

# Psychobiology

## 8

# Animal learning and cognition

## Route map

In the first two sections of this chapter, we will address the two dominant theories of learning: classical conditioning and operant conditioning. The application of associative learning theories illustrates how experience can influence biological responses. In the third section of this chapter, we will look at cognitive learning. In the final section, the possible underlying neural mechanisms of learning are addressed.

## Introduction

It would be easy to assume that biology determines behaviour. In part it does – we are born with the necessary equipment to learn and adapt. This is called preparedness (see Chapter 33, page xxx). An organism is not born with a complete set of programmes to deal with every situation it could ever encounter – it has to adapt its behaviour for survival.

An example of this is imprinting (Lorenz, 1937).

Imprinting is when a newly born animal attaches itself to a moving object. In the case of Lorenz's ducks, they followed him rather than their mother. These adaptations and experiences shape future behaviour and also physiology. The organism learns from experience.

From an evolutionary perspective, behaviour that favours survival will be selected. Those behaviours that are not useful will not be selected. There are many similarities between the learning theories and evolutionary theories (e.g. adaptation to the environment). The main difference between the two is timescale. Learning is within an organism's lifetime, whereas evolution transcends the life of an individual.

Two notable theorists have dominated the field of animal learning: Pavlov and Skinner. Their initial learning theories have been adapted, refined and supported by empirical study in both animals and humans. The two main theories – classical conditioning and operant conditioning – are referred to as 'associative learning'; this is because associations are made between stimuli and their responses.

## Habituation

**Habituation** is the simplest and most ubiquitous form of learning. It is when you learn to ignore a stimulus that does not convey any meaning.

Habituation can be measured in the rat. A loud noise, say,

can induce a startle response in a rat. The rat jumps because it has been startled. If the rat is repeatedly exposed to the noise and that noise has no consequence, the magnitude of the startle response diminishes.

From an evolutionary perspective, habituation is an adaptation that aids survival. It makes good sense for the animal to respond to a stimulus that it has never experienced before. A novel stimulus may, or may not, pose a threat. However, if the stimulus is repeated with no consequences the animal habituates to it. This enables the animal to get on with the important business of survival. Thus the only stimuli that are attended to are those that may pose a threat to survival. A rat, then, should habituate to traffic noise but not to a cat. The cat is a predator. Habituation is important to the researcher and can influence the conclusion arrived at in an experiment (see Research methods box 8.1).

## RESEARCH METHODS BOX 8.1

### Habituation in psychopharmacology

In Chapter 7 we saw how a drug can increase the action of a neurotransmitter – an agonist. A dopamine agonist, such as amphetamine, makes rats run about (see Clarke and White, 1987). However, different conclusions can be arrived at on the basis of the rat's previous experience.

When an animal is put into a test arena for the first time it explores the environment. This is seen as increased motor activity. Within a one-hour session short-term habituation occurs and the motor activity diminishes. If the rat is exposed to the test environment several times, long-term habituation occurs; the rat does

not engage in much exploratory behaviour at all and thus there is a decline in motor activity.

In a study by Chandler et al. (1990) two groups of mice were given a DA agonist. The first group had never experienced the test environment before (they were non-habituated). The second group had been exposed to the test environment many times (the habituated group).

The DA agonist produced very different results in the two groups of mice. Two measures were taken: motor activity and rearing. Rearing is illustrated in Figure 8.1. You can see clearly that the drug appeared to have no effect in the non-habituated mice. Note that the amount of rearing was consistently high (around 40 counts). However, in the habituated mice the baseline of control mice was reduced (about two counts). They had habituated, but after the DA agonist there was a dose-dependent increase in rearing.

This study indicates that the behavioural history of the animal is an important factor in determining the effects of a drug. The response to the drug was dependent on pre-exposure to the test environment. Conclusions from the non-habituated mice would lead to the notion of the drug being devoid of behavioural activity. In the habituated mice the conclusion is different. The DA agonist in these animals produced behavioural activation.

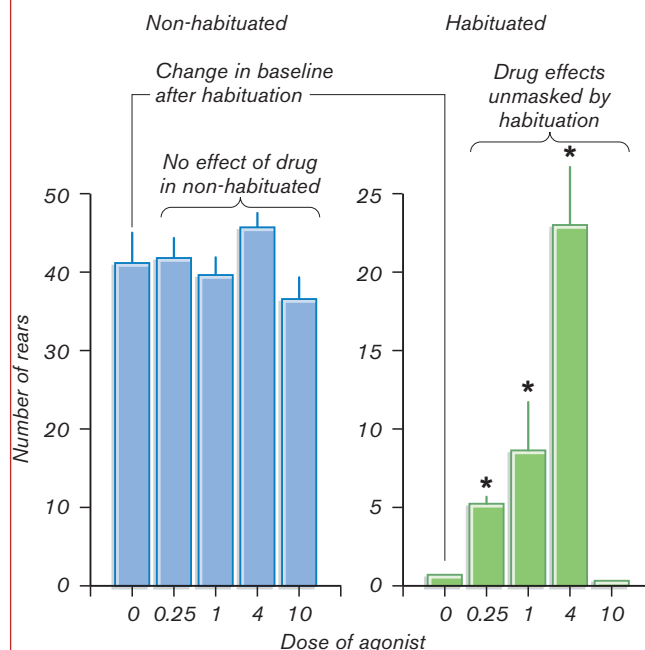


Figure 8.1 Habituation to the test environment

Humans can also habituate (see Applications box 8.1). If we hear a loud noise behind us, we respond by trying to locate its source. This is called the *orienting* response. If we observe that the source of the loud noise is non-threatening (e.g. a builder hammering) and the noise continues, we habituate to the noise. If the sound is indicative of a threat, like gunfire, we locate it and preferably avoid it.

### APPLICATIONS BOX 8.1

#### The Kiss

An example of habituation to auditory warnings was recently evident in the Sussex town of Lewes. An extremely valuable statue by Rodin – The Kiss – was placed on display in a public building. Normally such valuable items come with highly sophisticated security systems. The Kiss had a security guard with a whistle.

Why the low-key approach? Because people have learned to ignore (they are habituated to) electronic alarms and buzzers, such as car alarms. People would, however, respond to someone blowing a whistle.

In the city we hear false alarms sounding all the time; they no longer signal an intruder, say. The novelty of the whistle, and the fact that it has to be blown deliberately, means that anyone hearing it will orient to the source of the sound. Thus someone touching The Kiss will stop in their tracks on hearing the whistle.



#### Reflexes

The response of the organism during habituation is a reflex. A **reflex** is an automatic response to an external stimulus. Leg jerking in response to a tap on the knee area with a tendon hammer is a reflex.

A reflex involves closely related events. For a reflex to occur, an input stimulus is necessary. The input triggers the cellular events of neurotransmission. Stimulus input is via afferent neurons to the spinal column. The afferent neuron communicates with an interneuron. An **interneuron** is a neuron that is neither sensory nor motor but connects the two. The interneuron communicates with an efferent neuron. The efferent neuron activates muscles to execute the reflex.

If you touch something hot you automatically retract your hand from the source of the heat (the stimulus). You do not think: 'That's hot! I must remove my hand before I suffer tissue damage' (or words to that effect). The thermal information is sent along afferent neurons that connect to efferent neurons (via the interneuron) and the reflex of hand removal is executed (see Figure 8.2). Thus you avoid getting a serious burn to your hand.

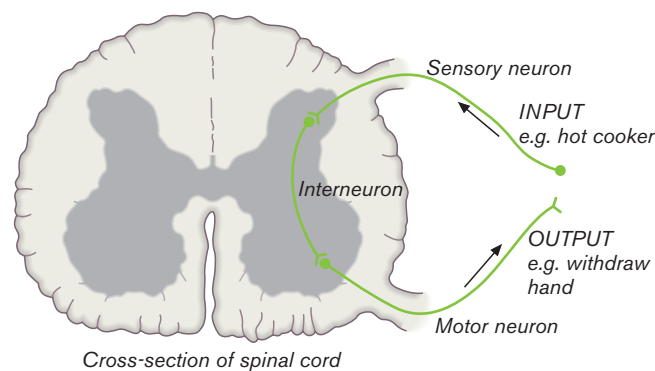
**Self-test:** What is habituation?

### Classical conditioning

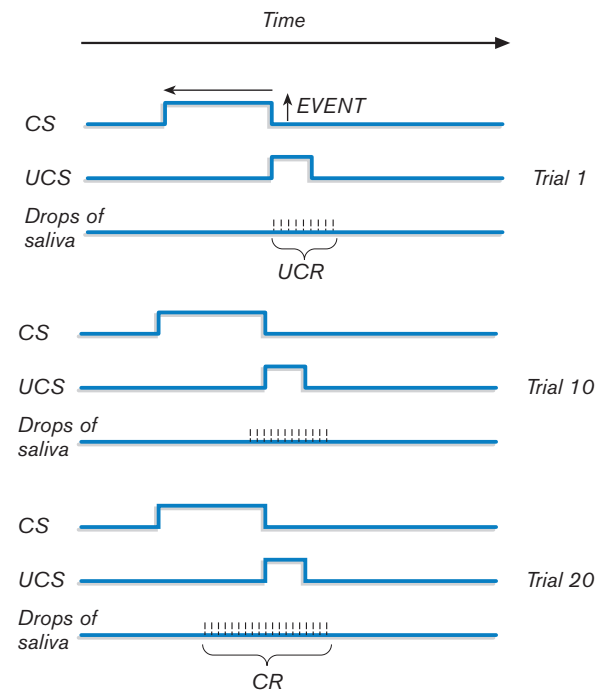
While they are automatic responses, reflexes can be subject to learning. The reflex is central to Ivan Pavlov's theory of **classical conditioning**. Classical conditioning is when a neutral stimulus becomes associated with a stimulus that is able to produce a reflex. The neutral stimulus, which previously had no effect, becomes able to produce the reflex.

Pavlov was investigating digestion in the dog. Incidental to this, Pavlov and his students noticed that dogs would salivate to stimuli that were predictive of feeding time. Like all good scientists they systematically investigated this phenomenon with experiments.

Pavlov put the dogs in a special apparatus that allowed saliva to be collected. When food was put into a dog's mouth, saliva was produced. Saliva contains enzymes that are used in the digestion of food. The saliva-producing response is a reflex to the orosensory stimulus of food in the mouth. In Pavlovian terms, the food is an **unconditioned stimulus (UCS)** and the production of saliva is an



**Figure 8.2** A reflex comprises the activation of an afferent nerve connected to an interneuron, which is in turn connected to an efferent neuron



**Figure 8.3** The development of classical conditioning: at Trial 1 only the UCS produces salivation; at Trial 20 the CS produces the CR of salivation

**unconditioned response (UCR).** A reflex can be described as an unconditioned response to an unconditioned stimulus.

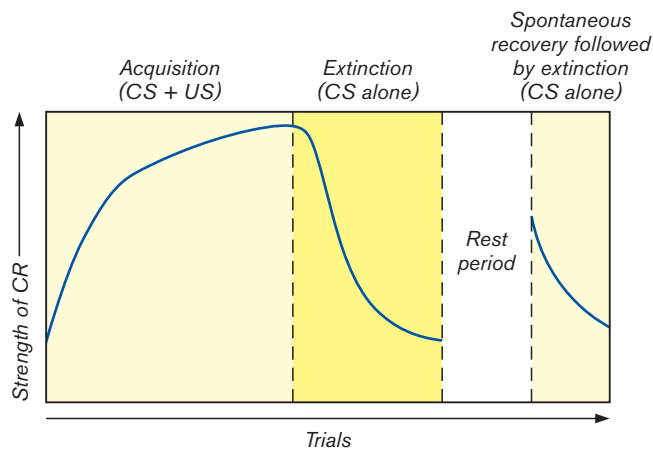
So far nothing had been learned by the dog in the experiment. During the next stage of the experiment, a tone was introduced (a bell), which accompanied the presentation of food. Initially, the tone was a neutral stimulus and did not produce a response. However, after a number of tone/food presentations the tone was presented alone and on its own produced salivation in the dog. This tone is referred to as the **conditioned stimulus (CS)**. The response to the tone, in this case salivation, is called the **conditioned response (CR)**. The dog is said to have acquired an association between the tone and the production of food (see Figure 8.3).

**Self-test:** Describe the basic process of classical conditioning and apply it to habituation.

### Measuring the CR

Measuring a CR is not an all-or-nothing observation. Such a measure would put us in danger of missing the subtleties of the conditioning process. There are three main ways of assessing the strength of a CR:

- 1 **Response amplitude** How large is the CR? In Pavlov's experiments, how much saliva does the dog produce? The more saliva, the stronger the conditioning.
- 2 **Response probability** How many times does a CR occur in response to a CS? A probability of 0.5 (50%) would



**Figure 8.4** The acquisition, extinction and subsequent spontaneous recovery of the CS: acquisition is gradual and when the CS is presented alone extinction occurs in which the animal no longer produces a strong CR; after a period of time the animal is presented with the CS again and a CR is emitted

indicate responding at the level of chance. A CR probability of 0.9 (or 90%) would indicate that there is a strong association between the CS and UCS. How many times does the dog salivate to the CS?

- 3 **Response latency** How long is it after the CS that the CR appears? The closer in time they occur, the stronger the conditioning. How long does it take for the dog to salivate after hearing the CS?

Pavlov's laboratory provided the basic premise of classical conditioning. Using this framework, a large number of behaviours can be described. A human example of classical conditioning in action is a phobia (see Chapter 33).

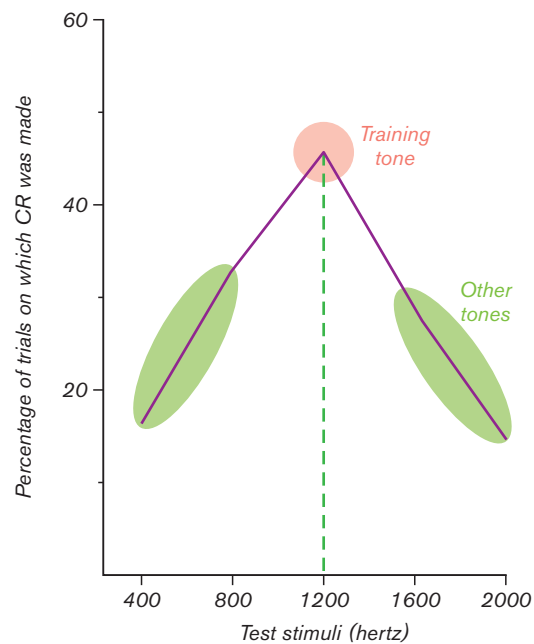
### Acquisition

Over successive pairings, the CS gradually becomes associated with the UCS, producing a CR. The more pairings (or trials), the stronger the conditioning (see Figure 8.4). However, numerous CS–UCS pairings do not result in a continual increase in learning – they reach what is called asymptote (a sort of impasse).

**Self-test:** What are the main measures of a conditioned response?

### Extinction

Once asymptote has been reached, presentation of the CS without the UCS would decrease the CR. If we stop giving a dog food after it hears the tone, it will eventually stop salivating to the tone. This is called **extinction**. The CR is extinguished gradually as the animal experiences the CS without the UCS (see Figure 8.4). Although there are many similarities, extinction is different from habituation (no associations have been made in habituation).



**Figure 8.5** The CS can both generalise to like stimuli or be discriminated from other stimuli

### Spontaneous recovery

After the extinction of the CR and a period of rest without experimentation, the CR can appear again in response to the CS. This phenomenon is known as **spontaneous recovery** (see Figure 8.4). The CR is not as strong as it was during earlier training. If training is restarted, learning the CS–UCS pairing will be quicker than it was in the initial learning period. Spontaneous recovery can occur after a substantial rest period, indicating the permanence of learning. Bouton (1994) asserts that extinction is not forgetting, but is similar to proactive interference in which new learning supersedes old.

### Stimulus generalisation and stimulus discrimination

Pavlov's experiments used a tone of a particular frequency as the CS. What would happen if another similar, but not identical, tone was used? If the new tone was similar to the CS then the CR would be strong. If the new tone was dissimilar to the CS then the CR would be weak. Similarly, an organism is able to differentiate between stimuli that are similar but not identical to the CS (see Figure 8.5).

**Self-test:** What is extinction and is it permanent?

### Conditioned emotional response

The **conditioned emotional response (CER)** is the basis for a classically conditioned phobia (see Chapter 33). In experiments to obtain a CER, rats are trained in an operant chamber (see later). In the chamber, the rats press a lever to

receive food. Rats are good at this task. Sometimes a tone will sound for 30 seconds. Following the tone an electric shock is given. As training continues, the rat stops pressing the bar for food when the tone is presented. This is called conditioned suppression or the conditioned emotional response (CER).

### Is the CR identical to the UCR?

So far in Pavlov's experiments the CR and UCR are both salivation. However, with a more detailed analysis of the saliva, differences in CR and UCR are evident. Saliva contains enzymes that are used for digestion. In the CR, there are fewer of these enzymes than there are in the UCR.

In the CER experiment in which a rat receives an electric shock, the CR and UCR are different. In response to the UCS (shock) the rat's heart rate increases and it jumps about the chamber. The response to the CS (tone) is different from the UCS. In this case, the rat's heart rate decreases and it remains still. The importance of the CR being different from the UCR is exemplified in drug tolerance (see Applications box 8.2).

### The relationship between the CS and the UCS

It should have become clear that the CS becomes associated with the UCS. That is, when there is a CS the chance of a UCS is high. The association between CS and UCS varies in

strength depending on the temporal characteristics (see Figure 8.6). The temporal relationship between the CS and the UCS is important. **Contiguity** is when the CS and UCS are presented close together in time. Rescorla (1968) suggested that contiguity was necessary but not sufficient for conditioning. Differential contingency was also required. Differential **contingency** refers to the likelihood (probability) of a UCS following a CS. If the probability of a UCS following a CS was 0.5, then there would be no learning. If the probability was 0.8, then the CS would be associated with the production of a UCS. If the probability was low (e.g. 0.2), then the absence of a CS indicates a higher likelihood of a UCS.

**Self-test:** Is the conditioned response the same as the unconditioned response?

### Applications

Classical conditioning has been used to explain behaviour such as phobias. Classical conditioning can also be used to explain sexual fetishes (see Activity box 8.1). It is also influential in understanding the phenomenon of drug tolerance and overdose (see Applications box 8.2). Aversive conditioning, as popularised in the book and film *A Clockwork Orange*, is also used in the psychopharmacological treatment of alcoholism (see Applications box 8.3).

## APPLICATIONS BOX 8.2

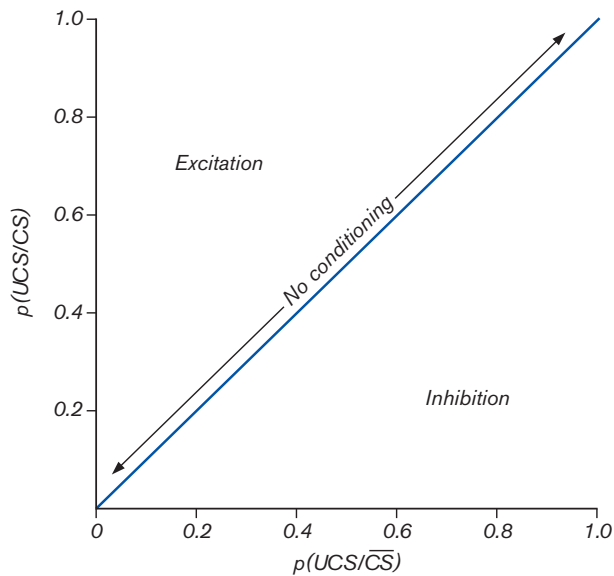
### Drug tolerance and overdose

The body likes to maintain homeostasis. This means that it does not like external agents upsetting its balance. Opponent processes compensate for changes in the body to achieve homeostasis. If you take morphine for pain relief the body compensates for the drug by producing a reaction in the opposite direction: more pain. After the drug has been given a number of times its effect is weakened. This is called tolerance. Tolerance could be seen as a pure biological activity in response to a drug. However, classical conditioning is very important in drug tolerance and can account for the overdose effect to a regular dose.

Using the example of heroin, the drug is a UCS that produces a UCR (euphoria and analgesia). However, drugs are not taken in an environmental vacuum and plenty of stimuli are associated with heroin intake (e.g. syringes, tin foil etc.). These stimuli act as a CS. The CS then produces a CR. The CR is the compensatory response from the body in the opposite direction. The CR produces dysphoria and hyperalgesia. Thus the compensatory CR negates the effect of the drug. The effect on the person is one of tolerance and the need for greater quantities of the drug in order to experience an effect.

Classical conditioning can also account for the overdose effect to a regular dose. Most people take their drug in a particular environment. The very nature of heroin use means it has to be taken in a clandestine manner. All the cues in the environment provide the users with a CR. What happens if you take the drug user out of their environment, put them somewhere new, and give them their regular dose? They may well die from their regular dose in what looks like an overdose. In the new environment the cues are no longer there to provide the user with a CR. The absence of the compensatory CR means that the intake of their normal dose of heroin has a greater effect because it does not have to account for the CR.

This is an effect that has been studied systematically in the rat under controlled conditions (Siegel et al., 1982). In this experiment one group of rats was exposed to heroin in the test environment and another in a different environment. A third group received neither (the control group). The group that received the heroin in a different environment showed the overdose effect, whereas the rats that received the same dose in the test environment did not.



**Figure 8.6** The temporal relationship between the CS and UCS: along the diagonal line there is no conditioning because a CS does not convey any information about the UCS; above the line the UCS has a higher probability of occurring if there has been a CS; below the line the probability of a UCS is higher in the absence of a CS

## Operant conditioning

Operant conditioning (or instrumental conditioning) is about the organism operating in the environment to produce an outcome. If we do something and the outcome is good, then there is a greater chance we will do it again.

### The law of effect

Thorndike (1898) put a cat in a cage with a latch on the door. Outside, he placed cat food. The cat wanted the food, moved around and scratched at the cage. Eventually, by accident the cat knocked the latch on the door. The door opened; the cat got the food. Successive trials of this nature led the cat to gain access to the food quickly. The behaviour exhibited by the cat was strengthened by its relationship with reward. Thorndike referred to this as the *law of effect*. In essence, the cat learns which of its many behaviours leads to freedom and food. It is a gradual process (see Figure 8.7), which leads to the strengthening of a stimulus–response (S–R) relationship.

## ACTIVITY BOX 8.1

### Fetishes

Fetishes are unusual sexual attachments. You only have to glance at late-night television to see that certain objects are linked with sexual arousal. The boot or high-heel fetish that many men would appear to have can be induced by classical conditioning. Rachman and Hodgson (1968) conducted such an experiment. They exposed people to pornographic images (UCS) along

## APPLICATIONS BOX 8.3

### Preventing alcohol consumption

The saying goes – one’s too many and a hundred isn’t enough. This is true for alcoholics. They can never have just one drink. Once they start, they just keep on going.

One way of preventing drinking is to stop the first drink. Easier said than done! Alcohol is highly addictive and people may have a genetic predisposition to it.

One method is to make the effects of alcohol unpleasant. This is called counterconditioning (an aversion therapy; see also Chapter 34), in which the pleasant effects of alcohol are replaced with unpleasant effects (see Schwartz, 1984).

To achieve counterconditioning the pleasant effects of the drug are replaced by nausea and vomiting. This can be induced by another drug called an emetic. Thus the unpleasant effects of the drug become associated with the taste of alcohol. Hopefully this should be sufficient for the alcoholic to avoid future drinking.

Another drug called disulfiram (Antabuse) is also used to produce unpleasant effects if alcohol is consumed. If it is consumed there is a rise in toxic metabolites. This toxicity produces facial flushing, nausea, vomiting, dizziness and confusion, shortness of breath and changes in heart rate (see Feldman et al., 1997). Altogether this is an unpleasant effect.

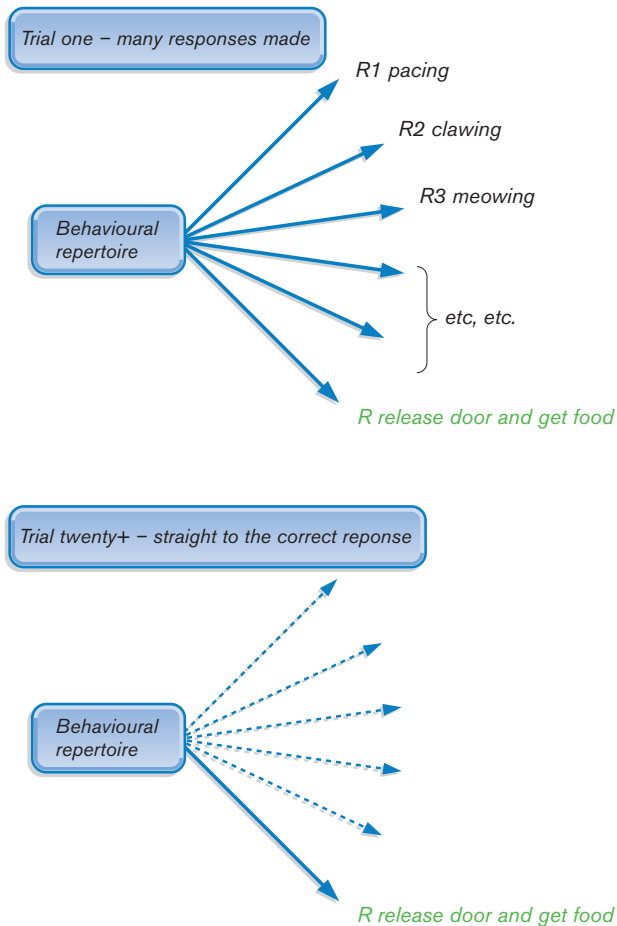
Disulfiram can also be placed within a classical conditioning framework. The benefit of disulfiram is that its pharmacological action lasts a number of days. Therefore the process of conditioning can take place outside a clinic.

## Behaviourism

Skinner was instrumental in shaping behaviourism (see Chapter 2) and put forward the view that behaviour followed laws (see Focus point 8.1). Skinner experimented with pigeons in a box, which became known as the Skinner box (or operant chamber; see Photo 8.2). Skinner boxes are used with many animals, especially rats. Using the laws of behaviourism, rats can be trained to perform complex laboratory tasks and also other activities that are associated

with neutral stimuli (CS). The pornographic images produced sexual arousal (UCR). After a number of UCS–CS exposures the CS was presented and produced sexual arousal in its own right (CR).

Using this framework let your imagination run wild and apply scenarios to whatever fetish springs to your mind. It may be the case that some males like pierced belly buttons because this is associated with their early sexual experiences in which women had staples across their midriffs (e.g. as magazine centrefolds)!



**Figure 8.7** The law of effect: after a number of trials the cat emits the correct response

## FOCUS POINT 8.1

### Skinner's view

According to Skinner (1971), 'As a science of behaviour adopts the strategy of physics and biology, the autonomous agent to which behaviour has traditionally been attributed is replaced by the environment – the environment in which the species evolved and in which the behaviour of the individual is shaped and maintained.'

more with dogs (see Applications box 8.4). The basic premise is the same as that of the law of effect: S–R associations.

### Reinforcement

Fundamental to operant conditioning is **reinforcement**. Reinforcement is when the consequences of a response

## APPLICATIONS BOX 8.4

### Landmines and rats

In war-torn areas of the world, landmines are often placed with devastating consequences. Metal detectors are not always effective and dogs can be too heavy. Thus the rat can be used or, more specifically, the Gambian giant pouched rats. Growing to a maximum weight of 2.8 kilograms it can scamper around a minefield without the risk of detonating antipersonnel devices that can be triggered by dogs. The rats are trained to detect mines and, when they locate one, they stop, sniff and start to scratch.



The Skinner box

increase the probability that the response will reoccur. If a rat presses a lever and gets food, it will be more likely to press the lever again. If you work hard at an essay and get a good mark, you are more likely to work hard at your next essay. The first example uses a primary reinforcer (e.g. food and water). The latter is an example of a secondary reinforcer. A secondary reinforcer is something that does not satisfy a physical need (e.g. money, praise or attention).

### Positive and negative reinforcement

Using reinforcement, behaviours can be selected and strengthened. There are two types of reinforcement: positive and negative. **Positive reinforcement** is when a reinforcer is presented after a response and increases the likelihood of that response recurring.

In the animal experiments, food is a positive reinforcer. For humans, money and praise (particularly in children) are positive reinforcers. Basically, you get something you want after you have done something (e.g. wages for working). Recently an experiment with monkeys demonstrated that they would reject unequal pay. In this experiment, they would not participate in the experiment if

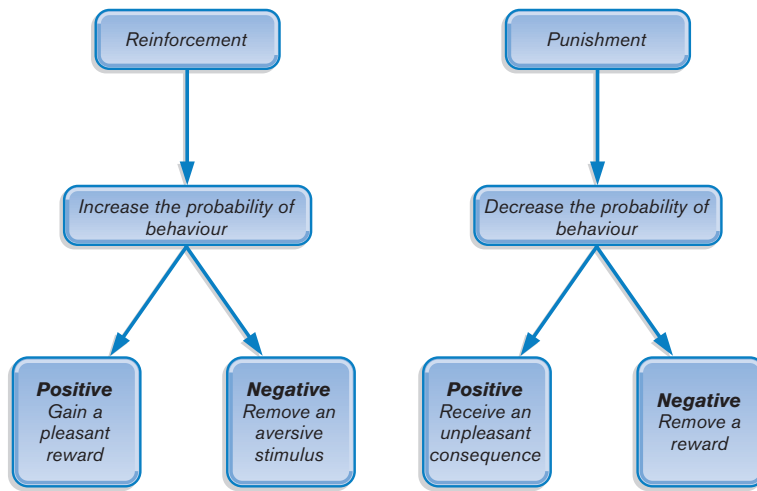


Figure 8.8 Reinforcement increases the likelihood of a behaviour while punishment decreases the likelihood of a behaviour

they saw another monkey get a better reward for less work (Brosnan and De Waal, 2003). Clearly, there is something more complex occurring in these monkeys than just associative learning.

**Negative reinforcement** also increases the probability of a particular response. However, in this case, it is the removal of an unpleasant event or circumstance that strengthens a response. For example, a rat will press a bar or lever to escape an electric shock. When a stimulus is indicative of electric shock, the rat will press a lever and thus avoid the shock. Similarly, humans respond to negative reinforcement. The roles of positive and negative reinforcement have been used to account for drug addiction (see Chapter 9).

### Punishment

The first point to note about **punishment** is that it is *not* negative reinforcement (see Figure 8.8). The difference between punishment and negative reinforcement focuses on what it does to a particular behaviour. Negative reinforcement *increases* the likelihood of a particular behaviour, whereas punishment *decreases* the likelihood of a particular behaviour. Thus, punishment is used to stop a behaviour whereas reinforcement is used to promote a behaviour.

Punishment can be subdivided into positive and negative punishment. Positive punishment is when behaviour leads to an undesired consequence. In the rat this could be an electric shock. In the human it could be a fine for illegal parking. Negative punishment is when behaviour results in the removal of or failure to obtain a desired reinforcer. In the rat, this could be restricted access to food (e.g. Chandler and Stolerman, 1997). In the child, it could be the removal of television time.

In order for punishment to be as effective as possible it should contain three features. First, the punishment has to come straight after the behaviour; there has to be contiguity between the response and the punishment. Second, the

behaviour has to be consistently punished; failure to be consistent means that an association between the behaviour and the punishment is not established. Third, the punishment needs to be sufficiently aversive, but not too aversive. If the punishment is not sufficient then the behaviour may continue. A slap on the wrist for armed robbery is insufficient to stop the criminal re-offending. If the punishment is too aversive, then other problems may occur, like high levels of fear and anxiety.

There are also a number of problems with punishment. The first is that the recipient of punishment may, via classical conditioning, come to fear the person *giving* the punishment rather than the punishment itself. In such a scenario, there is a failure to modify the undesired behaviour. Additionally, there is a new problem created – fear – which can be very difficult to eliminate (LeDoux, 2000). For example, a dog requires training. During training, the trainer may punish the dog. Consequently the dog may cower at the sight of its trainer (a CER) and not make the association between behaviour and punishment.

Due to the unpleasant consequences of punishment, a person may seek to escape it. To escape punishment, they may cheat and lie. If escape is not possible, the person may consider aggression and attack. Think of a bank robber – the consequence of punishment is sufficient to make the robber challenge police with violence. If eventually caught, the robber may lie about the crime. The robber will still engage in the activity, but become more devious in order to avoid detection.

Punishment may *suppress* many behaviours rather than eliminate one. The person may just give up and become apathetic. Finally, the punished may start to imitate the punisher. A child will imitate and learn from its parents. If parents use physical punishment, this is likely to be seen in their children.

**Self-test:** Define the difference between positive reinforcement, negative reinforcement and punishment.

## Schedules of reinforcement

When a particular behaviour is reinforced every time, it is said to be on a continuous reinforcement (CRF) schedule. Behaviourists consider all our actions under the control of operant conditioning. Clearly, we are not on a CRF schedule for all our behaviours, so how is behaviour maintained in the absence of a CRF schedule?

The answer can be found when we consider partial reinforcement. With partial reinforcement, the organism is not reinforced every time it responds. There are four schedules of reinforcement. The nature of the schedule can influence the response output of the organism (or, as in the examples that follow, the rat). After reading this section on schedules of reinforcement, try the exercise in Activity box 8.2.

### ACTIVITY BOX 8.2

#### Schedules of reinforcement

According to behaviourists we are controlled by schedules of reinforcement.

As you go about your daily business you may not be aware that you are being influenced by these schedules. Take a close look at your environment and try to determine what the schedules are.

To help you on your way, simple activities like using a pelican crossing place you on a schedule. You have to press a button to activate the lights. This may happen immediately or you may have to wait a short while.

What are the schedules? (Note that there may be more than one schedule in operation at any time.)

#### Fixed ratio (FR) schedules

With a **fixed ratio (FR) schedule**, the rat is reinforced after a number of bar presses. If the schedule is said to be FR10, this means that the rat is reinforced after the 10th response has been made. Similarly on an FR30 schedule the 30th response is reinforced. People on piecework are on FR schedules (i.e. they get paid for, say, every 100 boxes packed).

A rat on an FR schedule will respond (work) rapidly until the reinforcer is delivered. After reinforcement there is a pause, which is followed by another period of rapid responding (see Figure 8.9).

#### Variable ratio (VR) schedules

A **variable ratio (VR) schedule** is similar to the FR schedule, except that reinforcement occurs after a variable amount of responses. If the rat is on a VR10 schedule then it is reinforced *on average* after 10 responses. However, this varies around an average of 10. Sometimes the rat receives reinforcement after five responses and other times after 15. On a VR schedule, the rat does not know exactly when the reinforcement is going to occur. A VR schedule produces a high rate of rapid and constant responding (see Figure 8.9).

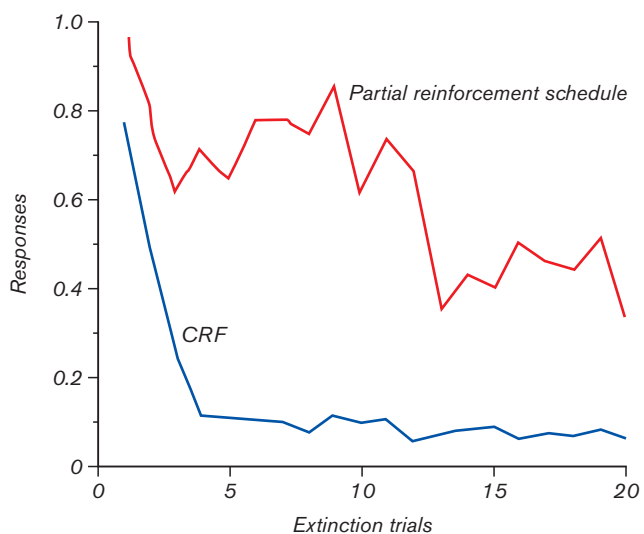
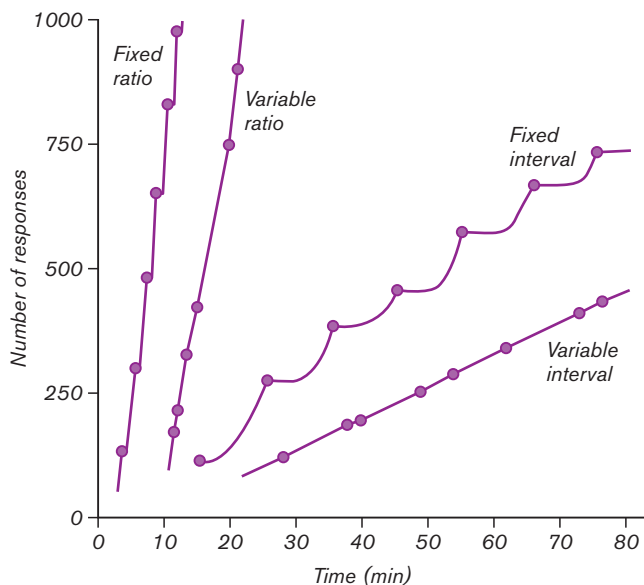


Figure 8.9 (a) Cumulative chart of the different schedules of reinforcement: the chart depicts the responses made; each response is added to the previous one (b) Extinction of a partial reinforcement schedule

The VR schedule is resistant to extinction. This is demonstrated clearly in gamblers. Slot machines are on VR schedules: sometimes you win but many times you do not. A machine is programmed to pay out on a VR schedule. You will get reinforced every so often but you cannot predict the payout. This schedule means that you will keep putting money in the machine.

#### Fixed interval (FI) schedules

A **fixed interval (FI) schedule** is when, after a specified period of time the rat receives reinforcement only if it has pressed the bar during that time. A rat on an FI30 schedule receives reinforcement every 30 seconds if it has pressed the

bar. The rat may press the bar once or many times in the intervening period between reinforcements. A clear scallop is produced in the cumulative response record (see Figure 8.9). This happens because the rat learns not to respond at the beginning of the interval and only starts responding towards the end of the interval.

### Variable interval (VI) schedules

A rat on a **variable interval (VI) schedule** receives reinforcement after an average period of time only if it has responded correctly. On a VI30 schedule the rat receives reinforcement on average after 30 seconds, but sometimes after 20 seconds and sometimes after 40. This schedule produces slow but consistent responding (see Figure 8.9). Home Office inspectors (see Chapter 6) visit animal laboratories on a VI schedule to spot-check that the law is being adhered to and animal welfare maintained. If they arrived on an FI schedule then the laboratories could predict an inspection and could put on a 'good show' just for the inspectors.

**Self-test:** Describe the different schedules of reinforcement.

### Acquisition

Animals, like people, do not learn immediately. A number of learning trials have to be completed before a rat can respond to a stimulus reliably. Many of the experiments you will read about have involved long, and sometimes complex, training regimes. The more complex the task, the longer the training. In the example of rats as drug connoisseurs, Garcha and Stolerman (1989) required up to 90 sessions of 15 minutes' duration for the rat to be a reliable detector of nicotine.

### Shaping and conditioning by successive approximations

A complex piece of behaviour cannot be learned overnight. In order to train an animal one must start with simple behaviours, which contribute to the overall goal behaviour. Once acquired, new behaviours can be worked on and refined. This process is called *shaping*. The shaping of the smaller subsets of behaviours is called 'shaping of successive approximations' – that is, one reinforces behaviours that are getting closer to the desired behaviour. Such procedures are used regularly in training animals (dogs in particular).

### Extinction

On a CRF, the animal stops responding soon after reinforcement stops. Initially, the rat presses the lever rapidly, but eventually this diminishes until it stops responding altogether. Partial reinforcement schedules make extinction of a response more difficult (see Figure 8.9).

### Spontaneous recovery

As is the case with classical conditioning, spontaneous recovery can occur. After a period of absence from training, the rat, on re-acquaintance with the apparatus, will start responding again.

### Discrimination and generalisation

The animal is able to discriminate between stimuli that bring about reinforcement and stimuli that do not. These stimuli are called **discriminative stimuli (SD)**. A pigeon will peck an illuminated key for food reinforcement. It will peck any key at first. However, if reinforcement is made contingent on pressing a green key (and not a red key) the pigeon learns to discriminate between the two stimuli. The green switch is called  $S^+$  (a stimulus that is contingent with reinforcement). The red key is  $S^-$  (a stimulus that is *not* contingent with reinforcement). The colour of the key is a clear SD. Other discriminative stimuli can be subtler. A pigeon may go on to discriminate between shades of green, for instance.

Unlike discriminative learning, generalisation refers to the phenomenon where an animal responds to different stimuli. The pigeon that is trained to discriminate between coloured switches initially generalises to all coloured switches.

### Interoceptive and exteroceptive stimuli

Up to this point the animal has produced a response to an SD (a light or a tone). This is an **exteroceptive stimulus** (sometimes called a stimulus cue). The rat detects the SD, presses a lever and gets a reward.

A rat can also respond to its internal physiological state (an **interoceptive stimulus** or cue). A procedure called drug discrimination is used to understand the stimulus properties of drugs. The rat uses the feelings derived from a drug to determine which bar in the operant chamber leads to reinforcement (see Research methods box 8.2).

**Self-test:** Describe how operant conditioning can be used to train an animal.

## RESEARCH METHODS BOX 8.2

### Drug discrimination: rats as drug connoisseurs

People take drugs for a number of reasons. One is that they like the effects of a drug (e.g. euphoria, alertness). These properties make up the feeling of a drug and thus its stimulus properties. People who smoke are aware of the different amounts of nicotine delivered from various cigarettes. Other drugs of abuse are also readily discriminated in both man and animal (e.g. heroin).

The capacity to detect a drug effect is also mirrored in the animals. After training, drugs can act as discriminative stimuli. By behaving appropriately the animal can indicate its ability to detect the presence of the drug in the body.

### Why use animals?

Stolerman (1993) said, 'Data from animals are often more precise, detailed and extensive than that from humans because animals may be trained and tested over longer periods of time and because they have more rigorously controlled behavioural and pharmacological histories.'

### How do they do this? They can't talk!

Of course, the use of animals does not permit the verbal measure of drug effects. In order to determine the stimulus properties of a drug the animal has to perform an operant task, such as pressing a bar for food reinforcement.

There are two bars, or levers, in the Skinner box. One is associated with the drug effect and results in reward. The other is associated with the vehicle (an inert injection of saline). This permits the data to be analysed in terms of overall responding (e.g. no specific drug effects) and drug-bar responding (specific discrimination of the bars).

The process of training a rat to discriminate a drug from saline is long. First, the rat has to be acclimatised to the environment and placed on restricted diet to motivate it to bar-press. The rat is introduced to the

food delivery system in the operant chamber. Then one bar is put in the chamber and made contingent for reinforcement (FR1). This is reversed the next day so the other bar is associated with reinforcement.

Progressively the FR is increased to FR10. When the rat gets good at this the injections of a drug start. Only one bar is contingent for reinforcement. When given a drug only the drug bar yields food; with saline only, the saline bar yields food. The process continues with saline and drug pairings in a random order. Both bars are present in the chamber.

Stolerman then introduces punishment to the process: when the rat makes an incorrect response the FR schedule is reset. If the animal makes nine correct responses and then makes one wrong one, it has to start again at the beginning. Additionally a VI component is introduced and is increased to 60 seconds. The rat is then on a tandem schedule (VI60-FR10). The VI schedule stops the animal from receiving too many reinforcers in a session and also stops it being able to predict reward. Thus the rat works hard for little pay.

This process takes many months. Once the rats can reliably discriminate the drug from saline, tests can be carried out to see if the stimulus properties are dose dependent; they can then generalise to other drugs.

Alternatively, they can be blocked by antagonists of the training drug. A drug that is like the training drug will generalise to the discriminative cue; drugs that are not like the training drug appear to be more like saline.

The stimulus may be important to explain why people smoke. Perkins et al. (1994) showed that people can discriminate between different doses of nicotine delivered in a nasal spray. Pratt et al. (1983) used the procedure described above and showed that rats could discriminate nicotine from saline reliably without a reduction in the overall response rate. The effects of nicotine are mediated by a receptor for ACh in the brain. They are sensitive to antagonism from nicotine receptor antagonists.

Drug discrimination experiments can tell us a lot about the nature of a drug's effect and the mechanisms underlying that effect.

## Cognition in animals

Strict behaviourists reject all forms of cognitive explanation that are in opposition to behavioural explanations, but it is possible to conceptualise them in cognitive terms see (Bouton & Moody, 2004) or an interaction of the two (McDonald et al., 2004). More recent theories of animal learning do argue that cognition and cognitive processes underlie learning in animals. Cognition here refers to mental processes that are not subject to direct behavioural observation. In fact, according to Lieberman (2000), the

behaviourist view and cognitive view of animal learning have become increasingly similar.

Tolman (1948), who championed the cognitive view, presented the idea of cognitive maps and latent learning. Rats learnt to navigate a maze quickly despite an absence of reward. When given reward these rats were quick to learn the whereabouts of the reinforcer. Tolman claimed that the rats had a cognitive map of the maze. After receiving reward the behaviour of the rat became observable, whereas previously learning was not observable. Behaviourists will

account for observable behaviour. Clearly, from Tolman's studies, learning had occurred that was not directly observable. This is referred to as **latent learning**.

Tolman (1932, 1959) argued that behaviour is goal directed and that animals (and humans) act as if they expect certain behaviours to lead to a desired goal. Dickinson (1989) has further accounted for expectancy in both classical and operant conditioning. His concepts of expectancy involve two types of information.

First, the contiguity between events gives rise to a representation of the associative link between those events. In Pavlov's experiments, the dog developed a representation of the CS and UCS, which would elicit the CR in response to the CS. That is, the dog develops associative expectations that the bell precedes food and produces salivation in response to the expectation of food.

Second, expectancy involves the belief that a particular behaviour will have a specific effect. In the operant conditioning experiment, the rat presses a bar to get food. That is, there is a *belief* that the behavioural response results in reward. Dickinson (1989) claims that, with increased training, stimulus-response habits emerge that do not involve the expectation that a particular behaviour will lead to reinforcement, i.e. the cognitive phenomenon of expectancy can eventually change into an automatic habit.

The area of animal cognition focuses on how the animal uses experience to form the basis for future behaviour. Of course, how the past affects our behaviour is to do with memory. Cognitive psychologists have demonstrated that there are numerous types of memory (see Chapter 14). One type of memory that has been extensively investigated in the animal is spatial learning and this has a neurophysiological substrate in the hippocampus.

In the experiments by Tolman, a maze was used. These experiments required the animal to retain information about the spatial features of the apparatus. There are numerous other methods of assessing memory in the animal (see Sarter et al., 1992a, 1992b). One method of assessing spatial memory is the water maze, which has been used to study potential treatments for Alzheimer's disease (see Research methods box 8.3; Activity box 8.3).

### RESEARCH METHODS BOX 8.3

#### The water maze

A water maze consists of a pool of water (with a circumference of about two metres) from which a rat cannot escape (see Fig. 8.10). The water is coloured to obscure a platform just below the surface. The rat is placed in the pool and to get out has to find the platform. Initially the rat just swims about until, by accident, it finds the platform. After a number of trials the rat is able to find the platform relatively easily. The rat uses spatial cues in the environment to locate the platform.

There are a number of measures that can be used to determine spatial learning in the water maze:

- latency
- path length
- average speed
- side wall proximity
- directionality
- quadrant times
- quadrant distances.

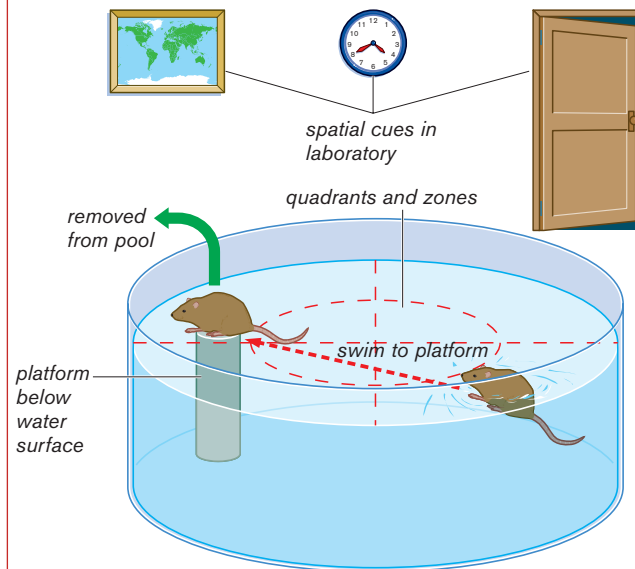


Figure 8.10 The water maze

### ACTIVITY BOX 8.3

#### Animal memory

- **Can animals remember?** Think of pets or animals in the wild. Does your dog remember? Do elephants ever forget?
- **How would you go about assessing memory in different animals?** Rats cannot do digit span and verbal tasks. You cannot ask them questions and ask them to repeat them after an interval. They can do spatial tasks such as mazes.
- **What sort of memory are you measuring?** There are many types of memory for example, episodic, long term, semantic and working memory.
- **What else might you be measuring as well as memory?** Memory is made up of different processes, e.g. attention, learning, encoding, storage and retrieval.

The phenomenon of learned helplessness (Seligman, 1975) also points to cognitive learning. The animal has to compute the probabilities of affecting the environment and receiving reward. In learned helplessness, a chance level of affecting the environment leads to there being no predictive information about reward contingencies. Underlying the computation of probability are neural mechanisms. Recently, DA neurons of the midbrain have been shown to be differentially active on presentation of different probabilities of reward (Fiorillo et al., 2003). Matsumoto et al. (2003) identified the lateral and medial prefrontal cortex (mPFC) as a site that is active when there is anticipation of reward. The mPFC was also identified as the place where responses are selected.

It may not be possible, and it may also be unnecessary, to provide a definitive answer to the cognitive versus associative learning debate. Lieberman (2000) states that the two forms of learning can coexist. Cognitive learning involves attention and concepts of abstraction and expectation. Associative learning may represent automatic processes that are well learnt and do not require conscious attention. This view is rather similar to the cognitive approach to the function of the frontal lobes proposed by Norman and Shallice (1980).

**Self-test:** What is latent learning?

## The neural bases of learning: long-term potentiation (LTP)

These studies just examined provide neural correlates of behaviour. The temporal lobes and the hippocampus are involved in learning and memory. Understanding the neuroanatomy is important but it does not tell us about the processes of learning and memory. Changes in hippocampal activity during associative learning have been identified (e.g. Wirth et al., 2003).

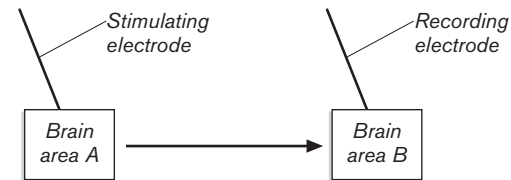
### What happens at the neural level?

Hebb's (1949) initial theory of changes in synaptic transmission has since been supported and refined by experimental evidence (Bliss and Lomo, 1973). With the induction of **long-term potentiation (LTP)** there is a facilitation of synaptic transmission. After there has been a period of high-frequency electrical stimulation of the presynaptic neuron by an electrode, the response to low-frequency stimulation is potentiated.

LTP can last for a long time and requires the activation of both pre- and postsynaptic neurons (Bliss and Gardner-Medwin, 1973; Sastry et al., 1986). Interestingly, in the context of this chapter on learning, Iriki et al. (1989) have found changes in the rat hippocampus after conditioning that are similar to LTP (see Figure 8.11).

The search for the neural mechanisms underlying LTP has focused primarily on the NMDA and AMPA receptors. The NMDA and AMPA receptors are configured to receive messages from glutamate (an excitatory amino acid). The

### LTP setup

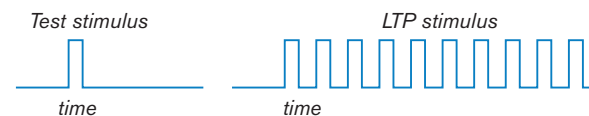


### LTP procedure

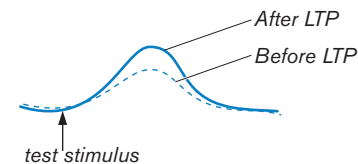
*Step 1: Give single test stimulus to area A and record neural response in area B*

*Step 2: Give trains of high frequency stimulation to area A*

*Step 3: Give single test stimulus to area A and record neural response in area B*



### Neural responses

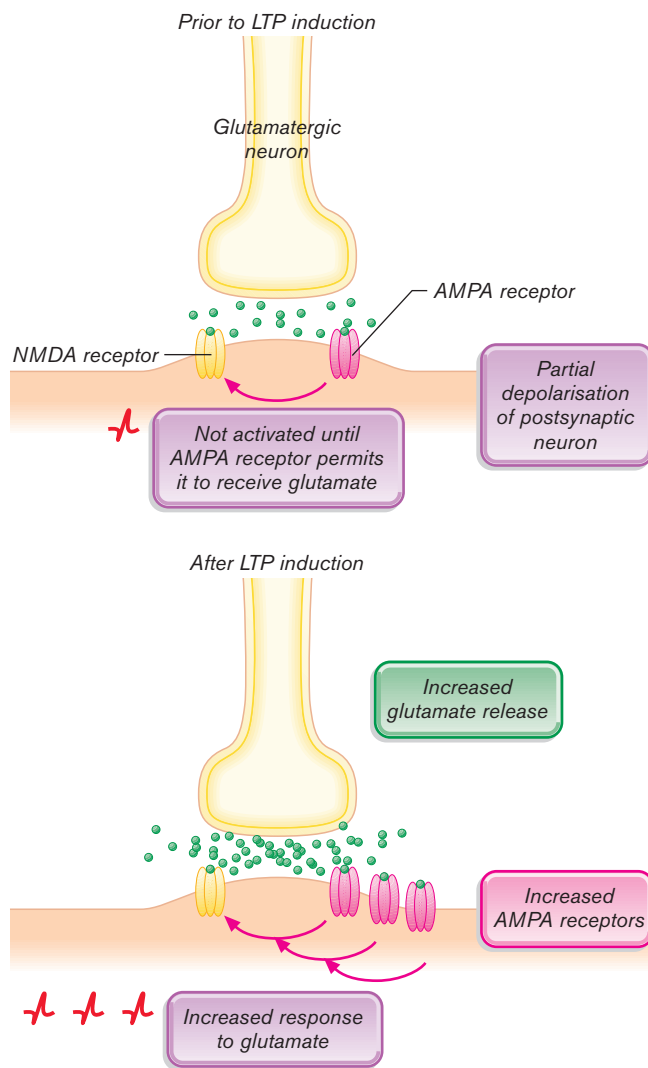


**Figure 8.11** The method to induce LTP in the hippocampus: a stimulating electrode in brain area (a) influences brain area (b); after high-frequency stimulation the response of brain area (b) is increased or potentiated  
Source: adapted from LeDoux (1998)

NMDA receptor and LTP share some similarities. Instead of high-frequency stimulation, the NMDA receptor can produce LTP from converging inputs (temporal and spatial summation).

If the NMDA receptor is to respond fully it requires: (1) glutamate to bind to the NMDA and AMPA receptors, and (2) partial depolarisation of the postsynaptic neuron. In the second requirement, partial depolarisations are produced by inputs to the AMPA receptor or other receptors nearby (see Figure 8.12). Thus, naturally occurring LTP requires the convergence of two inputs.

The postsynaptic neuron responds to stimulation by producing a series of biochemical events. Without going into fine detail, these events increase both glutamate release and the number of AMPA receptors. Therefore the initial stimulation results in synaptic changes that can be enduring. Supporting evidence for the involvement of the NMDA receptor comes from 'knockout mice', which do not express the receptor (Tsien et al., 1996) and



**Figure 8.12** The role of glutamate receptors in LTP: repeated activation of the AMPA receptor leads to long-term potentiation in the synaptic response to glutamate

psychopharmacological studies that use drugs to block the NMDA receptor (Morris et al., 1986).

While LTP offers great insight into putative neural mechanisms of memory there is still a link to be made with the psychology of learning and memory. The work of the cognitive neuroscientist is never done!

**Self-test:** Describe learning at the synapse.

## Learning outcomes

When you have completed this chapter, you should be able to:

- 1 Describe the two main theories of associative learning.
- 2 Apply the principles of associative learning to real-world situations.
- 3 Describe the limitations of associative learning.
- 4 Describe the possible neural mechanisms underlying learning.

### Further reading

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- 1 How can classical conditioning explain the evolution of a paraphilia or phobia?
 

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- 2 Using the terminology of operant conditioning, how would you modify the behaviour of a child who continues to bite other children while playing?
 

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- 3 Learning takes place at different levels of analysis. Discuss.
 

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### Web links

Drug Discrimination: <http://www.dd-database.org/>