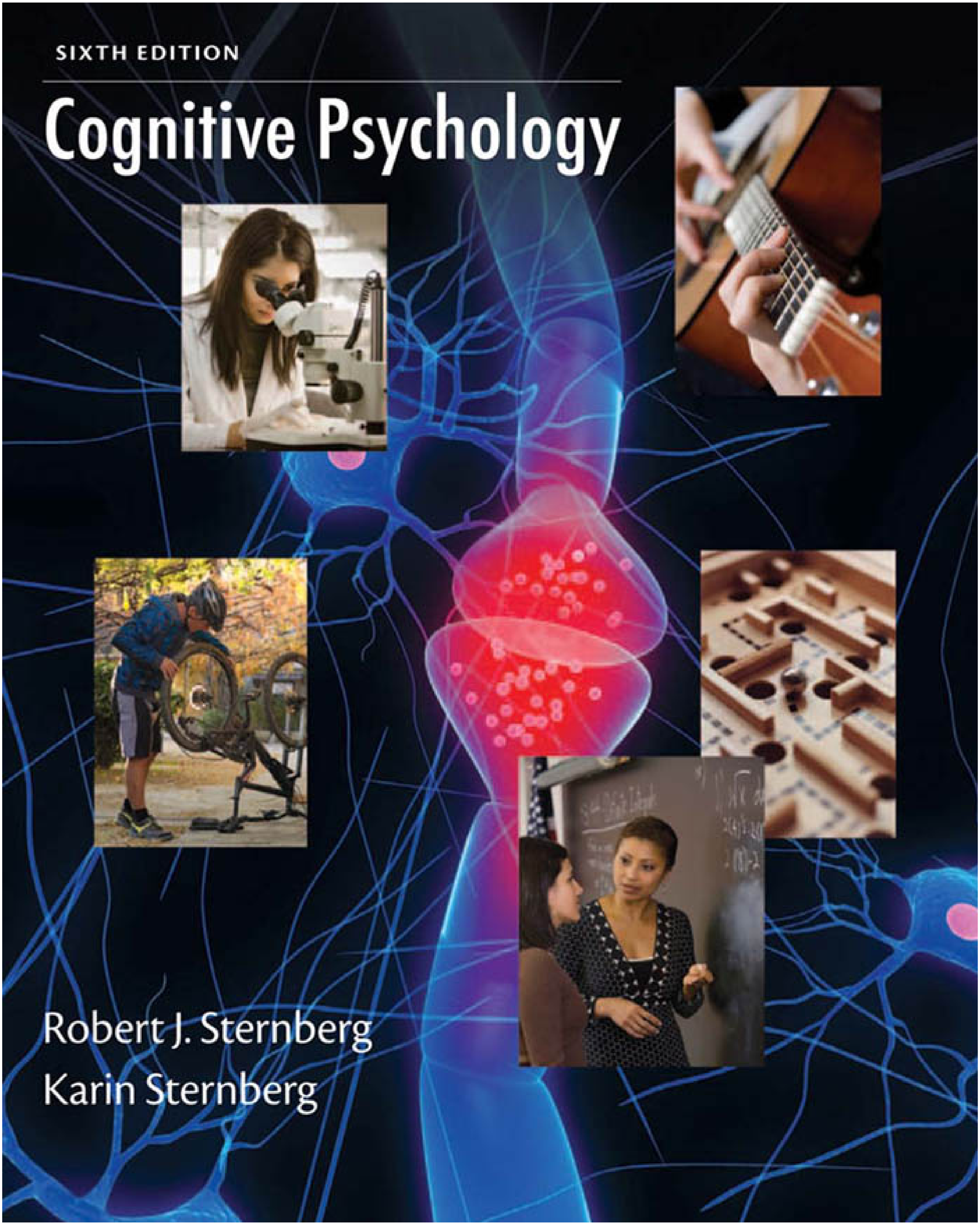
SIXTH EDITION
Cognitive Psychology
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CHAPTER

Decision Making and Reasoning

CHAPTER OUTLINE

Here are some questions we will explore in this chapter:

1. What are some of the strategies that guide human decision making?
2. What are some of the forms of deductive reasoning that people may use, and what factors facilitate or impede deductive reasoning?
3. How do people use inductive reasoning to make causal inferences and to reach other types of conclusions?
4. Are there any alternative views of reasoning?

■ BELIEVE IT OR NOT

Can a Simple Rule of Thumb Outsmart a Nobel Laureate's Investment Strategy?

If you wanted to invest your money in the stock market, would you rather rely on a Nobel laureate's strategy or on a simple heuristic (which is kind of a rule of thumb)? Researchers (De Miguel, 2007) compared the levels of success of 14 portfolio management strategies and compared them with the success of the simple 1/*N* heuristic. This heuristic simply suggests that you distribute your assets evenly among a given number of options. That is, each of the *N* options receives 1/*N* of the total investment. Among the other strategies evaluated was Nobel laureate Harry Markowitz's mean-variance model, according to which investors should optimize the trade-off between the mean and variance of a portfolio return. Markowitz suggested you minimize your risk and maximize your return by considering several factors, such as that sometimes certain groups of stocks go up in price whereas others go down (e.g., if the oil price goes up, airline profits will go down). The researchers found that the simple 1/*N* heuristic actually outperformed all 14 other models. In this chapter, you will learn more about how humans make decisions and what shortcuts (heuristics) they use when they are faced with uncertainty or more information than they can process.

Let's start this chapter with a puzzle. Read the following description in *Investigating Cognitive Psychology: The Conjunction Fallacy*, and rate the likelihood of the presented statements.

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The Conjunction Fallacy

Linda is 31 years old, single, outspoken, and very bright. She majored in philosophy. As a student, she was deeply concerned with issues of discrimination and social justice and also participated in anti-nuclear demonstrations.

Based on the preceding description, list the likelihood that the following statements about Linda are true (with 0 meaning completely unlikely and 100 meaning totally likely):

(a) Linda is a teacher in elementary school.
(b) Linda works in a bookstore and takes yoga classes.
(c) Linda is active in the feminist movement.
(d) Linda is a psychiatric social worker.
(e) Linda is a member of the League of Women Voters.
(f) Linda is a bank teller.
(g) Linda is an insurance salesperson.
(h) Linda is a bank teller and is active in the feminist movement.

(Tversky & Kahneman, 1983, p. 297).

If you are like 85% of the people Tversky and Kahneman studied, you rated the likelihood of item (h) as greater than the likelihood of item (f). Imagine a huge convention hall filled with the entire population of bank tellers. Now think about how many of them would be at a hypothetical booth for feminist bank tellers—a subset of the entire population of bank tellers. If Linda is at the booth for feminist bank tellers, she must, by definition, be in the convention hall of bank tellers. Hence, the likelihood that she is at the booth (i.e., she is a feminist bank teller) cannot logically be greater than the likelihood that she is in the convention hall (i.e., she is a bank teller). Nonetheless, given the description of Linda, we intuitively feel more likely to find her at the booth within the convention hall than in the entire convention hall, which makes no sense. This intuitive feeling is an example of a **fallacy**—erroneous reasoning—in judgment and reasoning.

In this chapter, we consider many ways in which we make judgments and decisions and use reasoning to draw conclusions. The first section deals with how we make choices and judgments. **Judgment and decision making** are used to select from among choices or to evaluate opportunities. Afterward, we consider various forms of reasoning. The goal of reasoning is to draw conclusions, either deductively from principles or inductively from evidence.

Judgment and Decision Making

In the course of our everyday lives, we constantly are making judgments and decisions. One of the most important decisions you may have made is that of whether and where to go to college. Once in college, you still need to decide on which courses to take. Later on, you may need to choose a major field of study. You make decisions about friends, dates, how to relate to your parents, how to spend money, and countless other things. How do you go about making these decisions?

Classical Decision Theory

The earliest models of how people make decisions are referred to as *classical decision theory*. Most of these models were devised by economists, statisticians, and philosophers, not by psychologists. Hence, they reflect the strengths of an economic perspective. One such strength is the ease of developing and using mathematical models for human behavior.

The Model of Economic Man and Woman

Among the early models of decision making crafted in the 20th century was that of *economic man and woman*. This model assumed three things:

1. Decision makers are fully informed regarding all possible options for their decisions and of all possible outcomes of their decision options.
2. They are infinitely sensitive to the subtle distinctions among decision options.
3. They are fully rational in regard to their choice of options (Edwards, 1954; see also Slovic, 1990).

The assumption of infinite sensitivity means that people can evaluate the difference between two outcomes, no matter how subtle the distinctions among options may be. The assumption of rationality means that people make their choices to maximize something of value, whatever that something may be.

Consider an example of how this model works. Suppose that a decision maker is considering which of two smartphones to buy. The decision maker, according to this model, will consider every aspect of each phone. The shopper will next decide on some objective basis how favorable each phone is on each aspect. The shopper then will weigh objectively each of the aspects in terms of how important it is. The favorability ratings will be multiplied by the weights. Then an overall averaged rating will be computed, taking into account all of the data. The shopper then will buy the smartphone with the best score. A great deal of economic research has been based on this model.

Subjective Expected Utility Theory

An alternative model makes greater allowance for the psychological makeup of each individual decision maker. According to *subjective expected utility theory*, the goal of human action is to seek pleasure and avoid pain. According to this theory, in making decisions, people will seek to maximize pleasure (referred to as positive utility) and to minimize pain (referred to as negative utility). In doing so, however, each of us uses calculations of two things. One is **subjective utility,** which is a calculation based on the individual's judged weightings of utility (value), rather than on objective criteria. The second is **subjective probability,** which is a calculation based on the individual's estimates of likelihood, rather than on objective statistical computations. The difference between this model and the former one is that here the ratings and weights are subjective, whereas in the former model they are supposedly objective.

Scientists soon noticed that human decision making is more complex than even this modified theory implies. In particular, when have you seriously considered every aspect of a decision, rated each possible choice, weighted the choice, and then used your favorability ratings and weights to compute an averaged evaluation of each of the choices? Probably not recently.

Heuristics and Biases

The world is full of information and stimuli of different kinds. In order to function properly and not get overwhelmed, we need to filter out the information we need among the many different pieces of information available to us. The same holds true for decision making. In order to be able to make a decision within a reasonable time frame, we need to reduce the available information to a manageable amount. Heuristics help us achieve this goal and at the same time decrease our efforts by allowing us to examine fewer cues or deal with fewer pieces of information (Shah & Oppenheimer, 2008). However, sometimes our thinking also gets biased by our tendencies to make decisions more simply. The mental shortcuts of heuristics and biases lighten the cognitive load of making decisions, but they also allow for a much greater chance of error. We will explore both heuristics and biases in more detail in the next section.

Heuristics

In the following sections, we discuss several heuristics people use in their daily decision making. **Heuristics** are mental shortcuts that lighten the cognitive load of making decisions.

Satisficing As early as the 1950s some researchers were beginning to challenge the notion of unlimited rationality. Not only did these researchers recognize that we humans do not always make ideal decisions and that we usually include subjective considerations in our decisions. But they also suggested that we humans are not entirely and boundlessly rational in making decisions. In particular, we humans are not necessarily irrational. Rather, we show **bounded rationality**—we are rational, but within limits (Simon, 1957).

Whereas classical decision theory suggested that people optimize their decisions, researchers began to realize that we have only limited resources and time to make a decision, so often we try to get as close as possible to optimizing, without actually optimizing.

One of the first heuristics that was formulated by researchers is termed satisficing (Simon, 1957). In **satisficing,** we consider options one by one, and then we select an option as soon as we find one that is satisfactory or just good enough to meet our minimum level of acceptability. When there are limited working-memory resources available, the use of satisficing for making decisions may be increased (Chen & Sun, 2003). Satisficing is also used in industrial contexts in which too much information can impair the quality of decisions, as in the selection of suppliers in electronic marketplaces (Chamodrakas, et al., 2010).

Of course, satisficing is only one of several strategies people can use. The appropriateness of this strategy will vary with the circumstance. For example, satisficing might be a reasonable strategy if you are in a hurry to buy a pack of gum and then catch a train or a plane, but a poor strategy for diagnosing a disease.

Elimination by Aspects We sometimes use a different strategy when faced with far more alternatives than we feel that we reasonably can consider in the time we have available (Tversky, 1972a, 1972b). In such situations, we do not try to manipulate

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According to Herbert Simon, people often satisfice when they make important decisions, such as which car to buy. They decide based on the first acceptable alternative that comes along.

mentally all the weighted attributes of all the available options. Rather, we use a process of **elimination by aspects**, in which we eliminate alternatives by focusing on aspects of each alternative, one at a time. If you are trying to decide which college to attend, the process of elimination by aspects might look like this:

- focus on one aspect (attribute) of the various options (the cost of going to college);
- form a minimum criterion for that aspect (tuition must be under $20,000 per year);
- eliminate all options that do not meet that criterion (e.g., Stanford University is more than $30,000 and would be eliminated);
- for the remaining options, select a second aspect for which we set a minimum criterion by which to eliminate additional options (the college must be on the West Coast); and
- continue using a sequential process of elimination of options by considering a series of aspects until a single option remains (Dawes, 2000).

Here is another example of elimination by aspects. In choosing a car to buy, we may focus on total price as an aspect. We may choose to dismiss factors, such as maintenance costs, insurance costs, or other factors that realistically might affect the money we will have to spend on the car in addition to the sale price. Once we have weeded out the alternatives that do not meet our criterion, we choose another aspect. We set a criterion value and weed out additional alternatives. We continue in this way. We weed out more alternatives, one aspect at a time, until we are left with a single option. In practice, it appears that we may use some elements of elimination by aspects or satisficing to narrow the range of options to just a few. Then we use more thorough and careful strategies. Examples would be those suggested by subjective expected utility theory. They can be useful for selecting among the few remaining options (Payne, 1976).

We often use mental shortcuts and even biases that limit and sometimes distort our ability to make rational decisions. One of the key ways in which we use mental shortcuts centers on our estimations of probability. Consider some of the strategies used by statisticians when calculating probability. They are shown in Table 12.1.

Another kind of probability is *conditional probability*, which is the likelihood of one event, given another. For example, you might want to calculate the likelihood

Table 12.1 Rules of Probability

Hypothetical Example	Calculation of Probability
Lee is one of 10 highly qualified candidates applying for one scholarship. What are Lee's chances of getting the scholarship?	Lee has a 0.1 chance of getting the scholarship.
If Lee is one of 10 highly qualified scholarship students applying for one scholarship, what are Lee's chances of not getting the scholarship?	$1 - 0.1 = 0.9$ Lee has a 0.9 chance of not getting the scholarship.
Lee's roommate and Lee are among 10 highly qualified scholarship students applying for one scholarship. What are the chances that one of the two will get the scholarship?	$0.1 + 0.1 = 0.2$ There is a 0.2 chance that one of the two roommates will get the scholarship.

of receiving an "A" for a cognitive psychology course, given that you receive an "A" on the final exam. The formula for calculating conditional probabilities in light of evidence is known as *Bayes's theorem*. It is quite complex, so most people do not use it in everyday-reasoning situations. Nonetheless, such calculations are essential to evaluating scientific hypotheses, forming realistic medical diagnoses, analyzing demographic data, and performing many other real-world tasks. (For a highly readable explanation of Bayes's theorem, see Eysenck & Keane, 1990, pp. 456–458.)

Representativeness Heuristic Before you read about representativeness, try the following problem from Kahneman and Tversky (1972).

All the families having exactly six children in a particular city were surveyed. In 72 of the families, the exact order of births of boys and girls was G B G B B G (G, girl; B, boy).

What is your estimate of the number of families surveyed in which the exact order of births was B G B B B B?

Most people judging the number of families with the B G B B B B birth pattern estimate the number to be less than 72. Actually, the best estimate of the number of families with this birth order is 72, the same as for the G B G B B G birth order. The expected number for the second pattern would be the same because the gender for each birth is independent (at least, theoretically) of the gender for every other birth. For any one birth, the chance of a boy (or a girl) is one of two. Thus, any particular pattern of births is equally likely $(1/2)^6$, even B B B B B B or G G G G G G.

Why do many of us believe some birth orders to be more likely than others? In part, the reason is that we use the heuristic of representativeness. In **representativeness,** we judge the probability of an uncertain event according to:

1. how obviously it is similar to or representative of the population from which it is derived; and
2. the degree to which it reflects the salient features of the process by which it is generated (such as randomness) (see also Fischhoff, 1999; Johnson-Laird, 2000, 2004).

For example, people believe that the first birth order is more likely because: (1) it is more representative of the number of females and males in the population; and (2) it looks more like a random order than does the second birth order. In fact, of course, either birth order is equally likely to occur by chance.

Similarly, suppose people are asked to judge the probability of flips of a coin yielding the sequence H T H H T H (H, heads; T, tails). Most people will judge it as higher than they will if asked to judge the sequence H H H H T H. If you expect a sequence to be random, you tend to view as more likely a sequence that "looks random." Indeed, people often comment that the numbers in a table of random numbers "don't look random." The reason is that people underestimate the number of runs of the same number that will appear wholly by chance. We frequently reason in terms of whether something appears to represent a set of accidental occurrences, rather than actually considering the true likelihood of a given chance occurrence. This tendency makes us more vulnerable to the machinations of magicians, charlatans, and con artists. Any of them may make much of their having predicted the realistic probability of a non-random-looking event. For example, in one out of ten cases two people in a group of 40 (e.g., in a classroom or a small nightclub audience) will share a birthday (the same month and day). In a group of 14 people, there are better than even odds that two people will have birthdays within a day of each other (Krantz, 1992).

That we frequently rely on the representativeness heuristic may not be terribly surprising. It is easy to use and often works. For example, suppose we have not heard a weather report prior to stepping outside. We informally judge the probability that it will rain. We base our judgment on how well the characteristics of this day (e.g., the month of the year, the area in which we live, and the presence or absence of clouds in the sky) represent the characteristics of days on which it rains. Another reason that we often use the representativeness heuristic is that we mistakenly believe that small samples (e.g., of events, of people, of characteristics) resemble in all respects the whole population from which the sample is drawn (Tversky & Kahneman, 1971). We particularly tend to underestimate the likelihood that the characteristics of a small sample (e.g., the people whom we know well) of a population inadequately represent the characteristics of the whole population.

We also tend to use the representativeness heuristic more frequently when we are highly aware of anecdotal evidence based on a very small sample of the population. This reliance on anecdotal evidence has been referred to as a "man-who" argument (Nisbett & Ross, 1980). When presented with statistics, we may refute those data with our own observations of, "I know a man who . . ." For example, faced with statistics on coronary disease and high-cholesterol diets, someone may counter with, "I know a man who ate whipped cream for breakfast, lunch, and dinner, smoked two packs of cigarettes a day, and lived to be 110 years old. He would have kept going but he was shot through his perfectly healthy heart by a jealous lover."

One reason that people misguidedly use the representativeness heuristic is because they fail to understand the concept of base rates. **Base rate** refers to the prevalence of an event or characteristic within its population of events or characteristics. In everyday decision making, people often ignore base-rate information, but it is important to effective judgment and decision making. In many occupations, the use of base-rate information is essential for adequate job performance. For example, suppose a doctor was told that a 10-year-old boy was suffering chest pains. The doctor would be much less likely to worry about an incipient heart attack than if the doctor were told that a 60-year-old man had the identical symptom. Why? Because the base rate of heart attacks is much higher in 60-year-old men than in 10-year-old boys. Of course, people use other heuristics as well. People can be taught how to use base rates to improve their decision making (Gigerenzer, 1996; Koehler, 1996).

Availability Heuristic Most of us at least occasionally use the **availability heuristic,** in which we make judgments on the basis of how easily we can call to mind what we perceive as relevant instances of a phenomenon (Tversky & Kahneman, 1973; see also Fischhoff, 1999; Sternberg, 2000). For example, consider the letter *R*. Are there more words in the English language that begin with the letter *R* or that have *R* as their third letter? Most respondents say that there are more words beginning with the letter *R* (Tversky & Kahneman, 1973). Why? Because generating words beginning with the letter *R* is easier than generating words having *R* as the third letter. In fact, there are more English-language words with *R* as their third letter. The same happens to be true of some other letters as well, such as *K*, *L*, *N*, and *V*.

The availability heuristic also has been observed in regard to everyday situations. In one study, married partners individually stated which of the two partners performed a larger proportion of each of 20 different household chores (Ross & Sicoly, 1979). These tasks included mundane chores such as grocery shopping or preparing breakfast. Each partner stated that he or she more often performed about 16 of the 20 chores. Suppose each partner was correct. Then, to accomplish 100% of the work in a household, each partner would have to perform 80% of the work. Similar outcomes emerged from questioning members of college basketball teams and joint participants in laboratory tasks.

Although clearly 80% + 80% does not equal 100%, we can understand why people may engage in using the availability heuristic when it confirms their beliefs about themselves. However, people also use the availability heuristic when its use leads to a logical fallacy that has nothing to do with their beliefs about themselves. Two groups of participants were asked to estimate the number of words of a particular form that would be expected to appear in a 2,000-word passage. For one group the form was _ _ _ _ing (i.e., seven letters ending in *-ing*). For the other group the form was _ _ _ _ _n_ (i.e., seven letters with *n* as the second-to-the-last letter). Clearly, there cannot be more seven-letter words ending in *-ing* than seven-letter words with *n* as the second-to-the-last letter. But the greater availability of the former led to estimates of probability that were more than twice as high for the former, as compared with the latter (Tversky & Kahneman, 1983).

Anchoring A heuristic related to availability is the *anchoring-and-adjustment heuristic*, by which people adjust their evaluations of things by means of certain reference points called *end-anchors*. Before you read on, quickly (in less than 5 seconds) calculate in your head the answer to the following problem:

$$8 \times 7 \times 6 \times 5 \times 4 \times 3 \times 2 \times 1$$

Now, quickly calculate your answer to the following problem:

$$1 \times 2 \times 3 \times 4 \times 5 \times 6 \times 7 \times 8$$

Two groups of participants estimated the product of one or the other of the preceding two sets of eight numbers (Tversky & Kahneman, 1974). The median (middle) estimate for the participants given the first sequence was 2,250. For the participants given the second sequence, the median estimate was 512. (The actual product is 40,320 for both.) The two products are the same, as they must be because the numbers are exactly the same (applying the commutative law of multiplication). Nonetheless, people provide a higher estimate for the first sequence than for the second because their computation of the anchor—the first few digits multiplied by each other—renders a higher estimate from which they make an adjustment to reach a final estimate. Furthermore, the adjustment people make in response to an anchor is bigger when the anchor is rounded than when it seems to be a precise value. For example, when the price of a TV set is given as $3,000, people adjust their estimate of its production costs more than when the price is given as $2,991 (Janiszewski & Uy, 2008). Anchoring effects occur in a variety of settings, for example at art auctions, where the price of paintings is anchored by the price the painting achieved in prior sales, or monthly economic forecasts, which are anchored toward the past month (Beggs & Graddy, 2009; Campbell & Sharpe, 2009).

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Although riding a car is statistically much more risky than riding in a plane, people often feel less safe in a plane, in part because of the availability heuristic. People hear about every major U.S. plane crash that takes place, but they hear about relatively few car accidents.

Framing Another consideration in decision theory is the influence of *framing effects*, in which the way that the options are presented influences the selection of an option (Tversky & Kahneman, 1981). For instance, we tend to choose options that demonstrate risk aversion when we are faced with an option involving potential gains. That is, we tend to choose options offering a small but certain gain rather

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Framing Effects

Suppose that you were told that 600 people were at risk of dying of a particular disease. Vaccine A could save the lives of 200 of the people at risk. With Vaccine B, there is a 0.33 likelihood that all 600 people would be saved, but there is also a 0.66 likelihood that all 600 people will die. Which option would you choose? Explain how you made your decision.

We tend to choose options that demonstrate risk seeking when we are faced with options involving potential losses. That is, we tend to choose options offering a large but uncertain loss rather than a smaller but certain loss (as is the case for Vaccine B), unless the uncertain loss is either tremendously greater or only modestly less than certain. Here is an interesting example.

Suppose that for the 600 people at risk of dying of a particular disease, if Vaccine C is used, 400 people will die. However, if Vaccine D is used, there is a 0.33 likelihood that no one will die and a 0.66 likelihood that all 600 people will die. Which option would you choose?

In the preceding situations, most people will choose Vaccine A and Vaccine D.

Now, try this:

- Compare the number of people whose lives will be lost or saved by using Vaccines A or C.
- Compare the number of people whose lives will be lost or saved by using Vaccines B or D.

The expected value is identical for Vaccines A and C; it is also identical for Vaccines B and D. Our predilection for risk aversion versus risk seeking leads us to quite different choices based on the way in which a decision is framed, even when the actual outcomes of the choices are the same.

than a larger but uncertain gain, unless the uncertain gain is either tremendously greater or only modestly less than certain. The first example in *Investigating Cognitive Psychology: Framing Effects* is only slightly modified from one used by Tversky and Kahneman (1981).

Framing effects have public relevance. Messages from politicians, political parties, and other stakeholders can be framed in different ways and therefore take on a different connotation. A message about the Ku Klux Klan, for example, can be framed either as a free-speech issue or as a public-safety issue. Framing effects are less persuasive when they come from sources of low credibility (Druckman, 2001).

Biases

In the next section, we discuss several biases that frequently occur when people make decisions: illusory correlation, overconfidence, and hindsight bias.

Illusory Correlation We are predisposed to see particular events or attributes and categories as going together, even when they do not. This phenomenon is called **illusory correlation** (Hamilton & Lickel, 2000). In the case of events, we may see spurious cause-effect relationships. In the case of attributes, we may use personal prejudices to form and use stereotypes (perhaps as a result of using the representativeness heuristic). For example, suppose we expect people of a given political party to show particular intellectual or moral characteristics. The instances in which people show those characteristics are more likely to be available in memory and recalled more easily than are instances that contradict our biased expectations. In other words, we perceive a correlation between the political party and the particular characteristics.

Illusory correlation even may influence psychiatric diagnoses based on projective tests such as the Rorschach and the Draw-a-Person tests (Chapman & Chapman, 1967, 1969, 1975). Researchers suggested a false correlation in which particular diagnoses would be associated with particular responses. For example, they suggested that people diagnosed with paranoia tend to draw people with large eyes more than do people with other diagnoses (which is not true). However, what happened when individuals expected to observe a correlation between a drawing with large eyes and the associated diagnosis of paranoia? They tended to see the illusory correlation, although no actual correlation existed.

Overconfidence Another common error is **overconfidence**—an individual's overvaluation of her or his own skills, knowledge, or judgment. For example, people answered 200 two-alternative statements, such as "Absinthe is (a) a liqueur, (b) a precious stone." (Absinthe is a licorice-flavored liqueur.) People were asked to choose the correct answer and to state the probability that their answer was correct (Fischhoff, Slovic, & Lichtenstein, 1977). People were overconfident. For example, when people were 100% confident in their answers, they were right only 80% of the time. In general, people tend to overestimate the accuracy of their judgments (Kahneman & Tversky, 1996). Why are people overconfident? One reason is that people may not realize how little they know. Another is that they may not realize that their information comes from unreliable sources (Carlson, 1995; Griffin & Tversky, 1992).

People sometimes make poor decisions as a result of overconfidence. These decisions are based on inadequate information and ineffective decision-making strategies. Why we tend to be overconfident in our judgments is not clear. One simple explanation is that we prefer not to think about being wrong (Fischhoff, 1988).

Businesses sometimes use our tendencies toward overconfidence to their own advantage. Think about the American cell phone market, for example. Many contracts consist of a monthly fee that includes usage of a certain amount of air-time minutes. If a person exceeds this amount, he or she will incur steep charges. There are good reasons for such a contract model, but from the company's point of view, not from the consumer's point of view. Consumers tend to overestimate their usage of minutes, so they are willing to pay for a high-minute usage in advance. At the same time, they are confident they will not go over their limit, so they do not even realize the high costs they will incur if they exceed their free air-time minutes, until they actually discover they have gone over (Grubb, 2009).

Hindsight Bias Finally, a bias that can affect all of us is **hindsight bias**—when we look at a situation retrospectively, we believe we easily can see all the signs and events leading up to a particular outcome (Fischhoff, 1982; Wasserman, Lempert, & Hastie, 1991). For example, suppose people are asked to predict the outcomes of psychological experiments in advance of the experiments. People rarely are able to predict the outcomes at better-than-chance levels. However, when people are told of the outcomes of psychological experiments, they frequently comment that these outcomes were obvious and could easily have been predicted in advance. Similarly, when intimate personal relationships are in trouble, people often fail to observe signs of the difficulties until the problems reach crisis proportions. By then, it may be too late to save the relationship. In retrospect, people may ask themselves, "Why didn't I see it coming? It was so obvious! I should have seen the signs."

Hindsight bias hinders learning because it impairs one's ability to compare one's expectations with the outcome—if one always expected the outcome that eventually happened, one thinks there is nothing to learn! And indeed, studies show that investment bankers' performance suffers when they exhibit a strong hindsight bias. Curiously, experience does not reduce the bias (Biais & Weber, 2009).

Fallacies

Heuristics and fallacies are often studied together because they go hand in hand. The application of a heuristic to make a decision may lead to fallacies in thinking. Therefore, when we discuss some fallacies, we refer back to some of the heuristics in association with which they often occur.

Gambler's Fallacy and the Hot Hand

Gambler's fallacy is a mistaken belief that the probability of a given random event, such as winning or losing at a game of chance, is influenced by previous random events. For example, a gambler who loses five successive bets may believe that a win is therefore more likely the sixth time. He feels that he is "due" to win. In truth, of course, each bet (or coin toss) is an independent event that has an equal probability of winning or losing. The gambler is no more likely to win on the 6th bet than on the 1st—or on the 1001st. Gambler's fallacy is an example of the representative heuristic gone awry: One believes that the pattern representative of past events is now likely to change.

A tendency opposite to that of gambler's fallacy is called the "hot hand" effect. It refers to a belief that a certain course of events will continue. Apparently, both professional and amateur basketball players, as well as their fans, believe that a player's chances of making a basket are greater after making a previous shot than after missing one. However, the statistical likelihoods (and the actual records of players) show no such tendency (Gilovich, Vallone, & Tversky, 1985; see also Roney & Trick, 2009). Shrewd players take advantage of this belief and closely guard opponents immediately after they have made baskets. The reason is that the opposing players will be more likely to try to get the ball to these perceived "streak shooters."

Conjunction Fallacy

Do you remember the experiment described in the section on the availability heuristic where people were asked to judge how often the form _ _ _ _ing (i.e., seven letters ending in *–ing)* or _ _ _ _ _n_ (i.e., seven letters with *n* as the second-to-the-last letter) appears in a passage? The availability heuristic might lead to the conjunction fallacy. In the *conjunction fallacy,* an individual gives a higher estimate for a subset of events (e.g., the instances of *-ing*) than for the larger set of events containing the given subset (e.g., the instances of *n* as the second-to-the-last letter). This fallacy also is illustrated in the chapter opening vignette regarding Linda.

People often mistakenly believe in the gambler's fallacy. They think that if they have been unlucky in their gambles, it is time for their luck to change. In fact, success or failure in past gambles has no effect on the likelihood of success in future ones.

The representativeness heuristic may also induce individuals to engage in the conjunction fallacy during probabilistic reasoning (Tversky & Kahneman, 1983; see also Dawes, 2000). Tversky and Kahneman asked college students:

> *Please give your estimate of the following values: What percentage of the men surveyed [in a health survey] have had one or more heart attacks?*
>
> *What percentage of the men surveyed both are over 55 years old and have had one or more heart attacks? (p. 308)*

The mean estimates were 18% for the former and 30% for the latter. In fact, 65% of the respondents gave higher estimates for the latter (which is clearly a subset of the former). However, people do not always engage in the conjunction fallacy. Only 25% of respondents gave higher estimates for the latter question than for the former when the questions were rephrased as frequencies rather than as percentages (e.g., "how many of the 1,000 men surveyed have had one or more heart attacks?"). The way statistical information is presented influences how likely it is that people draw the correct conclusions (see also Gigerenzer & Hoffrage, 1995).

Sunk-Cost Fallacy

An error in judgment that is quite common in people's thinking is the *sunk-cost fallacy* (Dupuy, 1998, 1999; Strough et al., 2008). This fallacy represents the decision to continue to invest in something simply because one has invested in it before and one hopes to recover one's investment. For example, suppose you have bought a car. It is a lemon. You already have invested thousands of dollars in getting it fixed. Now you have another major repair on it confronting you. You have no reason to believe that this additional repair really will be the last in the string of repairs. You think about how much money you have spent on repairs and reason that you need to do the additional repair to justify past amounts already spent. So you do the repair rather than buy a new car. You have just committed the sunk-cost fallacy. The problem is that you already have lost the money on those repairs. Throwing more money into the repairs will not get that money back. Your best bet may well be to view the money already spent on repairs as a "sunk cost" and then buy a new car.

Similarly, suppose you go on a two-week vacation. You are having a miserable time. Should you go home a week early? You decide not to, thereby attempting to justify the investment you have already made in the vacation. Again, you have committed the sunk-cost fallacy. Instead of viewing the money simply as lost on an unfortunate decision, you have decided to throw more money away. But you do so without any hope that the vacation will get any better.

The Gist of It: Do Heuristics Help Us or Lead Us Astray?

Heuristics do not always lead to wrong judgments or poor decisions (Cohen, 1981). Indeed, we use these mental shortcuts because they are so often right. Sometimes, they are amazingly simple ways of drawing sound conclusions. For example, a simple heuristic, *take-the-best,* can be amazingly effective in decision situations (Gigerenzer & Brighton, 2009; Gigerenzer & Goldstein, 1996; Marsh, Todd, & Gigerenzer, 2004). The rule is simple. In making a decision, identify the single most important criterion to you for making that decision. For example, when you choose a new automobile, the most important factor might be good gas mileage, safety, or appearance. Make your choice on the basis of that attribute.

On its face this heuristic would seem to be inadequate. In fact, it often leads to very good decisions. It produces even better decisions, in many cases, than far more complicated heuristics. Thus, heuristics can be used for good as well as for bad decision making. Indeed, when we take people's goals into account, heuristics often are amazingly effective (Evans & Over, 1996).

The take-the-best heuristic belongs to a class of heuristics called fast-and-frugal heuristics (FFH). As the name implies, this class of heuristics is based on a small fraction of information, and decisions using the heuristics are made rapidly. These heuristics set a standard of rationality that considers constraints including, time, information, and cognitive capacity (Bennis & Pachur, 2006; Gigerenzer, Todd, & the ABC Research Group, 1999). Furthermore, these models consider the lack of optimum solutions and environments in which the decision is taking place. As a result, these heuristics provide a good description of decision making during sports.

Fast-and-frugal heuristics can form a comprehensive description of how people behave in a variety of contexts. These behaviors vary from lunch selections to how physicians decide whether to prescribe medication for depression, to making business decisions (Goldstein & Gigerenzer, 2009; Scheibehenne, Miesler, & Todd, 2007; Smith & Gilhooly, 2006).

The work on heuristics and biases shows the importance of distinguishing between intellectual competence and intellectual performance as it manifests itself in daily life. Even experts in the use of probability and statistics can find themselves falling into faulty patterns of judgment and decision making in their everyday lives. People may be intelligent in a conventional, test-based sense. Yet they may show exactly the same biases and faulty reasoning that someone with a lower test score would show. People often fail to fully utilize their intellectual competence in their daily life. There can even be a wide gap between the two (Stanovich, 2010). Thus, if we wish to be intelligent in our daily lives and not just on tests, we have to be street smart. In particular, we must be mindful of applying our intelligence to the problems that continually confront us.

Opportunity Costs

Opportunity costs are the prices paid for availing oneself of certain opportunities. Taking opportunity costs into account is important when judgments are made. For example, suppose you see a great job offer in San Francisco. You always wanted to live there. You are ready to take it. Before you do, you need to ask yourself a question: What other things will you have to forego to take advantage of this opportunity? An example might be the chance, on your budget, of having more than 500 square feet of living space. Another might be the chance to live in a place where you probably do not have to worry about earthquakes. Any time you take advantage of an opportunity, there are opportunity costs. They may, in some cases, make what looked like a good opportunity look like not such a great opportunity at all. Ideally, you should try to look at these opportunity costs in an unbiased way.

Naturalistic Decision Making

Many researchers contend that decision making is a complex process that cannot be reproduced adequately in the laboratory because real decisions are frequently made in situations where there are high stakes. For instance, the mental state and cognitive pressure experienced by an emergency room doctor encountering a patient is difficult to reproduce outside a clinical setting.

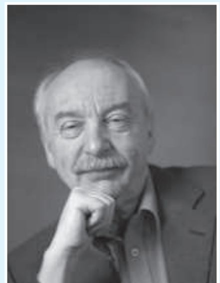
This criticism has led to the development of a field of study that is based on decision making in natural environments (naturalistic decision making). Much of the research completed in this area is from professional settings, such as hospitals or nuclear plants (Carroll, Hatakenaka, & Rudolph, 2006; Galanter & Patel, 2005; Roswarski, & Murray, 2006). These situations share a number of features, including the challenges of ill-structured problems, changing situations, high risk, time pressure, and sometimes, a team environment (Orasanu & Connolly, 1993). A number of models are used to explain performance in these high-stakes situations. These models allow for the consideration of cognitive, emotional, and situational factors of skilled decision makers; they also provide a framework for advising future decision makers (Klein, 1997; Lipshitz et al., 2001). For instance, Orasanu (2005) developed recommendations for training astronauts to be successful decision makers by evaluating what makes current astronauts successful, such as developing team cohesion and managing stress. Naturalistic decision making can be applied to a broad range of behaviors and environments. These applications can include individuals as diverse as badminton players, railroad controllers, and NASA astronauts (Farrington-Darby et al., 2006; Macquet & Fleurance, 2007; Orasanu, 2005; Patel, Kaufman, & Arocha, 2002).

Group Decision Making

Groups form decisions differently than individuals. Often, there are benefits to making decisions in groups. However, a phenomenon called "groupthink" can occur that seriously impairs the quality of decisions made. In the next sections we will explore group decision making in more detail.

IN THE LAB OF GERD GIGERENZER

Making Decisions in an Uncertain World



GERD GIGERENZER

If you were in my lab, you would talk to pre-docs, post-docs, and researchers from ten different disciplines as well as nationalities. We investigate *bounded rationality*, that is, how humans make decisions in an *uncertain* world. This differs from the study of deductive reasoning, syllogisms, or classical decision theory, where all alternatives, consequences, and probabilities are known for certain. In the real world, omniscience is absent and surprises can happen; nevertheless, people have to make decisions, such as whom to trust, what medication to take, or how to invest money. How does this *rationality for mortals* work?

The first question we pose is descriptive: What heuristics do people rely on, consciously or unconsciously, to make decisions in an uncertain world? A heuristic is a strategy that focuses on the most relevant pieces of information and ignores the rest. We have investigated a number of these, including those relying on:

- recognition (the recognition and fluency heuristics),
- one good reason (such as *take-the-best*), and
- on the wisdom of others (such as *imitate-the-majority*).

The study of the *adaptive toolbox* investigates the heuristics used, their building blocks, and the core cognitive capacities they exploit.

Our second question is prescriptive: In what environment does a heuristic work, and where would it fail? To find answers, one needs to develop formal models of heuristics, using analysis and computer simulation. One surprising discovery we made is that simple heuristics that rely on only one good reason (such as take-the-best) can actually make more accurate predictions than can complex strategies such as multiple regression or neural networks. In contrast to what many textbooks still preach, this result shows that heuristics are not second-best, and that less information, computation, and time can lead to better decisions. In fact, unlike in certain worlds, in an uncertain world one needs to ignore part of the information to make good judgments.

The study of the *ecological rationality* of a given heuristic investigates in what world it succeeds.

The third question concerns intuitive design. Here we use the results of our research to design heuristics and environments that help experts and laypeople make better decisions. For instance, based on our work, physicians in Michigan hospitals use heuristics called *fast-and-frugal trees* when making ICU allocations. These simple heuristics mirror the sequential, intuitive thinking of doctors, are fast and frugal, and are nevertheless better than complex linear regression models at predicting heart attacks.

A particularly relevant aspect of intuitive design is risk communication. Consider the contraceptive pill scare in the United Kingdom. The media reported that third-generation pills increase the risk of potentially life-threatening blood clots (thrombosis) by 100%. Distressed by this news, many women stopped taking the pill, which led to unwanted pregnancies and an estimated 13,000 additional abortions in England and Wales. How big is 100%? The studies on which the warning was based had shown that out of every 7,000 women who took the earlier second-generation pill, about 1 had a thrombosis; this number increased to 2 among women who took third-generation pills. That is, the *absolute risk increase* was only 1 in 7,000 while the *relative risk increase* was indeed 100%. Had the media reported the absolute risks, few women would have panicked. The pill scare illustrates how citizens' fears are manipulated by framing numbers in a misleading and non-transparent way. We study and develop transparent representations—such as absolute risks and natural frequencies—that help people understand health statistics. During the last few years, I have trained some 1,000 physicians and dozens of U.S. federal judges in understanding risks, for instance when evaluating cancer screening or DNA tests. Few physicians and lawyers have been educated in risk communication, and this blind spot is an important area in which psychologists can apply their knowledge and help.

Benefits of Group Decisions

Working as a group can enhance the effectiveness of decision making, just as it can enhance the effectiveness of problem solving. Many companies combine individuals into teams to improve decision making. By forming decision-making teams, the group benefits from the expertise of each of the members. There is also an increase in resources and ideas (Salas, Burke, & Cannon-Bowers, 2000). Another benefit of group decision making is improved group memory over individual memory (Hinsz, 1990). Groups that are successful in decision making exhibit a number of similar characteristics, including the following:

- the group is small;
- it has open communication;
- members share a common mind-set;
- members identify with the group; and
- members agree on acceptable group behavior (Shelton, 2006).

In juries, members share more information during decision making when the group is made up of diverse members (Sommers, 2006). The juries are thereby in a position to make better decisions. Furthermore, in examining decision making in public policy groups, interpersonal influence is important (Jenson, 2007). Group members frequently employed tactics to affect other members' decisions (Jenson, 2007). The most frequently used and influential tactics were inspirational and rational appeals.

Groupthink

There can be disadvantages associated with group decision making, however. Of these disadvantages, one of the most explored is groupthink. *Groupthink* is a phenomenon characterized by premature decision making that is generally the result of group members attempting to avoid conflict (Janis, 1971). Groupthink frequently results in suboptimal decision making that avoids non-traditional ideas (Esser, 1998).

What conditions lead to groupthink? Janis cited three kinds:

(1) an isolated, cohesive, and homogeneous group is empowered to make decisions;
(2) objective and impartial leadership is absent, within the group or outside it; and
(3) high levels of stress impinge on the group decision-making process.

Another cause of groupthink is anxiety (Chapman, 2006). When group members are anxious, they are less likely to explore new options and will likely try to avoid further conflict.

The groups responsible for making foreign policy decisions are excellent candidates for groupthink. They are usually like-minded. Moreover, they frequently isolate themselves from what is going on outside their own group. They generally try to meet specific objectives and believe they cannot afford to be impartial. Also, of course, they are under very high stress because the stakes involved in their decisions can be tremendous.

But what exactly is groupthink? Janis (1971) delineated six symptoms of groupthink:

1. *Closed-mindedness*—the group is not open to alternative ideas.
2. *Rationalization*—the group goes to great lengths to justify both the process and the product of its decision making, distorting reality where necessary in order to be persuasive.

3. *Squelching of dissent*—those who disagree with the group are ignored, criticized, or even ostracized.
4. *Formation of a "mindguard"* for the group—one person appoints himself or herself the keeper of the group norm and ensures that people stay in line.
5. *Feeling invulnerable*—the group believes that it must be right, given the intelligence of its members and the information available to them.
6. *Feeling unanimous*—members believe that everyone unanimously shares the opinions expressed by the group.

Defective decision making results from groupthink, which in turn is due to examining alternatives insufficiently, examining risks inadequately, and seeking information about alternatives incompletely.

Consider how groupthink might arise in a decision when college students decide to damage a statue on the campus of a football rival to teach a lesson to the students and faculty in the rival university. The students rationalize that damage to a statue really is no big deal. Who cares about an old ugly statue anyway? When one group member dissents, other members quickly make him feel disloyal and cowardly. His dissent is squelched. The group's members feel invulnerable. They are going to damage the statue under the cover of darkness, and the statue is never guarded. They are sure they will not be caught. Finally, all the members agree on the course of action. This apparent feeling of unanimity convinces the group members that far from being out of line, they are doing what needs to be done.

Antidotes for Groupthink

Janis has prescribed several antidotes for groupthink. For example, the leader of a group should encourage constructive criticism, be impartial, and ensure that members seek input from people outside the group. The group should also form subgroups that meet separately to consider alternative solutions to a single problem. It is important that the leader take responsibility for preventing spurious conformity to a group norm.

In 1997, members of the Heaven's Gate cult in California committed mass suicide in the hope of meeting up with extraterrestrials in a spaceship trailing the Hale-Bopp comet. Although this group suicide is a striking example of conformity to a destructive group norm, similar events have occurred throughout human history, such as the suicide of more than 900 members of the Jonestown, Guyana, religious cult in 1978. In 2010, a series of incredibly bad decisions by a group of oil-rig operators on the Deepwater Horizon, situated in the Gulf of Mexico, led to the largest oil-well leak in history. And even in the 21st century, suicide bombers are killing themselves and others in carefully planned attacks.

Neuroscience of Decision Making

As in problem solving, the prefrontal cortex, and particularly the anterior cingulate cortex, is active during the decision-making process (Barraclough, Conroy, & Lee, 2004; Kennerley et al., 2006; Rogers et al., 2004). Explorations of decision making in monkeys have noted activation in the parietal regions of the brain (Platt & Glimcher, 1999). The amount of gain associated with a decision also affects the amount of activation observed in the parietal region (Platt & Glimcher, 1999).

Examination of decision making in drug abusers identified a number of areas involved in risky decisions. The researchers studied drug abusers because drug abuse,

Erich Kaiser/AP Photos

In 1997, 39 members of the Heaven's Gate cult committed mass suicide in order to "evacuate" Earth and meet with a UFO that would lead them to a better existence.

by its very nature, produces risky decisions. They found decreased activation in the left pregenual anterior cingulate cortex of drug abusers (Fishbein et al., 2005). These findings suggest that during decision making, the anterior cingulate cortex is involved in the consideration of potential rewards.

Another study had healthy participants play the gambling game Blackjack. The researchers found that suboptimal decisions (too risky or too cautious) were associated with increased activity in the anterior cingulate cortex (Hewig et al., 2008).

Another interesting effect seen in this area is observed in participants who have difficulty with a decision. In one study, participants made decisions concerning whether an item was old or new and which of two items was larger (Fleck et al., 2006). Decisions that were rated lowest in confidence and that took the most time to answer were associated with higher activation of the anterior cingulate cortex.

These findings suggest that this area of the brain is involved in the comparison and weighing of possible solutions.

✔ CONCEPT CHECK

1. Why can the model of the economic man and woman not explain human decision making satisfactorily?
2. Why do we use heuristics?
3. What is the difference between overconfidence and hindsight bias?
4. Name and describe three fallacies.
5. What are the symptoms of groupthink?
6. Which parts of the brain play prominent roles in decision making?

Deductive Reasoning

Judgment and decision making involve evaluating opportunities and selecting one choice over another. A related kind of thinking is reasoning. **Reasoning** is the process of drawing conclusions from principles and from evidence (Leighton & Sternberg, 2004; Sternberg, 2004; Wason & Johnson-Laird, 1972). In reasoning, we move from what is already known to infer a new conclusion or to evaluate a proposed conclusion.

Reasoning is often divided into two types: deductive and inductive reasoning. We explore both kinds of reasoning in the remainder of this chapter.

What Is Deductive Reasoning?

Deductive reasoning is the process of reasoning from one or more general statements regarding what is known to reach a logically certain conclusion (Johnson-Laird, 2000; Rips, 1999; Williams, 2000). It often involves reasoning from one or more general statements regarding what is known to a specific application of the general statement.

Deductive reasoning is based on logical propositions. A **proposition** is basically an assertion, which may be either true or false. Examples are "Cognitive psychology students are brilliant," "Cognitive psychology students wear shoes," or "Cognitive psychology students like peanut butter." In a logical argument, **premises** are propositions about which arguments are made. Cognitive psychologists are interested particularly in propositions that may be connected in ways that require people to draw reasoned conclusions. That is, deductive reasoning is useful because it helps people connect various propositions to draw conclusions. Cognitive psychologists want to know how people connect propositions to draw conclusions. Some of these conclusions are well reasoned; others are not.

Much of the difficulty of reasoning is in even understanding the language of problems (Girotto, 2004). Some of the mental processes used in language understanding and the cerebral functioning underlying them are used in reasoning, too (Lawson, 2004).

Conditional Reasoning

One type of deductive reasoning is conditional reasoning. In the next sections, we will explore what conditional reasoning is and how it works.

What Is Conditional Reasoning?

One of the primary types of deductive reasoning is **conditional reasoning,** in which the reasoner must draw a conclusion based on an *if-then* proposition. The conditional if-then proposition states that if antecedent condition p is met, then consequent event q follows. For example, "If students study hard, then they score high on their exams." Under some circumstances, if you have established a conditional proposition, then you may draw a well-reasoned conclusion. The usual set of conditional propositions from which you can draw a well-reasoned conclusion is, "If p, then q. p. Therefore, q." This inference illustrates deductive validity. That is, it follows logically from the propositions on which it is based. The following is also logical:

"If students eat pizza, then they score high on their exams. They eat pizza. Therefore, they score high on their exams."

As you may have guessed, deductive validity does not equate with truth. You can reach deductively valid conclusions that are completely untrue with respect to the world. Whether the conclusion is true depends on the truthfulness of the premises. In fact, people are more likely mistakenly to accept an illogical argument as logical if the conclusion is factually true. For now, however, we put aside the issue of truth and focus only on the **deductive validity,** or logical soundness, of the reasoning.

One set of propositions and its conclusion is the argument:

"If *p*, then *q*. *p*.
Therefore, *q*,"

which is termed a *modus ponens* argument. In the *modus ponens* argument, the reasoner affirms the antecedent (*p*). For example, take the argument "If you are a husband, then you are married. Harrison is a husband. Therefore, he is married." The set of propositions for the *modus ponens* argument is shown in Table 12.2.

In addition to the *modus ponens* argument, you may draw another well-reasoned conclusion from a conditional proposition, given a different second proposition:

"If *p*, then *q*. Not *q*. Therefore, not *p*."

This inference is also deductively valid. This particular set of propositions and its conclusion is termed a *modus tollens* argument, in which the reasoner denies the consequent. For example, we modify the second proposition of the argument to deny the consequent:

"If you are a husband, then you are married. Harrison is not married. Therefore, he is not a husband."

Table 12.2 shows two conditions in which a well-reasoned conclusion can be reached. It also shows two conditions in which such a conclusion cannot be reached.

Table 12.2 Conditional Reasoning: Deductively Valid Inferences and Deductive Fallacies

Two kinds of conditional propositions lead to valid deductions, and two others lead to deductive fallacies; *p* is called the *antecedent*; *q* is called the *consequent*. → stands for *then*, and ∴ stands for *therefore*.

Type of Argument		Conditional Proposition	Existing Condition	Inference
Deductively valid inferences	*Modus ponens—affirming the antecedent*	$p \rightarrow q$ If you are a mother, then you have a child.	p You are a mother.	$\therefore q$ Therefore, you have a child.
	Modus tollens—denying the consequent	$p \rightarrow q$ If you are a mother, then you have a child.	$\neg q$ You do not have a child.	$\therefore \neg p$ Therefore, you are not a mother.
Deductive fallacies	*Denying the antecedent*	$p \rightarrow q$ If you are a mother, then you have a child.	$\neg p$ You are not a mother.	$\therefore \neg q$ Therefore, you do not have a child.
	Affirming the consequent	$p \rightarrow q$ If you are a mother, then you have a child.	q You have a child.	$\therefore p$ Therefore, you are a mother.

As the examples illustrate, some inferences based on conditional reasoning are fallacies, which lead to conclusions that are not deductively valid. When using conditional propositions, we cannot reach a deductively valid conclusion based either on denying the antecedent condition or on affirming the consequent. Let's return to the proposition, "If you are a husband, then you are married." We would not be able to confirm or to refute the proposition based on denying the antecedent: "Joan is not a husband. Therefore, she is not married." Even if we ascertain that Joan is not a husband, we cannot conclude that she is not married. Similarly, we cannot deduce a valid conclusion by affirming the consequent: "Joan is married. Therefore, she is a husband." Even if Joan is married, her spouse may not consider her a husband.

The Wason Selection Task

Conditional reasoning can be studied in the laboratory using a "selection task" (Wason, 1968, 1969, 1983; Wason & Johnson-Laird, 1970, 1972). Participants are presented with a set of four two-sided cards. Each card has a number on one side and a letter on the other side. Face up are two letters and two numbers. The letters are a consonant and a vowel. The numbers are an even number and an odd number. For example, participants might be presented with the set of cards shown in Figure 12.1.

Each participant then is told a conditional statement. For example, "If a card has a consonant on one side, then it has an even number on the other side." The task is to determine whether the conditional statement is true or false. One does so by turning over the exact number of cards necessary to test the conditional statement. That is, the participant must not turn over any cards that are not valid tests of the statement. But the participant must turn over all cards that are valid tests of the conditional proposition. Which cards would you turn?

Table 12.3 illustrates the four possible tests participants might perform on the cards. Two of the tests (*modus ponens:* affirming the antecedent, and *modus tollens:* denying the consequent) are both necessary and sufficient for testing the conditional statement:

- That is, to evaluate the deduction, the participant must turn over the card showing a consonant to see whether it has an even number on the other side. He or she thereby affirms the antecedent (the *modus ponens* argument).
- In addition, the participant must turn over the card showing an odd number (i.e., not an even number) to see whether it has a vowel (i.e., not a consonant) on the other side. He or she thereby denies the consequent (the *modus tollens* argument).

The other two possible tests (denying the antecedent and affirming the consequent) are irrelevant. That is, the participant need not turn over the card showing a

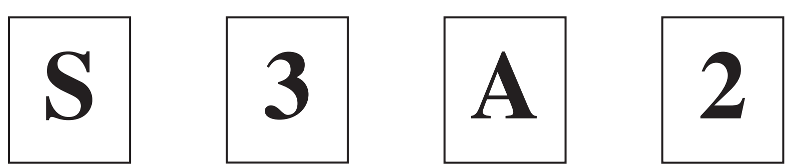


Figure 12.1 Which two cards would you turn to confirm the rule, "If a card has a consonant on one side, then it has an even number on the other side"?

Table 12.3 Conditional Reasoning: Wason's Selection Task

In the Wason selection task, Peter Wason presented participants with a set of four cards, from which the participants were to test the validity of a given proposition. This table illustrates how a reasoner might test the conditional proposition ($p \rightarrow q$), "If a card has a consonant on one side (p), then it has an even number on the other side (q)."

Proposition based on what shows on the face of the card	Test	Type of Reasoning	
p A given card has a consonant on one side (e.g., "S," "F," "V," or "P")	**∴ *q*** Does the card have an even number on the other side?	Based on *modus ponens*	Deductively valid inferences
¬ *q* A given card does not have an even number on one side. That is, a given card has an odd number on one side (e.g., "3," "5," "7," or "9").	**∴ ¬ *p*** Does the card not have a consonant on the other side? That is, does the card have a vowel on the other side?	Based on *modus tollens*	
¬ *p* A given card does not have a consonant on one side. That is, a given card has a vowel on one side (e.g., "A," "E," "I," or "O").	**∴ ¬ *q*** Does the card not have an even number on the other side? That is, does the card have an odd number on the other side?	Based on denying the antecedent	Deductive fallacies
q A given card has an even number on one side (e.g., "2," "4," "6," or "8").	**∴ *p*** Does the card have a consonant on the other side?	Based on affirming the consequent	

vowel (i.e., not a consonant). To do so would be to deny the antecedent. He or she also need not turn over the card showing an even number (i.e., not a odd number). To do so would be to affirm the consequent.

Most participants knew to test for the *modus ponens* argument. However, many participants failed to test for the *modus tollens* argument. Some of these participants instead tried to deny the antecedent as a means of testing the conditional proposition.

Conditional Reasoning in Everyday Life

Most people of all ages (at least starting in elementary school) appear to have little difficulty in recognizing and applying the *modus ponens* argument. However, few people spontaneously recognize the need for reasoning by means of the *modus tollens* argument. Many people do not recognize the logical fallacies of denying the antecedent or affirming the consequent, at least as these fallacies are applied to abstract reasoning problems (Braine & O'Brien, 1991; O'Brien, 2004; Rips, 1988, 1994). In fact, some evidence suggests that even people who have taken a course in logic fail to demonstrate deductive reasoning across various situations (Cheng et al., 1986). Even training aimed directly at improving reasoning leads to mixed results. After training aimed at increasing reasoning, there is a significant increase in the use of mental models and rules. However, after this training, there may be only a moderate increase in the use of deductive reasoning (Leighton, 2006).

Why might both children and adults fallaciously affirm the consequent or deny the antecedent? Perhaps they do so because of invited inferences that follow from normal discourse comprehension of conditional phrasing (Rumain, Connell, & Braine, 1983). For instance, suppose that a textbook publisher advertises, "If you buy the *Introduction to Ethics* textbook, then we will give you a $5 rebate."

You probably correctly infer that if you do not buy this textbook, the publisher will not give you a $5 rebate. However, formal deductive reasoning would consider this denial of the antecedent to be fallacious. The statement says nothing about what happens if you do *not* buy the textbook. Similarly, you may infer that you must have bought this textbook (affirm the consequent) if you received a $5 rebate from the publisher. But the statement says nothing about the range of circumstances that lead you to receive the $5 rebate. There may be other ways to receive it. Both inferences are fallacious according to formal deductive reasoning, but both are quite reasonably invited inferences in everyday situations. It helps when the wording of conditional reasoning problems either explicitly or implicitly disinvites these inferences. People are then much less likely to engage in these logical fallacies.

The demonstration of conditional reasoning also is influenced by the presence of contextual information that converts the problem from one of abstract deductive reasoning to one that applies to an everyday situation. For example, participants received both the Wason Selection Task and a modified version of the Wason Selection Task (Griggs & Cox, 1982). In the modified version, the participants were asked to suppose that they were police officers. As officers, they were attempting to enforce the laws applying to the legal age for drinking alcoholic beverages. The particular rule to be enforced was:

"If a person is drinking beer, then the person must be over 19 years of age."

Each participant was presented with a set of four cards:

(1) drinking a beer
(2) drinking a Coke
(3) 16 years of age
(4) 22 years of age.

The participant then was instructed to "Select the card or cards that you definitely need to turn over to determine whether or not the people are violating the rule" (p. 414). On the one hand, none of Griggs and Cox's participants had responded correctly on the abstract version of the Wason Selection Task. On the other hand, a remarkable 72% of the participants correctly responded to the modified version of the task; that is, they turned cards 1 and 3.

Influences on Conditional Reasoning

A more recent modification of the task based on drinking and age has shown that beliefs regarding plausibility influence whether people choose the *modus tollens* argument (denying the consequent—checking to see whether a person who is younger than 19 years of age is not drinking beer). When the test involves checking to see whether an 18-year-old is drinking beer, people are far more likely to try the *modus tollens* argument than when they have to check whether a 4-year-old is drinking beer. Nevertheless, the logical argument is the same in both cases (Kirby, 1994).

How do people use deductive reasoning in realistic situations? Two investigators have suggested that, rather than using formal inference rules, people often use pragmatic reasoning schemas (Cheng & Holyoak, 1985). **Pragmatic reasoning schemas** are general organizing principles or rules related to particular kinds of goals, such as permissions, obligations, or causations. These schemas sometimes are referred to as *pragmatic rules*. These pragmatic rules are not as abstract as formal logical rules. Yet, they are sufficiently general and broad so that they can apply to a wide variety of specific situations. Prior beliefs, in other words, matter in reasoning (Evans & Feeney, 2004).

Alternatively, one's performance may be affected by *perspective effects*—that is, whether one takes the point of view of the police officers or of the people drinking the alcoholic beverages (Almor & Sloman, 1996; Staller, Sloman, & Ben-Zeev, 2000). So it may not be permissions *per se* that matter. Rather, what may matter are the perspectives one takes when solving such problems.

Thus, consider situations in which our previous experiences or our existing knowledge cannot tell us all we want to know. Pragmatic reasoning schemas help us deduce what might reasonably be true. Particular situations or contexts activate particular schemas. For example, suppose that you are walking across campus and see someone who looks extremely young. Then you see the person walk to a car. He unlocks it, gets in, and drives away. This observation would activate your permission schema for driving: "If you are to be permitted to drive alone, then you must be at least 16 years old." You might now deduce that the person you saw is at least 16 years old. In one experiment, 62% of participants correctly chose *modus ponens* and *modus tollens* arguments when the conditional-reasoning task was presented in the context of permission statements. Only 11% did so when the task was presented in the context of arbitrary statements unrelated to pragmatic reasoning schemas (Cheng & Holyoak, 1985).

Researchers conducted an extensive analysis comparing the standard abstract Wason selection task with an abstract form of a permission problem (Griggs & Cox, 1993). The standard abstract form might be "If a card has an 'A' on one side, then it must have a '4' on the other side." The abstract permission form might be, "If one is to take action 'A,' then one must first satisfy precondition 'P.' " Performance on the abstract-permission task was still superior (49% correct overall) to performance on the standard abstract task (only 9% correct overall) (Griggs & Cox, 1993; Manktelow & Over, 1990, 1992).

Evolution and Reasoning

A different approach to conditional reasoning takes an evolutionary view of cognition (Cummins, 2004). This view asks what kinds of thinking skills would provide a naturally selective advantage for humans in adapting to our environment across evolutionary time (Cosmides, 1989; Cosmides & Tooby, 1996). To gain insight into human cognition, we should look to see what kinds of adaptations would have been most useful in the distant past. So we hypothesize on how human hunters and gatherers would have thought during the millions of years of evolutionary time that predated the relatively recent development of agriculture and the very recent development of industrialized societies.

How has evolution influenced human cognition? Humans may possess something like a schema-acquisition device (Cosmides, 1989). It facilitates our ability to quickly glean important information from our experiences. It also helps us to organize that information into meaningful frameworks. In Cosmides' view, these schemas are highly flexible. But they also are specialized for selecting and organizing the information that will most effectively aid us in adapting to the situations we face. One of the distinctive adaptations shown by human hunters and gatherers has been in the area of social exchange. There are two kinds of inferences in particular that social-exchange schemas facilitate: inferences related to cost-benefit relationships and inferences that help people detect when someone is cheating in a particular social exchange. In earlier times, detecting a cheater may have made the difference between life and death.

Syllogistic Reasoning: Categorical Syllogisms

In addition to conditional reasoning, the other key type of deductive reasoning is syllogistic reasoning, which is based on the use of syllogisms. **Syllogisms** are deductive arguments that involve drawing conclusions from two premises (Maxwell, 2005; Rips, 1994, 1999). All syllogisms comprise a major premise, a minor premise, and a conclusion. Unfortunately, sometimes the conclusion may be that no logical conclusion may be reached based on the two given premises.

What Are Categorical Syllogisms?

Probably the most well-known kind of syllogism is the categorical syllogism. Like other kinds of syllogisms, categorical syllogisms comprise two premises and a conclusion. In the case of the **categorical syllogism,** the premises state something about the category memberships of the terms. In fact, each term represents all, none, or some of the members of a particular class or category. As with other syllogisms, each premise contains two terms. One of them must be the middle term, common to both premises. The first and the second terms in each premise are linked through the categorical membership of the terms. That is, one term is a member of the class indicated by the other term. However the premises are worded, they state that some (or all or none) of the members of the category of the first term are (or are not) members of the category of the second term. To determine whether the conclusion follows logically from the premises, the reasoner must determine the category memberships of the terms. An example of a categorical syllogism would be as follows:

All cognitive psychologists are pianists.

All pianists are athletes.

Therefore, all cognitive psychologists are athletes.

Logicians often use circle diagrams to illustrate class membership. They make it easier to figure out whether a particular conclusion is logically sound. The conclusion for this syllogism does in fact follow logically from the premises. This is shown in the circle diagram in Figure 12.2. However, the conclusion is false because the premises are false. For the preceding categorical syllogism, the *subject* is cognitive psychologists, the *middle term* is pianists, and the *predicate* is athletes. In both premises, we asserted that all members of the category of the first term were members of the category of the second term.

There are four kinds of premises (see also Table 12.4):

1. Statements of the form "All A are B" sometimes are referred to as *universal affirmatives*, because they make a positive (affirmative) statement about all members of a class (universal).
2. *Universal negative statements* make a negative statement about all members of a class (e.g., "No cognitive psychologists are flutists.").
3. *Particular affirmative statements* make a positive statement about some members of a class (e.g., "Some cognitive psychologists are left-handed.").
4. *Particular negative statements* make a negative statement about some members of a class (e.g., "Some cognitive psychologists are not physicists.").

In all kinds of syllogisms, some combinations of premises lead to no logically valid conclusion. In categorical syllogisms, in particular, we cannot draw logically valid conclusions from categorical syllogisms with two particular premises or with two negative premises. For example, "Some cognitive psychologists are left-handed. Some

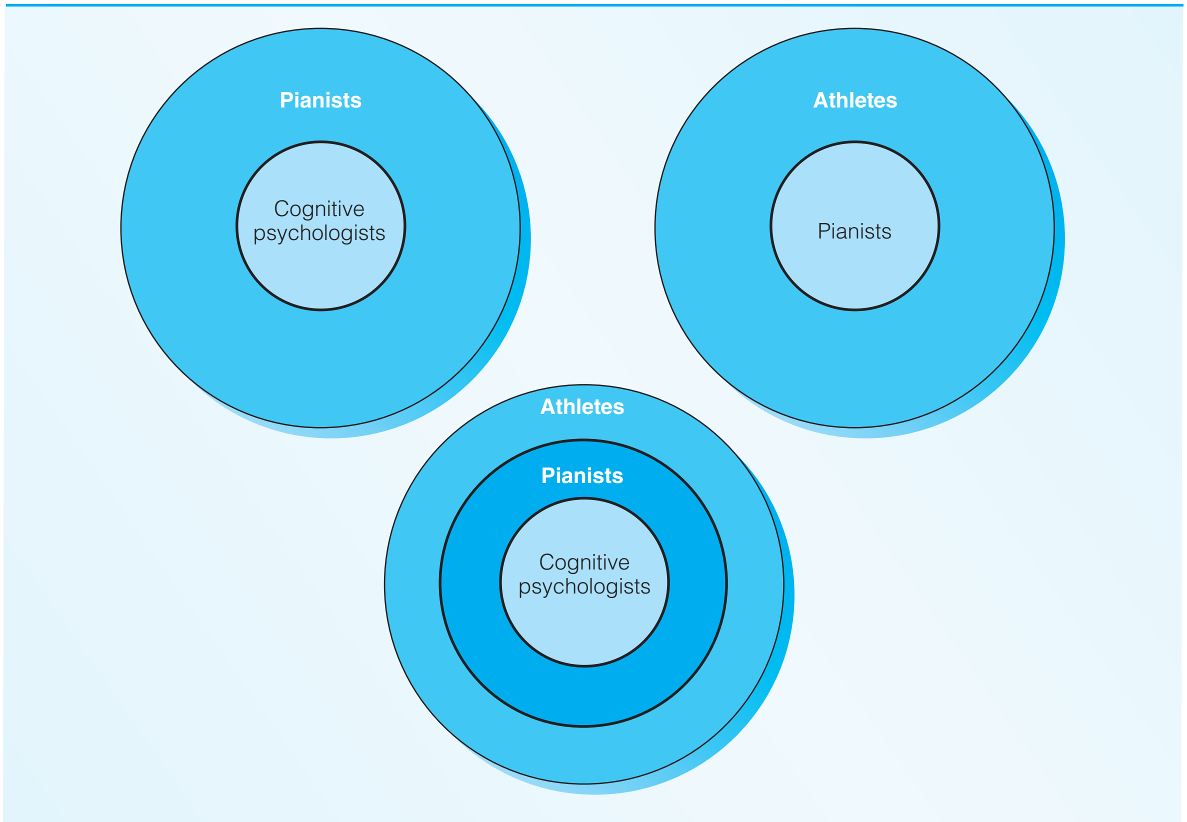


Figure 12.2 Circle Diagrams Representing a Categorical Syllogism.

Circle diagrams may be used to represent categorical syllogisms such as the one shown here: "All cognitive psychologists are pianists. All pianists are athletes. Therefore, all cognitive psychologists are athletes." It follows from the syllogism that all cognitive psychologists are athletes. However, if the premises are not true, a deduction that is logically valid still is not necessarily true, as is the case in this example.

Source: From In *Search of the Human Mind*, by Robert J. Sternberg. Copyright © 1995 by Harcourt Brace & Company. Reproduced by permission of the publisher.

left-handed people are smart." Based on these premises, you cannot conclude even that some cognitive psychologists are smart. The left-handed people who are smart might not be the same left-handed people who are cognitive psychologists. We just don't know. Consider a negative example: "No students are stupid. No stupid people eat pizza." We cannot conclude anything one way or the other about whether students eat pizza based on these two negative premises. As you may have guessed, people appear to have more difficulty (work more slowly and make more errors) when trying to deduce conclusions based on one or more particular premises or negative premises.

How Do People Solve Syllogisms?

Various theories have been proposed as to how people solve categorical syllogisms. One of the earliest theories was the atmosphere bias (Begg & Denny, 1969; Woodworth & Sells, 1935). There are two basic ideas of this theory:

Table 12.4 Categorical Syllogisms: Types of Premises

The premises of categorical syllogisms may be universal affirmatives, universal negatives, particular affirmatives, or particular negatives.

Type of Premise	Form of Premise Statements	Description	Examples	Reversibility*
Universal affirmative	All A are B.	The premise positively (affirmatively) states that all members of the first class (universal) are members of the second class.	All men are males.	All men are males ≠ All males are men. Non-reversible All A are B ≠ All B are A.
Universal negative	No A are B. (Alternative: All A are *not* B.)	The premise states that none of the members of the first class are members of the second class.	No men are females. *or* All men are not females.	No men are females = No females are men. ↔Reversible↔ No A are B = No B are A.
Particular affirmative	Some A are B.	The premise states that only some of the members of the first class are members of the second class.	Some females are women.	Some females are women ≠ Some women are females. Non-reversible Some A are B ≠ Some B are A.
Particular negative	Some A are not B.	The premise states that some members of the first class are not members of the second class.	Some women are not females.	Some women are not females ≠ Some females are not women. Non-reversible Some A are not B ≠ Some B are not A.

*In formal logic, the word *some* means "some and possibly all." In common parlance, and as used in cognitive psychology, *some* means "some and not all." Thus, in formal logic, the particular affirmative also would be reversible. For our purposes, it is not.

1. If there is at least one negative in the premises, people will prefer a negative solution.
2. If there is at least one particular in the premises, people will prefer a particular solution. For example, if one of the premises is "No pilots are children," people will prefer a solution that has the word *no* in it.

Nonetheless, the theory does not account very well for large numbers of responses.

Other researchers focused attention on the conversion of premises (Chapman & Chapman, 1959). Here, the terms of a given premise are reversed. People sometimes believe that the reversed form of the premise is just as valid as the original form. The idea is that people tend to convert statements like "If A, then B" into "If B, then A." They do not realize that the statements are not equivalent. These errors are made by children and adults alike (Markovits, 2004).

A more widely accepted theory is based on the notion that people solve syllogisms by using a semantic (meaning-based) process based on mental models (Ball & Quayle, 2009; Espino et al., 2005; Johnson-Laird & Savary, 1999; Johnson-Laird & Steedman, 1978). This view of reasoning as involving semantic processes based on mental models may be contrasted with rule-based ("syntactic") processes, such as those characterized by formal logic. A **mental model** is an internal representation of information that corresponds analogously with whatever is being represented (see Johnson-Laird, 1983). Some mental models are more likely to lead to a deductively valid conclusion than are others. In particular, some mental models may not be effective in disconfirming an invalid conclusion.

For example, in the Johnson-Laird study, participants were asked to describe their conclusions and their mental models for the syllogism, "All of the artists are beekeepers. Some of the beekeepers are clever. Are all artists clever?" One participant said, "I thought of all the little . . . artists in the room and imagined they all had beekeeper's hats on" (Johnson-Laird & Steedman, 1978, p. 77). Figure 12.3 shows two different mental models for this syllogism. As the figure shows, the choice of a mental model may affect the reasoner's ability to reach a valid deductive conclusion. Because some models are better than others for solving some syllogisms, a person is more likely to reach a deductively valid conclusion by using more than one mental model. In the figure, the mental model shown in (a) may lead to the

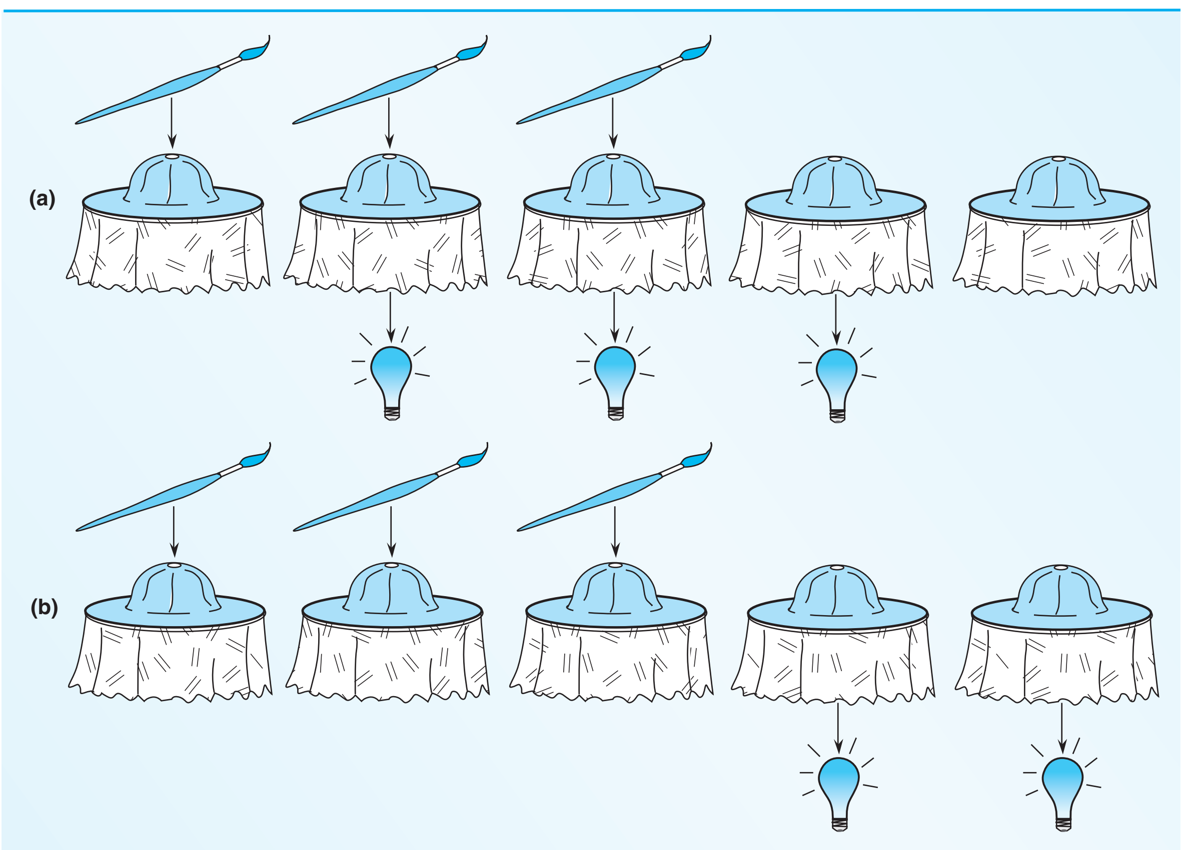


Figure 12.3 Mental Models Representing a Syllogism.

Philip Johnson-Laird and Mark Steedman hypothesized that people use various mental models analogously to represent the items within a syllogism. Some mental models are more effective than others, and for a valid deductive conclusion to be reached, more than one model may be necessary, as shown here. (See text for explanation.)

deductively invalid conclusion that some artists are clever. By observing the alternative model in (b), we can see an alternative view of the syllogism. It shows that the conclusion that some artists are clever may not be deduced on the basis of this information alone. Specifically, perhaps the beekeepers who are clever are not the same as the beekeepers who are artists.

As mentioned previously, circle diagrams are often used to represent categorical syllogisms. In circle diagrams, you can use overlapping, concentric, or non-overlapping circles to represent the members of different categories (see Figure 12.2). People can learn how to improve their reasoning by being taught how to draw circle diagrams (Nickerson, 2004). Amazingly, even congenitally blind persons are able to create spatial mental models to assist them in their reasoning processes (Fleming et al., 2006; Knauff & May, 2006).

The difficulty of many problems of deductive reasoning relates to the number of mental models needed for adequately representing the premises of the deductive argument (Johnson-Laird, Byrne, & Schaeken, 1992). Arguments that entail only one mental model may be solved quickly and accurately. However, to infer accurate conclusions based on arguments that may be represented by multiple alternative models is much harder. Such inferences place great demands on working memory (Gilhooly, 2004). In these cases, the individual must simultaneously hold in working memory each of the various models. Only in this way can he or she reach or evaluate a conclusion. Thus, limitations of working-memory capacity may underlie at least some of the errors observed in human deductive reasoning (Johnson-Laird, Byrne, & Schaeken, 1992).

In two experiments, the role of working memory was studied in syllogistic reasoning (Gilhooly et al., 1993). In the first, syllogisms were simply presented either orally or visually. Oral presentation placed a considerably higher load on working memory because participants had to remember the premises. In the visual-presentation condition, participants could look at the premises. As predicted, performance was lower in the oral-presentation condition. In a second experiment, participants needed to solve syllogisms while at the same time performing another task. Either the task drew on working-memory resources or it did not. The researchers found that the task that drew on working-memory resources interfered with syllogistic reasoning. The task that did not draw on these resources did not.

Other factors also may contribute to the ease of forming appropriate mental models. People seem to solve logical problems more accurately and more easily when the terms have high imagery value (Clement & Falmagne, 1986).

Some deductive reasoning problems comprise more than two premises. For example, transitive-inference problems, in which problem solvers must order multiple terms, can have any number of premises linking large numbers of terms. Mathematical and logical proofs are deductive in character and can have many steps as well.

Aids and Obstacles to Deductive Reasoning

In deductive reasoning, as in many other cognitive processes, we engage in many heuristic shortcuts. These shortcuts sometimes lead to inaccurate conclusions. In addition to these shortcuts, we often are influenced by biases that distort the outcomes of our reasoning. In this section, we examine heuristics and biases in deductive reasoning. Finally, we look at ways to enhance your deductive reasoning skills.

Heuristics in Deductive Reasoning

Heuristics in syllogistic reasoning include *overextension errors*. In these errors, we overextend the use of strategies that work in some syllogisms to syllogisms in which the strategies fail us. For example, although reversals work well with universal negatives, they do not work with other kinds of premises. We also experience *foreclosure effects* when we fail to consider all the possibilities before reaching a conclusion. In addition, *premise-phrasing effects* may influence our deductive reasoning, for example, the sequence of terms or the use of particular qualifiers or negative phrasing. Premise-phrasing effects may lead us to leap to a conclusion without adequately reflecting on the deductive validity of the syllogism.

Biases in Deductive Reasoning

Biases that affect deductive reasoning generally relate to the content of the premises and the believability of the conclusion. They also reflect the tendency toward **confirmation bias**. In confirmation bias, we seek confirmation rather than disconfirmation of what we already believe. Suppose the content of the premises and a conclusion seem to be true. In such cases, reasoners tend to believe in the validity of the conclusion, even when the logic is flawed (Evans, Barston, & Pollard, 1983).

Confirmation bias can be detrimental and even dangerous in some circumstances. For instance, in an emergency room, if a doctor assumes that a patient has condition X, the doctor may interpret the set of symptoms as supporting the diagnosis without fully considering all alternative interpretations (Pines, 2005). This shortcut can result in inappropriate diagnosis and treatment, which can be extremely dangerous. Other circumstances where the effects of confirmation bias can be observed are in police investigations, paranormal beliefs, and stereotyping behavior (Ask & Granhag, 2005; Biernat & Ma, 2005; Lawrence & Peters, 2004). To a lesser extent, people also show the opposite tendency to disconfirm the validity of the conclusion when the conclusion or the content of the premises contradicts the reasoner's existing beliefs (Evans, Barston, & Pollard, 1983; Janis & Frick, 1943).

Enhancing Deductive Reasoning

To enhance our deductive reasoning, we may try to avoid heuristics and biases that distort our reasoning. We also may engage in practices that facilitate reasoning. For example, we may take longer to reach or to evaluate conclusions. Effective reasoners also consider more alternative conclusions than do poor reasoners (Galotti, Baron, & Sabini, 1986). In addition, training and practice seem to increase performance on reasoning tasks. The benefits of training tend to be strong when the training relates to pragmatic reasoning schemas (Cheng et al., 1986) or to such fields as law and medicine (Lehman, Lempert, & Nisbett, 1987). The benefits are weaker for abstract logical problems divorced from our everyday life (see Holland et al., 1986; Holyoak & Nisbett, 1988).

One factor that affects syllogistic reasoning is mood. When people are in a sad mood, they tend to pay more attention to details (Schwarz & Skurnik, 2003). Perhaps surprisingly, they tend to do better in syllogistic reasoning tasks when they are in a sad mood than when they are in a happy mood (Fiedler, 1988; Melton, 1995). People in a neutral mood tend to show performance in between the two extremes.

PRACTICAL APPLICATIONS OF COGNITIVE PSYCHOLOGY

IMPROVING YOUR DEDUCTIVE REASONING SKILLS

Even without training, you can improve your own deductive reasoning through developing strategies to avoid making errors. For example, an unscrupulous politician might state that, "We know that some suspicious-looking people are illegal aliens. We also know that some illegal aliens are terrorists. Therefore, we can be sure that some of those people whom we think are suspicious are terrorists, and that they are out to destroy our country!" The politician's syllogistic reasoning is wrong. If some A are B and some B are C, it is not necessarily the case that any A are C. This is obvious when you realize that some men are happy people and some happy people are women, but this does not imply that some men are women.

Make sure you are using the proper strategies in solving syllogisms. Remember that reversals only work with universal negatives. Sometimes translating abstract terms to concrete ones (e.g., the letter C to cows) can help. Also, take the time to consider contrary examples and create more mental models. The more mental models you use for a given set of premises, the more confident you can be that if your conclusion is not valid, it will be disconfirmed. Thus, the use of multiple mental models increases the likelihood of avoiding errors. The use of multiple mental models also helps you to avoid the tendency to engage in confirmation bias. Circle diagrams also can be helpful in solving deductive-reasoning problems.

Is the use of fingerprints in solving a crime an example of deductive reasoning? Why or why not?

✓ CONCEPT CHECK

1. Which are deductively valid inferences in conditional reasoning?
2. What are categorical syllogisms?
3. How can mental models be helpful when solving categorical syllogisms?
4. What does "reversibility" mean with respect to premises?
5. Name some biases that we are prone to in deductive reasoning.

Inductive Reasoning

We now consider inductive reasoning in more detail. First, we discuss what inductive reasoning is. Next, we will explore how we make causal inferences. Last, we will consider categorical inferences and reasoning by analogies.

What Is Inductive Reasoning?

Inductive reasoning is the process of reasoning from specific facts or observations to reach a likely conclusion that may explain the facts. The inductive reasoner then may use that probable conclusion to attempt to predict future specific instances (Johnson-Laird, 2000). The key feature distinguishing inductive from deductive reasoning is that, in inductive reasoning, we never can reach a logically certain conclusion. We only can reach a particularly well-founded or probable conclusion. With deductive reasoning, in contrast, reaching logically certain—deductively valid—conclusions is possible.

For example, suppose that you notice that all the people enrolled in your cognitive psychology course are on the dean's list (or honor roll). From these observations, you could reason inductively that all students who enroll in cognitive psychology are excellent students (or at least earn the grades to give that impression). However, unless you can observe the grade-point averages of all people who ever have taken or ever will take cognitive psychology, you will be unable to prove your conclusion. Furthermore, a single poor student who happened to enroll in a cognitive psychology course would disprove your conclusion. Still, after large numbers of observations, you might conclude that you had made enough observations to reason inductively.

The fundamental riddle of induction is how we can make any inductions at all. As the future has not happened, how can we predict what it will bring? There is also an important so-called new riddle of induction (Goodman, 1983). Given possible alternative futures, how do we know *which one* to predict? For example, in the number series problem 2, 4, 6, ?, most people would replace the question mark with an 8. But we cannot know for sure that the correct number is 8. A mathematical formula could be proposed that would yield any number at all as the next number. So why choose the pattern of ascending even numbers? Partly we choose it because it seems simple to us. It is a less complex formula than others we might choose. And partly we choose it because we are familiar with it. We are used to ascending series of even numbers. But we are not used to other complex series in which 2, 4, 6, may be embedded, such as 2, 4, 6, 10, 12, 14, 18, 20, 22, and so forth.

Inductive reasoning forms the basis of the empirical method (Holyoak & Nisbett, 1998). In it, we cannot logically leap from saying, "All observed instances to date of *X* are *Y*" to saying, "Therefore, all *X* are *Y*." It is always possible that the next observed *X* will not be a *Y*. For example, you may say that all swans that you have ever seen are white. However, you cannot form the conclusion then that all swans are white because the next swan you happen upon might be black. Indeed, black swans do exist.

In research, when we reject the null hypothesis (the hypothesis of no difference), we use inductive reasoning. We never know for sure whether we are correct in rejecting a null hypothesis.

Cognitive psychologists probably agree on at least two of the reasons why people use inductive reasoning. First, it helps them to become increasingly able to make sense out of the great variability in their environment. Second, it also helps them to predict events in their environment, thereby reducing their uncertainty. Thus, cognitive psychologists seek to understand the *how* rather than the *why* of inductive reasoning. We may (or may not) have some innate schema-acquisition device. But we certainly are not born with all the inferences we manage to induce.

We already have implied that inductive reasoning often involves the processes of generating and testing hypotheses. In addition, we reach inferences by generalizing some broad understandings from a set of specific instances. As we observe additional instances, we further broaden our understanding. Or, we may infer specialized exceptions to the general understandings. For example, after observing quite a few birds, we may infer that birds can fly. But after observing penguins and ostriches, we may add to our generalized knowledge specialized exceptions for flightless birds.

Causal Inferences

One approach to studying inductive reasoning is to examine **causal inferences**—how people make judgments about whether something causes something else (Cheng, 1997, 1999; Spellman, 1997). The philosopher David Hume observed that we are most likely to infer causality when we observe covariation over time: First one thing happens, then another. If we see the two events paired enough, we may come to believe that the first causes the second.

Perhaps our greatest failing is one that extends to psychologists, other scientists, and non-scientists: We demonstrate confirmation bias, which may lead us to errors such as illusory correlations (Chapman & Chapman, 1967, 1969, 1975). Furthermore, we frequently make mistakes when attempting to determine causality based on correlational evidence alone. Correlational evidence cannot indicate the direction of causation. Suppose we observe a correlation between Factor A and Factor B. We may find one of three things:

1. it may be that Factor A causes Factor B;
2. it may be that Factor B causes Factor A; or
3. some higher order, Factor C, may be causing both Factors A and B to occur together.

Based on the correlational data we cannot determine which of the three options indeed causes the observed phenomenon.

A related error occurs when we fail to recognize that many phenomena have multiple causes. For example, a car accident often involves several causes. It may have originated with the negligence of several drivers, rather than just one. Once we have identified one of the suspected causes of a phenomenon, we may commit what is known as a *discounting error*. We stop searching for additional alternative or contributing causes.

Confirmation bias can have a major effect on our everyday lives. For example, we may meet someone, expecting not to like her. As a result, we may treat her in ways that are different from how we would treat her if we expected to like her. She then may respond to us in less favorable ways. She thereby "confirms" our original belief that she is not likable. Confirmation bias thereby can play a major role in schooling. Teachers often expect little of students when they think them low in ability. The students then give the teachers little. The teachers' original beliefs are thereby "confirmed" (Sternberg, 1997). This effect is referred to as a *self-fulfilling prophecy* (Harber & Jussim, 2005).

Categorical Inferences

On what basis do people draw inferences? People generally use both bottom-up strategies and top-down strategies for doing so (Holyoak & Nisbett, 1988). That is, they use both information from their sensory experiences and information based on what they already know or have inferred previously. Bottom-up strategies are based on observing various instances and considering the degree of variability across instances. From these observations, we abstract a prototype (see Chapters 8 and 9). Once a prototype or a category has been induced, the individual may use focused sampling to add new instances to the category. He or she focuses chiefly on properties that have provided useful distinctions in the past. Top-down strategies include selectively searching for constancies within many variations and selectively combining existing concepts and categories.

Reasoning by Analogy

Inductive reasoning may be applied to a broader range of situations than those requiring causal or categorical inferences. For example, inductive reasoning may be applied to reasoning by analogy. Consider an example analogy problem:

Fire is to asbestos as water is to: (a) vinyl, (b) air, (c) cotton, (d) faucet.

In reasoning by analogy, the reasoner must observe the first pair of items ("fire" and "asbestos" in this example) and must induce from those two items one or more relations (in this case, surface resistance because surfaces coated with asbestos can resist fire). The reasoner then must apply the given relation in the second part of the analogy. In the example analogy, the reasoner chooses the solution to be "vinyl" because surfaces coated with vinyl can resist water.

Some investigators have used reaction-time methodology to figure out how people solve induction problems. For example, using mathematical modeling you might be able to break down the amounts of time participants spent on various processes of analogical reasoning. Most of the time spent in solving simple verbal analogies is spent in encoding the terms and in responding (Sternberg, 1977). Only a small part actually is spent in doing reasoning operations on these encodings.

The difficulty of encoding can become even greater in various puzzling analogies. For example, in the analogy:

RAT : TAR :: BAT : (a. CONCRETE, b. MAMMAL, c. TAB, d. TAIL),

the difficulty is in encoding the analogy as one involving letter reversal rather than semantic content for its solution. In a problematic analogy such as the following, the difficulty is in recognizing the meanings of the words:

AUDACIOUS : TIMOROUS :: MITIGATE :
(a. ADUMBRATE, b. EXACERBATE, c. EXPOSTULATE, d. EVISCERATE)

If reasoners know the meanings of the words, they probably will find it relatively easy to figure out that the relation is one of antonyms. (Did this example audaciously exacerbate your difficulties in solving problems involving analogies?)

An application of analogies in reasoning can be seen in politics. Analogies can help governing bodies come to conclusions (Breuning, 2003). These analogies also can be effectively used to conveying the justification of the decision to the public (Breuning, 2003). However, the use of analogies is not always successful. This highlights both the utility and possible pitfalls of using analogies in political deliberation. In 2010, opponents of the war in Afghanistan drew an analogy to Vietnam to argue for withdrawing from Afghanistan. They asserted that the failure of U.S. policies to lead to a conclusive victory were analogous between Vietnam and Afghanistan. Some members of government then turned the tables, using an analogy to Vietnam to argue that withdrawal from Afghanistan could lead to mass slaughter, as they asserted happened in Vietnam after the Americans left. Thus, analogies can end up being largely in the eye of the beholder rather than in the actual elements being compared.

Analogies are also used in everyday life as we make predictions about our environment. We connect our perceptions with our memories by means of analogies. The analogies then activate concepts and items stored in our mind that are similar to the current input. Through this activation, we can then make a prediction of what is likely in a given situation (Bar, 2007). For example, predictions about global warming are being guided in part by people drawing analogies to times in the past when the people believed either that the atmosphere warmed up or did not.

Whether a given individual believes in global warming depends in part upon what analogy or analogies the individual decides to draw.

✔ CONCEPT CHECK

1. What is inductive reasoning?
2. Which strategies do people use to draw inferences?
3. What is an analogy?
4. What leads analogies to succeed or fail?

An Alternative View of Reasoning

By now you have reasonably inferred that cognitive psychologists often disagree—sometimes rather heatedly—about how and why people reason as they do. An alternative perspective on reasoning, *dual-process theory,* contends that two complementary systems of reasoning can be distinguished. The first is an *associative system*, which involves mental operations based on observed similarities and temporal contiguities (i.e., tendencies for things to occur close together in time). The second is a *rule-based system*, which involves manipulations based on the relations among symbols (Barrett, Tugade, & Engle, 2004; Sloman, 1996).

The associative system can lead to speedy responses that are highly sensitive to patterns and to general tendencies. Through this system, we detect similarities between observed patterns and patterns stored in memory. We may pay more attention to salient features (e.g., highly typical or highly atypical ones) than to defining features of a pattern. This system imposes rather loose constraints that may inhibit the selection of patterns that are poor matches to the observed pattern. It favors remembered patterns that are better matches to the observed pattern. An example of associative reasoning is use of the representativeness heuristic.

Another example is the *belief-bias effect* in syllogistic reasoning (Markovits et al., 2009; Tsujii et al., 2010). This effect occurs when we agree more with syllogisms that affirm our beliefs, whether or not these syllogisms are logically valid. An example of the workings of the associative system may be in the *false-consensus effect*. Here, people believe that their own behavior and judgments are more common and more appropriate than those of other people (Ross, Greene, & House, 1977). Suppose people have an opinion on an issue. They are likely to believe that because it is their opinion, it is likely to be shared and believed to be correct by others (Dawes & Mulford, 1996; Krueger, 1998). Associating others' views with our own simply because they are our own is a questionable practice, however.

The rule-based system of reasoning usually requires more deliberate, sometimes painstaking procedures for reaching conclusions. Through this system, we carefully analyze relevant features (e.g., defining features) of the available data, based on rules stored in memory. This system imposes rigid constraints that rule out possibilities that violate the rules. Evidence in favor of rule-based reasoning includes:

1. We can recognize logical arguments when they are explained to us.
2. We can recognize the need to make categorizations based on defining features despite similarities in typical features. For example, we can recognize that a coin with a 3-inch diameter, which looks exactly like a quarter, must be a counterfeit.

3. We can rule out impossibilities, such as cats conceiving and giving birth to puppies.
4. We can recognize many improbabilities. For example, it is unlikely that the U.S. Congress will pass a law that provides annual salaries to all full-time college students.

According to Sloman, we need both complementary systems. We need to respond quickly and easily to everyday situations, based on observed similarities and temporal contiguities. Yet we also need a means for evaluating our responses more deliberately.

The two systems may be conceptualized within a connectionist framework (Sloman, 1996). The associative system is represented easily in terms of pattern activation and inhibition, which readily fits the connectionist model. The rule-based system may be represented as a system of production rules (see Chapter 8).

An alternative connectionist view suggests that deductive reasoning may occur when a given pattern of activation in one set of nodes (e.g., those associated with a particular premise or set of premises) entails or produces a particular pattern of activation in a second set of nodes (Rips, 1994). Similarly, a connectionist model of inductive reasoning may involve the repeated activation of a series of similar patterns across various instances. This repeated activation then may strengthen the links among the activated nodes. It thereby leads to generalization or abstraction of the pattern for a variety of instances.

Connectionist models of reasoning and the other approaches described in this chapter offer diverse views of the available data regarding how we reason and make judgments. At present, no one theoretical model explains all the data well. But each model explains at least some of the data satisfactorily. Together, the theories help us understand human intelligence and cognition.

Consider a concrete example of the interface between intelligence and cognition in *Investigating Cognitive Psychology: When There Is No "Right" Choice*.

✔ CONCEPT CHECK

1. What are the two complementary systems of reasoning?
2. How does a connectionist model conceptualize deductive reasoning?

Neuroscience of Reasoning

As in both problem solving and decision making, the process of reasoning involves the prefrontal cortex (Bunge et al., 2004). Further, reasoning involves brain areas associated with working memory, such as the basal ganglia (Melrose, Poulin, & Stern, 2007). One would expect working memory to be involved because reasoning involves the integration of information (which needs to be held in working memory while it is being integrated).

The basal ganglia are involved in a variety of functions, including cognition and learning. This area is also associated with the prefrontal cortex through a variety of connections (Melrose, Poulin, & Stern, 2007).

However, when a person is presented with a statement that is either to be remembered, on the one hand, or to be used for reasoning, on the other, the processes

INVESTIGATING COGNITIVE PSYCHOLOGY

When There Is No "Right" Choice

Consider this passage from Shakespeare's *Macbeth:*

> First Apparition: *Macbeth! Macbeth! Beware Macduff; Beware the thane of Fife. Dismiss me: enough….*
>
> Second Apparition: *Be bloody, bold, and resolute; laugh to scorn the power of man, for none of woman born shall harm Macbeth.*
>
> Macbeth: *Then live, Macduff: what need I fear of thee? But yet I'll make assurance double sure, and take a bond of fate: thou shalt not live; that I may tell pale-hearted fear it lies, and sleep in spite of thunder.*

In this passage, Macbeth mistakenly took the Second Apparition's vision to mean that no man could kill him, so he boldly decided to confront Macduff. However, Macduff was born by abdominal (Cesarean) delivery, so he did not fall into the category of men who could not harm Macbeth. Macduff eventually killed Macbeth because Macbeth came to a wrong conclusion based on the Second Apparition's premonition. The First Apparition's warning about Macduff should have been heeded.

Suppose you are trying to decide between buying an SUV or a subcompact car. You would like the room of the SUV, but you would like the fuel efficiency of the subcompact car. Whichever one you choose, did you make the right choice? This is a difficult question to answer because most of our decisions are made under conditions of uncertainty. Thus, let us say that you bought the SUV. You can carry a number of people, you have the power to pull a trailer easily up a hill, and you sit higher so your road vision is much better. However, every time you fill up the gas tank, you are reminded of how much fuel this vehicle takes. On the other hand, let us say that you bought the subcompact car. When picking up friends at the airport, you have difficulty fitting all of them and their luggage; you cannot pull trailers up hills (or at least, not very easily); and you sit so low that when there is an SUV in front of you, you can hardly see what is on the road. However, every time you fill up your gas tank or hear someone with an SUV complaining about how much it costs to fill up his or her tank, you see how little you have to pay for gas. Again, did you make the right choice? There are no "right" or "wrong" answers to most of the decisions we make. We use our best judgment at the time of our decisions and think that they are more nearly right than wrong as opposed to definitively right or wrong.

in the brain do differ somewhat. This means there may be more going on than encoding for recall when a person knows he or she will have to reason with a statement. In particular, for syllogistic reasoning, the left lateral frontal lobe (Broca's areas 44 and 45) is more active than when a statement just needs to be remembered. This activation cannot be found for processing of conditional premises.

While people were engaged in the integration of the information (solving the syllogistic and conditional reasoning problems), the left fronto-lateral cortex as well as the basal ganglia were activated for both conditional and syllogistic reasoning. However, syllogistic reasoning also involved activation in the lateral parietal cortex, precuneus, and left ventral fronto-lateral cortex (Reverberi et al., 2010). Thus, syllogistic and conditional reasoning seem to involve processing in different parts of the brain.

Exploration of conditional reasoning through event-related potential (ERP) methods revealed an increased negativity in the anterior cingulate cortex approximately 600 milliseconds and 2,000 milliseconds after task presentation (Qui et al., 2007). This negativity suggests increased cognitive control, as would be expected in a reasoning task.

In one study exploring moral reasoning in persons who show antisocial behaviors indicative of poor moral reasoning, malfunctions were noted in several areas within the prefrontal cortex, including the dorsal and ventral regions (Raine & Yang, 2006). Additionally, impairments in the amygdala, hippocampus, angular gyrus, anterior cingulate, and temporal cortex were also observed. Recall that the anterior cingulate is involved in decision making and the hippocampus is involved in working memory. Therefore, it is to be expected that malfunctions in these areas would result in deficiencies in reasoning.

✔ CONCEPT CHECK

1. Which parts of the brain are prominently involved in reasoning processes?
2. Why can we expect that the parts of the brain that are involved in working memory are also active during reasoning?

Key Themes

Several of the themes discussed in Chapter 1 are relevant to this chapter.

Rationalism versus empiricism. One way of understanding errors in syllogistic reasoning is in terms of the particular logical error made, independently of the mental processes the reasoner has used. For example, affirming the consequent is a logical error. One need do no empirical research to understand at the level of symbolic logic the errors that have been made. Moreover, deductive reasoning is itself based on rationalism. A syllogism such as, "All toys are chairs. All chairs are hot dogs. Therefore, all toys are hot dogs," is logically valid but factually incorrect. Thus, deductive logic can be understood at a rational level, independently of its empirical content. But if we wish to know psychologically why people make errors or what is factually true, then we need to combine empirical observations with rational logic.

Domain generality versus domain specificity. The rules of deductive logic apply equally in all domains. One can apply them, for example, to abstract or to concrete content. But research has shown that, psychologically, deductive reasoning with concrete content is easier than reasoning with abstract content. So although the rules apply in exactly the same way generally across domains, ease of application is not psychologically equivalent across those domains.

Nature versus nurture. Are people preprogrammed to be logical thinkers? Piaget, the famous Swiss cognitive developmental psychologist, believed so. He believed that the development of logical thinking follows an inborn sequence of stages that unfold over time. According to Piaget, there is not much one can do to alter either the sequence or timing of these stages. But research has suggested that the sequence Piaget proposed does not unfold as he thought. For example, many people never reach his highest stage, and some children are able to reason in ways he would not have predicted they would be able to reason until they were older. So once again, nature and nurture interact.

Summary

1. **What are some of the strategies that guide human decision making?** Early theories were designed to achieve practical mathematical models of decision making and assumed that decision makers are fully informed, infinitely sensitive to information, and completely rational. Subsequent theories began to acknowledge that humans often use subjective criteria for decision making, that chance elements often influence the outcomes of decisions, that humans often use subjective estimates for considering the outcomes, and that humans are not boundlessly rational in making decisions. People apparently often use satisficing strategies, settling for the first minimally acceptable option, and strategies involving a process of elimination by aspects to eliminate an overabundance of options.

   One of the most common heuristics most of us use is the representativeness heuristic. We fall prey to the fallacious belief that small samples of a population resemble the whole population in all respects. Our misunderstanding of base rates and other aspects of probability often leads us to other mental shortcuts as well, such as in the conjunction fallacy and the inclusion fallacy.

   Another common heuristic is the availability heuristic, in which we make judgments based on information that is readily available in memory, without bothering to seek less available information. The use of heuristics, such as anchoring and adjustment, illusory correlation, and framing effects, also often impairs our ability to make effective decisions.

   Once we have made a decision (or better yet, another person has made a decision) and the outcome of the decision is known, we may engage in hindsight bias, skewing our perception of the earlier evidence in light of the eventual outcome. Perhaps the most serious of our mental biases, however, is overconfidence, which seems to be amazingly resistant to evidence of our own errors.
2. **What are some of the forms of deductive reasoning that people may use, and what factors facilitate or impede deductive reasoning?** Deductive reasoning involves reaching conclusions from a set of conditional propositions or from a syllogistic pair of premises. Among the various types of syllogisms are linear syllogisms and categorical syllogisms. In addition, deductive reasoning may involve complex transitive-inference problems or mathematical or logical proofs involving large numbers of terms. Also, deductive reasoning may involve the use of pragmatic reasoning schemas in practical, everyday situations.

   In drawing conclusions from conditional propositions, people readily apply the *modus ponens* argument, particularly regarding universal affirmative propositions. Most of us have more difficulty, however, in using the *modus tollens* argument and in avoiding deductive fallacies, such as affirming the consequent or denying the antecedent, particularly when faced with propositions involving particular propositions or negative propositions.

   In solving syllogisms, we have similar difficulties with particular premises and negative premises and with terms that are not presented in the customary sequence. Frequently, when trying to draw conclusions, we overextend a strategy from a situation in which it leads to a deductively valid conclusion to one in which it leads to a deductive fallacy. We also may foreclose on a given conclusion before considering the full range of possibilities that may affect the conclusion. These mental shortcuts may be exacerbated by situations in which we engage in confirmation bias (tending to confirm our own beliefs).

   We can enhance our ability to draw well-reasoned conclusions in many ways, such as by taking time to evaluate the premises or propositions carefully and by forming multiple mental models of the propositions and their relationships. We also may benefit from training and practice in effective deductive reasoning. We are particularly likely to reach well-reasoned conclusions when such conclusions seem plausible and useful in pragmatic contexts, such as during social exchanges.
3. **How do people use inductive reasoning to reach causal inferences and to reach other types of conclusions?** Although we cannot reach logically certain conclusions through inductive reasoning, we can at least reach highly probable conclusions through careful reasoning. When

making categorical inferences, people tend to use both top-down and bottom-up strategies. Processes of inductive reasoning generally form the basis of scientific study and hypothesis testing as a means to derive causal inferences. In addition, in reasoning by analogy people often spend more time encoding the terms of the problem than in performing the inductive reasoning. Reasoning by analogy can lead to better conclusions, but also to worse ones if the analogy is weak or based on faulty assumptions. It appears that people sometimes may use reasoning based on formal-rule systems, such as by applying rules of formal logic, and sometimes use reasoning based on associations, such as by noticing similarities and temporal contiguities.

4. **Are there any alternative views of reasoning?** A number of scientists have suggested that people have two distinct systems of reasoning: an associative system that is sensitive to observed similarities and temporal contiguities and a rule-based system that involves manipulations based on relations among symbols. The two systems can work together to help us reach reasonable conclusions in an efficient way.

Thinking about Thinking: Analytical, Creative, and Practical Questions

1. Describe some of the heuristics and biases people use while making judgments or reaching decisions.
2. What are the two logical arguments and the two logical fallacies associated with conditional reasoning, as in the Wason Selection Task?
3. Which of the various approaches to conditional reasoning seems best to explain the available data? Give reasons for your answer.
4. Some cognitive psychologists question the merits of studying logical formalisms such as linear or categorical syllogisms. What do you think can be gained by studying how people reason in regard to syllogisms?
5. Based on the information in this chapter, design a way to help high school students more effectively apply deductive reasoning to the problems they face.
6. Design a question, such as the ones used by Kahneman and Tversky, which requires people to estimate subjective probabilities of two different events. Indicate the fallacies that you may expect to influence people's estimates, or tell why you think people would give realistic estimates of probability.
7. Suppose that you need to rent an apartment. How would you go about finding one that most effectively meets your requirements and your preferences? How closely does your method resemble the methods described by subjective expected utility theory, by satisficing, or by elimination by aspects?
8. Give two examples showing how you use rule-based reasoning and associative reasoning in your everyday experiences. In what kinds of instances do you believe each type of reasoning works better, or not as well?

Key Terms

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Typical Reasoning

Wason Selection Task