PL3248 Learning & Conditioning

Elicited behaviour, Habituation, & Sensitization

Elicited behaviour

- **Reflex**: involves an *eliciting stimulus* and a *corresponding response*, which are linked.
- **Modal action pattern (MAP)**: response sequences typical of a particular species.
  - Dependent on the physiological state of the animal, and its recent actions or readiness.
  - Dependent on the presence of environmental cues.
  1. **Sign/Releasing stimulus**: specific feature of an object/animal eliciting a MAP.
  2. **Supernormal stimulus**: a sign stimulus whose features have been artificially enhanced or exaggerated to produce an abnormally large MAP.
- **Appetitive behaviour**: occurs early in a natural behaviour sequence and serves to bring the organism in contact with a releasing stimulus.
- **Consummatory behaviour**: serves to bring a natural sequence of behaviour to consummation or completion.
  - Consummatory responses tend to be species-typical MAPs.
  - Appetitive behaviours are more variable, and more apt to be shaped by learning.

Effects of repeated stimulation

- **Habituation**: a progressive decrease in the vigor of elicited behaviour that may occur with *repeated presentations of the eliciting stimulus*.
  - Response fails because of changes that disrupt neurotransmission involving interneurons.
  - Habituation is **stimulus-specific** and **response-specific**.
  - **Attention to the taste stimulus** and **obesity** influence the rate of taste habituation.
  - Susceptible to **spontaneous recovery**.
- **Tolerance**: *active suppression* of one's behaviour.
- **Sensitization**: an increase in the vigor of elicited behaviour that may result from repeated presentations of the eliciting stimulus or from exposure to a strong extraneous stimulus.
  - Sensitization is *not highly stimulus-specific*.
- **Sensory adaptation**: temporary reduction in the sensitivity of sense organs caused by repeated or excessive stimulation (i.e., *impairment of sensory neurons*).
  - Sensory neurons have adapted to the context.
  - Decrease in responding is *response-general*.
- **Fatigue**: temporary decrease in behaviour caused by repeated or excessive use of the muscles involved in the behaviour (i.e., *impairment of motor neurons*).
  - Motor neurons have adapted to the context.
  - Decrease in responding is *stimulus-general*.

Dual-process theory of sensitization

- **Dual-process theory**: assumes that different types of underlying neural processes are responsible for increases and decreases in responsiveness to stimulation.
  - Habituation processes are assumed to occur in the **S-R system**, the shortest neural pathway that connects the sense organs stimulated by an eliciting stimulus and the muscles involved in making the elicited response.
  - Sensitization processes are assumed to occur in the **state system**, neural structures that determine the general level of responsiveness or arousal of the organism.

Opponent process theory of motivation

- **Opponent process theory**: assumes that an emotion-arousing stimulus pushes a person's emotional state away from neutrality, and an opponent process is triggered that counteracts the shift away from emotional neutrality.
  - **Primary/a process**: first process elicited by a biologically significant stimulus.
  - **Opponent/b process**: compensatory mechanism that occurs in response to the primary process elicited by biologically significant events. It causes physiological and behavioural changes that are the opposite of those caused by the a process.
- Over time, the size of the a process remains the same, whereas the b process increases in magnitude, starts earlier, and lasts longer.
- If a regular user takes drugs outside of his normal setting/routine, he may overdose since the b process (serving as the CR) may not kick in to offset the effects of drug usage in the new environment.

Classical Conditioning

- **Object learning**: the association of one feature of an object with another.
- **Unconditional stimulus (US)**: a stimulus that elicits a particular response without the necessity of prior training.
- **Unconditional response (UR)**: a response that occurs to a stimulus without the necessity of prior training.
- **Conditional stimulus (CS)**: a stimulus that does not elicit a particular response initially, but comes to do so as a result of becoming associated with an US.
- **Conditional response (CR)**: the response that comes to be made to the CS as a result of classical conditioning.

Features:

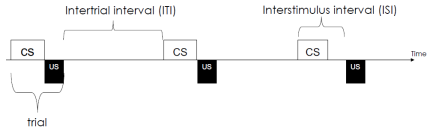
- **Automatic responses**.
- **Response-independent outcomes**: depends solely on the presence of the CS.
- **Predictive learning**: prepares us for what comes next in the environment.

Paradigms to study classical conditioning:

- **Aversive/Fear conditioning** (i.e., **conditioned suppression**): suppression of ongoing behaviour produced by the presentation of a CS that has been conditioned to elicit fear through association with an aversive US.
- **Eyeblink conditioning**: eyeblinks can be conditioned to serve as a CR to a CS; failure to respond could indicate underlying issues (e.g., Alzheimer's, fetal alcohol syndrome).
- **Appetitive conditioning**:
  - **Sign tracking/Autoshaping**: movement toward and possibly contact with a CS that signals the availability of a positive reinforcer.
    - For sign tracking to occur, the CS must be (1) **visual**, (2) **discrete**, and (3) **localized**.
    - It is unnecessary for obtaining the US, and is merely a remnant of our evolutionary history.
  - **Goal tracking**: conditioned behaviour elicited by a CS that consists of approaching the location where the US is usually presented.
    - Sign trackers are more likely to engage in addictive behaviours; goal trackers are more likely to inhibit these behaviours.
- **Conditioned taste aversion**: (1) can be learned with just one pairing, (2) long-delay learning (i.e., occurs even if the illness occurs only after a long delay following exposure to the novel taste), (3) highly resistant to extinction and decay, and (4) occurs independent of rational thought processes & knowledge.
  - **Evaluative conditioning**: changing the attitudes toward an initially neutral stimulus by having that stimulus associated with something that is already liked/disliked.
- **Human contingency learning** (i.e., **conditioned expectation**): people tend to acquire knowledge based on whichever outcome has the highest probability of occurring from particular stimuli.

Excitatory Pavlovian conditioning

- **Intertrial interval (ITI)**: amount of time that elapses between 2 successive trials.
- **Interstimulus/CS-US interval (ISI)**: amount of time that elapses between the start of the CS and the start of the US during a classical conditioning trial.



- Common conditioning procedures: (in descending order of strength of CR)
  1. **Short-delay conditioning**: the CS is initiated shortly before the US on each conditioning trial; CS lasts until the US begins.
  2. **Long-delay conditioning**: the US occurs more than several minutes after the start of the CS; CS lasts until the US begins.
  3. **Trace conditioning**: the US is presented after the CS has been terminated for a short period (the gap between the CS and US is the **trace interval**).
  4. **Simultaneous conditioning**: the CS and US are presented at the same time on each conditioning trial.
  5. **Backward conditioning**: the CS is presented shortly after the US on each trial.

  Long delay and backwards excitatory conditioning may also serve as **inhibitory conditioning procedures**.
- Quantification of behaviour:
  - **Magnitude** of CR: how much the behaviour occurs.
  - **Likelihood/Probability** of responding: how often the CS elicits a CR.
  - **Latency** of CR: how soon the CR occurs after the onset of the CS.
- Control procedures:
  - **Pseudo-conditioning**: increased responding that may occur to a stimulus whose presentations are intermixed with presentations of a US in the absence of the establishment of an association between the stimulus and the US.
  - **Random control**: procedure in which the CS and US are presented at random times with respect to each other.
  - **Explicitly unpaired control**: procedure in which both CS and US are presented, but with sufficient time between them so that they do not become associated with each other.
- **Temporal coding hypothesis**: the idea that Pavlovian conditioning procedures lead not only to learning that the US happens, but exactly when it occurs in relation to the CS.

Inhibitory Pavlovian conditioning

- **Inhibitory conditioning**: the CS becomes a signal for the *absence* of the US.
  - Inhibitory conditioning and inhibitory control of behaviour occur only if there is an excitatory context for the US in question.
- Related concepts:
  - **Extinction**: CS continues but US halts, target learns that the CS is no longer a predictor of the US.
  - **Differential inhibition**: the presence of an excitor predicts the presence of the US, whereas the presence of an inhibitor predicts the absence of the US.
    - Difference vs cond. inhibition: inhibitor does not co-occur with the excitor.
  - **Explicitly unpaired inhibition**: only inhibitors are present, which predict the absence of the US.
- Measuring conditioned inhibition:
  - **Test of negative summation**: procedure that identifies a stimulus as a conditioned inhibitor if that stimulus reduces the responding elicited by a conditioned excitatory stimulus.
    - The CI is tested with a *transfer excitor* rather than the *training excitor* to ensure that inhibition does not occur due to the sequencing of trials, but rather due to subjects having learnt the idea that the presence of the CI inhibits the presence of the US.
  - **Test of retardation**: procedure that identifies a stimulus as a conditioned inhibitor if that stimulus is slower to acquire excitatory properties than a comparison stimulus.
    - The strength of a CI is tested indirectly because behaviour to a CI alone cannot be differentiated from behaviour to an associatively neutral stimulus.
- **Counterbalancing**: to ensure that the response seen w.r.t. an excitor is not due to the nature of the stimuli, but due to the training (i.e., control for potentially confounding features of the stimuli).

Effectiveness of stimuli

- Variables influencing the **effectiveness of conditioning**:
  1. **Contiguity**: closeness in time or space between two events.
     - ↓ contiguity → ↓ conditioning (cf. trace conditioning).
  2. **Contingency**: whether the presence of the behaviour reliably predicts the presence/absence of the consequence.
     - ↓ contingency → ↓ conditioning (cf. latent inhibition, partial reinforcement).
  3. **Novelty** of stimulus:
     - **Latent inhibition/CS-preexposure effect**: interference with conditioning produced by repeated exposures to the CS before the conditioning trials.
     - **US-preexposure effect**: interference with conditioning produced by repeated exposures to the unconditioned stimulus before the conditioning trials.
  4. **Intensity** and **salience** of stimulus: more salient CS/US (**overshadowing**) → faster conditioning.
     - Stimuli are more salient when they are more (1) **intense**, (2) have greater **biological relevance** (e.g., necessary for survival), (3) occur in the subject's **natural environment**, (4) **novel**, or (5) **predictive** of a CR.
     - Conditioning may be weakened by salient extraneous stimuli.
  5. **Surprisingness** of US/**Informativeness** of CS:
     - ↓ surprising/informative → ↓ conditioning.
     - **Blocking**: interference with the conditioning of a novel stimulus because of the presence of a previously conditioned stimulus to the same US.
     - **Unblocking**: adding/changing the US → surprise → learning.
     - **Recovery from blocking**: extinguishing blocking cue → learning.
  6. **Belongingness** (a.k.a. CS-US relevance): we have a genetic predisposition for the selective learning of certain combinations of conditioned and unconditioned stimuli (e.g., sickness → food; sickness ↛ knee injury).
- Variables influencing the **conditioned response/behaviour**:
  1. **Nature of US**:
     - **Stimulus substitution**: the idea that as a result of classical conditioning, participants come to respond to the CS in much the same way that they respond to the US.
  2. **Behaviour system** activated by the US: harder to train a CR that is a part of an unnatural behaviour system toward the US (e.g., staying still when anticipating food).
  3. **CS identity**: what the CS is (e.g., a female rat vs food → social instead of foraging behaviour).
  4. **CS-US interval**:
     - **Long** CS-US intervals activate responses that **prepare the organism** for the US in the future.
     - **Short** CS-US intervals activate responses that are appropriate for **dealing with the present**.

Higher-order conditioning

- **Higher-order conditioning**: a previously conditioned stimulus (CS_1) is used to condition a new stimulus (CS_2).
  - **First-order conditioning**: pairing of CS_1 with US.
  - **Second-order conditioning**: we may see a response to CS_2 due to 3 reasons:
    1. **Two S-S associations**: chaining of $CS_2 \rightarrow CS_1 \rightarrow US$.
    2. **Single S-S association**: the learning of an association between two stimuli, with the result that exposure to one of the stimuli comes to activate a representation, or "mental image", of the other stimulus.
    3. **Single S-R association**: the learning of an association between a stimulus and a response, with the result that the stimulus comes to elicit the response directly.
       - When we start learning a language, S-S associations are in place; but as we get more fluent, S-R associations begin to take over.

    We can test which is the case by in the following order:
    1. **Extinguish** the first-order CS.
    2. **Devaluate** the US: reduction in the attractiveness of an unconditioned stimulus, usually achieved by aversion conditioning or satiation.
       - If the underlying mechanism of the learned behaviour is S-S, devaluating the US should lead to a reduction in the CR.
       - If S-R, devaluating the US should not affect the CR.
  - N^{th}**-order conditioning**: pairing of CS_N with CS_{N-1}.
  - **Sensory preconditioning**: a biologically weak stimulus (CS_2) is first repeatedly paired with another biologically weak stimulus (CS_1), and then CS_1 is conditioned with a US.
    - Subsequently, CS_2 will also elicit the CR, even though CS_2 was never directly paired with the US.
    - CR in SPC is driven by S-S associations, whereas CR in SOC is driven by a single S-R association.

  Even though the procedure is similar to conditioned inhibition ($CS_2 \rightarrow CS_1 \rightarrow US$), the number of training trials for the second phase differs.
  - With few trials, we see conditioned excitation of CS_2.
  - As the number of trials ↑, conditioned inhibition will gradually develop.
- **Conditioned diminution of the UR**: a reduction in the magnitude of the response to a US caused by presentation of a CS that had been conditioned with that US.
  - **Conditioned analgesia**: a CS that has been paired with a painful US will stimulate the release of endogenous opiates, and the US becomes less painful with successive conditioning trials.
  - **Conditioned drug tolerance**: over time, the CS elicits physiological processes (e.g., the opponent process) that counteract the drug effect.

Theories of associative learning

- We use different models to understand and explain different aspects of learning and behaviour.
- **Bush & Mosteller model** (1955): the goal of learning is to reduce predictive error.
  - Learning occurs according to a **local error reduction** rule:

    $$\Delta V = \lambda - V^n$$

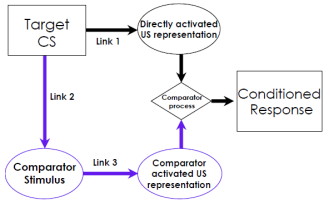
    and **associative strength of a CS** on trial $n + 1$ is given as

    $$V^{n+1} = V^n + \Delta V^{n+1}.$$

    - λ: the **total amount of conditioning** that a US can support on a given trial ($\lambda = 1$: US present, 0: US absent).
    - V: cue's **associative strength**, $-1 \leq V \leq 1$ (V -ve: CS predicts US *absence*, +ve: CS predicts US *presence*).
    - n: trial number.
    - ΔV: **predictive error**, the difference between what we predict will happen and what actually occurred.
- **Rescorla-Wagner model** (1972): learning is dependent on the associative strength of *all cues* present during training.
  - Compared to Bush & Mosteller, this model:
    1. Explains how the **presence of other conditioned stimuli** influence learning about the target cue.
    2. Includes parameters to indicate the **salience** of the CS and US.
    3. Captures **overshadowing**, **blocking**, **conditioned inhibition**, and **overexpectation**.
  - Learning rule for **total error reduction**:

    $$\Delta V^{n+1} = \alpha\beta(\lambda - \Sigma V^n).$$

    - $\Sigma V^n = V_T$: **total associative strength** of all CSs present on trial n.
    - α: **associability** of the **CS**.
    - β: **associability** of the **US**.
      - **Associability**: corresponds to salience/intensity of the stimulus, $0 < \alpha, \beta < 1$.
  - However, the model fails to capture:
    1. **Latent inhibition**.
       - It predicts that CS preexposure does not affect subsequent training.
    2. **Spontaneous recovery**: increased responding to an extinguished CS after a retention interval.
       - It assumes that a previously-trained CS's associative strength returns to 0 after *extinction* (i.e., it becomes indistinguishable from neutral stimuli).
    3. **Retrospective revaluation**: changes in CR to CS_1 as a result of manipulating the associative value of CS_2.
       - According to the model, associative strength (and CR) does not change on trials where the CS is absent.
- **Comparator hypothesis**: learning occurs based on contiguity alone, competition occurs at the time of responding.
  - Specifically, to determine responding,
    1. The strength of the **target CS-US** association (link 1) is compared with
    2. The strength of the **target CS-comparator CS** association (link 2) together with (product) the strength of the **comparator CS-US** association (link 3)
       - **Comparator CS**: another stimulus that is also associated with the CS and the US.



  - This model assumes competition between stimuli over **behavioural expression**, whereas R-W assumes competition between stimuli over **acquisition of associative strength**.
    - It captures **overshadowing** and **recovery from overshadowing**.
- **Attention models**: the effectiveness of conditioning is in part driven by attention to the CS. Specifically,
  1. Increased attention to the CS facilitates learning about the CS, and
  2. The outcome of a given trial will alter the degree of attention commanded by the CS on future trials.
  - **Mackintosh (1975)**: attention increases to cues that are **reliable predictors of the US**.
  - **Pearce & Hall (1980)**: attention is determined by **how surprising the US was** on the preceding trial.
    - More surprising → more attention paid on the subsequent trial.

- **Hogarth et al. (2010)**: there are 3 types of attention which facilitate learning:
  1. **Looking for action**: attention that a stimulus commands after it has become a good predictor of the US.
  2. **Looking for learning**: attention that is involved in processing cues that are not yet good predictors of the US.
  3. **Looking for liking**: attention that stimuli command because of their emotional value.
- **Timing models**:
  - **Temporal coding hypothesis**: organisms can integrate different temporal maps with a **common element**.
    - E.g., trial 1 = US $\rightarrow$ CS_1, trial 2 = CS_2 $\rightarrow$ CS_1, organism learns that CS_2 is more predictive of the US as compared to CS_1 (due to integration of temporal maps arising from each trial).
  - **Relative waiting time hypothesis**: organisms compare **how long they have to wait** for the US **during the CS** (i.e., T) relative to how long they have to wait for the US **during the inter-trial interval** (I).
    - $T < I \rightarrow$ high I/T ratio $\rightarrow$ CS becomes informative predictor of US $\rightarrow$ stronger CR.
    - $T >= I \rightarrow$ low I/T ratio $\rightarrow$ CS provides little information about US $\rightarrow$ weaker CR.

    It emphasizes that CR does not only depend on what happens during the CS, but also on what happens in other aspects of the experimental situation.

Instrumental Conditioning

- Difference versus CC: requires both (1) *CS presentation* + (2) ***IR being made***.
- **Law of effect**: role of the reinforcer is to strengthen the S-R association.
  1. If a response is followed by a **satisfying event/appetitive stimulus**, the S-R association will be strengthened.
  2. If a response is followed by an **annoying event/aversive stimulus**, the S-R association will be weakened.
- Components:
  - **Positive reinforcement**: +ve contingency between IR and appetitive stimulus/reinforcer $\rightarrow \uparrow$ conditioned IR.
  - **Negative reinforcement**: -ve contingency between IR and aversive stimulus $\rightarrow \uparrow$ conditioned IR.
  - **(Positive) punishment**: +ve contingency between IR and aversive stimulus $\rightarrow \downarrow$ conditioned IR.
  - **Negative punishment** (a.k.a. **omission training**): IR prevents the delivery of a reinforcing stimulus.
    - **Differential reinforcement of other behaviour (DRO)**: positive reinforcer is periodically delivered only if the participant does something other than the target response.
  - **Instrumental behaviour/response**: activity that occurs because of its effectiveness in obtaining reinforcement.
    - Reinforcement can be defined in terms of either **novelty** or **response variability**.
      - Without explicit reinforcement of variability, responding becomes more **stereotyped** with continued IC.
  - **Operant response**: response that is defined by the effect it produces in the environment.

Instrumental conditioning procedures

- **Discrete-trial procedure**: participant is allowed to perform the IR only during specified periods, usually determined either by placement of the participant in an experimental chamber or by the presentation of a stimulus.
- **Free-operant procedure**: permits repeated performance of the IR without intervention by the experimenter.
- **Magazine training**: preliminary stage of IC, where a stimulus is repeatedly paired with the reinforcer to enable the participant to learn to go and get the reinforcer when it is presented.
- **(Response) shaping**: reinforcement of successive approximations to a desired IR. To successfully shape behaviour,
  1. Define the final response to be performed.
  2. Assess the starting level of performance.
  3. Divide the progression from start to end into appropriate training steps or successive approximations.

  Behaviours that are **(physically) impossible**, or succeeding an **imperceptible stimulus**, cannot be shaped.

Elements of instrumental conditioning

- How **instrumental responses** influences IC:
  - **Belongingness**: an organism's evolutionary history makes certain responses belong with certain reinforcers.
  - **Instinctive drift**: gradual drift of IR away from the responses required for reinforcement, to species-typical responses related to the reinforcer and other stimuli in the environment.
- How **instrumental reinforcers** influence IC:
  - **Quantity** & **quality**: better/more reinforcement $\rightarrow \uparrow$ IR.
  - **Magnitude** of a reinforcer: longer reinforcement $\rightarrow \uparrow$ IR.
  - **Behavioural contrast**: change in the value of a reinforcer produced by *prior experience* (or *anticipation*).
    - **Positive contrast effect**: prior experience with a **lower valued** reinforcer $\rightarrow \uparrow$ reinforcer value and IR.
    - **Negative contrast effect**: prior experience with a **higher valued** reinforcer $\rightarrow \downarrow$ reinforcer value and IR.
    - **Anticipatory contrast effect**: expected reward better than current reward $\rightarrow \downarrow$ IR.
- How **response-reinforcer relations** influence IC:
  - **Temporal relation**: $\uparrow$ delay of reinforcement $\rightarrow \downarrow$ IR. To avoid the effects of delayed reinforcement, use:
    1. **Secondary/Conditioned reinforcer**: stimulus that is associated with a primary reinforcer (e.g., clicker).
    2. **Marking**: mark the target IR with a distinctive event, making it distinguishable from other activities.
  - **Response-reinforcer contingency**: extent to which the reinforcer's delivery depends on the occurrence of the IR.
    1. **Perceived** contingency is more important than *actual* contingency.
    2. **Controllable** aversive events are preferred over predictable but uncontrollable events.
       - **Learned-helplessness**: reduced/no responding to aversive stimuli after prior responses having no effect.
    - **Accidental/Adventitious reinforcement**: delivery of a reinforcer happens to coincide with a particular response, even though that response was not responsible for the reinforcer presentation.
  - **Learned-helplessness hypothesis**: exposure to inescapable aversive stimulation (1) **reduces motivation** to respond and (2) **disrupts subsequent ability to learn**.
    - **Activity-deficit hypothesis**: inescapable shocks encourage animals to become inactive or freeze.
    - **Attention-deficit hypothesis**: exposure to inescapable shock reduces the extent to which animals pay attention to their own behaviour, and that is why these animals show a learning deficit.
    - **Stimulus relations in escape conditioning**: learning to predict when we will encounter the stressful event (and when we will not encounter it) can be just as effective in reducing the harmful effects of stress.

Reinforcement schedules

- **Schedule of reinforcement**: rule that determines how and when a response will be followed by a reinforcer.
  1. **Ratio schedule**: reinforcement depends only on # responses the participant performs, independent of time.
     (a) **Fixed-ratio (FRn) schedule**: a fixed # responses must occur for the next response to be reinforced.
       - **Continuous reinforcement (CRF)**: FR1, every occurrence of the IR produces the reinforcer.
       - **Partial/Intermittent reinforcement**: FRn ($n > 1$), only some occurrences of the IR are reinforced.
       - **Post-reinforcement pause**: pause in responding, typically after reinforcer delivery on FR and FI schedules.
       - **Ratio run**: high and invariant rate of responding after the post-reinforcement pause on FR schedules.
       - **Ratio strain**: disruption of responding on ratio schedules when the response requirement $\uparrow$ too rapidly.

     (b) **Variable-ratio (VRn) schedule**: # responses necessary to produce reinforcement varies from trial to trial.
       - Post-reinforcement pauses are shorter and less prominent than with FR schedules.
  2. **Interval schedule**: presence of a delay after the previous reinforcement before the next reinforcer can be obtained.
     (a) **Fixed-interval (FIn) schedule**: reinforcement for the first IR after a fixed amount of time.
       - **Fixed-interval scallop**: gradually increasing rate of IR between successive reinforcements on FI schedules.
       - **Limited hold**: restriction on how long a reinforcer remains available after the start of an interval.

     (b) **Variable-interval (VIn) schedule**: reinforcement for the first IR after a variable amount of time.
  - **Variable** $>$ **fixed**: (1) more reinforcing and (2) sustainable.
  - **Ratio** $>$ **interval**, because:
    1. Reinforcement of short **inter-response times (IRT)**: interval between successive responses.
    2. **Feedback function**: reinforcement is considered to be the feedback/consequence of responding.
- **Concurrent schedule**:
  - **Matching law**: the relative rate of responding equals the relative rate of reinforcement for a response alternative,
    $$B_L/B_R = b(r_L/r_R)^s.$$
    - B: rate of responding/behaviour.
      - L: left alternative.
      - R: right alternative.
    - r: rate of reinforcement.
    - s: *sensitivity* of the choice behaviour to the relative rates of reinforcement for the response alternatives.
    - b: *response bias*.
  - Mechanisms of the matching law:
    1. **Molecular maximizing**: choosing the response that is most likely to be reinforced at a given moment in time.
       - **Molecular theory**: focuses on what happens at the level of individual responses.
    2. **Molar maximizing**: distributing responses among alternatives to maximize reinforcement earned over time.
       - **Molar theory**: explains aggregates of responses.
    3. **Melioration**: responding to improve the local rates of reinforcement for response alternatives.
- **Concurrent-chain schedule of reinforcement**: *choice link* $\rightarrow$ *terminal link* (with different reinforcement schedules).
  - Involves **choice with commitment**: subject is stuck with the option it has chosen at the choice link.
- **Delay discounting**: $\downarrow$ value of a reinforcer as time delay to obtain it $\uparrow$s.
  - **Value discounting function**:
    $$V = M/(1 + kD).$$
    - V: value of a reinforcer.
    - M: reward magnitude.
    - D: reward delay.
    - k: discounting rate parameter.
  - To $\uparrow$ self-control, **impose a small delay** before the smaller (but more immediate) reward.
  - Steeper **delay-discounting curve** $\rightarrow$ greater **impulsivity**, higher **educational levels** and **incomes**.

Motivational mechanisms

1. **Associative structure of IC**:
   - **Three-term contingency**: the conditional S(R-O) relation in IC.
     (a) **S-R association**: enables IR to persist even when the outcome is devalued.
     (b) **R-O association**: if response arises from an R-O association, devaluation of reinforcer $\rightarrow \downarrow$ rate of responding.
     (c) **S-O association**: creates the expectancy of reward.
       - **Two-process theory**: during IC, the stimuli in the presence of which the IR is reinforced become associated with the outcome through CC, resulting in an S-O association.
         - CC mediates IR by conditioning +ve/-ve emotions based on the emotional valence of the reinforcer.
       - **Pavlovian instrumental transfer (PIT)** experiment:
         i. Participants receive IC without the CS (formation of R-O association).
         ii. Participants receive CC with the CS (formation of S-O association).
         iii. **Critical transfer phase**: participants perform the IR, with the CS presented periodically.

         Results: IR $\uparrow$ in the presence of an appetitive CS; IR $\downarrow$ in the presence of an aversive CS.
2. **Behaviour/Response allocation approaches**: based on the idea that some behaviours can be rewarding.
   - **Consummatory-response theory**: species-typical consum. responses (e.g., eating) are inherently rewarding.
   - **Premack principle**: a behaviour with higher baseline probability can reinforce a behaviour with lower probability.
   - **Response-deprivation hypothesis**: restricting a behaviour below its baseline rate can make doing it reinforcing.
   - **Minimum-deviation model**: organisms will redistribute their behaviour in a way that minimizes the total deviation of the two responses from the behavioural bliss point.
     - **Behavioural bliss point**: distribution of an organism's activities before response allocation is constrained.
     - **Reinforcement effect**: $\uparrow$ IR above the baseline level to get nearer to the behavioural bliss point.
3. **Behavioural economics**:
   - **Price/Cost**: how much IR is required; **income**: ability to perform the response.
   - **Elasticity of demand**: influence of prices on consumption ($\uparrow$ elasticity $\rightarrow$ price has $\uparrow$ effect on consumption).
     (a) **Availability of substitutes**/alternative reinforcers.
     (b) **Price range**: a %$\uparrow$ in price has weaker effect at lower than higher prices.
     (c) **Income level**: higher income $\rightarrow$ less deterred by $\uparrow$ in price.
     (d) **Link to complementary commodity**: $\downarrow$ demand for sth $\rightarrow \downarrow$ demand for linked commodity.

Stimulus control

- Most behaviours are normal when performed in the presence of certain stimuli/contextual cues.
  - In the absence of these stimuli (i.e., **modulators**), the same behaviours are considered abnormal.
  - **Conditional relation**: a cue's ability to control the outcome is modulated by another stimulus.
    - **Occasion setting/Facilitation**: procedure in which one cue designates when another cue will be reinforced.
      - **Positive occasion setting**: presence of one cue reinforces the other cue.
      - **Negative occasion setting**: presence of one cue inhibits the other cue.
- **Stimulus generalization** occurs if organisms have not learned to distinguish differences among the stimuli.
  - **Stimulus discrimination**: differential responding in the presence of two or more stimuli.
    - **Stimulus discrimination procedure**: CS+ is paired with the US on some trials and CS- is presented without the US on other trials, resulting in CS+ eliciting a CR and CS- inhibiting this CR.
    - Without special procedures, one cannot reliably predict which stimuli will gain control over one's IR.
  - **Stimulus generalization**: responding to test stimuli which are different from the training cues.
    - **Generalization gradient**: IR gradually $\downarrow$ with stimuli that increasingly differ from the training stimulus.
    - Strong **stimulus control** = strong **stimulus discrimination** = **evidence of learning**.
- Approaches to stimulus control:
  1. **Elemental/Stimulus-element approach**: response to a compound stimulus is based on its distinct elements.
     - **Relative stimulus validity training**: a compound is reinforced (AB+), but not when some part differs (AC-).
  2. **Configural-cue approach**: compound stimulus $>$ sum of elements; response is based on similarity to training CS.
     - **Positive patterning**: a compound stimulus is reinforced (AB+), but its individual elements are not (A-, B-).
     - **Negative patterning**: two stimuli are reinforced (A+, B+), but not when they appear simultaneously (AB-).
- Factors influencing stimulus control:
  1. **Cue complexity**: intradimensional (stimuli which differ in only one aspect, e.g., colour) discrimination is harder.
  2. **Sensory capacity**: ability of the organism to detect certain stimuli (e.g., range of audible frequencies for humans).
  3. **Stimulus salience**: other cues more easily conditioned (**overshadowing**) $\rightarrow \downarrow$ learning.
  4. **CS-US belongingness**: some stimuli are more likely to control behaviour in appetitive than in aversive situations.
  5. **Prior experience**: prior learning $\rightarrow \uparrow$ stimulus control.
  6. **Stimulus similarity**: training S+ $\approx$ S- $\rightarrow$ narrower generalization gradient $\rightarrow \uparrow$ stimulus control.
  7. **Presentation method**.
  8. Presence of **modulators/higher-order variables**: signals whether the CS-US relationship is in effect.
- **Spence's theory of discrimination learning**: assumes that
  1. Reinforcement of a response to S+ $\rightarrow$ conditions excitatory response tendencies to S+.
  2. Non-reinforcement of responding to S- $\rightarrow$ conditions inhibitory properties to S- which suppresses IR.
  - **Peak-shift effect**: highest rate of responding shifts away from the S+, in a direction opposite to the S-.
  - **Negative summation**: net strength of responding arising from an inhibitor summing with an excitor.
  - **Acquired equivalence**: generalization across different stimuli due to prior experience (e.g., learning).
    - **Common outcome training**: linking each of several different stimuli to a common outcome.
    - **Common response training**: training same response to different stimuli $\rightarrow$ induces **functional equivalence**.

    For a category, (1) not all stimuli must be trained, (2) changing the value of one stimulus affects the other stimuli.

Extinction of Conditioned behaviour

- **Forgetting**: loss of a learned response because of information loss due to the passage of time.
- **Extinction**:
  - In **CC**: reduction of a learned response because the CS is no longer paired with the US.
  - In **IC**: reduction of the IR because the reinforcer no longer follows the IR (rather than the passage of time).
  1. Target response decreases when the response no longer results in reinforcement.
  2. Produces an increase in response variability.
  3. Often produces strong emotional effects, e.g., **frustration**.
- Paradoxical reward effects:
  - **Overtraining extinction effect**: more FR1 training $\rightarrow \uparrow$ frustration during extinction $\rightarrow$ faster extinction.
  - **Magnitude reinforcement extinction effect**: larger reinforcer used in training $\rightarrow$ faster extinction.
  - **Partial-reinforcement extinction effect (PREE)**: persistence of IR in extinction after partial reinforcement (PR).
    - **Discrimination hypothesis**: '.' difficulty in detecting the onset of extinction.
    - **Frustration theory**: '.' IR becomes conditioned to the anticipation of frustrative nonreward.
    - **Sequential theory**: '.' IR becomes conditioned to the memory of nonreward.
    - **Behaviour momentum theory**: '.' resistance to changes in reinforcement contingencies/behaviour.
- Recovery from extinction:
  - **Spontaneous recovery**: caused by the passage of time.
  - **Renewal**: caused by a shift away from the contextual cues present during extinction (types: ABA, ABC, AAB).
  - **Reinstatement**: caused by exposure to the US/reinforcer (context-specific).
  - **Resurgence**: caused by the extinction of another behaviour.
  - **Concurrent recovery**: caused by the acquisition of a second IR.
  - **Facilitated re-acquisition**: faster learning towards an extinguished excitatory CS relative to a novel stimulus.
- Enhancing extinction:
  1. Use **larger numbers of extinction trials**.
  2. **Spaced trials** produce a more enduring extinction effect.
  3. Conduct **extinction in different contexts**.
  4. **Repeat the extinction/test cycle**.
  5. **Present retrieval cues** for extinction during tests for recovery of extinguished behaviour.
  6. **Presenting two stimuli** at the same time that are **both undergoing extinction**.
     - If a stimulus is compounded with a CI (instead of another CS), the effectiveness of extinction is reduced.
  7. Conducting extinction while fear memory is in the **reconsolidation window**.
     - **Reconsolidation window**: period during which an activated memory can be modified.
- Extinction does not involve *unlearning*, but **interference** due to the learning of inhibitory S-R associations.
  - **Interference**: 2 S-R associations are trained separately; **(cue) competition**: 2 stimuli are trained in compound.
    - $\uparrow$ similarity between phases $\rightarrow \uparrow$ interference.
  - Interference can be classified as:
    - **Proactive** (forgetting of the latter due to the former) vs **retroactive** (forgetting of the former due to the latter).
    - **Cue** (variations in the stimuli) vs **outcome** (variations in the consequent/outcome).

    Extinction represents *retroactive outcome* interference.
  - **Bouton's retrieval theory**: context becomes a cue for when the IR is not reinforced (i.e., negative occasion setter).

Aversive Control

- **Avoidance**: IR prevents the delivery of an aversive stimulus (-ve contingency) $\rightarrow \uparrow$ IR (a.k.a. *active avoidance*).
  - **Two-process theory of avoidance**: both CC/IC are involved in avoidance learning, they depend on each other.
    1. Classical conditioning of fear to the CS.
    2. Instrumental reinforcement of the avoidance response through fear reduction.
  - Methods of investigation:
    - **Discriminated/Signaled avoidance**: CS signals occurrence of aversive US, IR terminates CS and stops US.
      - **Avoidance trial**: aversive US not yet presented $\rightarrow$ IR made $\rightarrow$ **prevents delivery** of the aversive stimulus.
      - **Escape trial**: aversive US presented $\rightarrow$ IR made $\rightarrow$ **termination** of aversive stimulus.
      - **Shuttle avoidance**: required IR consists of shutting between two sides of an apparatus on successive trials.
    - **Non-discriminated/Free-operant avoidance**: an aversive US is presented periodically and not signalled.
      - **Shock-shock (S-S) interval**: interval between successive presentations of the US when IR is not performed.
      - **Response-shock (R-S) interval**: interval between the onset of IR and the next presentation of the US.
    - **Escape from fear (EFF) procedure**: subjects learn an IR to escape from/terminate a CS that elicits fear.
  - Alternative theoretical accounts of avoidance:
    - **Safety-signal hypothesis**: safety signals accompanying avoidance behaviours may reinforce these behaviours.
      - Introducing an explicit feedback stimulus facilitates the learning of an avoidance response.
    - **Shock-frequency reduction**: reduction in the frequency of shock serves to reinforce avoidance behavior.
    - **Bolles' theory**: the configuration of the environment determines which particular **SSDR** occurs.
      - **Species-specific defense reactions (SSDRs)**: species-typical responses performed in an aversive situation.
    - **Predatory imminence continuum**: different species-typical defense responses occur with different degrees of predatory imminence.
      - **Predatory imminence**: the perceived likelihood of being attacked by a predator.
    - **Expectancy theory**: encounters with aversive events trigger a conscious process of threat appraisal that generates expectations of future threat (or lack of threat) based on cues and responses.
  - Extinction of avoidance:
    - **Response blocking**: subject is exposed to and prevented from engaging in the IR to escape a fear stimulus.
    - **Flooding**: the CS is presented while the participant is prevented from making the avoidance response.
- **Punishment**: +ve contingency between IR and an aversive stimulus $\rightarrow \downarrow$ IR (a.k.a. *passive avoidance*).
  - Method of introduction:
    - **Time out**: period during which the opportunity to obtain positive reinforcement is removed.
    - **Overcorrection**: participants are required to correct a mistake and to extensively practice the correct response.
  - Factors affecting effectiveness of punishment:
    - **Intensity** and **duration**: $\uparrow$ intensity/duration $\rightarrow$ more effective.
    - **Contingency** of aversive stimulus relative to target behavior: less contingent $\rightarrow$ less effective.
    - **Contiguity**: greater delay $\rightarrow$ less effective.
    - **Punishment schedules**: higher FR schedules $\rightarrow$ less responses punished $\rightarrow$ less effective.
    - **Presence of positive reinforcement**: inherently reinforcing/reinforcement not addressed $\rightarrow$ less effective.
    - Punishment as a **signal for the availability of positive reinforcement**: if so $\rightarrow$ less effective.
    - **Availability of alternative methods** for obtaining reinforcement: absent $\rightarrow$ less effective.
    - Whether punishment intensity **gradually increases over time**: Y $\rightarrow$ less effective.
    - **Discriminative punishment**: responding is only punished in the presence of a particular stimulus.
      - The suppressive effects of punishment will be limited to the presence of the discriminative stimulus.
  - Theories of punishment:
    - **Conditioned emotional response theory**: punishment suppresses behaviour through by eliciting freezing, which is incompatible with the punished behaviour, thus suppressing the behaviour.
    - **Avoidance theory**: organisms learn to escape from the aversive stimuli (punishment) by engaging in other behaviour that is incompatible with the punished activity, thus suppressing the behaviour.
    - **Negative law of effect**: punishment is an aversive outcome which weakens the S-R association.