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Animal Cognition

The Mental Lives of Animals

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Other Ways of Seeing the World – II: Abstract Dimensions

'What sort of insects do you rejoice in, where *you* come from?' the Gnat inquired.

'I don't *rejoice* in insects at all,' Alice explained, 'because I'm rather afraid of them – at least the large kinds. But I can tell you the names of some of them.'

'Of course they answer to their names?' the Gnat remarked carelessly.

'I never knew them do it.'

'What's the use of their having names,' the Gnat said, 'if they won't answer to them?'

'No use to *them*,' said Alice; 'but it's useful to the people who name them, I suppose. If not, why do things have names at all?'

'I can't say,' the Gnat replied. (Lewis Carroll, *Through the Looking Glass*, 1871)

The way the world appears to an animal is not just a question of the animal's perceptual abilities – what it can hear, see, smell or sense in any other way. There is also the question of how the pieces of experience can be put together to organize the relationship between raw perceptual experience and what is going on in the world. It is this more abstract level of conceptual perception that is the subject of this chapter.

Research on the ability of animals to form concepts is, with a few worthy exceptions, the product of just the last few decades. Consequently it is not surprising that most of the research carried out so far has taken human conceptual abilities as its starting point. While there is a danger here of failing to take an appropriately species-centred point of view, experimental tasks used in human psychology, particularly those designed by developmental psychologists, have certainly proven useful.

We start this chapter with a discussion of a very simple extension from direct perceptual experience – the question of object permanence. Can an animal understand that a hidden object continues to exist even when it is out of sight? This apparently simple concept does not appear to be clear to most of the species that have been tested. A handful of not very closely related species (dogs, chimpanzees and gorillas) can solve even the most difficult object permanence tasks, while others such as birds and cats fail consistently.

This leads us to a consideration of some other, to us very simple, concepts such as recognizing what is 'same' and what is 'different'. These matters are so deeply engrained in us that it is surprising to find that it has proven very difficult to

demonstrate that any animal species can learn to discriminate between objects on the basis of whether they are the same as or different from each other. An even more basic conceptual distinction is to recognize that all trees have something in common that distinguishes them from non-trees. Fish, people and chairs are further examples of these perceptual concepts. Although this is one of the older branches of research in animal concept formation, there is still controversy over whether other species form perceptual concepts in the same way as we do.

The study of the concept of time in animals is probably the oldest area of study in animal concept formation. Many species have been shown to have a strong sense of the time of day, as well as the ability to learn about shorter and variable intervals between important events.

Finally, in this chapter we consider the evidence for animals' sense of number. Although the study of animals' numerical ability got off to a bad start in the nineteenth century with Clever Hans – the horse who fooled everybody into thinking that he could perform advanced mathematical calculations (see Chapter 1) – more recent studies have uncovered some important evidence of basic numerical ability in a range of species.

Research on animals' conceptual abilities is still at an early stage, but there is already evidence of both commonality and diversity across species. Some abstract dimensions of experience, such as time, seem to be appreciated by a very wide range of species and, as far as we can tell, in very similar ways. On the other hand a concept as simple as object permanence – the idea that a hidden object continues to exist – has proven far harder to demonstrate in any non-human species. It is to the concept of object permanence that we turn first.

Object permanence

If I take a chocolate in one hand, pass my hand behind a box, stop for a moment and then bring my hand out and show you that it is empty, where would you expect to find the chocolate? Most likely, behind the box. You saw everything that happened: if the chocolate is not in my hand then it must be behind the box. Your ability to reason in this way is known as 'object permanence' – you have a concept that objects continue to exist even when they disappear from sight. Object permanence was recognized by the famous child psychologist Jean Piaget. Small children below about 12 to 18 months of age, Piaget (1952) found, do not yet appreciate that objects that disappear from view continue to exist.

Testing for object permanence is straightforward. One test is simply to make a desired object disappear from view and see whether the subject searches for the object in the spot where it was previously placed – just like the example above with the chocolate behind the box. A task of this type is known as 'visible displacement'. There is no 'trick' – everything that happens to the object is clearly visible to the subject (adult human, child or animal). Somewhat more complex is the 'invisible displacement' task. In this case a desired object is first placed in a container, which is then taken behind a screen, out of the subject's sight, and the object is removed from the container. Finally, the empty container is shown to the subject, who is then free to search for the desired object. An individual
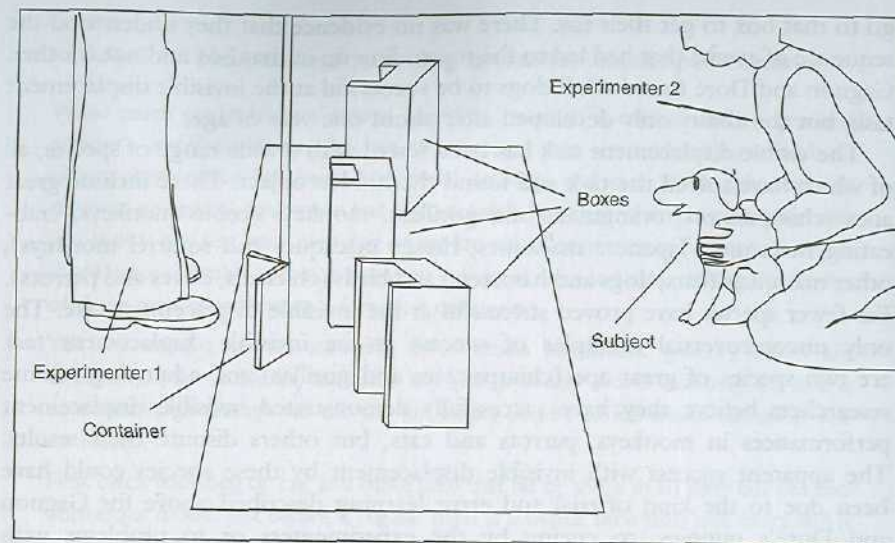
Figure 5.1   Gagnon and Doré's testing arena for dogs. Experimenter 2 holds the dog while experimenter 1 moves the desired object (Gagnon and Doré, 1994)

capable of object permanence will recognize that if the object is no longer in the container, then it must have been removed while it was behind the screen. Consequently this subject will search for the object behind the screen. Children can solve the simpler task, the visible displacement, at around 12 months of age. Only children above about 18 months are able to solve invisible displacement problems (see also Box 5.1 below).

Figure 5.1 shows a typical arrangement for studying object permanence in animals. In their study of the development of object permanence in puppies, Sylvain Gagnon and François Doré (1994) allowed a puppy to watch as an experimenter placed a favourite toy behind one of the three boxes. Once the object was hidden the puppy was released and allowed to search for the toy. The puppy was scored as being successful at this visible displacement task if it went straight to the box where the toy was hidden. Gagnon and Doré found that puppies started to master this test at around seven weeks of age.

For an invisible displacement test, in full view of the puppy the experimenters placed the toy into a small opaque container. The container with the toy was then placed behind one of the boxes shown in Figure 5.1. While out of sight behind the box the toy was removed from the container. Next, the now empty container was removed from behind the box and shown to the puppy so that it could see that the container was empty. Where would the puppy search for the missing toy? Very few of even the oldest puppies showed any sign of searching for the toy behind the box where it had been left. After several tests some of the dogs did search in the right spot, but it seems likely that this was just trial and error learning. With repeated testing using the same target box, the dogs simply learned to

go to that box to get their toy. There was no evidence that they understood the sequence of events that had led to the toy ending up in that box and not another. Gagnon and Doré found adult dogs to be successful at the invisible displacement task, but the ability only developed after about one year of age.

The visible displacement task has been tested with a wide range of species, all of which have solved the task and found the hidden object. These include great apes (chimpanzees, orangutans and gorillas), monkeys (cebus monkeys, crab-eating macaques, Japanese macaques, rhesus macaques and squirrel monkeys), other mammals (cats, dogs and hamsters) and birds (chickens, doves and parrots). Far fewer species have proved successful at the invisible displacement task. The only uncontroversial examples of success at the invisible displacement task are two species of great ape (chimpanzees and gorillas) and adult dogs. Some researchers believe they have successfully demonstrated invisible displacement performances in monkeys, parrots and cats, but others dispute their results. The apparent success with invisible displacement by these species could have been due to the kind of trial and error learning described above for Gagnon and Doré's puppies, to cueing by the experimenters or to problems with experimental design.

Sonia Goulet and her colleagues (1994, 1996) studied the factors that lead to apparent success at invisible displacement tasks in cats. They found that the cats in the study were more successful at finding a hidden toy if they were prevented from looking for it until 20 seconds had elapsed since the placing of the toy. Why should these cats have been *more* successful if they were forced to wait 20 seconds before making their response? Surely with time their memory of where the toy had been placed should have decayed – not improved (see Chapter 6 for more on animal memory)? Indeed cats' memory does decay, and this is precisely why they do better after 20 seconds than if they are free to make a response imme-diately. The cat's memory of where the toy is fails to take account of the toy's invisible displacement, and is therefore incorrect. After 20 seconds, the cat has forgotten where it last saw the toy and therefore makes fewer incorrect choices. In Goulet *et al.*'s study, by making fewer incorrect choices there was an inevitable, but purely coincidental, increase in the incidence of cats searching behind the box where the toy had indeed been hidden.

Just why should so many species be capable of solving visible displacement tasks, and so few succeed at invisible displacements? The suggestion has been put forward that visible displacement tasks reflect more ecologically meaningful prob-lems than invisible displacements. Visible displacement is the sort of thing any predator animal has to put up with. A hunted prey animal disappears behind a rock. Clearly there is an adaptive advantage to be had from looking behind the rock. Conversely it has been suggested that invisible displacements do not cor-respond to any problem that an animal would confront in its daily life. But con-sider again the predator searching for prey. The prey slips behind a stone and then, unseen by the predator, leaves that stone for the next stone. Our predator goes up to the first stone and fails to find its prey. In the design of invisible displacement experiments this would be counted as an error. To be scored as successful, the subject must *not* look behind the first stone where the prey

Box 5.1 How to test your dog or cat for object permanence

While much contemporary animal cognition research is carried out on rats and pigeons – excellent lab species, but not common pets – considerable research on object permanence has been performed on dogs and cats. Since this research requires no special equipment and is completely harmless, there is no reason why you should not test your own dog or cat for object permanence. In my experience there is considerable variation between individual dogs and cats, making the results of these tests by no means a foregone conclusion.

You will need a human assistant, three boxes (cardboard grocery boxes are excellent), your subject's favourite toy (it's probably worth washing it!) and a container large enough for the toy (an empty yogurt or ice cream container will do nicely).

First catch your dog or cat, and make sure that he or she is in an alert but not too boisterous mood. Just before a regular meal is a better time than just after; and it is wise to maintain a sober demeanour so as not to overexcite your animal.

While your assistant holds the cat or dog arrange the three boxes about 20 centimetres apart in a semicircle about one metre from your animal. Lay them on one side so that the open edge faces towards you and away from the animal (Figure 5.1).

To ensure that your dog or cat's motivation and general sensory abilities are up to the task, show him the toy and let him go. Check that he can find the toy by sight alone (many older dogs and cats have poor eyesight, in which case the experiment is impossible for them). Once he has found the toy, praise him and let him enjoy it for a moment. If it seems necessary to maintain motivation you might want to give him a small treat.

Assuming that your dog or cat has passed this preliminary test, start the visible dis-placement task. One of you (experimenter 2 in Figure 5.1) should hold your subject while the other (experimenter 1) visibly places the toy in one of the three boxes. Place it deep inside so that it can only be seen by going right inside the box. While you are doing this maintain eye contact with the other experimenter – don't follow the toy with your eyes as your animal might follow your eyes instead of the toy. Now experimenter 2, let your subject go and see where he searches for the toy. If he heads straight for the box containing the toy, score that as a successful trial. If the first box he searches out is any other, score that as a failure. Try this a few times, selecting a different box each time.

If your dog or cat succeeds at the visible displacement test it is time to try invisi-ble displacement. To do this, set up the boxes and subject as at the beginning of the visible displacement experiment (Figure 5.1). Place the toy inside the yogurt carton (or other container) in full view of your subject. Now move the container with the toy behind one of the boxes and quietly empty the container into the box. Move the now empty container back out from behind the box and show your

Box 5.1   (cont'd)

subject that it is empty (turn the container to face your subject). Finally – experimenter 2, let your dog or cat loose to see where he searches for the object. A success is only scored if he heads straight for the box containing the toy. It does not count as a success if your subject gradually improves over several trials with the toy hidden behind the same box – he could be learning by trial and error always to go to that one box. If you perform multiple trials, you must use a different box each time.

If your dog or cat is successful at the invisible displacement test you might like to try a better-controlled version of the task. Instead of reaching in and removing the toy from the container, set up a container that makes it possible for the toy to be removed without any movement by the experimenter that is visible to the subject. Figure 5.1 shows a V-shaped container on a pole. With this set-up Gagnon and Doré were able to release the toy from the container simply by twisting the pole to which the container was attached – an operation that could not be seen by the animal under test. You could construct a V-shaped container of your own out of cardboard.

With this very simple testing arrangement the controversies in the literature can be addressed in your own backyard. Is it the case for example, as Goulet et al. have claimed, that success at the invisible displacement test improves if a delay is imposed before the animal is released to fetch the toy? Or does your dog or cat perform better if he is already moving towards the toy at the point when it disappears?

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animal disappeared. It would typically make sense for a predator first to search in the last place where the prey had been seen for sure, before widening the search to places to which it may have moved. This makes the task a rather unrealistic one compared with the demands of life beyond the realms of psychological experiments.

An invisible displacement task has many components to it. To be successful the subject must understand that an object can be carried by another object (the toy is carried inside a container). The subject must also appreciate that the object can be removed from the container without any obvious intervention. Since the object in these tests is inanimate there is no strong reason why the subject should appreciate that it can leave the container without any visible intervention. Then, on being shown the empty container, the subject must remember where the container has been. This form of memory may be difficult for many subjects because they are given no cue to indicate that they are going to have to remember where the container had gone.

Given the many cognitive demands made by the invisible displacement task, it is perhaps not surprising that most of the species tested have failed. As so often in the study of animal cognition, these failures raise many more questions than

they answer. For example would a cat be more successful at the task if the hidden object were animate (a mouse, say)? Would subjects be more successful if they were given some kind of cue to encourage memorization of the pattern of movement of the container? While it is refreshing to see species other than the standard rats and pigeons being tested, it would be valuable to assess object permanence in the more commonly studied species. With rats and pigeons we have far more knowledge of their abilities in the domains of memory and attention (see Chapter 6). Armed with this knowledge, interpretation of success and failure at invisible displacement tasks might be easier.

Concept learning

What is a concept? For our purposes a concept is an abstract or perceptual category: it is a grouping together of items that share common features or functionality. The concept of a chair, for example, groups together as equivalent a great many objects that differ in any number of ways, but share a certain functionality – they can all be sat on. The concept of fish groups together all those animals that live in water, have a backbone, gills and various other qualities that biologists have determined qualify them as fish. Some simple concepts, such as triangles, may be defined by certain common features that all triangles share (three straight lines intersecting at three angles). With natural concepts such as chairs and fish, however, the boundaries of the category may be much fuzzier. There is probably no single feature common to all chairs. Concepts such as this can be called perceptual concepts because they group together some objects and differentiate them from others on the basis of certain properties that are available to our senses. Some other concepts, however, have nothing to do with individual objects at all, but say something about the relationship between objects. Consider the concept 'same'. How do we know what counts as the same as what? This may sound like a very trivial question, but it turns out to be by no means a straightforward issue. For humans, for example, notions of same and different vary between different cultures. Where English speakers consider objects on one side of them to be in the same position, no matter where they are standing, native speakers of Guugu-Yimithirr (a language of the native peoples of north-eastern Australia) only consider objects placed at the same point of the compass to be in the same position, irrespective of where they are standing and whether the object is on their left or right.

Research on concept learning in animals is still very much in its infancy, but some exciting discoveries have already been made.

Same–different

Evidence that any animal species can learn to identify objects as being the same or different has been a long time coming. Anthony Wright and his colleagues (1988) trained pigeons to identify pairs of pictures presented on a computer screen as either the same or different. The apparatus used in this study is shown in Figure 5.2. Each trial started with the presentation of a stimulus that the
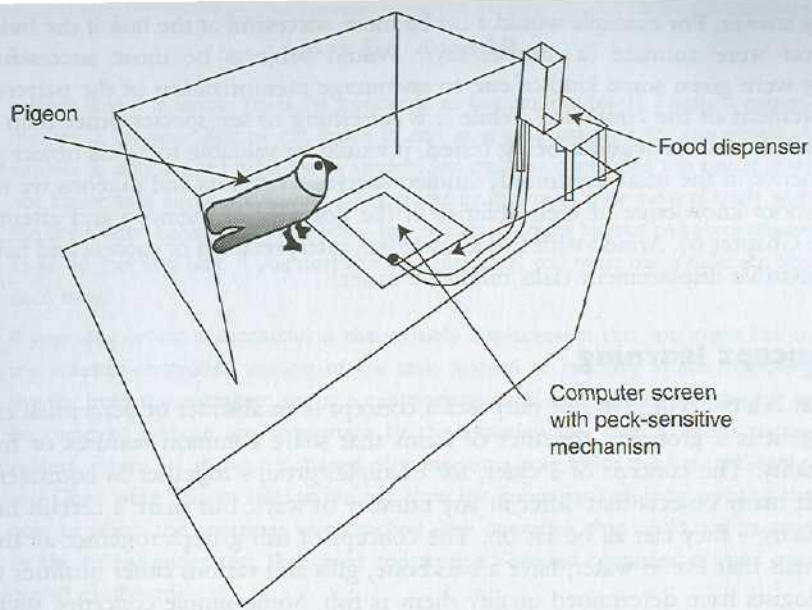
Figure 5.2 The apparatus used by Wright and his colleagues to study pigeons' comprehension of the same–different concept. The pigeon pecked onto a horizontally mounted computer screen and correct responses were rewarded with food grains dropped onto the screen from food hoppers mounted on top of the testing chamber (from Wright *et al.*, 1988)

pigeon had to peck a couple of times (this is known as the 'sample' stimulus). As soon as it had done this, two comparison stimuli were placed next to the original stimulus. One of the comparison stimuli was the same as the original stimulus, the other was different. The pigeon's task was to peck the comparison stimulus that was identical to the original stimulus (known as the 'matching' stimulus). One group of pigeons was trained with just two sample stimuli: these pigeons mastered the problem in little more than two weeks. A second group of pigeons was trained with 152 sample stimuli that were presented only once each in each daily training session. These subjects required 18 months to master the same task.

The critical question in concept learning, however, is not just whether the subjects can learn to respond to the correct stimuli during training, but whether they have abstracted the conceptual rule under investigation. To test whether the two groups of pigeons had abstracted the same–different concept, Wright *et al.* presented each group of pigeons with a completely new set of stimuli they had never seen before. The question now was whether the pigeons would apply the same–different rule to these new stimuli. It was found that the pigeons that had been trained with just two stimuli, although they had learnt quickly, had not abstracted any kind of rule – they were completely stumped by the novel stimuli. The pigeons that had been trained with 152 stimuli, on the other hand, although

they had learnt very slowly, were much better able to categorize the novel stimuli as either the same or different. This indicates that they had learnt an abstract rule.

Successful tests of the same–different concept have been conducted with rhesus monkeys, chimpanzees, California sea lions and a dolphin.

Stimulus equivalence

A more extended notion of 'sameness' is the recognition that some things, although they are not the same as each other, may share certain properties that make them equivalent. A picture of an apple comes to have the same significance for a child as the spoken word 'apple', and later as the written word. An apple is a red or green spherical object that can be eaten: the word 'apple' – spoken or written – has none of these qualities, and yet it functions in some of the same ways as the object it names. This ability of objects to substitute for each other under certain conditions is known as 'stimulus equivalence' and is an important prerequisite for symbolic thought. Peter Urcioli, Thomas Zentall and their colleagues conducted an extensive study of whether and to what extent pigeons could learn about stimulus equivalence (Urcioli *et al.*, 1989). In their training method a single stimulus (the sample stimulus) is presented alone, followed by two simultaneously presented comparison stimuli. Depending on which sample stimulus is presented, response to one or other of the comparison stimuli is rewarded. Thus a pigeon may be trained to respond to a circle stimulus after presentation of a red sample, but it must respond to a dot stimulus after presentation of a green sample. This is the original phase 1 training. In phase 2 the pigeon is trained to expect new comparison stimuli to go with some of the familiar sample stimuli. In the example shown in Figure 5.3, the pigeon learns that

Phase 1: Original training	
Sample stimulus:	*Comparison stimulus:*
Red	Circle (not dot)
Vertical	Circle (not dot)
Green	Dot (not circle)
Horizontal	Dot (not circle)
Phase 2: Equivalence training	
Sample stimulus:	*Comparison stimulus:*
Red	Blue (not white)
Green	White (not blue)
Phase 3: Test for equivalence	
Sample stimulus:	*Comparison stimulus:*
Vertical	Blue or white?
Horizontal	White or blue?

Figure 5.3 Design of Urcioli *et al.*'s (1989) stimulus equivalence experiment

the red sample goes with a blue comparison stimulus and the green sample goes with a white comparison stimulus. The question of interest now is, what will the pigeon make of the vertical and horizontal sample stimuli when it is given blue and white comparison stimuli? Will it recognize that because red and vertical (and green and horizontal) stimuli had similar consequences in the original training, and red and green now have new consequences, that those new consequences will also apply to the vertical and horizontal stimuli, or will it simply be confused when it is given sample stimuli followed by comparison stimuli that it has not been trained to expect? Urcioli *et al.* (1989) found that pigeons tended to choose the blue comparison after the vertical sample, and the white comparison after the horizontal sample. This suggests that the pigeons treated the red and vertical (and green and horizontal) stimuli as equivalent because they had had the same consequences in the first phase of training.

Perceptual concepts

Nearly thirty years ago Richard Herrnstein and his colleagues (1976) performed a simple but very interesting experiment on pigeons. These pigeons were presented with photographs – many hundreds of them – one at a time. Some of the photographs contained images of people, in others there were no people present. If the photograph contained a person, the pigeon could earn a food reward by pecking at it: if there was no person present the pigeon had to withhold its responses or the delay to the next rewarded picture would be lengthened (the Go/Nogo method, see Box 4.1). Even though the photographs were very varied the pigeons gradually mastered the distinction. In subsequent experiments Herrnstein *et al.* explored pigeons' ability to categorize photographs containing trees, bodies of water or even a specific person. Thousands of pictures were used in these experiments (making memorization of individual pictures highly unlikely), but the pigeons learnt to discriminate between them and achieved considerable success when a novel example from the category was presented to them for the first time.

These early demonstrations of perceptual conception in pigeons inspired a number of imitations. Pigeons have been found capable of discriminating between the locations used in pictures. They can form concepts of cats, fish, flowers, oak leaves, other pigeons, cars and chairs, and correctly generalize examples of concepts they have never seen before. In a study by Shigeru Watanabe and his colleagues (1995), pigeons were even able to discriminate between paintings by Monet and Picasso. The pigeons also correctly identified novel paintings by these two artists. In the first study of the categorization of schools of art by a non-human subject, paintings by Cezanne and Renoir were spontaneously categorized as belonging to the Monet school, while paintings by Braque and Matisse were categorized as belonging to the Picasso school.

Several of these studies compared pigeons' success at categorizing stimuli grouped according to concepts that arise naturally in human language (for example chair, fish and so on), compared with groups of stimuli formed according to no specific rule – just a random conglomeration of items. This kind of comparison serves two functions. First, it ensures that the pigeons are not just memorizing all the stimuli and learning what to do to obtain a reward when they come along – in other words it acts as a control for rote learning (pigeons have a prodigious capacity for rote learning – see Chapter 6). The second and more interesting function of these so-called 'pseudo-category' tasks is that they test the hypothesis that conceptualization requires language. It has been argued that we need the word 'tree' in order to conceptualize trees successfully. The fact, however, that pigeons more successfully discriminate between pictures containing trees and those not containing trees than they do between two random groups of pictures suggests that they have also formed a concept of a tree. Since pigeons do not have language, this implies that there is something about the visual image of trees that enables them to be conceptualized as a group of similar objects even without the need for the linguistic term 'tree'.

Although very little research has been conducted on perceptual conception in species other than pigeons, it has been shown that monkeys are able to demonstrate the concept of a person through the use of person and non-person photographs and methods broadly similar to those employed with pigeons. Monkeys have successfully classified pictures of other monkeys and people (Schrier *et al.*, 1984). Likewise blue jays can classify pictures of cryptic moths and leaves damaged by cryptic caterpillars (Real *et al.*, 1984).

But how do we know that these animals are really learning *concepts* and not just noticing features that photographs and slides (positive and negative) have in common? We know (see Chapter 6) that many animals, particularly pigeons, have an astonishing ability to memorize many hundreds of slides. In addition it has been known since the early days of psychological study on animals that they can *generalize*. Generalization is the ability, having been trained to respond to one stimulus, to respond similarly to other stimuli that are similar in some way. Certainly Herrnstein and the other researchers who performed the original studies on conceptualization in pigeons included a 'pseudo-concept' control – where half the slides were randomly positive and the other half negative. The pigeons were unsuccessful in this task, suggesting that there was something about the sorting of slides into those containing the concept in question and those without it that made the slides easier to learn for the pigeons. This control procedure, however, and the pigeons' failure to master it, does not guarantee that when the pigeons do learn to differentiate between person and non-person slides (to take just one example) that what they have learnt is really the concept of a person, as we understand it.

It must be admitted that even among psychologists who study concept learning in human beings there is no consensus about what it is that makes a concept a concept. There are, however, results from animal research that strongly suggest that, whatever a concept may be to a human being, pigeons and monkeys are not learning concepts in the same way.

Michael D'Amato and Paul van Sant (1988) trained *Cebus apella* monkeys to discriminate between slides containing people and slides that did not. The monkeys quickly learnt to do this. Then the monkeys were presented with novel slides they had never seen before and which either contained people or similar

scenes with no people in them. Here also the monkeys spontaneously classified the majority of slides correctly. So far, so good – clear evidence that the monkeys had not just learnt the particular slides they had been trained with, but had also abstracted a person concept from the slides that they then successfully applied to pictures they had never seen before. Or had they? D'Amato and van Sant did not end their analysis with the observation that the monkeys had successfully transferred their learning to novel slides – rather they went on to look carefully at the kinds of error the monkeys had made. Although largely successful with the novel slides, the monkeys had made some very puzzling mistakes. For example one of the person slides that the monkeys had failed to recognize as a picture of a human being had been a head and shoulders portrait, which to another human would have been a classic image of a person. One of the slides that the monkeys had incorrectly classified as containing a human had actually been a shot of a jackal carrying a dead flamingo in its mouth; both jackal and its prey were also reflected in the water beneath them. What person in their right mind could possibly confuse a jackal with a flamingo in its mouth with another human being?

The explanation of both these mistakes is the same: the monkeys had generalized on the basis of the particular features contained in the slides they had been trained with, rather than learning the more abstract concept that the experimenters had intended. The head and shoulders portrait of the person had lacked the head-torso-arms-legs body shape that had been common among the images that the monkeys had been trained with, and consequently they had rejected it as not similar enough to the positive image they were looking for. Similarly, during the training period the only slides that had contained flashes of red happened to be those of people. Three of the training slides had contained people wearing a piece of red clothing, whereas none of the non-person slides had contained the colour red. Consequently when the jackal with prey slide had come along during testing and it had contained the colour red, the monkeys had classified it as a person slide. Richard Herrnstein and Peter de Villiers (1980) drew similar conclusions from a detailed analysis of the errors pigeons made when categorizing slides of fish, such as those shown in Figure 5.4.

The above findings may suggest that non-human species learn to categorize images by relying more on particular features of images than humans do. This, however, is to overlook the fact that in humans perceptual categorization takes a very long time to develop. Young children commonly make misclassifications, such as calling all four-legged animals sheep for many years (to the amusement of those around them). The fine distinctions of adulthood take a long time to develop. Although experiments on perceptual categorization among non-humans use hundreds of images and may involve a year or more of training, that is very little compared with the child's continuous exposure to an unlimited set of perceptual experiences. A child's experience involves real three-dimensional objects viewed from many angles, not just the flat images used in animal studies. The richness of the three-dimensional world may discourage learning based on individual features and encourage a more holistic view. Perhaps future experiments on animal conceptualization may find ways to capture more of the real world
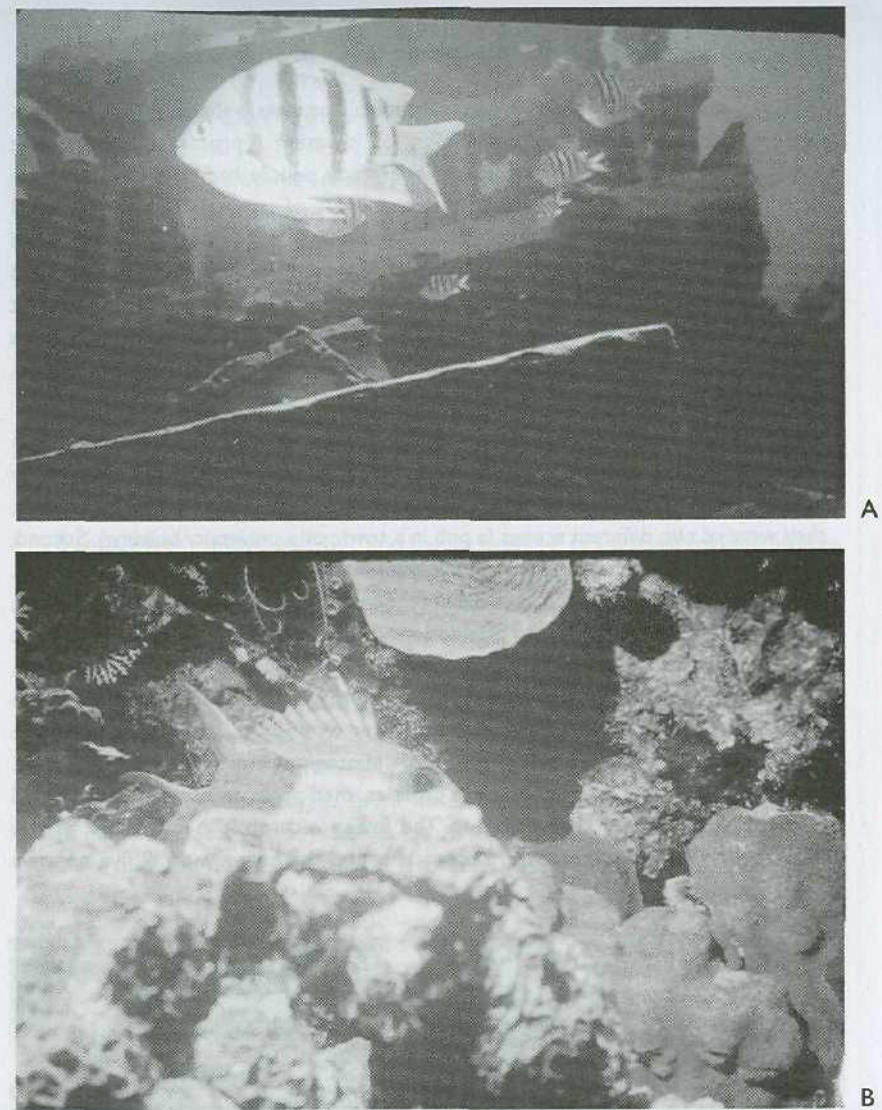
Figure 5.4   Examples of stimuli readily classified by pigeons as fish (A), and pictures commonly misclassified (B) in Herrnstein and de Villiers's experiment (courtesy of P. de Villiers)

experience of learning about concepts, and answer the question of whether animals are really able to generalize from individual features when they learn perceptual concepts.

Although the range of species that have been studied for their conceptual abilities is not large, Evelyn Hanggi (1999) has recently reported on the categorization ability of horses. Two horses were trained to select a black circle stimulus

Box 5.2   Can pigeons learn prototypes?

One explanation of how humans learn perceptual concepts is that they do so by recognizing a prototype of the concept under consideration. A prototype is the perfect example of a concept. For example in one study people had to classify cartoon drawings into one of two categories. In one category of cartoon, the faces had small foreheads, short noses and closely spaced eyes. In the other category the faces had larger foreheads, longer noses and more widely spaced eyes. Once the subjects had passed this test they were introduced to new cartoons. The novel test cartoons that were most successfully classified represented the average of all the training cartoons in each category. The average cartoons were the easiest to categorize, it is argued, because they were representative of the prototype of each class of cartoon.

Lorenzo von Fersen and Stephen Lea (1990) trained pigeons to discriminate between sets of photographs of outdoor scenes in order to see if the pigeons did this by forming prototypes. These photographs differed from each other in five ways. First, they were of two different scenes (a pub in a town, or a university building). Second, they were photographed under two different weather conditions (sunny or cloudy). Third, the photos were taken at two different camera distances (near or far). Fourth, there were two different camera orientations (horizontal or oblique). And fifth, there were two different camera heights (ground level or 20 metres above the ground). Two sample images from this study are shown in Figure 5.5. For each of these five dimensions, one value was arbitrarily designated as positive. If an image had three or more positive qualities, then pecks at that photograph were rewarded with food. If an image had three or more negative qualities, then pecks at it were not rewarded (the Go/Nogo method, see Box 4.1). The image with positive values for all five qualities was taken as the positive prototype, and the image with all five negative

A   B

Figure 5.5   Two sample images from the experiment by Fersen and Lea. The image on the left shows a university building, photographed from street level on an overcast day with the camera at an oblique angle. The right-hand image shows the opposite conditions. It is a photograph of a pub, taken on a sunny day from 20 metres above the ground and with the camera held level (courtesy of S. E. G. Lea)

Box 5.2   (cont'd)

qualities was deemed the negative prototype. Fersen and Lea found that their pigeons responded fastest to the positive prototype. This result cannot, however, be seen as strong evidence that the pigeons had formed a prototype to solve the discrimination problem – they may simply have been responding on the basis of the features individually. The positive prototype image may have been responded to fastest just because it contained more of the features that were individually associated with reward.

A stronger demonstration that pigeons form prototypes comes from an experiment by Aydan Aydin and John Pearce (1994). These investigators also showed images to pigeons that contained features whose discrimination would be followed by reward or non-reward. In this case the images consisted of three bars of different colours and patterns placed together on a computer screen. There were six different types of bar altogether, which for simplicity were designated as A, B, C, D, E and F. Bars A, B and C were positive; bars D, E and F were negative. In any given trial the pigeons saw three bars and these were always either two positive and one negative (response to these patterns was followed by a food reward), or one positive and two negative (no reward). Once the pigeons had mastered this discrimination exercise they were tested on a pattern of wholly positive bars (A, B and C) and a pattern of wholly negative bars (D, E and F), which had never been presented during the training period. These patterns could be considered as the prototypes of the concepts the pigeons had learnt during training, and sure enough they responded at a higher rate to the positive prototype, and a lower rate to the negative prototype than their response rates for any of the patterns they had been trained with. This suggests they had conceptualized the prototype during training, even though they had never seen it.

Aydin and Pearce go on to suggest, however, that prototype extraction, in humans as well as animals, can be explained with simple learning rules and the laws of generalization. In essence their argument is that the positive prototype, even though it had never been seen during training, contained more of the elements associated with reward than did any of the training patterns.

with a contrasting centre in preference to a solid black circle . Once this had been mastered, the horses were trained on additional but similar stimuli – selection of a contrasting-centred stimulus always being rewarded. (One of Hanggi's horses is shown making a choice in Figure 5.6.) By the end of their exposure to a series of 15 pairs of stimuli, the horses were making very few errors when presented with a novel pair of items, indicating that they had abstracted the concept of always choosing the stimulus with the contrasting centre.

Hank Davis and his colleagues (1997) carried out an interesting series of studies on whether different species can recognize individual people. In one study they found that rats, given just one ten-minute opportunity to interact with a
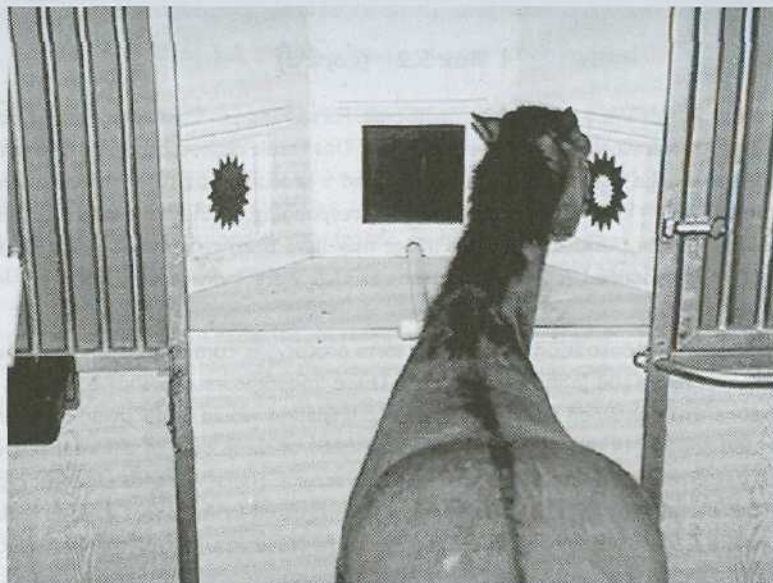
Figure 5.6   One of Hanggi's horses choosing between a filled and an open sun-like stimulus (courtesy of E. Hanggi)

specific human being, would later choose that person when given a choice between two different people seated at a table. In subsequent studies Davis *et al.* found a similar ability to discriminate between individual people in chickens, rabbits, sheep, cows, seals, llama and even penguins.

Research on perceptual conception in a number of species indicates that the ability to categorize objects – even quite abstract objects such as paintings by different artists – is widespread among mammals and birds. The evidence from more detailed studies of just how animals achieve these feats of conceptual learning suggests that the mechanisms may be relatively simple forms of associative learning and generalization. Complex behaviour can often arise as the outcome of relatively simple underlying principles.

Time

Learning about the time of day

Most animals and many plants show typical daily rhythms of activity. Bean seedlings open out their leaves each morning to catch the sun, and close them again in the evening. Likewise many flowers open during the day and close at night. Many animals are more active during the day than at night, but many others are more active during the night than the day: hamsters, rats and cockroaches, for example, all engage in more movement during the night. Some

animals, such as fiddler crabs and some lizards, change their body colour from day to night. Sparrows, like most birds, are more active during the day than at night, for the simple reason that they would probably bump into things if they tried to fly in the dark. Bees can learn that certain sources of food are available at certain hours of the day and not at others. Humans have these circadian (approximately day-length) rhythms too – as anyone who has flown more than a couple of time zones can attest.

As the experience of jet lag suggests, we and other species do not simply become active because the sun has risen. There is an internal component to circadian cycles of activity. Experiments have been performed in which animals were left in an environment that did not change in terms of light or in any other way over a 24-hour period. Despite the lack of external stimulation, the animals developed a pattern of waking and sleeping, activity and inactivity, flying and not flying, or whatever other behaviour was being measured, that approximated the 24-hour cycle of the normal day. Sparrows left in the dark, for example, developed a spontaneous rhythm of hopping and not hopping that was repeated approximately every 24 hours.

Although jet lag shows us that our pattern of waking and sleeping has an endogenous component, the fact that jet lag ultimately passes and we become accustomed to the day and night cycle of the time zone we have moved to shows that circadian rhythms are entrainable. Factors that can entrain the natural daily rhythm of an animal's activity are given the German name *Zeitgeber* – literally 'time-giver'. Although the natural daily rhythm has a 24-hour cycle, many animals will entrain to shorter or longer periods of time given the right *Zeitgeber*. Light is a very important *Zeitgeber*. Other signals that animals use to set their circadian rhythm include temperature (it is usually cooler at night than during the day); social factors (two sparrows in adjacent cages entrain each other to the same circadian rhythm); and feeding (delivery of food at regular times can entrain the circadian rhythm even when other *Zeitgeber* are absent). With suitable entrainment, many animals can adapt to cycles of activity of less than 24 hours (in some cases as short as 16 hours, but most animals cannot adapt to cycles of less than 20 or 22 hours). The upper limit in plants as well as animals is around 28 to 30 hours, although entrainment to such extreme values requires bright light.

The circadian clock is also very accurate. Bees and rats, to take two random examples, can regulate their daily activity patterns with an error of between five and ten minutes. This represents an accuracy of over 99 per cent.

The importance of circadian rhythms is not just that they ensure that an animal's activity is suited to the environment in which it lives, though that is certainly important, but also an internal sense of the time of day is extremely useful to animals that have to navigate. As we saw in Chapter 4, pigeons, bees and other animals that navigate combine their sense of time of day with the position of the sun in order to establish their bearings. It is not known how many species use this trick, but its presence in two such unrelated species suggests it may be quite widespread.

Learning about short time intervals

The ability to gauge accurately the time of day – circadian timing – is without doubt highly useful to animals. It enables them to structure effectively their patterns of activity throughout the day, as well as providing the basis for the sun compass. Circadian timing, however, has two limitations. The first is that it is restricted to periods of approximately 24 hours. Many of the things that happen in this world at regular intervals are not restricted to a period of approximately one day. The arrival of predators, prey and other important events may reoccur at intervals of seconds, minutes or hours. The second drawback with circadian timing is that it can only be used to place events within a daily cycle – animals are not able to use the circadian clock to judge arbitrary time intervals.

Long-tailed hermit hummingbirds feed on nectar-bearing flowers in the Costa Rican jungle, where their feeding habits have been studied by Frank Gill (1988). Male hummingbirds need a great deal of energizing food to survive, but foraging time is scarce as male hummingbirds spend as much time as possible trying to impress female hummingbirds. Every moment that the male hummingbird is away looking for nectar is a possible mating opportunity lost. To add to the difficulty of the male hummingbird's situation, flowers are not always full of nectar. After the nectar has been removed, different flowers refill at different rates. The longer the hummingbird waits before going off on a foraging trip, the greater the probability that the flowers he last visited will have refilled with nectar, but there is also an increased risk that another bird will have made off with that nectar. Consequently the hummingbird is confronted with a difficult timing problem. He needs to time his nectar foraging trips so that the interval between his visits to the flowers coincides as closely as possible with the length of time it takes each flower to refill. Any shorter and he will fail to pick up the maximum amount of nectar from each flower; any longer and there is a risk that another bird will get there first.

Gill (ibid.) set up some artificial flowers that he could fill with nectar whenever he wanted in order to test how well hummingbirds are able to time their flower visits. Just as his field observations had suggested, Gill found that when he refilled the flowers with artificial nectar ten minutes after the birds' last visit, the birds adjusted the interval between their visits to a little longer than the ten-minute refill time. How soon a hummingbird returned to a flower also depended on whether the bird had exclusive use of that flower, or whether other birds were feeding from the same nectar source.

But sensitivity to time intervals is not an obscure ability of a handful of species that have special timing problems to deal with. One of the most direct ways of ascertaining any animal's sensitivity to time intervals is simply to give it food at regular intervals – say once every two minutes. The first couple of times the animal receives the food it may be surprised, but it will very quickly come to expect the food at the two-minute point and will demonstrate this expectation by approaching the feeder about half way through the interval. Other species-specific food-directed behaviours may also develop. A pigeon may peck any food-like detail in the environment; a rat might gnaw on something near the

feeder; a cat may meow and rub itself against a suitable object. Each of these behavioural patterns occurs at characteristic points in the interval, and they indicate that the animal has an ability to time the interval, and that this ability is quickly entrained.

An experiment that is only slightly more involved than this requires a rat or pigeon (though many other species have been used) to make at least one response on a lever (for rats) or a pecking key (for pigeons) after a set interval has elapsed. In order to obtain food a response is required *after* the interval has elapsed, but hungry pigeons and rats (and other species) start making their lever or key responses well before the interval is up. Typically, responding starts after about one third of the interval has elapsed, and then gradually increases in rate so that the animal is responding very quickly as the interval reaches its end and the reward becomes available. In this situation, known as a fixed interval schedule, the fact that the pigeon or rat will start responding earlier if the interval is shortened, or later if the interval is lengthened, is further evidence of these animals' sensitivity to time intervals.

A simple modification to the fixed interval procedure provides further insight into the way in which these animals assess time intervals. Now, instead of food being provided at the end of each interval, occasional intervals do not end with food. Instead they run for three or four times the normal length. Under this condition it has been found that, with training, the response rate peaks at around the time the food would normally be delivered. For this reason, this modified fixed interval procedure is known as the 'peak interval' procedure. The fact that the response rate peaks at the time when food would normally be delivered suggests that the animals tested have an expectation of when the food will arrive. Figure 5.7 shows a typical pattern of response from a peak interval experiment with rats.

The fixed interval and peak interval procedures are examples of situations where an animal's sense of time becomes apparent in the patterns that develop in its own behaviour. The rats used to compile the data for Figure 5.7 revealed their awareness that food would normally be delivered after 40 seconds by producing their highest response rate at the 40-second point. In another type of procedure, animals are presented with stimuli of different durations and indicate their perception of these durations by responding to different alternatives.

Rats can be trained to make a response on one lever after a short stimulus (a tone of two seconds' duration, say) and on a different lever after a longer stimulus (a tone of eight seconds). The same task can be given to pigeons, using pecking keys rather than levers. In experiments like these, standard laboratory species such as rats and pigeons readily show an ability to discriminate between stimuli of different durations. If they are given stimuli similar in duration to the original training stimuli they indicate that they recognize this similarity by making the response they have been trained to make to the original duration stimulus. Thus for a pigeon trained to respond on one key (we shall call this the 'short' key) after a two-second stimulus and another (the 'long' key) after an eight-second stimulus, a novel three-second stimulus will produce a response on the short key, and a novel seven-second stimulus will produce a response on the long key.
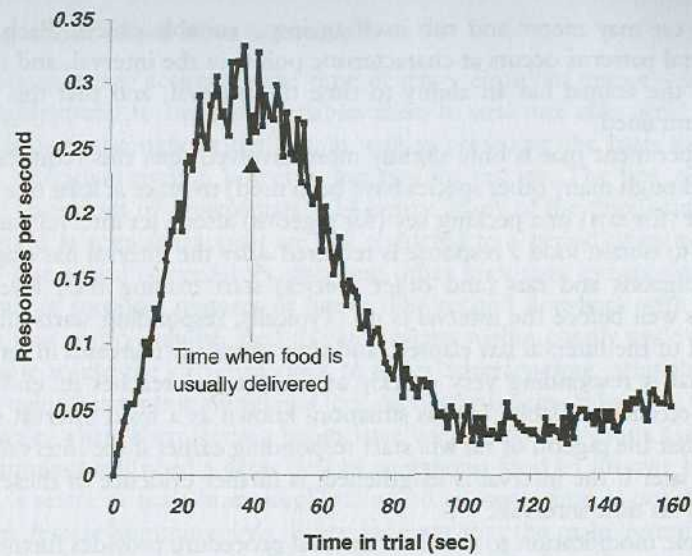
Figure 5.7 This graph shows the average rate of lever pressing for a group of rats accustomed to receiving a food reward every 40 seconds. In this trial the interval between food was 160 seconds, but it can be seen that the rats' rate of lever pressing peaked at around 40 seconds – the time when food would normally be delivered (data provided by E. Ludvig)

Box 5.3 How do animals time short intervals?

For many years the dominant explanation of how animals time short intervals has been based on a sort of internal clock theory. According to 'scalar timing' theory, proposed by Russell Church (1978), timing in animals is controlled by something akin to a ticking clock. When an event happens that the animal wishes to time, the ticks of the clock are counted into a short-term memory store. The animal knows that the correct time has elapsed when the number of ticks in the short-term memory matches the number of ticks stored (on the basis of previous experience) in the long-term memory.

Although this theory can account for many of the results obtained from fixed interval and peak interval procedures as well as the duration comparison task, it has been criticized in recent years by John Staddon and his collaborators. Staddon has proposed an alternative theory that does away with the idea that animals have a digital clock (Staddon and Higa, 1999). In Staddon and Higa's theory, timed behaviour is controlled by a steadily decaying memory of salient events. For example on a fixed interval schedule (where, as described above, food is given for the first

Box 5.3 (cont'd)

response made after an interval of time has elapsed), each food reward sets up a memory trace that gradually decays in the interval until the next food reward is delivered. Animals, it is proposed, can learn to associate a particular level of this memory trace with an action. Once the memory trace decays below that memorized level the subject starts to make responses.

What this theory implies is that if the food reward is made larger, then the memory trace will start off larger. If the memory trace starts at a high level, then it will take longer to decay to the critical level at which responding commences. Consequently larger food rewards will lead to delayed responses in fixed interval experiments. Conversely the replacement of a food reward with a neutral stimulus of equal duration (for example a light) should lead to a shorter response delay in such experiments. Both of these findings were published many years ago (Staddon, 1970), but they were largely ignored because they did not fit the dominant theory of animal timing.

Although interval timing is far more flexible than circadian timing, that flexibility does come at a cost. When events of approximately daily frequency can be timed with an accuracy of around 99.5 per cent, the accuracy of interval timing decreases with the length of the interval being timed. Consequently, though an interval of seconds or a few minutes can be timed quite effectively, the error in timing an interval of several hours in this way is catastrophic. In a simple but interesting experiment, David Eckerman (1999) compared the ability of pigeons to time intervals from 12 to 48 hours. Just as would be expected in interval timing, accuracy was generally proportional to the duration of the interval – longer intervals were less accurately timed than shorter ones. However at intervals of 24 hours, and also 12 and 48 hours (simple multiples or sub-divisions of 24 hours), an anomaly appeared – the pigeons' timing was much more accurate than with slightly shorter or longer intervals. This must have been because the pigeons switched to their circadian timing ability, which, though less flexible, is far more accurate.

Numbers

What does it mean to have a sense of number? At its simplest, it can just mean being aware that ten items are more than five items. This is known as relative number judgment, which differs from the (presumably simpler) judgment of quantity, by virtue of it being the total number of items that is critical in making the judgment – not their total amount. Twenty ants are larger in number than two elephants, despite being much smaller in terms of quantity. The next level of complexity in the appreciation of numbers is the recognition that all quantities of the same number have something in common. This is called absolute

number judgment: what it is that three cars have in common with three plums. Counting implies more than just a relative and an absolute sense of number. To count implies at least using certain number names in a consistent order to 'tag' groups of items, and recognizing that the name of the last item in a counted group is the name for the number of items in the whole group. Counting can also mean using arithmetical operations.

Relative number judgments: more or less

As we saw in Chapter 1, the study of animal cognition started out with a terrible embarrassment in the consideration of animals' numerical perception – the case of Clever Hans. This inhibited research on animals' ability to judge number for close on a century. During this period, however, there were a couple of exceptional individuals who maintained an active interest in the subject. One of these was Otto Koehler. Koehler, together with his students and colleagues, studied the numerical ability of several species of bird. Jackdaws, crows, budgerigars, ravens, magpies and pigeons were favoured subjects in experiments where the subject had to choose between containers with different numbers of grains glued to their lids. If the bird chose incorrectly no food reward was forthcoming from the container, and if necessary the bird was shooed away verbally, by hand or, in recalcitrant cases, with something akin to a fly swatter. Koehler and his coworkers were able to demonstrate that pigeons could learn to choose the container with the smaller or the larger number of grains glued to its lid. The pigeons found it easier to choose when the alternatives presented to them were further apart in number (for example seven versus four) than when they were consecutive (such as five versus four).

There was a problem with these early studies however, of which Koehler was fully aware. How could he be sure that the pigeons and other subjects were attending to the *number* of grains when they made their choice? They could have been making their choice on the basis of some other, perhaps simpler, aspect of the containers' grain-covered lids. For one thing, when there were fewer grains on a lid, less of the lid would have been covered over – hence there might have been confusion between number and the area of the lid that was covered. Though Koehler did try to control for this problem in one experiment by using lumps of plasticine instead of grains, the equipment available in his day did not permit wide-ranging control of the problem. Another problem with the early studies was that, with such small numbers of grains, the birds may have recognized the characteristic visual patterns that small numbers of items typically make. One item is always just a point; two items form a line; three items typically form a triangle; four items a quadrilateral. With larger numbers this becomes less of an issue, but with small numbers it is a considerable problem, particularly when modern knowledge about the number of visual patterns that animals are able to learn by rote is taken into account (see Chapter 6).

Jacky Emmerton adapted Koehler's experiment using modern methods to control for the alternative ways that birds might be choosing between fewer or more items, apart from the control by number of items that we are interested in

(Emmerton *et al.*, 1997; Emmerton, 1998). Emmerton's subjects were pigeons, trained in a Skinner box (see Figure 3.6) to respond to slides containing different numbers of dots. During their initial training the pigeons were rewarded for pecking on one response key if six or seven ('many') dots appeared on a slide, and rewarded for pecking a different response key if one or two ('few') dots appeared. Emmerton's results suggested that the pigeons had abstracted a concept of number because the birds, after their initial training had taught them to discriminate between six or seven dots and one or two, performed correctly when given choices between three, four or five dots. Unlike Koehler, Emmerton was able to test that it really was the number of dots that was influencing the pigeons' choices, and not some other factor, by systematically varying other dimensions of the stimuli that might have been important to the pigeons, and observing whether these variations had an impact. The factors Emmerton considered included the shape of the dots, their size, brightness and how closely packed together they were. Emmerton's results show clearly that pigeons are capable of learning the abstract concept of relative number – that is, they can discriminate between 'fewer' and 'more', at least for numbers up to seven. Similar results have been obtained with monkeys and – using sounds instead of images – rats.

Absolute number

As well as understanding that seven is more than five, using the concept of number effectively also means understanding that every group of five items has something in common. This quality – which, say, a certain number of ants share with the same number of elephants – is known as 'absolute number'. Otto Koehler and his students were the first to investigate absolute number in animals. A raven called Jakob was trained to choose a pot with five spots on its lid from among five pots with different numbers of dots on their lids. Jakob succeeded at this task even though the area on the lids that the different numbers of dots occupied varied 50-fold.

More recently Hank Davis (1984) and various colleagues conducted detailed studies of several species' ability to comprehend absolute number. In one experiment a raccoon named Rocky learned to pick out a clear plastic cube containing three objects (grapes or small metal balls) from a set of plastic cubes containing from one to five items. Only the cube containing three items could be opened. Rocky's rewards for a correct choice included being able to eat the grapes or wash the metal balls. In addition Rocky was given a social reward in the form of hugs from a researcher (Figure 5.8).

Davis and his colleagues carried out several other experiments on absolute number using the more familiar rat subjects. In an experiment reminiscent of Monty Python's holy hand-grenade ('The number thou shalt count shall be three'), Hank Davis and Melody Albert (1986) demonstrated that rats could learn to make a response only after three bursts of white noise, not two or four. These bursts of noise were of random duration, so the rats could not solve the task on the basis of their ability to judge time intervals. In a follow-up experi-

Figure 5.8   The left-hand photo shows Rocky the raccoon selecting the transparent cube containing an object in an early phase of training. In the right-hand photo Rocky is receiving social reinforcement (courtesy of H. Davis)

ment Davis and his colleagues (1989) considered whether rats could distinguish between three touches to their whiskers and two or four. In this experiment, the timing of the whisker touches was also randomized so that the rats had to distinguish the number of touches, and not their timing. Other studies showed that rats could learn to restrict their feeding to a fixed number of food items even if the type of food was changed after the original training. Different groups of rats were designated as three-eaters, four-eaters or five-eaters. If they ate the correct number of items they were praised verbally and given an extra food item. If, however, they tried to eat too many items they were punished with a loud 'no' and a frightening hand clap (Davis and Bradford, 1991).

Studies with a quite different design support the hypothesis that rats can distinguish absolute numbers. Hank Davis and Sheree Bradford (1986) trained rats to take food from the third of six tunnels. All the tunnels contained food (so odour cues were controlled), but all except the third tunnel had their doors jammed so that the rat could not enter and eat the food within. The exact positions of the tunnels could be moved around so that positional cues were controlled for. Figure 5.9 shows part of the apparatus and a rat choosing the correct tunnel. With training the rats would go directly to the third tunnel, ignoring the others on their way.

Research by other investigators has shown that rats and pigeons can be trained to make a specific number of responses on a response lever. Accuracy is only high for fairly small numbers (below ten – Mechner, 1958), but some evidence of
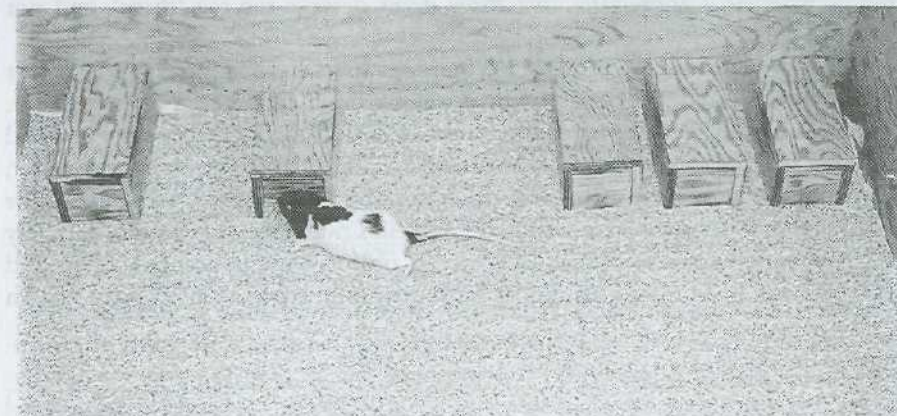
Figure 5.9   One of Davis and Bradford's rats selecting the correct tunnel (courtesy of H. Davis)

perception of the number of responses made has been demonstrated with numbers up to 50 (Rilling and McDiarmid, 1965).

Counting

Though some would use the term 'counting' to refer to any ability to perceive numbers, there is really much more to counting than just the relative and absolute number competencies we have considered so far. In order to count it is not just necessary to recognize that five items are more than four items (relative number). It is not even enough to recognize that every group of five items has something in common with every other group of five items (absolute number), whatever those items may be. Counting also means recognizing at least two further qualities of numbers:

1. *Tagging*: a certain number's name or tag goes with a certain quantity of items. In our language the name 'one' or symbol '1' stands for a single item. 'Two' or '2' goes with a pair of items, and so on. These tags must always be applied in the same order
2. *Cardinality*: the tag applied to the last item of a set is the name of the number of items in that set. Thus if I tag the pens on my desk I call the first one 'one', the next one 'two' and the last one 'three'. 'Three' is consequently the correct name for the number of pens on my desk.

Although, as we have just seen, there is some evidence that at least a few species of animal are sensitive to the concept of number, evidence that animals can count is harder to come by. For one thing, to demonstrate an appreciation of tagging and cardinality a subject has to be able to produce a range of different responses. Without a range of different number tags available to it, an animal could never

tell us whether it appreciates that three items deserve the tag 'three', and not 'two' or 'four'.

Some of the strongest evidence of counting comes from an African grey parrot called Alex, trained in a rather original way by Irene Pepperberg (1987, 1994). Box 5.4 outlines the training method used with Alex. Alex was trained to respond verbally in English to questions presented to him verbally by an experimenter. He would be presented with a tray of several objects and asked 'What's this?' or 'How many?' In tests with novel objects Alex was able to identify correctly the number of items in groups of up to six objects with an accuracy of around 80 per cent. Even mixed groups of more than one type of object were not an

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Box 5.4   How to train a parrot to count

Irene Pepperberg has developed a unique training procedure that takes advantage of the enthusiasm of African grey parrots to imitate human sounds. During training the parrot is encouraged to answer questions put to him by the experimenter using the model–rival technique. In this technique humans demonstrate the required response. A human acts as a model for the parrot by answering the experimenter's questions, and as a rival with the parrot for the experimenter's attention.

During training the experimenter might present a tray of objects to the parrot and the other human, and ask 'What colour?' If the parrot shows no inclination to answer, the second human will give a response and receive praise and a reward from the experimenter if correct. The second human sometimes makes errors, copying the kinds of mistake the parrot might make. Errors are 'punished' with disapproval from the experimenter, who removes the materials, shakes her head and says 'No' emphatically. The parrot's natural desire for attention and the opportunity to play with the objects presented is enough to encourage him to attempt to answer the question himself the next time it is asked. Thus the second human acts both as a model for the parrot to attempt to copy, and as a rival for the rewards the experimenter is offering. Reward for the parrot typically takes the form of an opportunity to play with the objects presented (which ensures he makes a detailed inspection of the objects). To encourage the parrot to keep working even when he is no longer interested in the objects being presented, he is also permitted to ask for and play with a more preferred object after he has answered a question correctly.

To test what the parrot has learnt, a different experimenter is brought in to ask questions. The primary trainer now sits facing away from the parrot and acts solely as an interpreter, repeating to an assistant the words the parrot has said (which can be difficult for an untrained ear to understand).

Using this method, one parrot, Alex, was trained to produce over 100 English words, and he could answer questions about several qualities of the objects presented to him, such as their colour, shape and material, as well as number.

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insurmountable problem for Alex, though his accuracy suffered a little. Only small numbers were tested, so Pepperberg took care to ensure that the objects did not fall into characteristic patterns on the tray. Alex was also able to answer questions such as 'How many purple wood?' when presented with a tray containing pieces of purple wood, orange wooden items, pieces of purple chalk and orange chalk all intermixed.

More evidence of what might be construed as counting comes from a chimpanzee, Ai. Ai was trained by Tetsuro Matsuzawa and coworkers to touch numerals on a computer screen in ascending numerical order (Biro and Matsuzawa, 1999; Kawai and Matsuzawa, 2000). Up to five numerals, selected at random from the range zero to nine, appeared simultaneously in randomized positions on the computer screen. Ai first had to touch the lowest numeral, which then disappeared. Then she had to pick the lower of the remaining numerals, and it too disappeared. This process was repeated until Ai touched the only remaining numeral (the highest number in the original set) and she received a small food reward. Ai succeeded at this task even when all the remaining numerals were replaced by white squares after the first numeral had been touched.

Experiments by Elizabeth Brannon and Herb Terrace (2000) on three macaque monkeys shared some of the design features of the research on Ai the chimpanzee. Brannon and Terrace's monkeys touched stimuli that appeared on a computer screen in order of numerosity. In Brannon and Terrace's experiments, however, the stimuli were not numerals (as Ai's had been), but different numbers of objects. These objects could be simple squares or circles of differing size, items selected from clip art software or even objects that differed in size, shape and colour. A sample array is shown in Figure 5.10. The monkeys were well able to select quantities from one to four in ascending or descending order, even though the stimuli used varied greatly throughout training.

Brannon and Terrace point out that it is not particularly difficult to train a monkey to respond to any series of four arbitrary items in a specific order. Their success in training monkeys to select quantities from one to four in certain orders might therefore have had nothing to do with counting, and could just be evidence of an ability to order arbitrary stimuli and responses. In a follow-up experiment to test this possibility, the monkeys were shown groups of two quantities at a time. The correct response involved selecting the groups of items in either ascending or descending order of numerosity depending on which type of training the monkey had undergone in the first experiment. Some of these stimuli involved quantities in the one to four range, which were familiar from earlier training; others contained quantities of five to nine, which the monkeys had not previously experienced. Tests involving novel quantities were not rewarded, and therefore served as a test of whether the monkeys really had abstracted the rules involved in counting objects, or had just learnt certain sequences of responding. All three monkeys performed at a very high level when choosing quantities of one to four, for which they had previously been rewarded. Choice in the five to nine range was less reliable, but exceeded the level of chance for two of the three monkeys – the two who had been trained to select quantities in ascending order. The third monkey, who had been trained to select quantities in descending order,
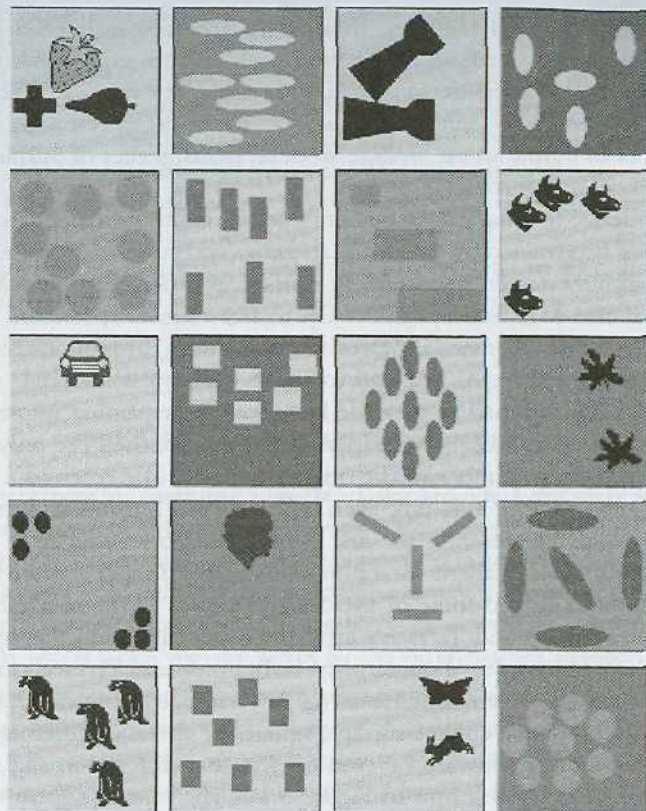
Figure 5.10 Examples of stimuli used by Brannon and Terrace showing different numbers of various kinds of object (the originals were coloured) (courtesy of E. Brannon)

was completely unsuccessful with the new quantities of five to nine. However all three improved in their performance on the novel quantities when a reward for correct choice was introduced.

Numbers are useful to us for more than just counting objects, they can also be used to add and subtract quantities of items. The only suggestion that an animal can use numbers in this way comes from one of Sarah Boysen's chimps, Sheba. Boysen (1992) and her colleagues first trained a group of chimpanzees to select cards with Arabic numerals on them and match them with a number of objects presented on a tray. As shown in Figure 5.11, the chimps were given cards bearing the numbers 1, 2 and 3, and they then had to choose the correct one to go with a tray containing three treats. Once this had been mastered, the task was reversed and the chimpanzees were required to pick the correct tray of items to match an Arabic numeral.

The quickest of these chimps, Sheba, was selected for further training on an arithmetical problem (Boysen and Berntson, 1989). Sheba was trained to make a circuit around three different places in her training environment (Figure 5.12).
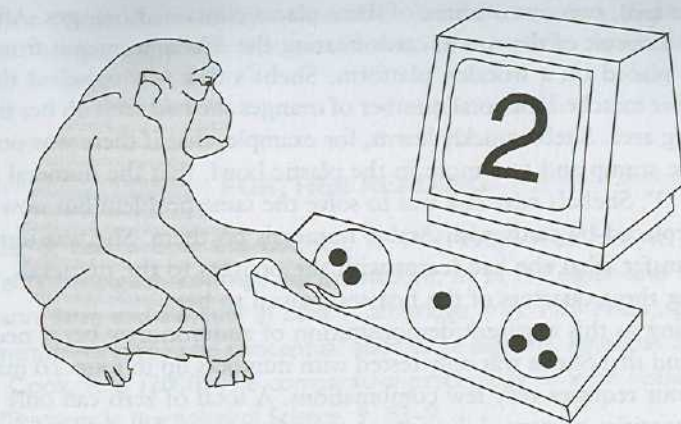
Figure 5.11 Sarah Boysen's chimp Sheba selecting the set of items that match the numeral shown on the screen (from Boysen, 1992)
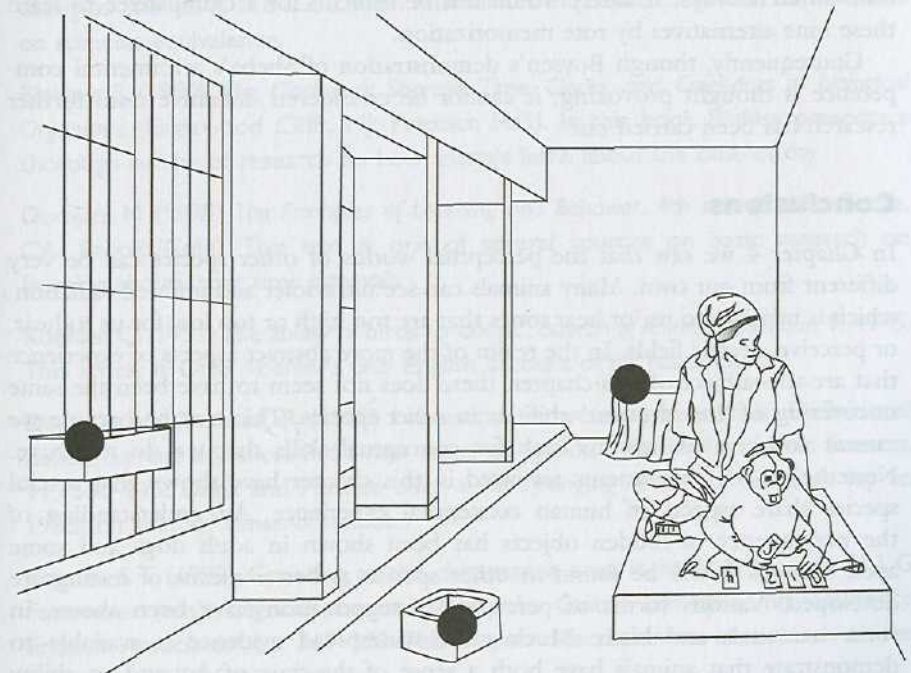
Figure 5.12 The room in which Sheba carried out the adding task. Dots mark the three places where Sheba might find oranges. She then had to pick the card bearing the numeral that corresponded to the total number of oranges she had seen (from Boysen and Berntson, 1989)

In any one trial, two out of three of these places contained oranges. After Sheba had made a circuit of the room, cards bearing the Arabic numerals from zero to four were placed on a wooden platform. Sheba's task was to select the Arabic numeral that matched the total number of oranges she had seen on her trip round the training area. Sheba quickly learnt, for example, that if there was one orange on the tree stump and two more in the plastic bowl, that the numeral she must select was '3'. Sheba's next task was to solve the same problem but now with the oranges replaced by cards with Arabic numerals on them. She was immediately able to transfer what she had learnt with the oranges to the numerals, correctly performing three quarters of the first tests given to her.

Intriguing as this apparent demonstration of addition may be, it needs to be kept in mind that Sheba was only tested with numbers up to four. To make totals of up to four requires very few combinations. A total of zero can only be made by two quantities of zero. Likewise a total of one can only be achieved in one way, by adding zero and one. Two can be constructed in two ways (zero plus two, or one plus one), as can three (zero plus three, or one plus two). Even a total of four can only be constructed in three ways (zero plus four, one plus three, or two plus two). Consequently the five possible totals can be achieved in just nine different ways. It surely would not be difficult for a chimpanzee to learn these nine alternatives by rote memorization.

Consequently, though Boysen's demonstration of Sheba's arithmetical competence is thought provoking, it cannot be considered definitive until further research has been carried out.

Conclusions

In Chapter 4 we saw that the perceptual worlds of other species can be very different from our own. Many animals can see ultraviolet and infrared radiation, which is invisible to us, or hear tones that are too high or too low for us to hear, or perceive electric fields. In the realm of the more abstract aspects of experience that are the subject of this chapter, there does not seem to have been the same uncovering of 'superhuman' abilities in other species. This may be because we cannot conceive of how to look for conceptual skills that we do not have. Nonetheless the experiments reviewed in this chapter have shown that several species share aspects of human conceptual experience. An understanding of the permanency of hidden objects has been shown in adult dogs and some apes. Perhaps it will be found in other species as better means of testing are developed. Various forms of perceptual categorization have been shown in some mammals and birds. Much more widespread evidence is available to demonstrate that animals have both a sense of the time of day and an ability to learn about short, arbitrary time intervals. Some aspects of the sense of number, including the ability to discriminate relative and absolute numbers, have been found in some birds and mammals. Some components of the more advanced aspects of number sense that contribute to the ability we call counting have been demonstrated by non-human primate species, as well as an African

grey parrot. That these abilities should be found in such a disparate group of animals suggests that further studies on other species may also produce successful results.

FURTHER READING

Watanabe, S, Lea, S E G and Dittrich, W H (1993) What can we learn from experiments on pigeon concept discrimination?, in H P Zeigler and H-J Bischof (eds), *Vision, Brain and Behavior in Birds* (Cambridge, MA: MIT Press), pp. 351–76; Wasserman, E A (1995) The conceptual abilities of pigeons, *American Scientist*, **83**, 246–55; Cook, R G (2000) The comparative psychology of avian visual cognition, *Current Directions in Psychological Science*, **9**, 83–9.

These three contributions review a range of studies on cognitive processes in pigeon vision.

Zentall, T R (2000) Symbolic representation by pigeons, *Current Directions in Psychological Science*, **9**, 118–22. Zentall summarizes the results of several experiments on stimulus equivalence.

Binkley, S (1990) *The Clockwork Sparrow: Time, Clocks, and Calendars in Biological Organisms* (Englewood Cliffs, NJ: Prentice Hall). In this book Binkley presents a thorough review of research on how animals learn about the time of day.

Domjan, M (1998) *The Principles of Learning and Behavior*, 4th edn (Pacific Grove, CA: Brooks/Cole). This text is one of several sources on basic research on learning about short time intervals.

Koehler, O (1951) The ability of birds to 'count', *Bulletin of Animal Behaviour*, **9**, 41–5. This article is Otto Koehler's only English account of his research.

Davis, H and Perusse, R (1988) Numerical competence in animals: Definitional issues, current evidence, and a new research agenda, *Behavioral and Brain Sciences*, **11**, 561–615. Davis and Perusse offer a wide-ranging review of research (up to 1988) on animals' sense of number.

Boysen, S T (1992) Counting as the chimpanzee sees it, in W K Honig and J G Fetterman (eds), *Cognitive Aspects of Stimulus Control* (Hillsdale, NJ: Lawrence Erlbaum Associates), pp. 367–383. This chapter offers a review of research on the counting ability of chimpanzees.

Hauser, M (2000) What do animals think about numbers?, *American Scientist*, **88**, 144–51. Hauser's article is an interesting survey of recent research on animals' sense of number, written for a wider audience. The text is also available on the web at http://www.amsci.org/amsci/articles/00articles/hauser.html

WEBSITES

This is the first academic text on any aspect of animal cognition to appear on the web. It includes contributions on bird visual cognition by several of the researchers mentioned in this chapter http://www.pigeon.psy.tufts.edu/avc/toc.htm

Irene Pepperberg's research on African grey parrots is surveyed at http://www.alexfoundation.org/index.html

A summary of the above research and a transcript of Alex using number terms are available at http://www.sciam.com/specialissues/1198intelligence/1198pepperberg.html

Evelyn Hanggi's research on horse cognition is summarized at http://members.aol.com/EquiResF/horse.html

Interesting research on how blue jays learn about cryptic moths is summarized at http://abcnews.go.com/sections/science/DailyNews/jays981007.html