Making choices

Decision-making in action

Neurobiologist Catherine McCrohan explains how a simple A-level practical investigating behavioural choice can underpin studies of brain function including the sense of smell, learning and memory

Making the right decisions is key to survival. Throughout their lives, animals have to choose — what to eat, which animal to mate with, whether to fight or run away. Decisions depend on the choices on offer and on the animal's immediate situation and motivation. Finding food may be a priority when you're hungry, even to the point where you are prepared to face up to a potential predator rather than run away.

Key words
Behaviour
Choice
Experiment
Learning
Olfaction

Decision-making involves pathways in the brain. The brain has to weigh up all available information and make what it considers the best choice to ensure the individual's survival. The basic principles of decision-making can be investigated and tested using simple experiments. At the very simplest, there may be a choice between two options — approach or retreat, or left or right. Part of the decision-making process usually takes into account the current external conditions. For example, an animal such
as a frog that is adapted to moist conditions will choo
spend most of its time in a dark, moist area of a tank ra
than sitting under a hot light.

One of the required practicals in AQA's A-level bio
specification is an 'Investigation into the effect o
environmental variable on the movement of an animal u
either a choice chamber or a maze'. This usually inv
placing common invertebrates, such as woodlice or mag
in a simple, homemade apparatus where they can ch
between different environmental conditions.

An example is illustrated in Figure 1. When placed i
chamber, the woodlice can choose between light versus
and between dry versus damp soil. Their choice is quant
by recording how many individuals end up in each o
four areas of the chamber, A to D. Woodlice are crustac
that are adapted to live in a terrestrial environment. T

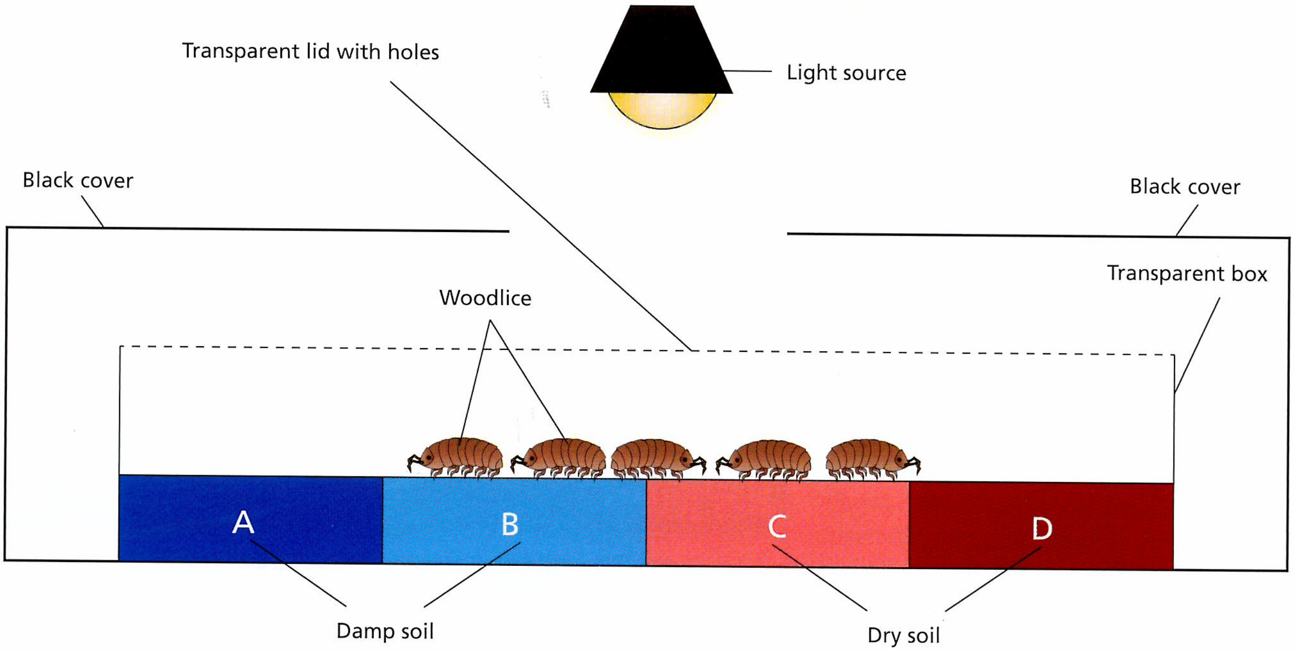


Figure 1 Simple apparatus for testing the effect of environmental variables on woodlice. A = damp/dark, B = damp/light, C = dry/light, D = dry/dark

Woodlice ×5

are mostly nocturnal and come out at night to feed mainly on dead plant material. They lose water easily through their thin exoskeleton. So we might expect them to prefer dark and damp conditions.

Keeping down the stress

You will acquire a number of important skills while carrying out this practical (see Box 1). The animals must be handled in a way that is ethical and stress free. Animals should always be treated with respect, whether or not they are experimental subjects. The UK Home Office has strict regulations (covered by the Animals (Scientific Procedures) Act 1986), which control and monitor animal experimentation. While these don't apply to invertebrates (apart from **cephalopods**, such as the octopus), ethical considerations should also apply to these simpler animals.

Aside from ethical concerns, it is important that experiments are carried out with no, or minimal, stress to the subjects. Results obtained from subjects that are stressed are likely to be unreliable. We know from our own experience that it is harder to make good decisions when we are under stress. It would be surprising if this were not also the case for a woodlouse or a maggot. So the woodlice should be kept in suitable conditions before the experiment and transferred carefully into the apparatus.

Good experimental design makes for good data

Good data come from experiments that are well designed, carefully executed, and rigorously analysed and interpreted. First you need a clear hypothesis, such as 'woodlice will choose to enter an area that is dark and damp, rather than light and/or dry'. Your measurements need to be meaningful. For example, the animals must be given enough time to make their choice. If you record their position too soon after placing them in the apparatus, they may not have had time to move to their preferred area.

Preliminary, so-called pilot, experiments can help you determine the best experimental procedure for recording your results. Other external variables such as noise, vibration and odours should be controlled, preferably by removing them altogether. And, finally, you will need to test enough animals to be sure that your data are statistically reliable — that is, there are sufficient data to be able to carry out your chosen statistical test. The measurements you take should be recorded systematically in a form that can be easily understood by you and by others. All of this is about using good scientific practices.

Having completed the practical, you will be able to form conclusions about some of the environmental conditions that are preferred by your animals. But what is the relevance of these experiments to scientific

Box 1 Skills you learn from carrying out the practical

- Handling animals ethically and stress-free
- Experimental design
- Data collection
- Data analysis
- Data interpretation
- Use of statistical tests to accept or reject a null hypothesis

Terms explained

Associative conditioning A learning process in which two events — a stimulus and behaviour — become associated with one another.

Cephalopod A class of marine molluscs with large heads and a set of tentacles (arms).

Synapse A specialised junction that enables transmission of an impulse between two nerve cells.

research in progress right now? Can such simple experiments tell us anything new or interesting about animal biology or physiology? The answer is 'yes'. Scientists today use simple choice experiments to study aspects of nervous system function, including sensory biology and learning and memory.

Choice experiments help us understand the brain

In my laboratory we study the sense of smell — olfaction. We use larvae (maggots) of the fruit fly *Drosophila melanogaster* (see centrespread). The 'nose' of the larva is extremely simple, containing only 21 pairs of sensory nerve cells, rather than the millions that are present in a human nose. As larvae, these animals spend most of their lives feeding. They move towards odours that are attractive — those found in rotting fruit — and away from those that are repulsive. An example of an odour that is repulsive to the larvae is iridomyrmecin — a chemical associated with species of wasp that is parasitic on the larvae.

Further reading

McCrohan, C. (2017) 'How clever is the octopus?', Biological Sciences Review, Vol. 29, No. 1, pp. 38–41

Prokop, A. (2016) 'Fruit flies in biological research', Biological Sciences Review, Vol. 28, No. 4, pp. 10–14.

Evolution of the human sense of smell — from cavemen to the modern day: **https://tinyurl.com/ldxtcvl**

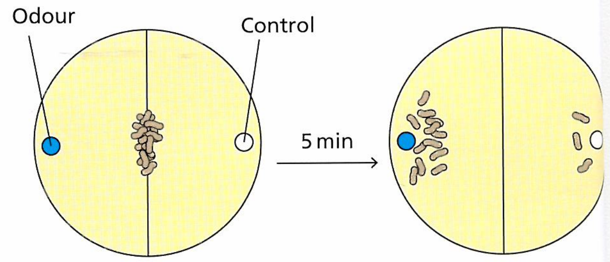


Figure 2 Simple behavioural choice experiment using *Drosophila* larvae. Maggots are placed in the centre of a Petri dish with an odour source on one side. The proportion of maggots recorded on the odour side of the dish after 5 min gives an index of the odour's attractiveness

In behavioural choice experiments, maggots are placed in a Petri dish and their movement towards or away from an odour source is measured (see Figure 2). This gives an index of the degree of attractiveness or repulsiveness of the odour.

We can also measure the ability of maggots to distinguish between odours by giving a choice between two odours. These simple experiments tell us that larvae can detect at least 60 (and probably hundreds of) different odours using just 21 pairs of sensory nerve cells. They do this using a combinatorial code in which each odour is represented by activation of a unique combination — or subset — of the 21 sensory cells (see Box 2). The brain then interprets this code, enabling it to make decisions about whether to approach, avoid, or ignore an odour.

Understanding how the olfactory code works has been made possible by combining simple behavioural choice experiments with more detailed study of the electrical responses in individual sensory nerve cells in the 'nose'. Other animals including humans use a similar, but numerically much more complex, combinatorial code. Scientists have also recorded activity in pathways in the brain that link olfaction with behaviour of larvae. It is here that decisions about which way to move are made.

Learning to make the right decisions

Making the right decisions for survival is influenced by previous experience. Animals are continuously learning about the world and this can alter the choices they make. One of the big questions for neuroscientists is how learning and memory are represented in, and controlled by, the brain. Neuroscientists use simple animals including molluscs and insects to investigate this question.

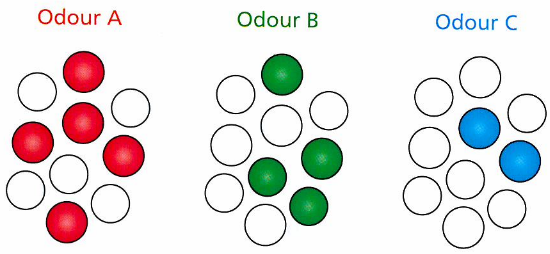
Drosophila maggots can learn using **associative conditioning**. After being presented repeatedly with an attractive odour (e.g. ripe banana) paired with an unpleasant taste (e.g. the bitter-tasting quinine), maggots subsequently show reduced attraction to the banana odour when it is given on its own. They have learned that the odour is associated with an unpleasant taste that could even represent a risk to survival, such as poisoning.

If the behavioural response to a stimulus (a given odour) is altered, then there must be a change somewhere in the

Box 2
The combinatorial code for olfaction

In Figure 2.1, each circle represents an olfactory sensory nerve cell in the nose. Each different odour activates a subset of all the nerve cells (filled circles). The brain identifies the odour based on which combination of nerve cells is active. This means that a small number of sensory cells in the nose (ten in the diagram) can potentially distinguish between a much larger number of different odours. If two different odours activate the same subset of cells, then the brain will interpret them as being the same odour — it cannot discriminate between them.

Figure 2.1



decision-making pathways in the brain. This could simply be reduced activity in the sensory nerve cells. However, research so far suggests that this is not the case and that the change occurs further along the pathway in the brain. Researchers are investigating the changes that occur in specific pathways in the brain when an animal learns. These involve changes in the strengt of the connections (**synapses**) between nerve cells, making it more or les likely that impulses will be successfully transmitted from one part of th brain to another.

Investigating sensory discrimination

Simple learning experiments can be used to investigate the sensor capabilities of a species. In the experiment described above, larvae lear to show a reduced response to banana odour, but their response t other odours remains the same. In other words, the learned change i behaviour is specific to the odour that was paired with the unpleasan taste. But this only works if the larva is able to discriminate betwee odours. If it perceives two odours — X and Y — as being different, the learning can be specific to just one of these. If it can't tell the two odour apart, then the learned response will be generalised to both odours X and Y. Experiments like these have been used to test the discriminator ability of many animal species, in a range of sensory modalities — vision hearing, smell and taste.

The simplest experiments, if well designed and addressing an importan question, are often the best. Many of the important discoveries in biolog started from a simple observation that sparked an idea or hypothesis tha could then be studied in more detail. The experiments you do in you A-level give you the skills you need to make this happen.

Catherine McCrohan is professor of comparative neurobiology at The University of Manchester and an editor of Biological Sciences Review. She is interested in sensory coding and how sensory cues drive behaviour.