Animal behaviour: Learning and memory

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Eumenes sp.
Behavourial studies

Darwinian theory: On the origin of species 1959
1. Variation
2. Heredity
3. Differential reproduction

17th Centaury
• Aristotle

18th Centaury
• Gilbert White
• Charles Darwin

19th Centaury
• Sherrington
• Konrad Lorenz
• Nikko Tinbergen
• Karl von Frisch
• Pavlov
• Skinner
• E. O. Wilson
• Maynard Smith
• Hamilton
• J B Haldane
• Alcock
• Manning
• Dwakins
Nobel prize 1973

Niko Tinbergen

Konrad Lorenz

Karl von Frisch
Behaviour

• The coordinated responses that an animal makes to stimuli. The responses are instinctive, learned or a combination of both

• Stimulus- internal or external or both

• Behaviour is a result of genetic and environmental inputs

• Instinct (inherited) & learned behaviours

Ethology

Describes an approach to the study of animal behaviour in which attempts to explain behaviour combine questions about its immediate causation, development, function and evolution
Evolution of behaviour: Beak-wiping in the courtship of three grass finches (Morris 1959)

Zebra pinch

Striated pinch

Spice pinch
Automeris sp.

How?: Proximate causes

Why? Ultimate causes
Ultimate effects on evolution of species

Genes contributed to next generation

Reproductive consequences

Behavior

Activated internal mechanisms

Proximate causes

The individual

Internal mechanisms

Physiological

Developmental

Genetic
Learning

Adaptive changes in animal behaviour as a result of experience

Stored – recalled next time – need

• Learning and instinct

Recalling Vs Recognition

Recalling difficult

Nonsense words written

Reciting easier task

Recalling difficult gives stimulus

Jog your memory

- Ipeck
- Uoegtj
- Bzquw
- Lmioge
- Eftoi

- Cat
- Dog
- Rat
- Man
- Boy
Learning

Young game bird
- Crouches to parents alarm call
- Must utilize pathways of brain
- Auditory input
- Motor system control crouching

Rat press the leaver (skinner box)
- Reward occurs again
- Stored in the NS
- That can be consulted or recalled in future occasion
Learning

- Behavioural changes influenced by experience
- New neural circuits formed in the brain
- Flexible - not genetically inherited
- Learning - motivation - associated with

(reward) → (punishment) → (±) reinforcement
Types of learning

Flexible

- Habituation
- Classical conditioning
- Trial and error
- Latent
- Discrimination

Restricted

- Imprinting
- Reasoning and insight
Learning

- Learning task → reinforcement (Reward or punishment)
- Learning → suits its own special requirement; varies from sp. to sp.
- Animals → learn key aspects of a fluctuating or changing environment
- They ignore distracting stimuli
- Animals → integrate their learning with discretion
Sensitization and Habituation

Smell of food
Arouse appetite
Prey just escaped from a predator
Sensitive to such stimuli in subsequent encounter

Stimulus
Prior
After

Rat on the box → small electric shock on its feet
Respond or jump
Novel flash of light or a tap on its box
normally evoke no response
Ragworm (*Nereis*): construct a tube in sandy sea floor

Kept in lab under dim light

Feeding made them sensitive more arousal

Retracted worms emerged

Fed in dim light

Flash of light

21% emerged

60% emerged

Flash of light

Habituation
**Habituation**

- Rewarding/punishment (reinforcement)
  - Sensitization
  - No repeated reinforcement → waning of sensitization
  - No more foot shock to rat → gradually cease to respond
  - No more food to *Nereis*

- Initially sensitized → calm down → eventually ignore the stimulus → waning of responsiveness → habituation
Habituation

Sensitization and habituation: process of learning

- Short lived. If repeated → food, water, predator, pain, shock
- Reinforcement is important → hence, response expected
- Birds → scarecrow → soon learn to ignore → habituation
  - simple form of learning

- Stimulus w/o reinforcement → affected
- Animals → alert to new stimuli
- Variety of stimuli → different effect
Habituation

Clark experiment

Nereis protracted → to feed stimuli
retract into the tube

Jarring the basin

Touching the head

Sudden shadow passing over

All worms habituated

stimulus repeated at 1min. interval

retract
protract within a minute
Habituation

Nereis

I expt. Rules out muscular fatigue
II expt. Recovered in 40 min to moving shadow
Habituation

Nereis

• Flash of light at ½ min. interval → 40 trials → habituation

• Flash of light at 5 min. interval → 80 trials → habituation

• Habituation → stimulus specific
Habituation

Sensory adaptation \(\rightarrow\) feeling of cloth

It is not habituation \(\rightarrow\) sensory fatigue

Repeated light stimulus \(\rightarrow\) Nereis habituated \(\rightarrow\) size the probe with its jaw

Persistent waning of response \(\rightarrow\) habituation \(\rightarrow\) CNS, but not sense organs

Nereis - recover within 24hr - not a appreciable memory; but min-to-min. response with respect of environment shadow (fish, bird or floating seaweed)

\[\downarrow\]

Nereis \(\downarrow\)

retract \(\downarrow\)

frequent shadow; it may be seaweeds

\[\downarrow\]

ignore
**Learning : habituation**

Predatory-prey respond in different ways

Cost and reward will be so differently balanced: ESS

Sensory adaptation → messages do not reach CNS

Habituation → messages reach the CNS

but are essentially ignored
Associative learning

Associative learning: acquire new responses and new capacities

Neutral stimulus → after repetition → animal response changes

Honey bees picks out blue dish with sugar solution among array of dishes → previous experience

Rodents take shortest rout to shelter → hawk or owl swoops

previous exp.
I. P. Pavlov dog salivation experiment

Associative learning; Classical conditioning; conditioned stimulus (the bell); unconditioned stimulus (the meat powder); conditioned reflex – conditioned response

- Dog- salivary reflex → meat powder → metronome sound
  CS → earlier neutral

- Classical conditioning

- Meat powder – UCS → produced UCR

- CS → should not produce response of its own

- Painful stimuli → flinching and distress → evoked salivation

- Reward/punishment → evoke response
  preceded with

- Electric shock → sound → respond by lifting the foot

- Dog → learn discrimination to various stimuli
  different tones

- respond to particular sound associated with reinforcement
Conditioned reflex: birds avoid brightly coloured caterpillars - evil taste

Birds → learn to associate colour with taste

Predator generalize → other palatable – resemble insects → mullarian mimicry

- Honey bees learn to associate flower colours and nectar load
- Location of food sources from their hive → sun position/polarized light/land marks
- Time vs nectar secretion
Learning abilities in honey bees

- Fragrance – Nectar load
- Colour – Nectar load
- Time – Nectar load
- Sun position – Nectar source - Nest
- Polarized light – Nectar source - Nest
- Landmarks – Nectar source - Nest
Apposmatic (warning) colouration

**Calotropis gigantia & C. procera** (Asclepiadaceae)

Sequester & store cardiac & cyanogenic glycosides & toxic alkaloids

Model: **Plain Tiger** (*Danaus chrysippus*)

Mimic: **Danaid Eggfly** (*Hypolimnas misippus*)
Pavlov’s dog learnt extra response despite controlled expt. sign of expectancy. Animals perform action in advance lead to reward or escape from punishment.

S-R animal associate with reinforcement.

e.g. bell  e.g. meat powder

Fig. Effect of the sequence of CS and UCS and evoking UCR.
Thorndike expt.

Problem box/Puzzle box ---Pure chance--- Door opens---- Cat escapes:

Trial and error learning /operant conditioning/instrumental

Voluntary behaviour, response and consequence
B. F. Skinner

Skinner box--- Pressing leaver-- yield reward

• Reinforcement necessary

• Above two expts.: animals learnt novel response w/o novel stimulus: response and consequence
Classical conditioning

Pigeon

Skinner box

novel stimulus (CS)  CR

eyes partly closed and bill opened  eyes opened and bill closed

Treat the key from animal point of view

built-in–predisposition

Treat key as for its requirement

food  water

requirement

Associative learning
Inherent biases in learning

Cat → lick/bite the lever → food
But difficult to train → turn treadle wheel with its paw → food
Built in-predisposition

can’t be trained → electric shock

Species-species biases  Avoidance conditioning

Rat → shuttle box
Bolles (1970)
Rat run between two compartments

electric shock at one half preceded by
Buzzer or light

Headgehog → shuttle box → crouch or freeze
Certain cases – learning occur – even reinforcement delayed for hours or a day

e.g. wild rat → nibble novel food → proved safe → eat in successive days

Rat deprived of thiamine → choose diet rich with thiamine → although benefits delayed

Rat → saccharin-flavoured water → through tube → light flashed → rat allowed to lick

Rat avoided saccharine water but not light

Rat avoided saccharine water + flash of light + electric shock

Subsequently licked S.W, but avoided light

Rat associate (learn) → taste and sickness → but not sickness and light

→ light and shock → but not taste and shock
Latent learning

Learning – hidden or in latent within animals - no immediate reward
Rat – maze, food, burrow

During acquiring the knowledge it had no apparent value
Learning ability

Digger wasp
Discrimination

Dogs – sounds. reward/punishment --- circle and oval

Pigeon – skinner box – colour of key

Primates – WGTA (Wisconsin General Test Apparatus)

Monkey

-ve reinforcement

banana +ve reinforcement
Imprinting:

Mostly birds
Imprinted at critical period
Once learnt at critical period – permanent

Imprinting
  acoustic
  visual
  odour

Song learning in birds

Males
  sing species specific songs

Young birds
  exposed to variety of songs
  learn their own songs

Singing
  at sexual maturity
  but learnt at maturing stage
White – crowned sparrows

Young males → hear older males singing

During summer

Unable to produce deafened sing only after 6-8 months in the next spring

normal song

Peter Marler expt:
White-crowned sparrows

10-50 days old males → learn the specific song

Prior –after this period → unable to learn
Some template in the brain → respond to correct input → critical period
Song Control Nuclei in the brain

Play important role in singing
Visual imprinting

Filial imprinting $\rightarrow$ young $\rightarrow$ following mother object

Sensitive period

Konnard Lorenz $\rightarrow$ susceptible to imprinting

Ducklings $\rightarrow$ filial imprinting

Hand-reared ducks $\rightarrow$ sexuality imprinted

Heinroth expt.
Precocial: *nidifugous*
Altricial: *nidicolous*

Goslings reared in incubator

First sighted object as their parent

Red box / green box / moving tin

Filial / sexual / social imprinting
Ducklings following Konard Lorenz
Immelmann expt.
Zebra finch – Bengalese finch
Cross-fostered

Filial and sexual imprinting

Chicken
Pecking
First two weeks

Odour ➔ mammals
(olfactory)
Sense of smell ➔ imprinted ➔ mice, rat, guinea pigs

Bowlby baby and mother ➔ 18-3 years ➔ physiological disturbance

Kolfar mother goat ➔ smell her kid within an hr.

5 min exposure ➔ imprinting

even separation for 3hrs does not affect
Insight learning → confined to apes & humans.

Animals solve problems suddenly w/o the benefit of previous experience.

Kohler expt.
Chimpanzee → banana
boxes & sticks
Not by trial & error → away from reach
Reasoning:

This is a mental process of taking inferences from two or more than two statements or happenings- found mainly in primates
Learning & memory

Stages of learning: acquisition, consolidation, retrieval & extinction

Memory: encoding, storage & retrieval (or forgetting) of information about past experience

Memory

Short term memory
- Persists sec. to min.
- e.g. telephone numbers
- If rehearsed

Long term memory
- lasts for days, weeks, months or year
- has no upper limit in capacity or retention
Long term memory

Procedural memory
(Implicit memory) non verbal

declarative memory

classical conditioning

Skill

Learning

priming

change in memory or
processing of a stimulus as a result of previous experience

person exposed to the word estrogen /butterfly
- fill the blank after seeing est........butter......
Declarative memory  →  knowing facts
(explicit memory) (verbal memory)

Declarative memory  →  semantic memory
Generally formed
forgotten easily

Declarative memory  →  episodic memory

Procedural memory  →  longer to form, but once learnt easier to retain – e.g. swimming, cycling
Memory

Working memory (STM)

similar to

Declarative & ST memory

Information changes on regular basis

Special memory

Memory for location of items or places in space

reference memory (LTM)

refers to association or discriminations requiring repetitious learning

e.g. how to navigate around an environment such as maze

or

learning some task

involves both special working memory special reference memory
Memory

Working memory (STM) similar to Declarative & ST memory

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e.g. how to navigate around an environment such as maze or learning some task involves both special working memory special reference memory
**Reactivation treatment**:
Radial-arm maze

Dewer et al. (1980) trained a rat in a 6 arm radial maze

I group → tested immediately after training → Immediate gp.

II gp → tested after 25 days → Delay gp

III gp → tested after 25 days → Reactive gp

reactivated just before testing
(placing the rats in a wire mesh cage next to the maze for 90 sec.)

I gp → high level of accuracy

II gp → decrements in performance → had forgotten the task

III gp → high level of accuracy similar to I gp
Rat

food
Fig. Hormonal influence on learning
Andjus (1955) expt.

Rats cooled down at $0^\circ$C-1hr

Memory stored in continues train of nerve impulses running for years?

Memory storage – chemico-physical form
STM – information remain continuously circulation in electric signaling form

LTM – experience well integrated - stored as chemical molecules

Remaining capacity of memory:
- 05 sec. – 0.8 material
- 10 sec. – 0.5
- 15 sec. – 0.43
- 20 sec. – 0.40

Memory leveling at 0.35
STM – 0.45
LTM – 0.35

Retrograde amnesia: distant past unaffected
- retrieval in reverse order
- event just before accident not recovered

Grater part of brain damage- Greater loss of memory
Fig: Honey bee learning association
**Drugs & memory**: Gold fish → bell ring → food reward

Lost just learnt subject
But not the old memory

Injected Puromycin (antibiotic)

**Fig**: Chicks dips in retrieval of memory
Fig: Effect of Electroconvulsive shock (ECS) treatment on reference memory in a shuttle box- light followed by shock
Sagittal section of human brain - vertical plane which passes from ventral (front) to dorsal (rear) dividing the part into right and left halves.

Brain stem and cerebellum removed to reveal more structure involved in memory formation.
Milky water

Spatial memory assessment in the Morris water maze
Retrograde amnesia:

Damage → neural structures of base of fore brain

adjacent to hypothalamus → especially

Leads to retrograde amnesia

\{ thalamus
  mamillary body
  hippocampus region \}

Bilateral damage to any one of these region leads to → inability to store new memory

HM story: loss of STM → brain operation to prevent epileptic seizures

Loss of memory after a few minutes, but learnt motor skills - bicycle riding
Memory transfer:

Planaria → trained → killed → homogenized

Exhibits behaviour → fed to new Planaria of killed animals

Cat → trained to jump to loud tone for 9 days

Brain removed → homogenized → injected

learnt to jump in 1.5 days ← brain of untrained cat
Neural mechanism of learning

- Hebbian Mechanisms explain Classical Conditioning and Learning in General

- *Neural Underpinnings of Hebbian Mechanisms*
  - Long-Term Potentiation (LTP) and Long-Term depression (LTD)

- Examples of Hebbian Mechanisms in *Visual Cortex* (via an LTP-like mechanism)
Whenever we learn something, the BRAIN must be changing

Donald Hebb: *Learning must be a change at the synapse*

Hebbian Mechanism: Increase in *synaptic strength (i.e., connectivity) between a PRE- and POST- synaptic neuron* when the two neurons are active simultaneously

OR

Neurons that fire together get wired together
Classical Conditioning

Neurons that fire together get wired together

This is an example for Implicit memory, but this kind of phenomenon happens for Explicit memories too.

salivation
Now..... Long Term Depression (LTD) (still Hebbian)
Neurons that *don’t fire together, become less wired together*: Anti-correlated activity between the PRE-synaptic and POST-synaptic neuron will *weaken the synapse between the two*. 
Examples of Hebbian Mechanisms in the Visual System:

1) **Monocular Deprivation:**
   Kittens reared with monocular lid suture - deprived eye
   All of visual cortex is devoted to the experienced eye!!

2) **Monocular Deprivation:**
   Kittens reared with monocular lid suture - deprived eye,
   while GABA (drug) agonist poured onto visual cortex
   (GABA = inhibitory)
   All of visual cortex is devoted to the deprived eye
Which Neurotransmitter / Receptors are involved in LTP?

**Neurotransmitter = Glutamate (Amino Acid)**

**Receptors for Glutamate:**

1) **AMPA (aminomethylphophonic acid) receptor:** When Glutamate binds to it, AMPA receptor lets in Na+, which depolarizes neuron (Cell membrane become more potential, become positive)

2) **NMDA (N-Methyl-D-aspartic acid) receptor:** When Glutamate binds to it, and if neuron is depolarized (from AMPA), NMDA receptor lets in Ca2+

Ca2+ is KEY. Produces a protein inside the neuron that makes the AMPA receptors more sensitive to glutamate in the future - this is LTP.

- Cannot produce LTP if use an antagonist drug that blocks NMDA.
- Once LTP is produced, NMDA receptors are no longer needed (and NMDA antagonists do not affect).... because LTP is really about a change in the AMPA receptor.
Glutamate is in the glutamate binding site and glycine is in the glycine binding site.

- **Allosteric** sites that would cause inhibition of the receptor are not occupied.
- NMDA requires the binding of two molecules of glutamate or aspartate and two of glycine.

NMDA also require the binding of the co-agonist glycine for the efficient opening of the ion channel, which is a part of this receptor.
A synapse is repeatedly stimulated.

More dendritic receptors.

More neurotransmitters

A stronger link between neurons.
LTP and Learning/Memory Behavior

- **Assumption:** LTP is a process underlying learning follow Hebbian principles

- **Known:** Functional NMDA receptors are necessary for the production of LTP (because they let in Ca2+, which is key).

- **Prediction:**
  - Drugs that block NMDA receptors should block *learning*
  - YES (at least in some cases, fish and rats)
  - Also, data from genetically modified mice
  - **Abnormal NMDA receptors** - impaired learning
  - **Extra NMDA receptors** - better than normal learning
Neural Mechanisms of Non-Associative (Non-Hebbian) Learning (also a change in synaptic strength, but not Hebbian) 
e.g., HABITUATION: a decreased response to repeated exposure

HABITUATION:
The withdrawal response becomes less intense over time
Neural Mechanisms of Habituation
Have relatively few and large (1 mm) neurons, which are easily identified.

First, what is NOT responsible for Habituation (in blue)

Then, what IS responsible for Habituation (in red)