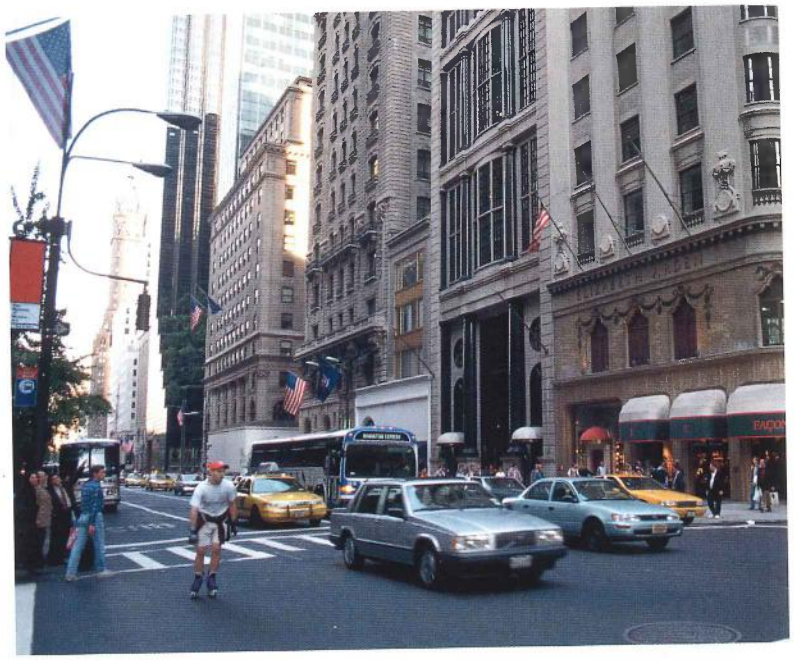
Representing Information

"To be a smell is one thing, to be known as a smell, another."
John Dewey

Our brains can hold an enormous amount of information: Most people know how to read, write, and say thousands of words; we know how to get from our homes to dozens of different places; psychologists have shown that we can remember thousands of different pictures. A great deal of research into the brain focuses on how it stores and represents this wealth of data.

In the modern world all sorts of devices represent information. Some, like books and maps, have been around for thousands of years. At the other extreme the World Wide Web did not exist until 1993, although the Internet has been around for several years longer. However, even the oldest book is a newcomer compared to the brain. The human brain has been representing information for millions of years.

For thousands of years philosophers have been trying to figure out how the mind stores and represents information. About a hundred years ago psychologists began conducting experiments to answer this question. To do an experiment, you have to have some idea of what you will find. Scientists call such an idea a hypothesis. As psychologists experimented, they searched for suitable hypotheses to express how the mind



If this city street were mapped, not every detail would be shown—maps are external representations that omit unnecessary information.

KEY DATES

1883 Francis Galton investigates mental imagery.
1892 Gottlob Frege writes *On Concept and Object*.
1932 Frederick Bartlett publishes *Remembering*.
1958 Ludwig Wittgenstein publishes *Philosophical Investigations*.
1966 Ross Quillian submits his Ph.D thesis on semantic hierarchies.
1969 Brent Berlin and Paul Kay publish their findings on color terms in different languages.
1973 Researchers show that people can remember a minimum of several thousand images.
1973 Eleanor Rosch shows that categories have typical and atypical members.
1977 Roger Schank and Robert Abelson propose script theory.
1981 James McClelland publishes a network theory of concept representation.
1983 Stephen M. Kosslyn writes *Ghosts in the Mind's Machine*.
1985 James McClelland and David Rumelhart propose a network model of category learning.
1986 David Rumelhart and colleagues write *Parallel Distributed Processing*.
1993 Denis le Bihan and colleagues show that the parts of the brain used for imagining pictures are the same as those used for seeing them.

might represent information. Was the process of committing something to memory like drawing a picture inside your head? Were the stories people knew by heart stored in the mental equivalents of books? Did the brain represent our understanding of different words in the same way that a dictionary does?

People share information in many different ways. Books are written, pictures are painted, and maps are drawn. However, books, pictures, and maps are not the same as the things they stand for. A map of New York is not New York, for example. Maps, books, and pictures are representations. Representations are objects that give us useful information about the world. They also omit useless information. For example, a tourist map of New York does not mark the position of manhole covers. Tourists do not need to know where the city's manhole covers are. The inclusion of unnecessary information on a map makes it harder to read and less useful.

> ***"I found that the great majority of the men of science . . . protested that mental imagery was unknown to them."***
>
> ***—Francis Galton, 1880***

Psychologists describe maps, books, and pictures as external representations. They are distinguished from internal representations, which are the ways that the brain stores and displays potentially useful information.

PICTURES IN THE BRAIN

People have theorized about internal representations for centuries. The Greek philosopher Aristotle (384–322 B.C.) argued that memory was like storing pictures in the head. Philosophers have debated this point ever since, but scientists only joined the debate around 120 years ago. In 1883 the English scientist Francis Galton (1822–1911) investigated the imagery used by the brain by asking a number of eminent friends to imagine the way their breakfast table had looked that morning. Quite a few said they had no mental picture of their breakfast table. They could remember what they had eaten, but did not think they had a picture of the table in their heads.

KEY POINTS

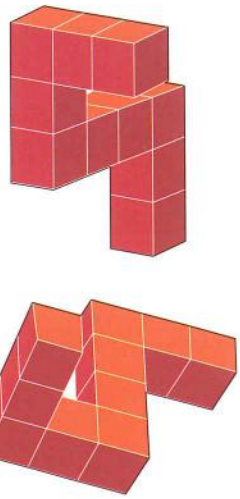
- Maps, books, and pictures are external representations. They give us useful information about the world and deliberately leave out unimportant information.
- Internal representations are the way the brain stores potentially useful information.
- When we imagine a picture, we use some of the same parts of the brain as when we see the picture.
- Imagined pictures (or mental images) are similar in some ways to photographs.
- Our memory for pictures is affected by the way that we interpret them.
- Although we can remember thousands of pictures, our memory for detail fades fast.
- Mental maps can take months of experience to establish.
- Categories are groups of objects that may include nouns, verbs, or abstract concepts.
- The defining attribute view of concepts states that all concepts can be described by a list of attributes. Each attribute is necessary, and together they define the concept.
- Category membership is not all-or-none, and members differ in their typicality. Psychological research has revealed, for example, that people classify a robin as a typical bird, but not a penguin.
- When people think about a category, they tend to think of its typical members.
- The brain may store information about categories in a feature-associative network. An alternative theory suggests that information is stored in a network of specific examples.
- Human brains contain general information about the usual events that occur in particular situations. Roger Schank and Robert Abelson referred to this information as scripts.
- Stories are classed by people according to their broad themes, or schemata.
- Our expectations about what generally happens in a situation affect our memory for what actually happened.
- Our ability to remember stories is influenced by their meaningfulness to us.
- Connectionism is a way of thinking about the mind that takes into account biological knowledge of the brain.

Mental Rotation

EXPERIMENT

Imagine you are looking at two pictures of the same object, but from different angles. People are usually able to deduce that the object is the same in each picture, but how do they come to this conclusion? Many people feel as if they are turning one object in their mind's eye until it is the same way up as the other. They can then tell that the two objects are the same.

Do people really turn objects in their mind's eye to compare them? In 1971 psychologists Roger Shepard and Jacqueline Metzler conducted a series of experiments to find out. They produced a number of drawings of a pair of objects. In some drawings the objects were identical; some were drawn at the same angle, but others were drawn at angles varying between 20 and 180 degrees to each other. A second set of pictures also showed a pair of objects at various angles, but one was the mirror image of the other.

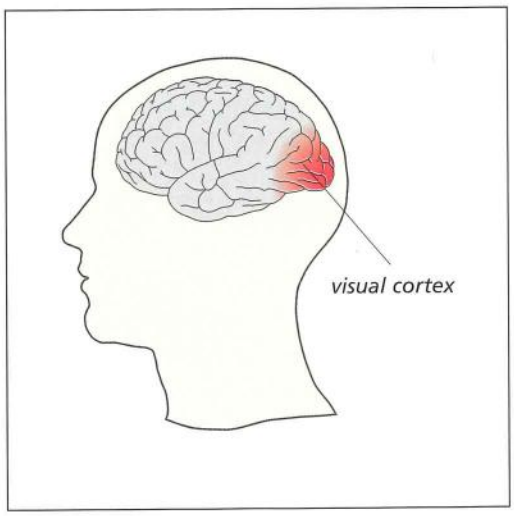


Shepard and Metzler showed images like these to subjects and asked whether or not they represented the same object at different angles. The researchers found a close link between the angle of rotation between the images and the time people took to decide whether or not the objects were identical.

The researchers showed the drawings to a group of people and timed how long they took to decide whether the two objects were the same. When they looked at the resulting data, Shepard and Metzler noticed that for every extra degree the object had been rotated through, people took a little longer to decide whether they were the same. It seemed that people were able to turn the images in their minds at a rate of about 50 degrees a second.

In a later experiment the scientists added an arrow to the drawings that indicated which way to mentally turn the objects. Most of the time the arrow told the truth. If it pointed in a clockwise direction, then it was more efficient to go clockwise rather than counterclockwise. However, a small number of the arrows pointed in the wrong direction. This misled the subjects into mentally rotating the objects the wrong way. Again, the researchers found a close link between the angle the image was rotated (and therefore the effective distance) and the time taken to recognize the image.

Shepard and Metzler's work on mental rotation sparked many interesting research projects. In 1982 Juan Hollard and Valerie Delius performed a similar experiment with pigeons. In contrast to the human subjects of Shepard and Metzler, the pigeons did not seem to mentally rotate the images. The time the birds took to decide whether images showed the same objects was not affected by differences in the angles between them.



The visual cortex lies toward the rear of the brain. It is connected via the optic nerves to the retina, a structure at the back of the eyeball that translates light into electrical nerve impulses. The activity of the visual cortex is high both when looking at an image and when remembering it later on.

Psychologists now know that people can generate mental images. Techniques that map brain function, such as fMRI (*see* Vol. 2, pp. 20–39), show which parts of a person's brain are most active. When people look at pictures, a part of the brain called the primary visual cortex starts working hard. When you take the picture away, the primary visual cortex relaxes. When you ask people to imagine the picture they have just seen, the primary visual cortex starts working hard again. In fact, it works almost as hard as when the picture was present. This research shows that the same

regions of the brain are highly active both when we see a picture and when we are are imagining it.

If imagining a picture we have just seen is just like seeing it, what about pictures we have never seen? People are good at forming mental images. Imagine a robin hopping across the ground. Now imagine that there is a cow standing behind it. The cow is bending its neck to look at the robin. Many people experience the same sequence of events as they imagine these pictures. First, they see a robin. The robin is large in their mental image, perhaps taking up half the picture. When they have to include the cow, they "zoom out" from the robin, or they make it smaller so there is enough space to fit the cow into the image.

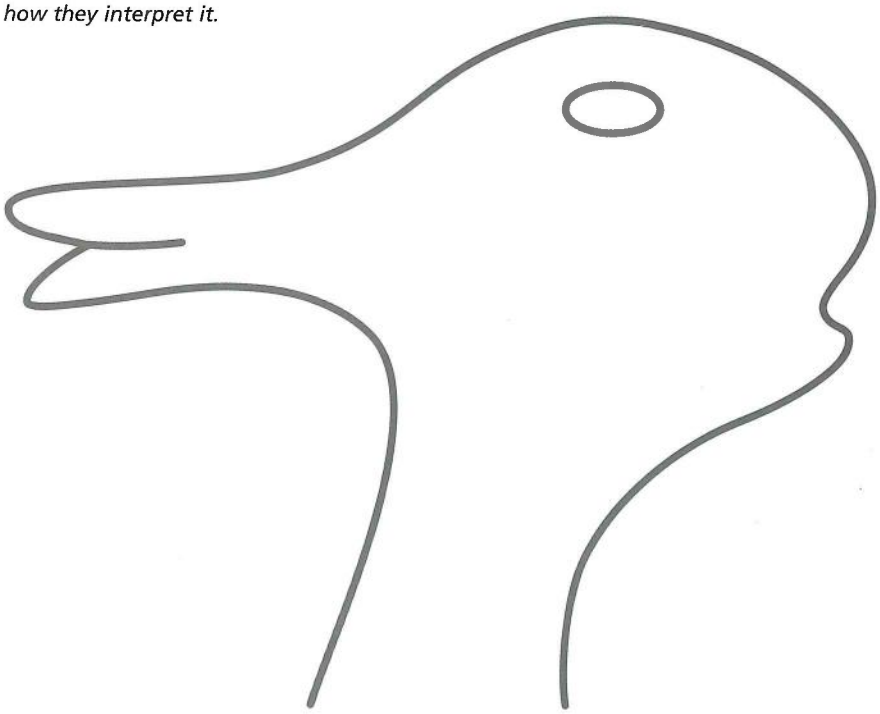
> ***"A word is like a key. When a word unlocks the correct stored memories, it is meaningful."***
>
> ***—Stephen Kosslyn, 1999***

In 1975 the American psychologist Stephen Kosslyn asked people to imagine a particular animal with another one standing next to it. For example, he asked someone to imagine a rabbit sitting next to an elephant. He then asked a question about the rabbit, such as "Does the rabbit have a pointed nose?" Kosslyn then asked a different person to imagine a rabbit, but this time with a fly sitting next to it. He asked that person the same question. Kosslyn found that people took longer to answer questions about the rabbit if it was standing next to the elephant.

When the subjects in the experiment made mental images, they had to "zoom in" or "zoom out" to fit both the animals in. The mental image of the rabbit is larger when the animal is next to a fly than when it is next to an elephant. Kosslyn showed that the time taken to answer questions about mental images was closely related to the amount of "zoom" required to bring details into view. If people are presented with large and small photographs of the same rabbit, they can spot whether the rabbit's nose is pointed more quickly when looking at the larger image. Kosslyn showed that the same was true for mental images. Just like photographs, the images we form in our minds have a limited size, and closer views are needed to determine small details.

It is tempting to describe mental images as photographs in the head. However, mental images do not represent what we have seen; rather, they represent our interpretation of what we have seen. In 1985 psychologists Deborah Chambers and Daniel Reisberg demonstrated this point in an elegant yet simple experiment. Show the image below to a friend very quickly before closing the book. Ask your friend what the picture showed, and whether there was anything else it could be. Next, ask your friend to draw the image as they remember it on a piece of paper, and then ask the questions again.

Most people think that the original picture shows either a duck or a rabbit. In fact, the picture is ambiguous. No one in the experiments could "see" both the duck and the rabbit in their mental image. However, almost all people could see the



Is this a duck, or is it a rabbit? The duck–rabbit experiment works best if the subject has never seen the object before, so why not try showing it to friends to see how they interpret it.