5

Cognition

- Logic, the formal way in which logical problems are solved, and PSYCHO-LOGIC, the way in which these problems are solved by the human mind, are not the same.
- Logical SYLLOGISMS are typically solved by creating a mental image of the objects and then reading off the answer from the image.
- Scientific thought, which involves CREATIVITY, often shows the CONFIRMATORY BIAS typical of Baconian science, rather than attempting to disprove hypotheses as required by Popperian science.
- Estimates of probability are often erroneous due to the HEURISTICS of REPRESENTATIVENESS, taking a stereotypical example as statistically representative, and AVAILABILITY, items more available to consciousness being treated as more frequent.

Cognition, or 'thinking', is the general intellectual process of weighing evidence, making decisions and coming to conclusions, using imperfect evidence from the senses, experience or memory. Its general nature, the wide range of problems tackled, and the absence of conscious introspection (answers apparently just appearing in consciousness unbidden) make it both the centre of modern psychology, and also one of its most difficult areas of study. Here we will look at three aspects of a vast problem.

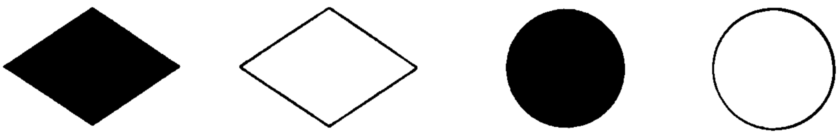
DEDUCTIVE LOGIC

Since people can solve logical problems it is assumed that they must use logic to solve them. That is not necessarily the case. My cat 'solves' complex three-dimensional problems when it catches a ball, although it knows little of Newton's laws or aerodynamics. Logic and PARA-LOGIC or PSYCHO-LOGIC (the ways logical problems are solved in our psyche) need not be the same. Consider a specific problem. You are given a simple SYLLOGISM, which states that 'If a patient's liver is enlarged then it is an abnormal liver'. You see a patient with a small liver. Can you assume it is normal? Many people will say 'yes', but that is an error. The rule does not say *only* large livers are abnormal.

Such errors of deduction are frequent, and yet usually we do not make serious errors of judgement. It seems that during a long chain of argument we make various guesses and assumptions. If we find a frank contradiction with earlier stages only then do we check and revise our earlier conclusions. If we decide our patient with a small liver has hepatic cirrhosis (i.e. an *abnormal* liver), then we will backtrack and spot our error, while if the liver is indeed normal then probably our error would stay undetected. Trial and error with continuous checking actually copes well with such problems.

Our problems with syllogisms suggest that deductive logic is not as straightforward psychologically as it might seem. Problem 1 below is an exercise in deductive logic for which 95% of students answer incorrectly. Try it yourself; the answer is at the end of the chapter.

Problem 1: Wason's THOG problem



In each of the above designs there is a particular shape and a particular colour such that any of the four designs, which has one, and only one, of the features, is called a THOG.

The black diamond is called a THOG. What can you say, if anything, about whether each of the three remaining designs is a THOG? Indicate for each figure whether it definitely is a THOG, definitely is not a THOG, or whether there is insufficient information to decide. The correct answer, with an explanation, will be found at the end of the chapter.

Adapted with permission from Wason P C (1977), in Johnson-Laird P N and Wason P C, Eds, *Thinking: readings in cognitive science*, Cambridge, Cambridge University Press, 114–28.

If logic alone is not used to solve problems in deductive logic, then how are they done? One method builds a mental image on which the various items can be placed, so that eventually the answer can then simply be read off. For the problem 'Arthur is taller than Bill, Bill is taller than Charles. Is Arthur taller than Charles?' we make a picture of Arthur, place a shorter Bill alongside, and place a yet shorter Charles alongside Bill. It is then immediately obvious that Arthur is taller than Charles. The evidence for such a process is that problem solving depends on how information is presented and the ease of making a picture. Problems are more difficult when abstract rather than concrete (e.g. 'A > B' rather than 'Arthur is taller than Bill'), when terms are inconsistent with reality (e.g. 'Britain is larger than the United States'), if items are in a non-obvious order (e.g. 'B > C;

A > B), if negatives are used (e.g. 'Arthur is not shorter than Bill'), and if mixed relations are used (e.g. 'A > B; C < B'). Since none of these manipulations affect the pure logical task, they must therefore alter the way in which we approach the tasks *psychologically*, with the implication that logical problems are not solved purely by the application of logic.

INDUCTIVE LOGIC

Inductive logic, a controversial topic in the philosophy of science, transcends specific evidence to produce a generalization. If I show you the numbers, '31,28,31,30,31' and ask what is next you might induce they are the days in each month, and hence that the next is 30, the number of days in June. Francis Bacon (1561–1626) suggested that science creates hypotheses ('they are days in the month') and confirms them by testing with the next member; if the prediction is correct we then accept the hypothesis as proven. That view of science is not now generally accepted, being replaced by the view of Sir Karl Popper (1902–) that hypotheses cannot be proved, only disproved. Although 30 might indeed be the correct next number, our hypothesis may still be wrong; the series might be '31,28,31,30, 31,30,31,28,31,30,31,30,31,28 . . .'. This differentiation of Baconian and Popperian science is seen also in the *psychology* of induction. People show a strong bias to prove theories, looking only for supportive evidence, and do not collect the awkward evidence that might disprove the theories. Problem 2 below gives an example of this CONFIRMATORY BIAS, which you can try for yourself.

Problem 2: The scientist and nature

This problem can only be tried out with the assistance of a friend. Sit the friend down and tell them that you are 'Nature' and that they are a 'Scientist' whose job is to understand the way in which Nature works. They should only tell you the rule for the working of Nature when they are fairly certain, in the same way that they would only publish a scientific paper when they are fairly certain of its correctness. The data for the 'experiments' consists of triplets of numbers synthesized by the Scientist, for which Nature then indicates whether they are valid or not. The actual rule with which Nature assesses the data is that valid sequences consist of numbers in ascending order of magnitude. To give the Scientist a start you tell them that the sequence '2, 4, 6' is a valid sequence. They then give you triplets of numbers until they announce the rule. Record the numbers they provide and the rules that they announce, until finally they announce the correct rule.

See the end of the chapter for three examples of the pattern being solved.

PROBABILITY

Assessments of risk in medicine involve probabilities. One in 20 of the population carry the gene for cystic fibrosis, 1 in 20 000 babies have phenylketonuria; three in a million young women on oral contraceptives suffer cerebrovascular complications per year. How well do people handle probability?

A problem. A medical officer of health surveys all families of six children in the area. In 72 families the children are born in the order Boy, Girl, Boy, Girl, Boy, Girl. In how many families are the children in the order Boy, Boy, Boy, Boy, Boy, Girl? Statistically unsophisticated people usually say much less than 72, although 72 is indeed the most likely figure. This error shows the error of REPRESENTATIVENESS; the first family is more typical of family composition, and is therefore assumed to be more common than the second, less typical family, although this is not actually the case. Problem 3 below gives another example for you to try.

Problem 3: Linda, the philosophy graduate

Here is a brief personality sketch. Read it and then carry out the task below.

Linda is 31 years old, single, out-spoken, and very intelligent. She studied philosophy at university. As a student she was deeply concerned with student politics, was involved in campaigns against racial and sexual discrimination, and took part in several demonstrations against nuclear power.

Below are eight statements. Please rank them according to their likelihood of describing Linda, using 1 for the most likely and 8 for the least likely.

a. Linda is a teacher in a primary school.
b. Linda works in a book shop and takes Yoga classes.
c. Linda is active in the feminist movement.
d. Linda is a psychiatric social worker.
e. Linda is a subscriber to New Statesman.
f. Linda is a bank clerk.
g. Linda sells insurance.
h. Linda is a bank clerk and is active in the feminist movement.

See the end of the chapter for an analysis of the problem.

Adapted with permission from Tversky A and Kahneman B (1982) in Kahneman B, Slovic P and Tversky A, (eds.) *Judgment under* *uncertainty*, Cambridge, Cambridge University Press, 84–98.

Another problem. Consider all the six letter English words which begin with the letter R (i.e. R-----). Now think of six letter words with an R in the third position (i.e. --R---). Which is more frequent? Most people say words beginning with R, although that is not actually the case. My word-processor found 1051 words beginning with R, and 1734 with R in the third position. However, we cannot search our memory so systematically; it is easier to find words beginning with R than with R in third place, and since the former are more AVAILABLE to consciousness we then assume they are more common. Problem 4 below gives another example, and Figure 5.2 shows results from a formal study of it.

Problem 4: Bus stops and sub-committees

For the two following problems, do not carry out any formal mathematical calculations; instead *estimate*, as quickly as possible, approximate answers to the questions.

a) A bus has 10 different stops between its Start and Finish. Consider a bus that makes exactly three stops on the route. How many different combinations of stops can it make? Alternatively consider a bus that makes exactly seven stops; how many combinations of stops can it make?

b) Consider a group of 10 people who have to form a committee. How many different sub-committees can be formed with just two members? How many sub-committees can be formed with exactly eight members?

Answers will be found at the end of the chapter.

Adapted with permission from Tversky A and Kahneman B (1982) in Kahneman B, Slovic P and Tversky A, Eds, *Judgement under uncertainty*, Cambridge, Cambridge University Press, 163–78.

These errors, which arise from the inappropriate application of the empirically derived working rules, or HEURISTICS, of availability and representativeness, can seriously distort probability estimates. Clinicians think cases typical of a disease are more common, and that cases remembered most easily (because bigger, nastier, bloodier, etc.) are more typical. Similarly the public estimates disease incidences from the reporting of cases in newspapers and media (Fig. 5.1). Diseases *thought* to be more common are those receiving most media exposure, and hence most *available*, even though they may not actually be more common.

These examples show thinking often goes wrong. Deductive logic is not always used accurately or systematically, inductive logic confirms rather than disproves hypotheses, and estimates of probability made from experience are frequently inaccurate. Such findings have important implications for diagnosis, scientific research and epidemiology.

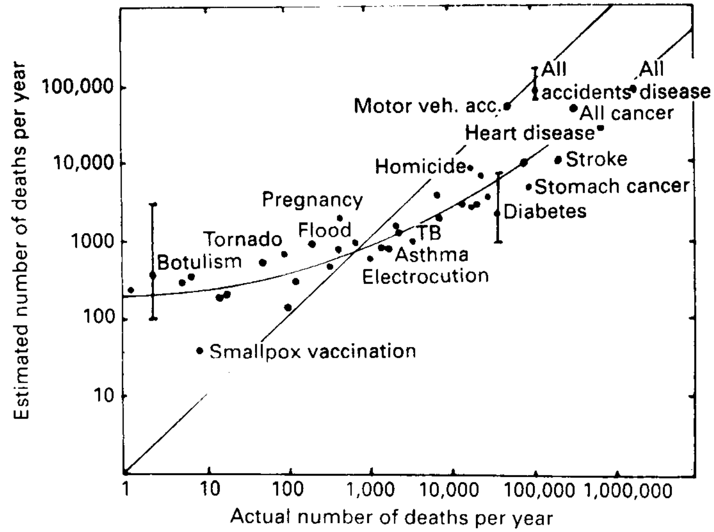


Fig. 5.1 Estimates made by American subjects of the numbers of deaths per year in the United States from a number of causes, compared with the actual number of deaths. The diagonal straight line indicates accurate estimates. The curved, fitted, line shows that, in general, rare causes of death are overestimated, and common causes underestimated. Causes of death that are overestimated relative to the general pattern (the curved line) are those which typically are reported more frequently in the media (road accidents, flood, tornado, botulism), whereas those under the curved line are typically under-reported by the media (stomach cancer, diabetes, electrocution, smallpox vaccination). Reproduced with permission from Slovic P, Fischoff B, and Lichtenstein S (1982), in Kahneman B, Slovic P and Tversky A, Eds, *Judgment under uncertainty*, Cambridge, Cambridge University Press.

Answer to problem 1: Wason's THOG problem

The white circle is definitely a THOG and the other two figures are definitely *not* THOGs. In many studies of medical students and other students, the most common response is to say that the white circle is definitely not a THOG and that the status of the other two figures cannot be determined.

The problem is difficult because of the phrase 'one, and only one, of these features'. In logic this is called an 'exclusive-OR', the whole being true only if *one* of the items is true, and false if both are true; it differs therefore from the more common use of 'or', the 'inclusive-OR', in which the whole is true if either *or both* components is true.

The key components of the figures are their shape and colour. The black diamond is a THOG and hence the defining characteristics of 'THOGness' must be either 'black and circle' or 'white and diamond', for then the black diamond would only have one characteristic, and therefore be a THOG. However, we do not know which pair of characteristics is correct. Assume that it is 'black and circle'. The white circle is then also a THOG (having only one characteristic, a circle) and the other two figures are not THOGs, having either none or two characteristics. However, the defining characteristics may be 'white and diamond'. If so then the white circle is still a THOG (because now it has the single feature of being white), and the other two figures still have none or two characteristics, and hence are not THOGs. Therefore without knowing the precise characteristics of being a THOG, formal deductive logic can nevertheless tell us the status of all the other figures.

The difficulty of this problem, especially when carried out only in our heads, and its straightforward demonstration by a simple written argument, shows that formal logic is not necessarily the manner in which psychological processes solve such problems.

Answer to problem 2: the scientist and nature

The usual error in this study is that subjects propose hypotheses which they have not attempted to falsify, but only to confirm, and hence the hypotheses are usually too narrow, encompassing only the limited range of data that have already been seen to be valid. As an example, below are shown three protocols of actual subjects tested by Wason. Words printed in italics are the 'final rules' produced by subjects, whereas words in roman type are working hypotheses spoken aloud by subjects. Subjects 4 and 6 show typical errors, whereas subject 2 forms working hypotheses which are then tested explicitly by falsification.

The demonstration shows clearly that repeated confirmations cannot prove a hypothesis, whereas a single falsification is sufficient to disprove it. In addition it also shows how scientific thought does not consist solely of formal, logical deduction, but that it is also has a large component of CREATIVITY or LATERAL THINKING, which can itself be explored scientifically using tasks such as this.

Subject 2. Female, aged 21.

'3 6 9: three goes into the second figure twice and into the third figure three times; 2 4 8: perhaps the figures have to have a lowest common denominator; 2 4 10: same reason; 2 5 10: the second number does not have to be divided by the first one; 10 6 4: the highest number must be last; 4 6 10: the first number must be the lowest; 2 3 5: it is only the order that counts; 4 5 6: same reason; 1 7 13: same reason.

The rule is that the figures must be in numerical order; (16 minutes).

Subject 4. Female, aged 19.

'8 10 12: two added each time; 14 16 18: even numbers in order

of magnitude; 20 22 24: same reason; 1 3 5: two added to preceding number.
The rule is that by starting with any number two is added each time to form the next number. 2 6 10: middle number is the arithmetic mean of the other two; 1 50 99: same reason.
The rule is that the middle number is the arithmetic mean of the other two. 3 10 17: same number, seven, added each time; 0 3 6: three added each time.
The rule is that the difference between two numbers next to each one is the same. 12 8 4: the same number is subtracted each time to form the next number.
The rule is adding a number, always the same one to form the next number. 1 4 9: any three numbers in order of magnitude.
The rule is any three numbers in order of magnitude.' (17 minutes).

Subject 6. Male, aged 23.
'8 10 12: step interval of two; 7 9 11: with numbers not divisible by two; 1 3 5: to see if rule may apply to numbers starting at two and upwards; 3 5 1: the numbers do not necessarily have to be in ascending or descending order; 5 3 1: could be in descending order.
The rule is that the three numbers must be in ascending order separated by intervals of two. 11 13 15: must have one number below ten in the series; 1 6 11: ascending series with regular step interval.
The rule is that the three numbers must be in ascending series and separated by regular step intervals.
The rule is that the first number can be arbitrarily chosen; the second number must be greater than the first and can be arbitrarily chosen; the third number is larger than the second by the same amount as the second is larger than the first. 1 3 13: any three numbers in ascending order.
The rule is that the three numbers need have no relationship with each other, except that the second is larger than the first and the third larger than the second.' (38 minutes).

Answers reprinted with permission of the author from Wason P C (1968), 'On the failure to eliminate hypotheses – a second look' in Wason P C and Johnson-Laird P H, *Thinking and Reasoning*, Harmondsworth, Penguin.

Answer to problem 3: Linda, the philosophy graduate

Only three of the statements, c, f and h are of interest, the rest being FILLERS, to obscure the true subject of the study. In a large group of subjects in a similar study, statement c, 'Linda is active in the feminist movement', was rated as second most likely, and statement f, 'Linda is a bank clerk' was rated as sixth most likely. Statement h, that 'Linda is a bank clerk and is active in the feminist movement' was

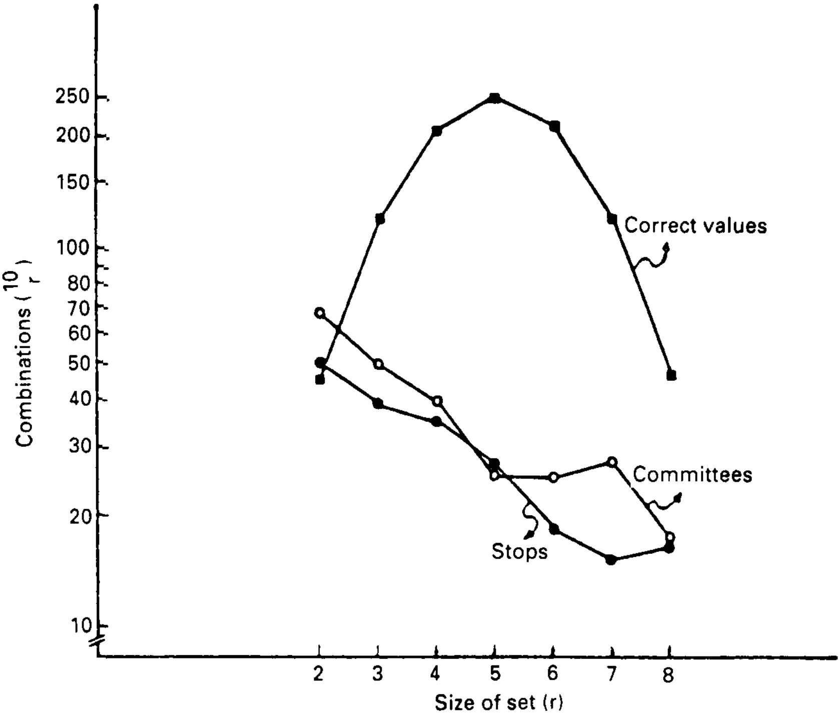


Fig. 5.2 Estimates of the number of combinations of items from 10 in the bus-stop and sub-committee problems described in problem 4. Each subject was asked to estimate the number of combinations of *r* items (between 2 and 8). Estimated values are compared with the correct values derived from probability theory. Reproduced with permission from Tversky A and Kahneman D (1982), in Kahneman B, Slovic P and Tversky A, Eds, *Judgment under uncertainty*, Cambridge, Cambridge University Press, 163–78.

rated as fourth most likely. Your results will show the same effect if item h is rated as more likely than the lower of c and f.

There must be some probability (P_c) that statement c is true, and similarly there is also a probability (P_f) that statement f is true. Since these probabilities must be less than one, then the probability that they are *both* true ($P_c \times P_f$) must be lower than the probability that either alone is true. But statement h, that 'Linda is a bank clerk and active in the feminist movement', is typically rated as *more* likely than one of its components.

The error arises due to a failure of the representative heuristic. The statements are regarded as typical of a particular sort of person, of a stereotype, and hence that stereotype is regarded as representative, so that the conjunction of the statements is accepted as more likely than its components.

Answer to problem 4: Bus stops and sub-committees

When presented with these problems, which are formally identical, statistically unsophisticated subjects, or even subjects who are sophisticated but under time pressure, will say that there are more patterns of three bus stops than of seven, and more committees of size two than of size eight (Fig. 5.2). In each problem the two answers should be identical (as can be seen intuitively by inverting the problem, by asking how many ways three stops can be *omitted* from the route, or how many ways can two people be *excluded* from the sub-committee).

The error occurs because of a failure of the availability heuristic. It is easier to think of combinations of three bus stops (1, 2 & 3; 1, 2 & 4; 1, 2 & 5; etc.) than of seven bus stops (1,2,3,4,5,6 & 7; 1,2,3,4,5,6 & 8; 1,2,3,4,5,6 & 9; etc.), and since the former are therefore more *available* to awareness they are judged as being more frequent.