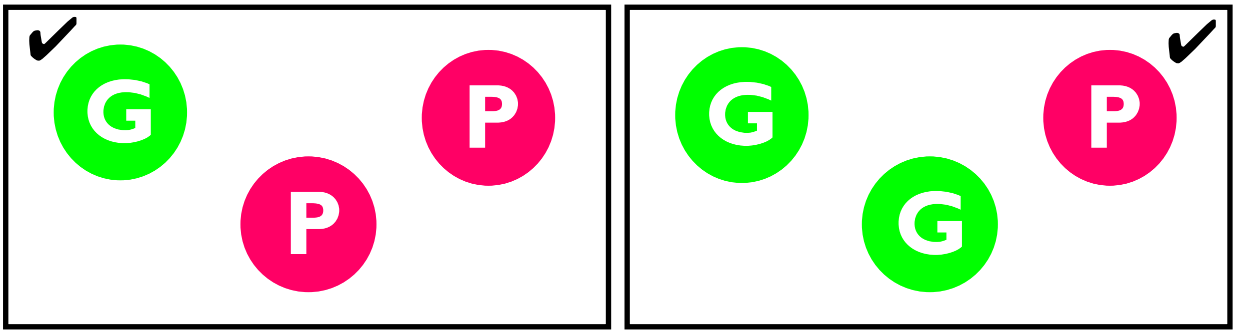
➲ Rapid learning = transfer of training

Oddity Task

① Teach animal to 'select' stimulus that differs from target



② Change the stimulus but continue to reward oddity



- Rule: select stimulus different from target

➲ Start from scratch: learnt exemplars

➲ Rapid learning = transfer of training

Mammals

➔ Success for chimpanzees, rhesus monkeys, dolphins, sea lions

➲ Specific exemplars ➔ Abstract rule?

Birds

➔ ***Pigeons***: Enormous difficulty

Tend to learn specific patterns

[Excellent visual memory]

➲ Difficulty learning abstract rule?

Good pattern learning, poor rule learning

➔ ***Crows***: Task is much easier

Similar sensory capabilities to pigeons

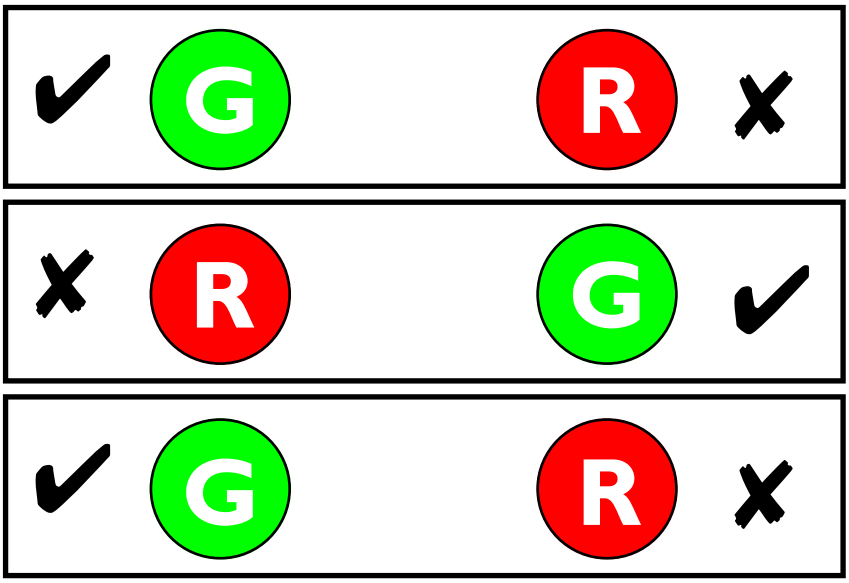
➲ Macintosh (1988): suggests a *qualitative* difference in bird learning mechanisms?

❷ Reversal and Learning Sets

Reversal Task

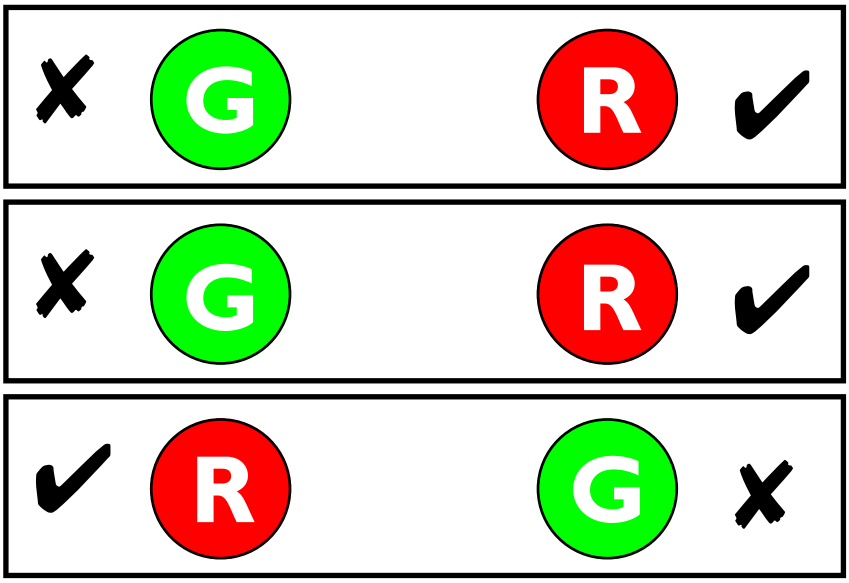
① Teach animal to select correct stimulus

E.g. food is under white cup, never black



② Then switch

E.g. food under black cup, never white

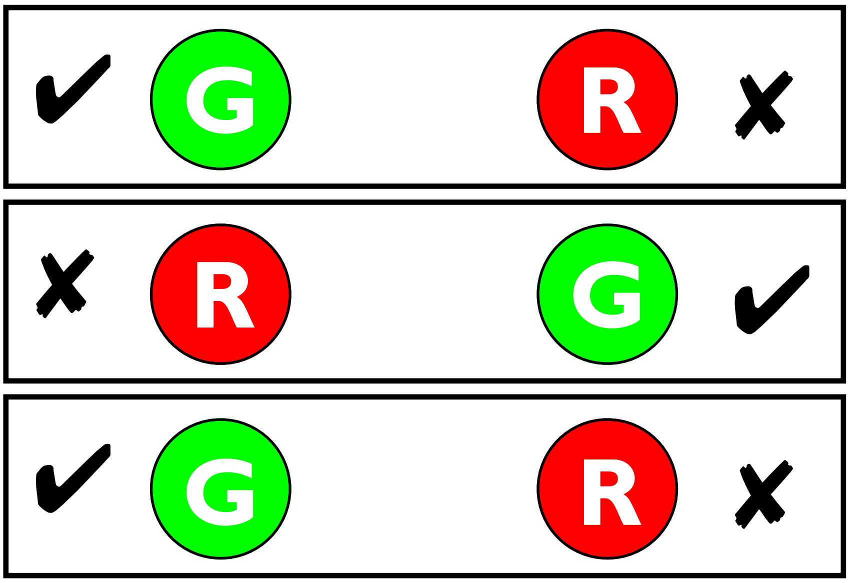


③ Then change again etc.

Learning Set Task

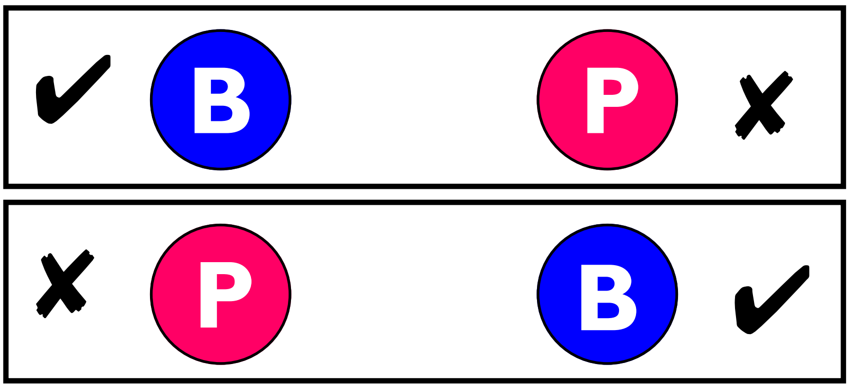
① Teach animal to select correct stimulus

E.g. food is always under white cup, never black cup, *this is the training set*



② Change the objects and the rule

E.g. food under small cup, not large cup



③ Then change again

E.g. food under yellow cup, not blue cup

- Reversal task:

➔ Win-stay, lose-shift strategy?

➲ Abstract rule: *Food associated with one stimulus*

- Look at % correct on trial 2 of reversal

➲ Start from scratch: concrete association

➲ Perfect performance from T2: learnt shift

- Learning set task:

➔ Win-stay, lose-shift strategy?

➲ Harder than reversal: abstract rule: *Food associated with one TYPE of stimulus*

- Look at % correct on trial 2 of new task

➲ Start from scratch: concrete association

➲ Perfect performance from T2: learnt rule

Reversals versus Learning Sets

➔ Macintosh (1988): similar species pattern to matching and oddity tasks

Mammals

➔ Warren (1973): Rhesus monkey **>** other monkeys **>** cats **>** rats and squirrels

➔ 250+ trials for rhesus monkeys
to learn fully task fully
> chimpanzees **>** 6/7 year old humans

➔ Apes, macaques and capuchins can learn *win / shift–lose / stay* (for both **R** and **LS**)

➔ Rats eventually learn **R** but poor at **LS**

Birds

- ➔ Pigeons: eventually learn **R**, poor at **LS**
- ➔ **R** training is no help for **LS**
- ➲ Can learn how to learn, but transfer of a rule between stimuli is much harder

- ➔ Crows: learning the training set is similar to pigeons
- ➔ But **R** and **LS** equivalent to some monkeys

Fish

- ➔ Goldfish very poor at **R** and cannot do **LS**

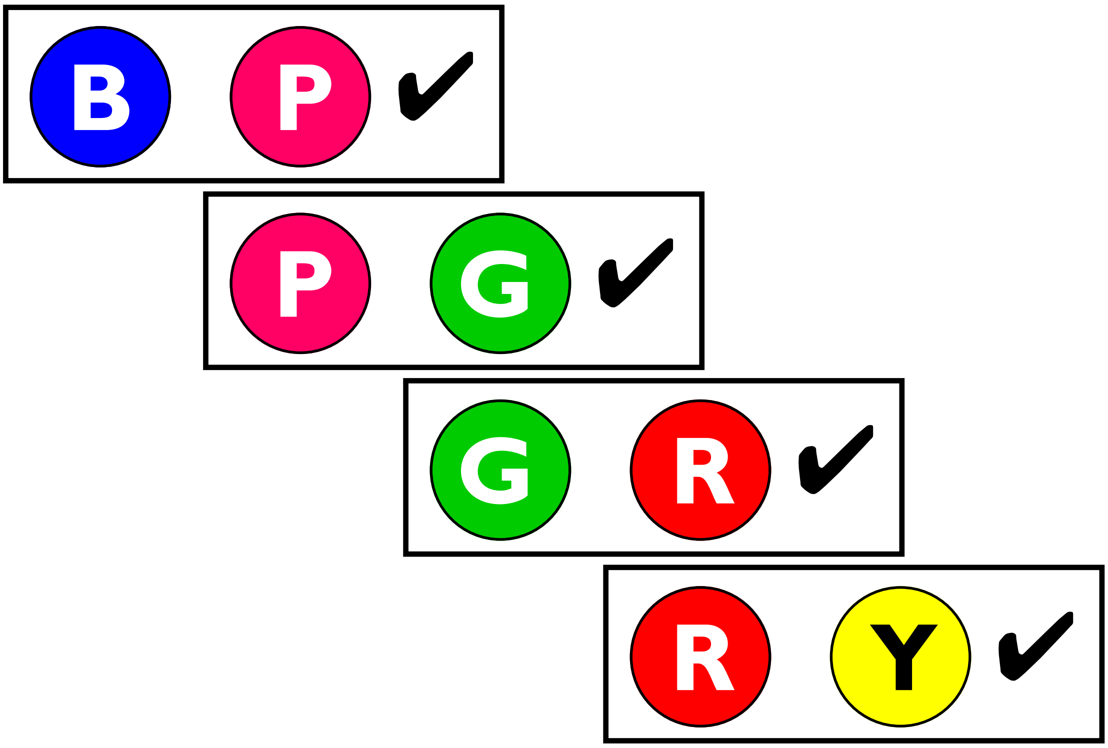
Overall

- ➲ Converging findings to matching tasks

❸ Transitive Inference

① Teach animal to select correct stimulus from each of several pairs

E.g. food in container A, not B, in B not C, in C not D, in D not E



② Test with non-adjacent pairs

➲ Can information be integrated to give an implicit sequence?

➔ Range of animals: Humans, chimpanzees, squirrel monkeys, sea lions, even pigeons

➔ Chimpanzees: Can be perfect, but individual differences

➔ McGonigle & Chalmers (1986): Squirrel monkeys show *Inferential Distance Effect*

➲ As for humans? Integrated representation?

➔ Pigeons can eventually solve, and show *IDE,* integrated representation too?

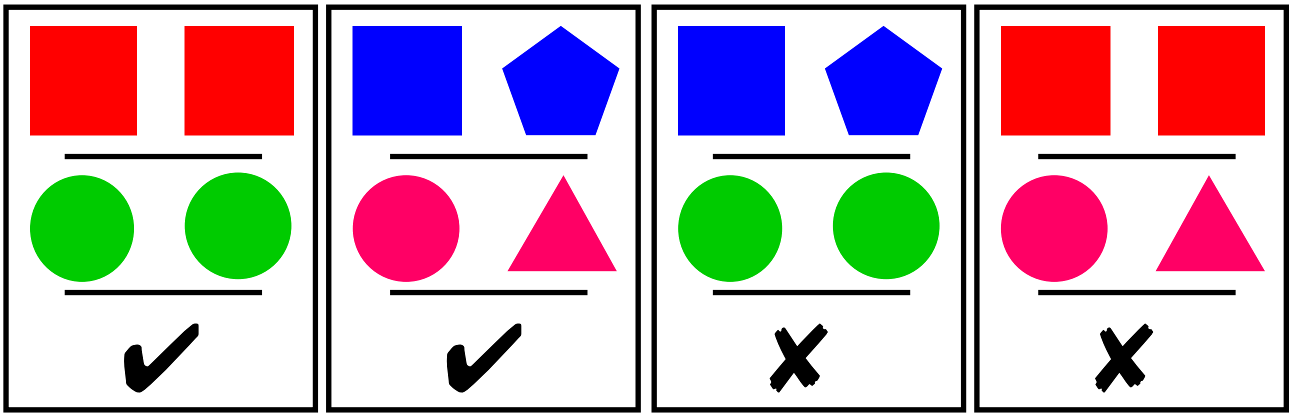
➔ Von Fersen et al. (1991): *value transfer:*

A always selected, E never selected
B associated with A (high value)
D associated with E (low value)

➲ *Same* behaviour but *different* mechanism

➲ Training time = important clue; associative versus discontinuous learning

❹ Higher Order Relationships



◎ Target relationship is *logical combination* of two lower order relationships

➔ Thompson, Oden, & Boysen (1997): 1000 trials: chimpanzees cannot learn

Unless special training with lower order relationships given

➔ Reznikova: some success with Baboons after 1000s of trials

➔ Children under six also find this difficult

➲ Limit of (non-ape) animal intelligence?

Mackintosh versus Macphail

- Mackintosh (1988):

  There are *qualitative differences* in animal learning ability

- All animals can associate

➲ If tasks only required associations, should be no qualitative differences

- Crows versus pigeons illuminating

➔ Similar sensory capabilities
Similar basic learning ability

➔ Pigeons: excellent memories for visual scenes and features

  Eventually learn transfer

➲ Crows: "increment in intelligence" despite inferior visual memory

➲ Performance not related to brain size

➲ Possess cognitive processes that pigeons do not?

- Macphail (1987):
  Qualitative differences unproven
- *An animal can never learn X* = impossible to prove

- Small details make a big difference
- Are all rewards equally motivating? (Wells, 1987)

➔ Monkeys perform better if they can manipulate the objects

➔ Dolphins are poor at visual learning set tasks but good at auditory set tasks

➔ Rats can succeed at olfactory learning sets

➔ Goldfish learn reversals if the gap between trials is short enough

➲ Wrong set up might suppress learning

➲ Cognitive capabilities underestimated

- Macphail (1987): The ***Null Hypothesis***

  Non-human vertebrates: no qualitative differences in intelligence

- Supposed failures to learn because of *contextual variables* (*cf* Richardson!)

➲ Animals learning abilities triggered in the right environment

➲ Failure to learn = inferior experiment, not inferior cognition

- Mackintosh (1988): unfalsifiable, trivial

➲ Obtain an overall picture: Lots of animals, lots of tasks, lots of stimuli

- Pearce (2007): Observe training baselines with simple tasks

➲ If equal training, motivation and perception matched and then:

  Differences in transfer of learning must be due to cognitive differences

Evaluation of Learning Task

- Delius & Delius (2006):

➔ Reasonably established rough sequence of ability [Jury still out on dolphins]

① Apes

② Monkeys = Parrots = Corvids

③ Other mammals = Other birds

④ Reptiles, amphibians, fish
[no learning set, no transitive learning]

➲ Many more species to investigate

➲ Related to brain size and cephalization

➲ Related to WMC/control differences?

➲ In some animals, highly specific abilities/motivations may detract from or enhance *g* [cf. pigeons versus crows] [See Reznikova (2007): *Instinctive Drift*]

4) The Ubiquitous *g* Factor

- Plenty of anecdotes for intelligent/less intelligent animals within species
- Differ in learning, memory, problem solving

- Chabris (2007):

  Within-species, if a range of tasks is administered, can a *g*-factor be identified?

	N	Tasks	+correl	Factor1 % var
Mice				
Bagg (1920)	71	8	28/28	**.61**
Locurto & Scanlon (1998)				
Sample A (F_2 cross)	34			
Speed		6	15/15	**.58**
Accuracy		4	6/6	**.44**
Sample B (CD-1 outbred)	41			
Speed		6	15/15	**.55**
Accuracy		4	6/6	**.48**
Galsworthy et al. (2002)	40	8	26/28	**.31**
Locurto et al. (2003)	60	6	11/15	**.27**
Matzel et al. (2003)	56	5	10/10	**.38**
Galsworthy et al. (2005)				
Study 1	84	6	15/15	**.35**
Study 2	167	11	41/55	**.18**
Kolata et al. (2005)	21	7	21/21	**.45**
Locurto et al. (2005)				
Experiment 1	47	5	4/10	**.28**
Experiment 2	51	5	9/10	**.34**
Dogs				
Anastasi et al. (1955)	73	10	30/45	**.26**
Nippak & Milgram (2005)	13	3	3/3	**.92**
Cats				
Warren (1961)	21	6	14/15	**.57**
Livesey (1970)	8	4	5/6	**.58**
Rhesus monkeys				
Paule (1990)	44-69	5	8/10	**.36**
Herndon et al. (1997)				
Analysis 1	30	6	n/a	**.48**
Analysis 2	53	3	n/a	**.62**
Humans (comparison)				
WAIS-R	365	11	55/55	**.48**

➔ Positive correlations between most tasks

➔ Despite different tasks between species

➔ Factor analysis: clear dominant factor

➔ Even evidence in honeybees

➲ Impressive correlations:

Laboratory animals genetically similar

Laboratory environments often impoverished

Often, only a few measures used

➲ *g* (general intelligence) is a universal property for all species, within all species

- Qualifies between-species data

➲ Star performers not necessarily *typical* representatives of species

➲ cf. exceptional vs typical humans

- Common needs and mechanism for *g*?

➲ All animals must respond to environment, and prioritise / solve / identify new goals

5a) Overview

- Can species X do Y = futile question
- ➲ How easily can species X learn = better
- ➲ Renders *Null Hypothesis* irrelevant

- With care a general species order of cognitive capability has been established
- ➲ Related to neurological factors?
- ➲ Related to WM capacity/control?

- Species matched for motivation and perceptual acuity can nonetheless differ
- ➲ Animals are not blank-slate random-seeded neural networks, nor humans

- *g* differences universal within species
- ➲ Effective WM, goal management, control vital for all animals, but some species members better endowed than others

5b) Unification

- Human intelligence:
  WMC + Control Processes =
  Induction + Goal Management

➔ Variation for humans, but qualitative differences hard to identify between them

- All learning animals:

  Must prioritise conflicting goals
  Must cancel completed goals
  Benefit from higher WM capacity

➔ General requirement for intelligence processes for all species

➔ Scope for differences within species

➔ Evidence for differences between species

- Qualitative differences between species do not imply different basic processes:

❶ Big differences in cephalisation are always associated with species differences

➲ Trivial qualitative differences created by a cognitive capacity/control gulf

❷ Species-specific directed cognition (e.g. attentional focus, virtual modules)

➲ May enhance or detract from general cognitive capacity/control

❸ Species-specific programmed modules

➲ May enhance specific tasks (e.g. spatial navigation) but may also interfere with general cognitive processes

➲ Can rank intelligence of species as long as domain specific differences understood

➲ Many findings in animal literature will make sense in the light of this

Major Sources

Delius, J.D., & Delius, J.M. (2006). Intelligence and brains: An evolutionary bird's eye view. In E.A. Wasserman & T.R. Zentall (eds.) *Comparative cognition: Experimental explorations of animal intelligence*. Oxford: OUP.

Pearce, J.M. (2008). *Animal cognition & learning (3rd ed)*. Hove: Psychology Press.

Reznikova, Z. (2007). *Animal Intelligence*. Cambridge: CUP.

References

Boden, M. (1989). *Artificial intelligence in Psychology*. Cambridge, Mass: MIT Press.

Brooks, R.A. (1991). Intelligence without representation. *Artificial Intelligence, 47,* 139-159.

Byrne, R. (1995). *The Thinking Ape*. Oxford: OUP.

Chabris, C.F. (2007). Cognitive and neurobiological mechanisms of the law of general intelligence. In M.J. Roberts (Ed.). *Integrating the mind*. Hove: Psychology Press.

Copeland, B.J. (1993). *Artificial Intelligence: A Philosophical Introduction*. Oxford: Blackwell.

Delius, J.D., & Delius, J.M. (2006). Intelligence and brains: An evolutionary bird's eye view. In E.A. Wasserman & T.R. Zentall (eds.) *Comparative cognition: Experimental explorations of animal intelligence*. Oxford: OUP.

Griffin, D.R. (1992). *Animal Minds*. Chicago: University of Chicago Press.

Hodos, W., & Campbell, C.B.G. (1969). Scala naturae: why there is no theory in comparative psychology. *Psychological Review, 76(4),* 337-350.

Humphrey, N.K. (1983). *Consciousness Regained*. Oxford: OUP.

Jensen, A.R. (1980). *Bias in Mental Testing*. London: Methuen.

Johnson-Laird, P.N. (1982). *Mental Models*. Cambridge: CUP.

Mackintosh, N.J. (1988). Approaches to the study of animal intelligence. *British Journal of Psychology, 79,* 509-525.

Macphail, E. (1987). The comparative psychology of intelligence. *Behavioral and Brain Sciences, 10,* 645-656.

McFarland, D. (1993). *Animal behaviour: Psychobiology, Ethology, and Evolution*. Harlow: Longman.

McGonigle, B.O., & Chalmers, M. (1992). Monkeys are rational. *Quarterly Journal of Experimental Psychology*, *45B*, 189-228.

Pearce, J.M. (2008). *Animal cognition & learning (3rd ed)*. Hove: Psychology Press.

Pinker, S. (1994). *The Language Instinct*. London: Allen Lane.

Thompson, R.K.R., Oden, D.L, & Boysen, S.T. (1997). Language-naive chimpanzees judge relations between relations in a conceptual matching task. *Journal of Experimental Psychology: Animal Behaviour Processes*, *23*, 30-43.

Velmans, M. (1991). Is human information processing conscious? *Behavioral and Brain Sciences*, *14*, 651-701

Von Fersen, L., Wynne, C.D.L, Delius, J.D., & Staddon, J.E.R. (1991). Transitive inference formation in pigeons. *Journal of Experimental Psychology: Animal Behaviour Processes*, *17*, 334-341.

Warren, J.M. (1973). Learning in vertebrates. In D.A. Dewsbury and D.A. Rethlingshafer (eds.). *Comparative Psychology: A Modern Survey.* New York: McGraw-Hill.

Wells, M.J. (1987). Invertebrate intelligence. In R.L. Gregory (ed.). *The Oxford Companion to the Mind*. Oxford: OUP.