Basic processes

2

Perception and sensation

- The passive, almost instantaneous and automatic process of SENSATION must be distinguished from the active, slower, interpretation of the sensory world found in PERCEPTION.
- Even simple sensory judgements involve a decision process, which can be understood by SIGNAL DETECTION THEORY.
- Differences in decision making can be interpreted in terms of SENSITIVITY, the true differences in effectiveness of the sensory apparatus, and CRITERION, a willingness to produce FALSE ALARMS or MISSES.
- Perception uses prior expectations and likelihoods, coupled with the information present in a stimulus, to produce the most likely interpretation of a stimulus.
- ILLUSIONS result when errors arise in the processing of sensory images. Psychology exploits errors in order to understand how systems function.

Although similar in ordinary usage, perception and sensation have distinct meanings; the difference between seeing and 'seeing'. Look at Figure 2.1. Although the areas of black and white are easily made out, you will not see anything else in the figure because it has intentionally been printed upside down. Turn the book round and look again. Initially there are still only unconnected black and white patches. Suddenly though you will begin to make out a picture. Have a few hints: there is a black and white dog to the right of centre, nose to the left, sniffing the ground, with a tree behind, and the ground strewn with leaves. By now you should have seen it. If not, then keep looking. It is not a hoax; indeed it is a genuine photograph. Perhaps ask a friend if you still cannot work it out. The aim of this demonstration is that suddenly you should have 'seen' the meaningless black and white patches as a complex picture. The 'Aha!' phenomenon, at which you may have worked quite hard, is PERCEPTION, whereas the instantaneous, easy, seemingly trivial process of being aware of the black and white patches is the process of SENSATION.

Perception is an *active* process that we work at, often for a long time, and whose success depends both upon our present state, previous experience and knowledge, and expectations, which is why a hint

Fig. 2.1 This figure has intentionally been printed upside down. Before turning the book around, read the beginning of Chapter 2. Photograph by R C James.

helps so much with Figure 2.1. Sensation, however, is the *passive* process of transducing physical events from the world into neural activity in the brain, so that we are aware of them; sensation is unaffected by knowledge, experience or expectations. Sensation and perception are clearly distinguished when we try to build machines hat can do them. Optical sensing devices that produce a voltage in proportion to light intensity have been known for many years and orm the basis of television cameras; such a device could easily ifferentiate the black and white areas in Figure 2.1. However omputers that can scan the output from a camera and print 'Dog, ark, autumn', do not exist and their construction provides many roblems, not merely technical, but reflecting our far deeper inability o program knowledge and experience. The uses of such a device would be enormous; an example would be automatically examining hotomicrographs of cervical smears to detect malignant change, a ask which presently is tedious, time-consuming, error-prone and nvolves large numbers of highly trained staff.

Although sensation is apparently totally passive, this is only true when the sensory system is considered in isolation. Any real judgement about sensation always actually involves higher psychological processing. Consider an actual study.

A doctor, D, palpated the abdomen of 65 patients with his hand and used tactile sensations to decide whether the spleen was enlarged.

Doctor's judgement

Doctor D		Normal	Enlarged	Total	Detection rate	False alarm rate	Overall success rate
	Normal	43	5	48			
Actual size					12/17 = 0.61	5/48 = 0.10	(43 + 12)/65 = 0.85
	Enlarged	5	12	17			
				65			

Doctor E		Normal	Enlarged	Total	Detection rate	False alarm rate	Overall success rate
	Normal	27	21	48			
Actual size					16/17 = 0.94	21/48 = 0.44	(27 + 16)/65 = 0.66
	Enlarged	1	16	17			
				65			

Doctor F		Normal	Enlarged	Total	Detection rate	False alarm rate	Overall success rate
	Normal	35	13	48			
Actual size					8/17 = 0.47	13/48 = 0.27	(35 + 8)/65 = 0.66
	Enlarged	9	8	17			
				65			

Fig. 2.2 Doctors' clinical judgements (based on palpation of the abdomen) of whether or not the spleen is enlarged or normal; the judgements are compared with an objective assessment of true spleen size obtained by technetium scintigraphy. Doctor D is an actual physician (data reported by Sullivan S and Williams R (1976), Reliability of clinical techniques for detecting splenic enlargement, *Br Med J*, **2**, 1043–4), whereas doctors E and F are hypothetical individuals to illustrate the principles of signal detection theory.

pleen size was also determined objectively by technetium scintigrahy. Figure 2.2 shows that in the 48 patients with a normal spleen, he doctor regarded the spleen as enlarged in five cases (10.4%), and n the 17 patients with an enlarged spleen the doctor recorded an nlarged spleen in 12 cases (70.6%). Therefore in a typical study of ability to carry out physical examinations, doctor D is moderately accurate, being correct in 55 of 65 patients (84.6%).

Now consider two other hypothetical doctors, E and F, who might also have done the study. Dr E is only correct in 42 (64.6%) of the patients, as is Dr F. Are then Drs E and F less sensitive than Dr D? Not necessarily. Drs E and F may be less *sensitive* (perhaps having poorer technique, or less sensitive fingers), but it might also be that Drs E and F differ in the *caution* that they use, and hence achieve a lower overall success rate. Consider the most cautious doctor imaginable, who worries so much about erroneously saying a spleen is enlarged that all patients are described as 'normal'. Although this decision is actually correct in 48 patients who truly had normal spleens, such data can say nothing about true ability to distinguish normal from abnormal, only about clinical and professional priorities.

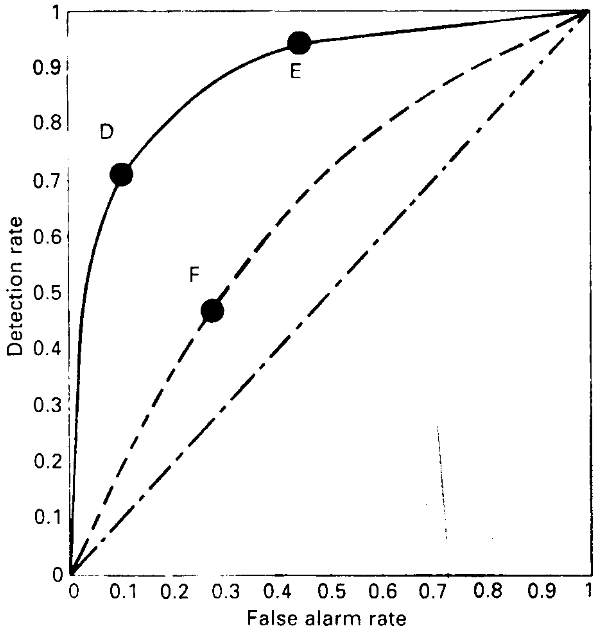

Fig. 2.3 The receiver operating curves (ROC) for the three individuals of Figure 2.2. The curved lines indicate lines of equal sensitivity (*d'*), so that Drs D and E are of equal true sensitivity. The straight, diagonal line indicates 'chance' or random responding in which the subject is completely unable to carry out the task (i.e. $d' = 0$). Increasing threshold or criterion (*beta*) is indicated by distances along the dashed curves from the bottom left-hand corner, so that Dr D is more cautious than Dr E, whereas Drs D and F are of similar degrees of caution.

Caution (or CRITERION) and SENSITIVITY can be distinguished from a subject's complete pattern of responses. Figure 2.2 shows the four esponse types that occur in each subject: two combinations are orrect (enlarged spleen reported as enlarged, and normal spleen eported as normal) and two types are incorrect; FALSE POSITIVES (normal pleen reported as enlarged), and false negatives or MISSES (enlarged pleen reported as normal). These responses are summarized as the ETECTION RATE, the proportion of enlarged spleens detected in those atients with enlarged spleens, and the FALSE ALARM RATE, the proportion f enlarged spleens reported in patients with normal spleens.

Figure 2.2 shows that Dr D has a moderate detection rate (71%) and a low false alarm rate (10%), whereas Dr E has a high detection rate (94%) and a very high false alarm rate (44%). Dr D is good at reassuring normal subjects, whereas Dr E is good at detecting disease in the abnormal. Dr F has both a low detection rate (47%) and a moderately high false alarm rate (27%). Figure 2.3 shows the data plotted on a RECEIVER OPERATING CURVE (ROC). The X-axis shows the false alarm rate and the Y-axis the 'hit-rate', the proportion of detections in patients with enlarged spleens. For such curves, subjects with similar criteria lie on lines running perpendicular to the diagonal, and subjects with similar sensitivities lie on the lines parallel to the diagonal. We can now better describe Drs D, E and F. Drs D and E are actually equally sensitive but Dr D is more cautious than Dr E. Dr F however, is less sensitive than Drs D and E. In the psychological literature this is known as a SIGNAL DETECTION EXPERIMENT, and the sensitivity and criterion are, for historical reasons, conventionally represented by *d'* and beta respectively. Figure 2.4 and its caption gives the mathematical background for understanding *d'* and *beta*.

Both *d'* and *beta* may differ in different subjects, and can also change within a single subject. Decreased attention or concentration can reduce *d'*, as may various drugs, whereas experience and learning can increase *d'*. Altering a task's rewards, costs and demands can alter *beta*: if the cost of failure (e.g. the patient dying of malaria, undiagnosed because the spleen was wrongly said to be normal) is greater than the cost of a false alarm (e.g. the patient receives a few weeks' drug treatment) then the proportion of detections and the false alarm rate will both rise. Reversing the costs of detections and false alarms will decrease the detection and false alarm rates.

Signal detection theory also shows how patients may differ in interpreting symptoms such as pain. In Chapter 20 we will ask if some patients are genuinely more *sensitive* to pain, or if they *report* pain more often. Do analgesic drugs act by *reducing* pain or do they alter the reporting of pain?

Signal detection theory applies both to the simplest of sensory judgements, such as detecting faint flashes of light, and to complex judgements, such as whether a patient requires immediate surgery. In all such situations differences in *true ability* must be distinguished from differences in *response tendency*.

PERCEPTION makes *decisions* based on the raw sensory information that is presented to the brain. A PARTICULAR sensory event, such as a pattern of light, is *interpreted* as a more UNIVERSAL response such as 'dog'; we recognize not only a specific animal, but also an object typical of the class of animals called dogs. Interpretation often goes beyond the information given, so we see what we *expect* to see. This is shown in an experiment in which Bruner asked subjects to sort a pack of playing cards by suit. As well as the four standard suits the pack also contained cards with a heart printed in black or a spade printed in red: few subjects noticed these cards, but instead sorted them as the standard suits which they had *expected* to see.

For any particular stimulus we have several hypotheses, which change in likelihood as further evidence is given. Occasionally we cannot settle on a single hypothesis, resulting in ILLUSIONS such as the

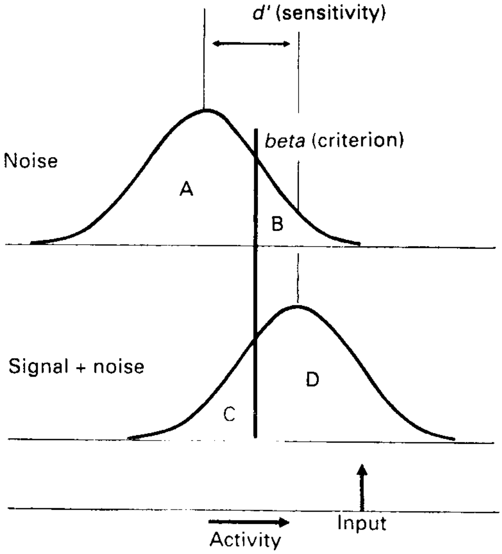

Fig. 2.4 Consider the activity occurring in a sensory nerve or in a central pathway. If no signal is present there will still be background or resting activity, or NOISE, varying from moment to moment, and probably distributed normally (see top distribution). When a true SIGNAL is present in addition to the background noise then the total activity will increase, and the overall distribution be shifted to the right (lower distribution). For any particular activity (e.g. 'Input', indicated at the bottom of the figure) the observer must decide if it results from a true signal or from background noise. The mathematically optimal strategy is to set a threshold, or criterion (*beta*), and say that all activity greater than this is signal and all activity less is noise. Thus since Input is greater than the criterion then it would be classified as a signal. Of course some actual signals (area C) will be reported as noise (misses), and some actual noise (B) will be reported as signals (false positives), although a majority of judgements (A + D) will be correctly assigned. As the observer shifts *beta* to left or right so the relative proportion of false positives to misses (B:C) will rise or fall; nevertheless *d'*, the true sensitivity of the observer, indicated by the differences in position of the peaks of the two distributions, remains the same. Only if the signal distribution shifts to the right (or if variabilities are reduced) does true sensitivity ncrease. The values plotted on the axes of the ROC curve are D/(D + C) on the ordinate and B/(A + B) on the abscissa.

ECKER CUBE (Fig. 2.5). After looking for a few moments you will see it eversing its perspective, so that it is seen from below rather than bove; and a few seconds later it reverses back again. And indeed it ever stops reversing. Perception continually works at the image, rying new hypotheses, but never reaching a definitive solution, ecause in this case there is insufficient evidence to distinguish them. The rate of reversal is proportional to intelligence, suggesting that in part intelligence is a continual searching for solutions to problems.

The Necker cube and the signal detection task illustrate an important feature of experimental approaches to psychology. Only when things

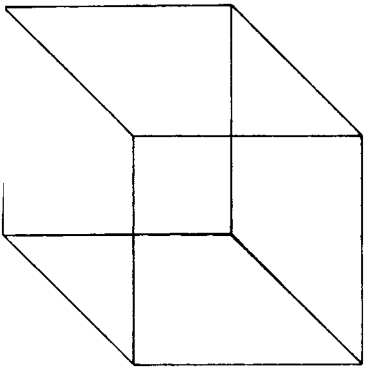

Fig. 2.5 The Necker cube, which can be seen either as a cube looked at from above and to the right, or as a cube looked at from below and to the left, the two interpretations continually and unpreventably alternating.

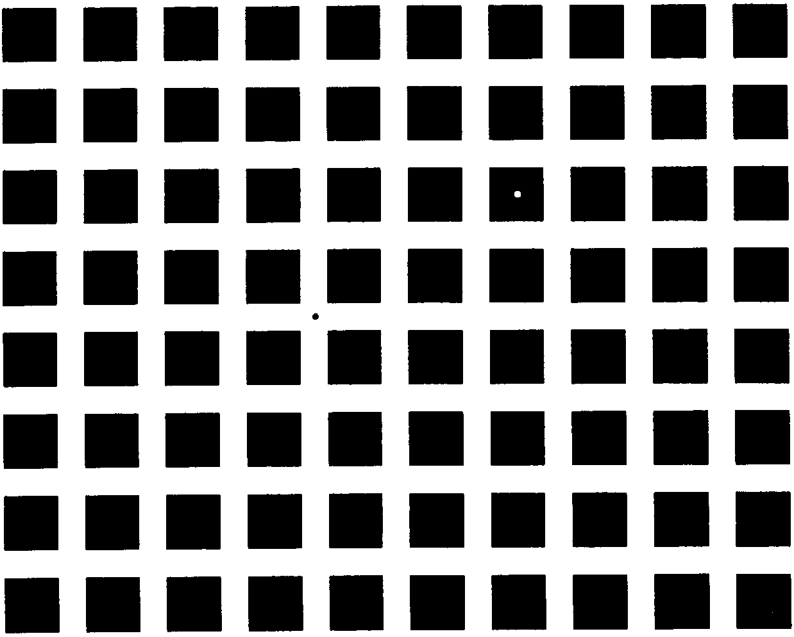

Fig. 2.6 A sensory illusion, the Hering Grid illusion. At the intersections can be seen a fuzzy grey spot, which is not truly present in the stimulus. The illusion is due to lateral inhibition in the ganglion cells of the retina. Note that the illusion is *not* an after-image. An after-image can be demonstrated in the figure by staring at the black dot for a minute or so, and then staring at the white spot. Superimposed on each black square should be seen a dark cross, which is an after-image resulting from the retinal activity arising from looking at the black dot. The after-image is due to fatigue of the cones in the retina.

go wrong, when we make *errors*, be they false positives, or the failure to see a set of lines as a single perception, do we gain insight into how the mind works. A perfect system tells us nothing about *how* it works.

Figures 2.6 and 2.7 shows several illusions coming from different sources. In the HERING GRID (Fig. 2.6) at the intersections between the

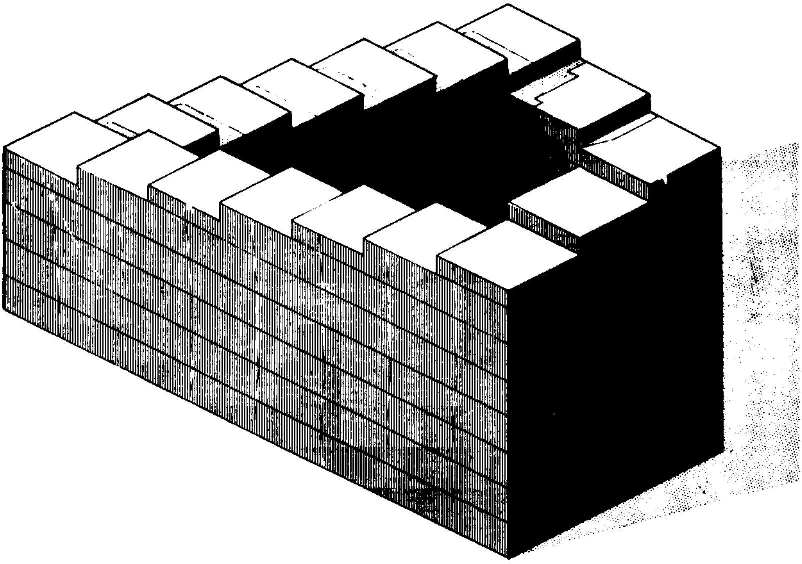

Fig. 2.7 A perceptual illusion, the Penrose figure. If you cannot see why Fig. 2.7 is impossible then start at the step nearest to you, and imagine yourself climbing to the next step and so on. You will find that you are always ascending, which is of course geometrically impossible. Reproduced with permission from Penrose L S and Penrose R (1958), Impossible objects: a special type of visual illusion, *Br J Psychol*, **49**, 31.

black boxes we see faint black dots, which are totally illusory. The dots are particularly clear at intersections we are *not* looking at, indicating that they come from non-foveal vision. This SENSORY ILLUSION arises from retinal lateral inhibition, in which cones stimulate ganglion cells corresponding to the area and *inhibit* ganglion cells slightly to the side of the area; this results in an overall sharpening of the image. Occasionally the process becomes visible, as in Figure 2.6, where ganglion cells at the intersection are so laterally inhibited that they apparently correspond to a darker area in the image. The workings of the sensory system are thus revealed to us by the illusion. Sensory illusions are distinguished from PERCEPTUAL ILLUSIONS, in which an error of *interpretation* is present, but the sensations are correct. However long we look at the Penrose figure (Fig. 2.7) we are unable to see it as a real three-dimensional figure, because the available information is conflicting.

Perception usually has to be learnt. As a demonstration, take a small electronic flash gun and ask a friend to hold it about six feet from you. Stare at the centre of the flash gun, and discharge it. You will get a strong AFTER-IMAGE, which is enhanced by blinking. Look at the palm of your hand and you will 'project' the after-image as a small purplish patch, shaped like the flash-gun aperture. Now look at a distant wall. The after-image looks larger. This is surprising because e after-image is fixed on your retina and cannot change its size. ontext alters the apparent size. Distant objects in reality have smaller tinal images than those that are close. If an object known to be far way (the wall) produces the same retinal image as a closer object our hand) then the only interpretation is that the more 'distant' ject is also larger. This is known as Emmert's Law, and it is due to ZE CONSTANCY: objects stay the same PHENOMENAL SIZE as they go further way, despite their retinal images shrinking. This constancy is parently learnt, small children genuinely thinking that distant bjects are indeed smaller.

Perception often makes assumptions about the way the world oks, for only then can it disambiguate otherwise indistinguishable ypotheses. Consider the problem of deciding whether a visual object moving. When an image moves across our retina, two possibilities rise: it corresponds to an object moving in the world, or it corresponds a motionless object viewed by a moving eye. There can be no *visual* formation that distinguishes these hypotheses. There are two ways which we might distinguish. We might have receptors in the eye-uscles, which tell us if our eyes are moving. Alternatively we might y, 'I have not told my eyes to move, therefore they cannot be oving, and therefore the moving image must correspond to a moving bject'. Although it seems unlikely, the latter explanation is shown be correct by a simple experiment.

Close your eyes and gently place your fingertip on the lower outer yelid, and then carefully open your eye and push gently on the yeball. The whole world seems to move. Of course the world is not ctually moving, so why do you perceive it as such? Pushing the eye roduces a moving visual image, but you have not told the eye to ove, and hence it must be that the world is moving; and so it ppears to be. Generally the assumption works well, but occasionally t fails, and we then have an illusion of the world moving and gain nsight into how the system works.

Sensation and perception are our only basis for a knowledge of the orld. All information has arrived through those systems, and hence ight be illusory or deceptive. As we encounter new stimuli we must sk whether they arise from outside or within our perceptual systems. Both we and our patients can be fooled by our perceptions, be it when we are examining an abdomen for an enlarged spleen, or looking at a chest X-ray or ultrasonogram, or when a patient is describing a pain or other symptom.