4. Learning and cognition

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Any animal that can predict the future has a tremendous advantage over one that cannot. Predicting, and to some extent controlling the future, is really what learning is all about. Through learning the animal gets the chance to respond to cues, e.g. the hen to react to the scratching sound of the beetle, before the relevant event happens - the beetle emerges and can be caught. It can even learn to modify its behaviour so that pleasant things happen and unpleasant things don't. Understanding the function of learning, that it helps animals to predict and control future events, will make it much easier to understand and remember the different principles found in this chapter.

Cognition

Cognition has been defined as psychic processes that can not be observed directly but for which there is scientific evidence from which they can be inferred. The problem however, is that scientist vary widely in what they consider to be scientific evidence and therefore in which cognitive capabilities they assign to animals. The stance taken in this chapter is a sceptical one, it is a sound scientific principle to always prefer the simplest explanation when more than one is offered. In psychology a special case of this principle was formulated by Lloyd Morgan and is therefore known as Lloyd Morgan's canon: "In no case may we interpret an action as the outcome of the exercise of a higher psychical faculty, if it can be interpreted as the outcome of one which stands lower in the psychological scale." (in Roberts 2000).

The question of awareness or consciousness is one that is often brought up when speaking about cognition. The most commonsense explanation is that animals, at least vertebrates, are conscious of what is happening around them. This does not constitute a valid scientific reason for assuming that that is the case however. In practice it has been shown to be well-nigh impossible to define and/or demonstrate consciousness in animals and today scientists range
from those stating that a wide range of animals are conscious (Griffin 1992) to those stating that only humans are so (MacPhail 1998). Among cognitive scientists, perhaps with the exception of primatologists, there is now a tendency to concentrate on how information is encoded and used rather than on the question of awareness.

It is all too easy to equate complex behaviours with complex cognitive or mental abilities. One famous example showing the dangers of this is the case of the hygienic and unhygienic bee strains. The hygienic bee strain uncaps cells with dead larvae, and removes these larvae from the hive while the unhygienic strain does not. The hygienic behaviour results in the removal of dead larvae from the hive, and it might be tempting to say that this is the goal of the individual bee. Crossing the two strains produces bees with different behaviour patterns. Some bees behave like the original hygienic and unhygienic strain, some of the offspring only uncaps, but does not remove the larvae, and some does not uncap the cells - but will remove any dead larvae if the cells are uncapped for them (Rothenbuhler 1964). The fact that "half" of the hygienic behaviour can exist (and that it doesn't fulfil any purpose on its own) clearly argues against any explanation involving very complex goal representations.

It is important to remember that the fact that there is no scientific evidence for a given capability does not mean that the animal does not have it. We have for example no scientific evidence for self-awareness in chickens - this is not to say they don't have it, just that we have not been able to show it. This distinction between what is scientifically proven and what may be proven in the future is especially important to make when dealing with questions of animal welfare. To give the animals "the benefit of the doubt" is not a valid scientific argument but can be a humanitarian one.

One-event learning

One-event learning is learning in which the reaction of an animal to an event is dependent on the fact that it has encountered an event previously. (There is no association between two specific events, as there would be for associative learning.) Types of one-event learning include habituation and sensitisation.
Habituation is the simplest type of learning, and one that seems ubiquitous in the animal kingdom. The definition of habituation is a decrease in an innate response caused by repeated presentations of the same stimulus. Habituation can occur in two slightly different types of situations. In the first the animal learns not to react to a stimulus that has little or no hedonic value. The first time a horse hears the wind rustling in the leaves it starts to flee, but if the rustling happens often enough, and nothing else occurs, the horse will stop responding to the rustling. Functionally this means that if a given stimulus is not followed by an important event (in the case above e.g. wolves bursting out of the woods), the animal stops attending to that stimulus. This type of learning shares many similarities with the phenomenon of extinction discussed below.

A slightly different type of habituation is the decrease in responding that occurs when a hedonic stimulus or a resource is continuously present, e.g. food for ad libitum fed laying hens. The easiest way of demonstrating the presence of this is by breaking the habituation, i.e. dishabituate the animal. If you take a hen that has free access to food, measure the amount of feeding during 10 minutes, and then measure the feeding for one minute after having stirred the food you will find an increase of the feeding behaviour. It is as if you had brought the food to the attention of the hen again. (The habituation of the horse in the previous example can of course also be broken, e.g. by an attack. The horse then starts responding to the rustling as if no habituation had occurred.)

Sensitisation is another type of one event learning. In sensitisation the animal encounters a hedonically laden stimulus or situation, e.g. is frightened by a predator; this makes the animal more likely to react to any new stimulus as if it was a predictor of a new attack. The same type of increased sensitivity can occur for many other motivational systems - e.g. foraging. A rooster that has recently encountered a beetle will tend to react to any new sound - or sudden movement - as if it was a sign that there is more food around. In the same way a rooster that has just been attacked will react to the same sounds as if it was a predator.

In a novel or slightly stressful environment the animal will often initially react with sensitisation, with the animal reacting very strongly to any change in the environment. If the level of stress is low enough the animal may subsequently gradually come to habituate to the new environment.
Associative learning

In associative learning the animal associates one event with another event. In classical conditioning the association is between two external events, whereas in instrumental conditioning the association occurs between a behaviour and its consequences.

Classical conditioning

A good blackbird is a blackbird that knows where to look for worms. To be able to predict where there are worms and where there are not, the blackbird has to be able to associate two events with each other, in this case the features of the habitat and the presence or absence of worms. This type of learning in which the animal associates two events is called classical or Pavlovian conditioning and was first studied by the Russian physiologist Ivan Pavlov with his famous salivating dogs.

![Diagram](image)

*Figure 1. The automatic or innate response to food is salivation, salivation is therefore an unconditioned response (UR), and the food is an unconditioned stimulus (US). By ringing a bell just before the presentation of the food, the bell and the food become associated. After a number of trials the dog will start salivating as soon as it hears the bell. The bell has become a conditioned stimulus (CS), while the salivation now is a conditioned response (CR). The same behaviour, salivation, can be either a UR, when it is a reaction to a US, or a CR when it is a reaction to a CS.*
The animal associates one event (which will become the conditioned stimulus, the CS) with another event (the unconditioned stimulus, the US). The association is detected when the animal starts to react to the conditioned stimulus as if it was the unconditioned stimulus (but see below). Pavlov's dog starts to salivate when it hears the bell (a conditioned response, CR, since it is a reaction to a conditioned stimulus), just as it salivated at the sight of the food (unconditioned response, UR, since it is an innate reaction to food). It is important to remember that what the dog has learned is an association between the bell and the food (Pavlov 1927, in Domjan 1998).

There are two possible alternatives for how the association might occur. The first is that the conditioned stimulus evokes the representation of the unconditioned stimulus and that this in turn elicits the response, the bell evokes the idea of the food and it is the idea of the food that causes the salivation (CS - US - R, a stimulus-stimulus association). The second alternative is that the conditioned stimulus itself begins to elicit the same response as the unconditioned stimulus; the bell has taken on the properties of food and therefore causes the salivation by itself (CS - R, a stimulus-response association). In the first case the animal in some sense "knows" that e.g. the bell predicts food (although it is impossible to say exactly how this knowledge is represented or if the animal is aware of it). In the second case however the animal just reacts to the bell in exactly the same way as it has reacted to the presentation of the food itself in the past, and it is not necessary to postulate any knowledge in the dog to explain its behaviour.

A number of experiments show that a CS-US-R association can be formed. Holland & Straub (1979) conditioned rats to associate a burst of noise with a new sort of food dropping down into a food trough - the unconditioned response to food is to approach it, so the animals started to approach the food trough as soon as they heard the tone. The animals were then given the new food in their home cage and thereafter injected with LiCl to induce nausea. (This treatment ensures that the rats will refuse to eat the food when they encounter it again, see the paragraph on predispositions below). The rats were then taken back to the tone chamber and exposed to a burst of noise. The reaction of the rats is thought to depend on the type of association they have acquired. If they have formed a CS-R association the
devaluation of the food should not affect the behaviour of the animal. The noise should evoke
the behaviour directly. If, on the other hand, the animal has formed a CS-US-R then the tone
should evoke the idea of the food, and since that specific type of food now is not considered
edible, it should not evoke the approach response. This latter alternative is in fact what
happened. There are very few studies on farm animals, but it seems likely that the mammalian
species can form this type of association; there is also recent evidence that this might be true
for the domestic hen (Forkman 2001, see also Regolin et al. 1995).

This devaluation study and others like it, shows one of the main advantages of a CS-US-R
association. The animal is able to vary its behaviour in a very flexible way and even perform
an adaptive response in a situation they have never encountered before.

That animals are able to imagine just what CS predicts also has other consequences. In a very
early experiment monkeys were required to select one of two food wells - in most cases they
were rewarded with a banana but occasionally they were given a lettuce leaf instead (monkeys
like bananas much more than they like lettuce). In most cases the monkeys refused to touch
the lettuce leaf, spent a lot of time looking in other places and sometimes flew into a rage and
started shrieking at the observers. The ability to have an expectancy makes it possible for an
animal to become disappointed or frustrated when that expectancy is not fulfilled. This
frustration is not exclusive to higher primates however; depriving e.g. chickens of expected
food will also lead to increased activity and aggression (Haskell et al. 2000).

The CS-R hypothesis is more parsimonious than the CS-US-R hypothesis but it is also a less
intuitive explanation - it is hard to imagine that Pavlov's dog does not know that the bell
predicts the food. However, there are studies showing that CS-R associations are sometimes
formed. Indeed, it seems probable that at least among birds and mammals both a CS-R and a
CS-US-R association is formed and that it is the relative strength of these two associations
that determines the behaviour of the animal. Which association is stronger will depend on a
number of things, including the species and the specific circumstances, and therefore has to be
determined for each specific case. Generally speaking however it seems that prolonged
training strengthens the CS-R association.

Classical conditioning is very widespread both between species and within species. It
probably helps the animal to decide e.g. what stimuli are considered alarming, or what to eat (Provenza & Balph 1987). It may also greatly affect the other type of associative learning - instrumental conditioning.

**Instrumental conditioning**

A squirrel that wants to open a hazelnut will gnaw at it. If it has never encountered a hazelnut before the gnawing will be random and it will take a long time for the squirrel to get at the kernel of the nut. An experienced squirrel however will crack the nut very rapidly and with a minimum of effort. Clearly the squirrel has learned something about the consequences of its behaviour, and is changing its behaviour based on those consequences.

Whereas in classical conditioning the animal associates two events, two stimuli, with each other, in instrumental conditioning the behaviour of an animal is dependent on the previous outcomes of that behaviour (this type of learning is also known as operant conditioning or trial-and-error learning). If the outcome is desirable, the animal will perform more of the behaviour. If on the other hand the outcome of the behaviour is aversive, the animal will perform less of that behaviour (Domjan 1998). There are four different possibilities, see table 1.

<table>
<thead>
<tr>
<th>Name</th>
<th>Consequence</th>
<th>Result</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive reinforcement</td>
<td>Response produces desirable conseq.</td>
<td>Increase in behaviour</td>
<td>When the dog sits it gets a cookie</td>
</tr>
<tr>
<td>Positive punishment</td>
<td>Response produces aversive conseq.</td>
<td>Decrease in behaviour</td>
<td>When the dog bites it gets yelled at</td>
</tr>
<tr>
<td>Negative reinforcement</td>
<td>Response stops or prevents aversive conseq.</td>
<td>Increase in behaviour</td>
<td>If the dog shows submissive behaviour it doesn't get bitten</td>
</tr>
<tr>
<td>Omission training</td>
<td>Response stops or prevents desirable conseq.</td>
<td>Decrease in behaviour</td>
<td>If the dog barks it doesn't get a cookie</td>
</tr>
</tbody>
</table>
Figure 2. Instrumental conditioning is often investigated in what is known as a Skinner box or operant conditioning box. In a typical Skinner box there is a buzzer to give an auditory signal, a lamp to give a visual signal and a lever to allow the rat (which is the species most commonly used) to make a response. There is also either a food trough or a water nipple so that positive reinforcements can be given. Finally the animal is standing on a grid that can be used to give a weak shock to the paws of the animal.

The behaviour itself is often insufficient to result in the following event, it is rather the performance of the behaviour in the presence of a discriminative stimulus that results in the event. The behaviour of sitting does not in itself result in getting a biscuit, sitting when someone says "sit" does however - if you are a dog that is. The discriminative stimulus can be a single stimulus (like "sit") but it can also be the whole context in which the conditioning takes place, e.g. the place, the smell and the sounds. This means that if the conditioning always occurs in the same place, e.g. you are always training your dog to sit while indoors, your dog will be less likely to obey you outdoors. Not because it is disobedient but simply because part of the discriminative stimulus that tells it that performing the behaviour will result in a reward is missing.

As we have seen earlier Pavlovian conditioning can occur either through CS-R or CS-US-R, a similar distinction can be made between two types of instrumental conditioning: the S-R (seeing a lever causes the rat to press on it) or S-R-US (the rat knows that pressing the lever will result in food). In the S-R-US case the animal is actually able to predict the outcome of a
behaviour it has not yet performed. This means that if, and only if, a species is capable of a S-R-US can it be said to have a goal with its behaviour. There is no way of knowing whether this prediction or goal by the animal takes the form of thoughts identical to our own but the similarities are obvious.

In operant conditioning there is some Pavlovian conditioning happening - especially when the animal is attending to the discriminatory stimulus. In some situations this may result in the animal reacting in a Pavlovian instead of instrumental way. An example of this is when you are trying to teach a dog to run away from you when you say "forward" by giving it a snack when it performs the behaviour. The dog will learn both the association between its behaviour and the reinforcer, but also form an association between the word "forward" and the reinforcer (and of course yourself and the reinforcer). This means that there is one tendency for the dog to run away from you since it is only then that he gets a reward, but also a second opposite tendency to not run away. This second tendency is there because the innate response to food is to approach it, not run away from it, and after conditioning it becomes the CR to the CS, i.e. the word "forward", and yourself. What the dog does will depend on the relative strength of the two processes. In most cases the behaviour of the animal is much closer in time to the reward than is the discriminative stimulus (e.g. the running away will always be closer to the reward than is the word "forward" since the running only occurs as a response to the command). If the dog is very hungry (i.e. the reinforcing property of the reward is very strong), you might see the dog hesitating to run away from you, or running only a short distance, even though you would have thought that it would be even more eager to perform the task and get the food.

Many of the problems you might encounter while trying to teach animals different tasks occur because of the conflict between the results of Pavlovian and operant conditioning. To enhance the effectiveness of any task that requires learning (e.g. automatic milking, transponder feeding etc) it is worthwhile to consider both the classical conditioning and the instrumental conditioning aspects of the task. What you should be asking yourself is whether the behavioural change you are trying to condition is compatible with the UR to the reinforcer you are offering.

A type of instrumental conditioning that deserves special attention is the case of active
avoidance behaviours. In active avoidance situations performing a given behaviour either stops or prevents an aversive stimulus from occurring (i.e. the behaviour is negatively reinforced). Unfortunately many species will rapidly learn to use aggressive behaviours as avoidance responses. A rat (or sow, horse or even rooster) will very rapidly learn to threaten and even attack you if you inadvertently teach it that attack is an appropriate avoidance behaviour. You do this by responding to the attack by hesitating. Not only is active avoidance conditioning rapidly established, unfortunately it is also typically very resistant to extinction!

**Extinction**

Extinction is a special type of learning that occurs when a stimulus or behaviour is no longer followed by a reinforcer. The first reaction to this is often a burst of activity but after a while the animal gradually stops responding to the stimulus. The animal does not forget what it has learned; instead it learns that the previous association no longer holds. The fact that the animal does not forget can be clearly seen in the phenomenon spontaneous recovery. If a hen that has learned to associate a scratching sound with a beetle one day is exposed to a number of scratching sounds without ever finding a beetle it will stop rushing towards the sound. On first hearing the scratching on a subsequent day however the hen will once more rush towards the sound. The extinction will be more rapid on the second day, however, and even more rapid on the third, and so on.

Not all associations are equally easy to extinguish. The ease of extinction depends on many things and is to some extent species specific (see the paragraph on predispositions below). In general, however, animals that have been trained on a schedule that gives reinforcement in a random manner are more resistant to extinction than those trained on a continuous reinforcement schedule (this is known as the partial reinforcement extinction effect or PREE). To train a dog not to beg at the table, when it has received a reward only now and then, is very difficult! Unfortunately there is no sense in starting to give it a reward the whole time planning to extinguish the behaviour at a later stage - once the animal has experienced the partial reinforcement schedule the resistance to extinction is there. It is as if the animal does not just learn about the association between the two events but also about the variability in that association. If the association is very variable it will be difficult to detect any change in
the association, and hence that it no longer holds true. The PREE is not just a problem however, it can also be put to good use if you want an animal to continue performing a response in the absence of reinforcers, e.g. in a competition.

Another type of association that is difficult to extinguish is the active avoidance behaviour discussed in the paragraph on instrumental conditioning.

Figure 3. A learning story: Any hen will approach (UR) a worm-like object (US). The hen in the picture however will also approach (CR) any dark leave (CS) because it has learned (Pavlovian conditioning) that there are worms (US) under them. The black colour is very salient but there are also other cues, e.g. the shape of the leaves of that bush, that signal food. When given the choice however, the hen will primarily go to the dark leaves (overshadowing). The hen has also learned to attack only the front part of the worm (instrumental conditioning). The front part of the worm tastes good (positive reinforcement) but it has a sting in its tail (negative reinforcement). Because there are only sometimes worms under the leaves (VI/VR) the hen will continue to search for them for a very long time (PREE) even when all the worms have disappeared. Eventually however the hen will stop approaching the dark leaves (extinction).
Factors affecting learning

As stated in the introduction, the function of learning is to make it possible for the animal to predict or manipulate the future. Imagine a hen that has just seen and eaten a fat beetle. Every animal experiences an almost infinite number of stimuli at any given time. How can the hen learn how to get more beetles?

Timing

The first factor is the timing of the events. Animals and humans form an association between the reinforcer and an event that occurred a very short time before. If a hen hears a scratching sound just before it finds the beetle an association is rapidly formed, if on the other hand the sound of the beetle comes 60 seconds before the hen finds it, the association will be formed much more slowly, if at all. If the sound occurs at the same time as the hen finds the beetle the association is also slow to be formed. This makes sense from a functional point of view, since the function of learning is to predict future events, and events that occur together are by definition simultaneous.

Strength and salience of reinforcer

The second factor is the strength or the salience of the reinforcer. An association is more easily formed if the strength of the reinforcer is large (i.e. the beetle is fat and juicy) than if it is small. This makes sense since, from an evolutionary point of view, it is more relevant to be able to predict a very important event than a less important one.

Strength and salience of stimulus

The third factor is the strength or salience of the predictive stimulus. The stronger the stimulus is the stronger will the association be. Some animal species pay more attention to certain modalities than others. Which stimulus that is the most salient is therefore not
dependent solely on the physical strength of the stimulus but also on the particular species and what the US is (see the section on predispositions below). The salience of the stimulus is also affected by the frequency with which the animal has experienced it previously, i.e. of how surprising it is (just as with the reinforcer). If the stimulus is completely novel - e.g. a sound that has never been heard before - then the animal will attend more to it and therefore form a stronger association between it and subsequent events. If on the other hand you are always whistling when you are walking with your dog you will have a hard time teaching the dog to attend to a specific whistle signal and learn what that means. The animal has already learnt that the whistling does not hold a predictive value, this is an example of learned irrelevance. In more general terms learned irrelevance occurs when an animal learns that a given stimulus does not have any predictive power.

**Predispositions**

The fourth factor concerns the innate learning preferences or predispositions of the animal. Not all stimuli can be equally well associated with a given reinforcer. One of the most striking examples of predispositions in conditioning is a series of experiments done by John Garcia and co-workers in the sixties and seventies. In the most classical of these studies rats were given water to drink. The water was either flavoured or the water had a clicker connected to it so that whenever the rat drank it heard a clicking sound. Drinking the water could result in either the rat receiving a shock, or experiencing nausea. The rat easily learned to associate sound and pain, but not sound and nausea. They also learned to associate taste and nausea but not taste and pain (Garcia & Koelling 1966). It is as if animals (and humans) had a given connection already formed between nausea and a smell or a taste - all we need to learn is which smell or taste. In the same way we have a connection formed between pain and a sound - we just have to learn which sound. The salience of a given stimulus is therefore not only dependent on the timing and "surprise factor" mentioned above, but also on the type of reinforcer it is to be associated with.

In an anti-predator situation it is very hard to instrumentally condition an animal to perform a behaviour that is not in its "anti-predator behaviour repertoire". This makes functional sense - trial and error learning with successive approximations is not the best way of dealing with an
attacking tiger. The reason for this is that the signal predicting the attack becomes associated with the attack and therefore elicits a conditioned response via Pavlovian rather than instrumental conditioning. This is not to say that it is impossible to instrumentally change the behaviour, just that it is very difficult.

Social learning

True imitation, i.e. that animals are learning completely new behaviours through imitating those of other animals is probably quite rare. In most cases the behaviour can instead be explained by a tendency of animals to behave towards the same parts of the environment that other animals are doing (local or stimulus enhancement), or by just repeating the same well-known behaviour (social facilitation). If one pig starts feeding, others will soon follow suit (social facilitation). If one hen starts feeding from a bowl with flowers other hens will prefer to feed from the same type of bowl (stimulus enhancement). These mechanisms ensure that the behaviours in a social group are synchronized, but can also function to transmit e.g. food preferences. While it is a good idea to be sceptical towards reports of the social transmission of new behaviours, there are some types of social transmission of information that are well documented and important (Shettleworth 2000).

Table 4.2. Three types of social learning and socially motivated behaviours. This is a classification based on the behaviour of the observer animal in relation to the situation.

<table>
<thead>
<tr>
<th>Name</th>
<th>New behaviour</th>
<th>Repeats behaviour</th>
<th>Acts towards the same type of stimulus</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>True imitation</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Orangutangs will attempt to make a fire after observing humans doing it</td>
</tr>
<tr>
<td>Social facilitation</td>
<td></td>
<td>X</td>
<td></td>
<td>You yawn, and every one else starts yawning</td>
</tr>
<tr>
<td>Local enhancement</td>
<td></td>
<td></td>
<td>X</td>
<td>Ducks will land where there are ducks already present</td>
</tr>
</tbody>
</table>
Alarm calling and mobbing, learning what is dangerous
In many species individuals learn to recognise predators through the reaction of conspecifics. The phenomenon has been seen and studied in monkeys, a number of different bird species, but also in fish. The observer animals often have a strong predisposition (see paragraph below) for what they should be fearful of; monkeys will rapidly learn to avoid a snake through observing the alarm reactions of other individuals. When a flower was used instead of the snake no such learning took place. This type of learning seems to follow the same pattern as that of more classical associative learning discussed later.

Food preference transmission, learning what is safe
One of the many problems an animal faces is what to eat. The transmission of food preferences, especially in rats has been extensively studied. One way in which food preferences can be learned is through local enhancement, as discussed before. However, rats also learn what food to eat in another way. When a rat feeds small food particles will get stuck on its whiskers and around its mouth. The smell of these food particles, together with the breath of the rat, is very attractive for other rats. They approach and sniff any returning individual around its mouth, and subsequently show a strong preference for that food (Galef 1996). While it is well known that other mammals, e.g. sheep (Provenza & Balph 1987, Thorvalsdottir et al. 1990), can learn what to eat through social learning, much less is known about the exact mechanism through which this occurs.
References


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