Courtesy of Jackie Saccoccio and 11R, NY

6 Thinking and Intelligence

In this chapter, we will consider how we use the information in our memories to think. **Thinking** is the processing of information to solve problems and make judgments and decisions. Because these processes are important aspects of intelligent thinking, we will also consider intelligence testing and some of the controversies surrounding the concept of intelligence. We will start our discussion with the most basic, higher-level cognitive process—problem solving. You will be asked to solve several problems. You will learn more from these exercises if you try to solve each problem before reading about its solution.

Problem Solving

A problem is a situation in which there is a goal, but it is not clear how to reach the goal. There are well-defined and ill-defined problems (Gilhooly, 1996). A **well-defined problem** is a problem with clear specifications of the start state (where you are), goal state (where you want to be), and the processes for reaching the goal state (how to get there). An **ill-defined problem** is a problem lacking clear specification of the start state, goal state, or the processes for reaching the goal state. Board games such as Monopoly and Scrabble represent well-defined problems. Their start states and goal states, along with the processes of moving from one to the other (the rules of the game), are all clearly specified. Getting your roommate to help clean the apartment would be an ill-defined problem. The start state and goal state are fairly well-defined, but the processes for moving between them are not. Most problems we confront are ill-defined, and to solve them we need to define the missing parts. We'll see that some blocks to solving problems may arise in this definition process before we even attempt to solve a problem.

thinking The processing of information to solve problems and make judgments and decisions.

well-defined problem A problem with clear specifications of the start state, goal state, and the processes for reaching the goal state.

ill-defined problem A problem lacking clear specification of either the start state, goal state, or the processes for reaching the goal state.

Before learning about some of these obstacles to problem solving, I would like you to attempt to solve the following problems. You may recognize one of the series problems from Chapter 1. Don't worry if you find these problems difficult; most people do. I will explain why.

(a) Instructions: For each of these two series problems, your goal is to predict the next alphabetic character in each of the series. The answer to the first series is not "O."

OTTFFSS?
EOEREXN?

(b) Instructions: Connect the nine circles using four straight lines without lifting your pen or pencil from the paper or retracing any of your lines. You should attempt this problem on a separate sheet of paper so that you can keep a record of your attempts. Once you have a four-straight-line solution, the next goal is to connect the nine circles with three straight lines using the same constraints as in the four-straight-line version.

Blocks to Problem Solving

Problem solving can be divided into two general steps: (1) interpreting the problem and (2) trying to solve the problem. For many problems, the path to a solution is blocked in the first step by incorrectly interpreting the problem. This is like answering a test question too quickly, only to find out later that you misinterpreted the question. If you are working with such a misinterpretation, you will probably fail to solve the problem. The two nine-circle problems are good examples of problems that often lead to misinterpretations. Let's see how.

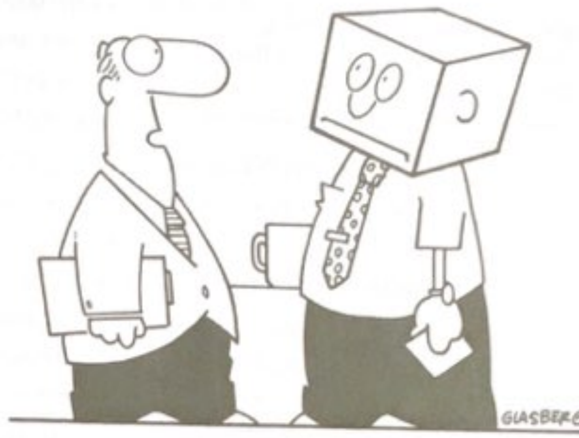
Interpreting the problem. Look at your failed attempts at solving the nine-circle problem involving four straight lines. Did you try to keep your lines within the mental square created by the circles? Most people do, and you cannot solve the problem this way (Wickelgren, 1974). Not only do most people create this misinterpretation, but they also continue to use it even though they make no progress toward solving the problem. This inability to "think outside the box" and create a new interpretation of a problem is called **fixation**. Reread the instructions. You were not required to keep your lines within this mental square. Any or all of the four lines can extend outside this space. The lines only have to be straight and connect all nine circles. Knowing this, try again to solve the problem. Draw a straight line that goes down through the first column of circles and continues on outside of the mental square. When you bring your next line back up, also continue it outside of the mental square. This should start you on your way to a solution, though it may still be elusive (Weisberg & Alba, 1981).

What about the second nine-circle problem—connecting all nine circles with three straight lines? If you didn't solve it, think about the assumptions that you made when you interpreted the problem. This problem is even more difficult, because you may have made two mistakes in your interpretation and fixated on them, making the problem impossible to solve. First, as in the four-straight-line problem, you might have assumed that you need to keep your lines within the mental

can't think outside box

fixation The inability to create a new interpretation of a problem.

square created by the circles. Second, you might have assumed that the lines need to go through the centers of the circles. Neither assumption is valid. Now try to solve this problem knowing that both of these assumptions are misinterpretations. Try drawing three straight lines that do not go through the centers of the circles and that travel outside the mental square. It might help to imagine using a very long ruler to draw your lines. If you're still stumped on either one of these problems, look at the sample solutions at the end of the chapter.



"Thinking outside of the box is difficult for some people. Keep trying."

Randy Glasbergen/glasbergen.com

Another obstacle to problem solving is **functional fixedness**—the inability to see that an object can have a function other than its typical one. This type of fixation also occurs during the problem definition stage. Functional fixedness limits our ability to solve problems that require using an object in a novel way (Duncker, 1945). This often happens to us in our everyday life. Maybe we need a screwdriver, but one isn't available. We have other things such as coins that could function as a screwdriver, but we may not think about using them in this novel way. Or, what if you just did some grocery shopping, and as you are about to walk out of the store it starts raining hard. You have no umbrella. How can you avoid getting soaked? You bought some large trash bags, but you may not think about using one as a raincoat to protect you from the rain. To combat functional fixedness, we should systematically think about the possible, novel uses of all the various objects in the problem environment. This is bound to increase our ability to solve the continual problems that come up in our daily lives.

Solving the problem. Problem misinterpretation and functional fixedness are good examples of the negative impact that our past experiences can have on our ability to solve current problems. Our past experience with problem solving can also lead to a phenomenon known as **mental set**—the tendency to use previously successful solution strategies without considering others that are more appropriate for the current problem. Mental set is especially common for strategies that have been used recently. Consider the two letter-series problems on page 243. If you had difficulty solving them, mental set may be what hindered you (Griggs, 2003). You probably attempted to solve these two problems with strategies that you have used successfully in the past with series problems. You may have viewed the letters in the series as single entities and looked for relationships between them. This strategy does not include viewing each of the letters as part of some larger entity. You cannot solve the series unless you do so. For the first series problem, you should think of the letters as the first letters in the words of a well-known ordering. It's as easy as 1-2-3.

functional fixedness The inability to see that an object can have a function other than its typical one in solving a problem.

mental set The tendency to use previously successful problem-solving strategies without considering others that are more appropriate for the current problem.

facilitated the solution of insight problems. The stimulation led to a threefold increase in solving difficult matchstick problems. Hence, maybe the advice to "think outside the box" should be amended to be "think outside the frontal lobes." Chi and Snyder (2012) also found that this same transcranial stimulation of the anterior temporal lobes will facilitate the solution of the nine-circle problem. None of the participants solved the problem before stimulation; 14 of 33 broke fixation and solved it as a result of receiving the stimulation. Chi and Snyder calculated that the probability that this fraction of the participants could solve it by chance is less than one in a billion.

You might wonder if there is any validity to prescriptive advice such as to "think outside the box." Metaphors such as this (and others such as to consider a problem "on one hand and then on the other") suggest a connection between concrete bodily experiences and creative problem solving in which physically enacting the metaphor would enhance creative problem solving. Leung et al. (2012) have provided the first evidence that such embodiment might activate cognitive processes that facilitate creativity. For example, subjects trying to solve an innovative verbal thinking task performed much better if they sat and thought outside rather than inside a 125-cubic-foot box made of plastic pipe and cardboard. Similar results were observed for another creativity task for subjects solving the task while walking freely outside a fixed rectangular path indicated by duct tape on the floor (marking out a box of about 48 square feet in area) versus walking along the path. Obviously much more research is needed on this experimental question, but these initial findings indicate that thinking "outside the box" may not be a cliché; you might just need to use an actual box.

We have discussed many potential blocks to problem solving, and it takes a very conscious, concerted effort to overcome them. What can you do? Ask yourself questions such as the following: Is my interpretation of the problem unnecessarily constraining? Can I use any of the objects in the problem in novel ways to solve the problem? Do I need a new type of solution strategy? If we do not make this effort, we are engaged in what is called mindless behavior—rigid, habitual behavior in which we fail to attend carefully to the details of the present situation (Langer, 1989, 1997). To be good problem solvers, we will need to be open to new interpretations of problems and to new ways of using objects to solve problems. We will also need to develop a broader, more effective set of solution strategies, which is our next topic.

Solution Strategies

Just as problem solving can be divided into two steps, solution strategies can be divided into two types—algorithms and heuristics. An **algorithm** is a step-by-step procedure that guarantees a correct answer to a problem. For example, when we solve a math problem with long division, we are using an algorithm. If we execute the steps correctly, we will get the correct answer. For many problems, however, we may not know the algorithm or an algorithm for the problem may not exist. To solve the

algorithm A step-by-step problem-solving procedure that guarantees a correct answer to a problem.

heuristic A problem-solving strategy that seems reasonable given one's past experience with solving problems, especially similar problems, but does not guarantee a correct answer to a problem.

problem in such cases, we have to use a **heuristic**, a solution strategy that seems reasonable given our past experiences with solving problems, especially similar problems. Think of a heuristic as an educated guess.

Sometimes you may even know the algorithm for a problem, but you don't use it because its execution would be too time-consuming. Instead you may try some heuristics, and they might pay off with a quicker answer, or they may lead to no answer or an incorrect one. This is the crucial difference between an algorithm and a heuristic. An algorithm guarantees a correct answer (if it's the correct algorithm for the problem and you execute it correctly), but a heuristic makes no guarantees. Let's consider some problems (anagram word puzzles) for which you likely know the algorithm, but because it would usually be too difficult to execute, you use heuristics instead. In an anagram puzzle, the letters of a word are presented in a scrambled order, and the problem is to rearrange them to determine the word. Now, what's the algorithm for such puzzles? Generate each possible sequence of the letters and check to see if each sequence is a word. This sounds simple, but it isn't. For example, there are over 5,000 possible sequences of the letters for a seven-letter anagram! So unless there are only a few letters in the anagram, we use heuristics based upon our knowledge of the English language. For example, we know that the letter U usually follows the letter Q and that certain letters such as B and C don't follow one another in words. We attempt to create words with the letters following such principles. To understand this strategy, let's work a couple of anagram puzzles. As you try to solve them, think about the strategy you are using.

Instructions: Rearrange the letters in each anagram puzzle to form a meaningful word in the English language.

1. LOSOGCYHYP **2. TERALBAY** Betrayal

The first puzzle is rather easy. The answer is especially relevant to this text. It's PSYCHOLOGY. Your use of heuristics was probably successful and led to a quick answer. The second puzzle is more difficult. Your use of heuristics may have failed and didn't yield a solution. Even so, you probably didn't switch to using the algorithm. You probably kept trying to find a solution by using heuristics. As you can see, heuristics might pay off with quick answers, but they may lead to no answer as in the second anagram puzzle. Now think about the algorithmic strategy. There are over 40,000 sequences for the eight letters in the second anagram puzzle; therefore, generating each of them to check if it's a word would take far more time and effort than we are willing to spend. However, if you did so, you would find that the answer is BETRAYAL.

Now let's consider three particular heuristics that are used fairly often in problem solving—the anchoring and adjustment, working backward, and means-end analysis heuristics. We'll start with the anchoring and adjustment heuristic.

Anchoring and adjustment. To help you to understand this heuristic, let's try an estimation problem taken from Plous (1993). The task involved in this problem would be impossible to execute. It is only a hypothetical problem that examines how we make estimates.

> **Estimate how thick a sheet of paper that is 0.1 millimeter thick would be if it were folded in on itself 100 times.**

Most people estimate the thickness to be only a few yards or so, which is not even close to the correct answer: 0.1 millimeter $\times 2^{100}$, which equals 800 trillion times the distance between the earth and the sun (Plous, 1993)! Why do we underestimate this thickness by so much? We are most likely using the **anchoring and adjustment heuristic** in which an initial estimate is used as an anchor and then this anchor is adjusted up or down. The difficulty in using the anchoring and adjustment heuristic is that we tend to attach too much importance to the starting anchor amount and do not adjust it sufficiently (Tversky & Kahneman, 1974). The folding problem is a good illustration of this bias. If you double the thickness of the sheet of paper a few times, you still have a rather small thickness. Using this small thickness as an anchor for making your estimate, you do not adjust the estimate sufficiently and usually guess only a few yards. In this case, the anchoring and adjustment heuristic leads us to ignore the fact that the powers of 2 grow exponentially as we double them and become very large very quickly.

This estimation problem was only a hypothetical exercise, but it shows how we fail to adjust the anchor enough when using the anchoring and adjustment heuristic. Anchoring is a very robust psychological phenomenon and has even been shown to hold when the anchors represent the same physical quantity, 7.3 kilometers and 7,300 meters (Wong & Kwong, 2000). Estimates for the 7.3 km group were much lower than those for the 7,300 m group. Anchoring has been shown to influence judgments in a variety of domains, such as making judgments in personal injury cases (Chapman & Bornstein, 1996), negotiating (Ritov, 1996), and playing the stock market (Paulos, 2003). In the real world, anchoring may have costs attached to it. A good example that you may have experienced is the inclusion of minimum payment information on credit card statements. These minimum payment amounts can act as psychological anchors (Stewart, 2009; Thaler & Sunstein, 2008). In a hypothetical bill-paying experiment manipulating the inclusion of minimum payment information, Stewart (2009) found that the inclusion of this information led to significant reductions in partial payment amounts, which in the real world would lead to increased interest charges. We should also beware of using this heuristic when meeting people. Our first impression of a person is similar to forming an anchor. We must be sure to process subsequent information about the person carefully and adjust our impression (anchor) sufficiently. Remember, the anchoring and adjustment heuristic leads us to fail to adjust the anchor enough. So do not become too attached to an anchor when making judgments and decisions.

Working backward. Working backward is a heuristic that you may have learned to use in your math classes. The **working backward heuristic** is attempting to solve a problem by

anchoring and adjustment heuristic A heuristic for estimation problems in which one uses his or her initial estimate as an anchor estimate and then adjusts the anchor up or down (often insufficiently).

working backward heuristic A problem-solving heuristic in which one attempts to solve a problem by working from the goal state back to the start state.

means–end analysis heuristic A problem-solving heuristic in which the distance to the goal state is decreased systematically by breaking the problem down into subgoals and achieving these subgoals.

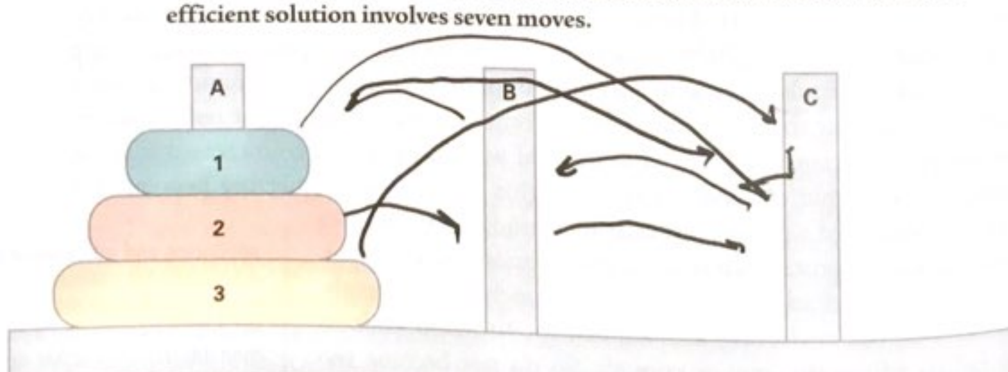
working from the goal state backward to the start state (Wickelgren, 1974). In math problems, this translates to working backward from the answer to the given information in the problem. To see how this heuristic would work, consider the following problem (Sternberg & Davidson, 1982):

Water lilies growing in a pond double in area every 24 hours. On the first day of spring, only one lily pad is on the surface of the pond. Sixty days later, the pond is entirely covered. On what day is the pond half covered?

Did you solve it? It is impossible to solve this problem working in a forward direction. However, if you work backward by starting with the fact that the pond is entirely covered on the sixtieth day, you can solve it rather easily. Just ask yourself how much of the pond would be covered on the fifty-ninth day if the pond were entirely covered on the sixtieth day. The answer is half. The working backward heuristic is ideal for problems that have many possible paths from the start state, but only one path (or a few) going backward from the goal state.

Means–end analysis. A good heuristic for working forward on a problem is means–end analysis. In the **means–end analysis heuristic**, the problem is broken down into subgoals and we work toward decreasing the distance to the goal state by achieving these subgoals. Consider the following Tower of Hanoi problem. It is a well-defined problem. The start state, the goal state, and the rules for moving from the start state to the goal state are all clearly specified.

Instructions: The problem is to create the same configuration of disks on Peg C as is on Peg A in the starting state. Rules, however, govern your moves. You can only move one disk at a time, and you cannot place a larger disk on top of a smaller disk. Try to solve this problem efficiently by minimizing the number of moves that have to be made. The most efficient solution involves seven moves.



Let's try to use means–end analysis to solve the problem. What would be the first subgoal? You have to get Disk 3 on Peg C. You cannot, however, achieve this immediately, so you have to set up another subgoal. What is it? You have to get the particular probability judgment. To understand, let's consider the following problem (Tversky & Kahneman, 1983).

> **You will read a brief description of Linda, and then you will be asked to make a judgment about her. Here's the description:**
>
> **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 antinuclear demonstrations.**
>
> **Which of the following alternatives is more likely?**
>
> **Linda is a bank teller.**
>
> **Linda is a bank teller and active in the feminist movement.**

representativeness heuristic A heuristic for judging the probability of membership in a category by how well an object resembles (is representative of) that category (the more representative, the more probable).

The representativeness heuristic. To decide which alternative is more probable, most people would use what is called the **representativeness heuristic**—a rule of thumb for judging the probability of membership in a category by how well an object resembles (is representative of) that category. Simply put, the rule is: the more representative, the more probable. Using this heuristic, most people, including undergraduates, graduate students, and professors, judge that the second alternative (Linda is a bank teller and active in the feminist movement) is more likely than the first alternative (Tversky & Kahneman, 1983). Why? Linda resembles someone active in the feminist movement more than she resembles a bank teller. However, it is impossible for the second alternative to be more likely than the first. Actually the description of Linda is totally irrelevant to the probability judgment!

Let's look at the set diagram in Figure 6.1. This diagram illustrates what is known as the conjunction rule for two different uncertain events (in this case, being a bank teller and being active in the feminist movement). The conjunction rule is that the likelihood of the overlap of two uncertain events (the green section of the diagram) cannot be greater than the likelihood of either of the two events because the overlap is only part of each event. This means that all of the tellers who are active in the feminist movement make up only part of the set of all bank tellers. Because the set of bank tellers is larger and includes those tellers who are active in the feminist movement, it is more likely that someone is a bank teller than that someone is a bank teller and active in the feminist movement. Judging that it is more likely that Linda is a bank teller and

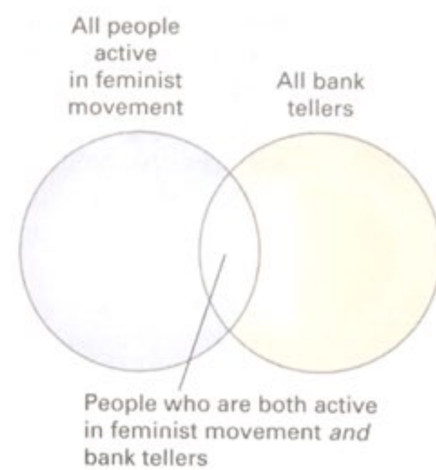


Figure 6.1 | The Overlapping Set Diagram for the Linda Problem | The overlap (the green area) of the two sets (all bank tellers and all people active in the feminist movement) indicates the probability of being both a bank teller and active in the feminist movement. Because this area is a subset (part) of each of the two sets, its probability has to be less than that for either of the two sets. This is the conjunction rule.

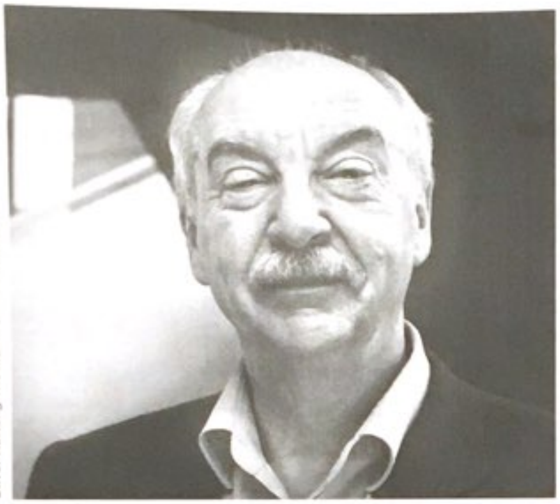
you would judge the reverse to be the case (that *r* occurs more often as the first letter). The **availability heuristic** is the rule of thumb that the more available an event is in our memory, the more probable it is (Tversky & Kahneman, 1973). We can think of more words beginning with the letter *r* than with *r* in the third position because we organize words in our memories by how they begin. This does not mean that they are more frequent, but only that it is easier to think of them. They are easier to generate from memory. The opposite is the case—words with *r* in the third position are more frequent. This is actually true for seven letters: *k*, *l*, *n*, *r*, *v*, *x*, and *z* (Tversky & Kahneman, 1973).

availability heuristic A heuristic for judging the probability of an event by how available examples of the event are in memory (the more available, the more probable).

Remember that a heuristic does not guarantee a correct answer. The availability heuristic may often lead to a correct answer; but as in the letter *r* problem, events are sometimes more easily available in our memories for reasons other than how often they actually occur. An event may be prominent in our memories because it recently happened or because it is particularly striking or vivid. In such cases, the availability heuristic will lead to an error in judgment. Think about judging the risk of various causes of death. Some causes of death (airplane crashes, fires, and shark attacks) are highly publicized and thus more available in our memories, especially if they have occurred recently. Using the availability heuristic, we judge them to be more likely than lesser publicized, less dramatic causes of death such as diabetes and emphysema, which are actually more likely but not very available in our memories (Lichtenstein, Slovic, Fischhoff, Layman, & Combs, 1978). In fact, the probability of dying from falling airplane parts is 30 times greater than

AP Photo

Because airplane crashes are so visually dramatic and highly publicized by the media, they tend to be very available in our memories. This availability leads us to greatly overestimate our likelihood of dying in a plane crash.


Oliver Hartung/The New York Times/Redux

Gerd Gigerenzer

intuitive process, I will show you a straightforward way to do it, so that you can make more informed medical decisions.

Much of the research that is focused on how successful doctors and patients are at correctly interpreting a positive result for a medical screening test and on how they can improve their performance has been conducted by Gerd Gigerenzer and his colleagues (Gigerenzer, 2002; Gigerenzer & Edwards, 2003; Gigerenzer, Gaissmaier, Kurz-Milcke, Schwartz, & Woloshin, 2007; Gigerenzer & Hoffrage, 1995). Both doctors and patients have been found to overestimate these conditional probabilities. An older study by Eddy (1982) with 100 American doctors as the participants illustrates this overestimation finding; but before considering it, some explanation is necessary. In medicine, probabilities are often expressed in percentages rather than as numbers between 0 and 1.0. Three terms relevant to screening tests, the base rate for a disease and the sensitivity and false positive rates for the test, also need to be explained before we continue. The base rate (prevalence) of a disease is simply the probability with which it occurs in the population. The sensitivity rate for a screening test is the probability that a patient tests positive if she has the disease, and the false positive rate is the probability that a patient tests positive if she does not have the disease. Now consider Eddy's problem. You should try to estimate the probability asked for in the problem before reading on.

> **Estimate the probability that a woman has breast cancer given a positive mammogram result and a base rate for this type of cancer of 1%, a sensitivity rate for the test of 80%, and a false positive rate for the test of 9.6%.**

What was your estimate? If you acted like the doctors, you overestimated the probability. Almost all of the doctors estimated this probability to be around 75%. The correct answer, however, is much less, only around 8%. Hoffrage and Gigerenzer (1998) replicated Eddy's finding with even more shocking results. Physicians' estimates ranged from 1% to 90%, with a 90% chance of breast cancer being the most frequent estimate. Given the doctors' overestimation errors, think of how many women who tested positive in this case would have been unnecessarily alarmed had this been real life and not an experiment. Think about the possible consequences, which are far from trivial—emotional distress, further testing, biopsy, more expense, and maybe even unnecessary surgery. To correctly compute the conditional probability that someone has the disease given a positive test result, Gigerenzer recommends that you convert all of the percentages (probabilities) into natural frequencies, simple counts of events. According to typically associated with a child's level of test performance. If a child's mental age were less than his or her chronological (actual) age, the child would need remedial work. The fact that Binet helped in the development of "mental orthopedics"—mental exercises designed to raise the intelligence of children classified as subnormal—clearly illustrated his bent toward the nurture side of the nature-nurture debate. The Binet-Simon test was revised in 1908 and again in 1911, the year Binet died unexpectedly at the age of 54 from a terminal disease whose exact nature is no longer known (Fancher, 1985). Within 10 years of Binet's death, translations and revisions of the Binet-Simon scale were in use all over the world (Miller, 1962). Ironically, the test was not used extensively in France until the 1940s—and only then when a French social worker who had been working in the United States brought the American version of the test back to France (Kaufman, 2009; Miller, 1962).


© Corbis
Alfred Binet

The next major figure in intelligence test development, Lewis Terman, had Galton's nature bias, but he used Binet and Simon's test. Working at Stanford University, Terman revised the intelligence test for use with American schoolchildren. This revision, first published in 1916, became known as the Stanford-Binet (Terman, 1916). To report Stanford-Binet scores, Terman used the classic intelligence quotient formula suggested by William Stern, a German psychologist (Stern, 1914). The **intelligence quotient (IQ)** formula was the following: IQ = (mental age/chronological age) × 100. Multiplying by 100 centered the scale at 100. When a child's mental age (as assessed by the test) was greater than the child's chronological age (actual age), the child's IQ was greater than 100; when chronological age was greater than mental age, the child's IQ was less than 100. The IQ formula, however, is no longer used to compute a person's intelligence test score on the Stanford-Binet. It is a confounded measure because a year's growth doesn't have a constant meaning from year to year for mental ability. Mental growth levels off, but age keeps increasing. How intelligence test scores are computed is explained in our discussion of the next major figure of intelligence testing, David Wechsler.

intelligence quotient (IQ) (mental age/chronological age) × 100.

David Wechsler was working as chief psychologist at Bellevue Hospital in New York City in the 1930s and was in charge of testing thousands of adult patients from very diverse backgrounds (Fancher, 1985). Like Binet, Wechsler thought that intelligence was nurtured by one's environment. Given that most of his patients were undereducated, he wanted to get a much broader assessment of their abilities. The Stanford-Binet wasn't well-suited for his purposes, because it only


Courtesy Stanford University Archives
Lewis Terman


Archives of the History of American Psychology, The Center for the History of Psychology, The University of Akron
David Wechsler

J.B. Handelsman/The New Yorker Collection/The Cartoon Bank

provided a single measure of abilities related to academic performance (IQ). The IQ formula was especially irrelevant for adults because, as we mentioned earlier, at some point mental age levels off but chronological age keeps increasing. Based on the Stanford-Binet, a person's IQ would automatically go down with age regardless of one's mental abilities.

Given all of these problems, Wechsler developed his own test, the Wechsler Bellevue Scale, in 1939 (Gardner, Kornhaber, & Wake, 1996). This test became known as the Wechsler Adult Intelligence Scale (WAIS) in 1955 and is appropriate for ages 16 and older. Wechsler also developed the Wechsler Intelligence Scale for Children (WISC) in 1949 for children aged 6 to 16. Both tests (the WAIS and WISC) provide finer analyses of a person's abilities by providing test scores for a battery of not only verbal tests (such as vocabulary and word reasoning) but also nonverbal, performance tests (such as block design, matrix reasoning, and visual puzzles). An item similar to those on the WAIS nonverbal Visual Puzzles subtest and some similar to those on the WAIS Cancellation subtest are given in Figure 6.3a and 6.3b, respectively.

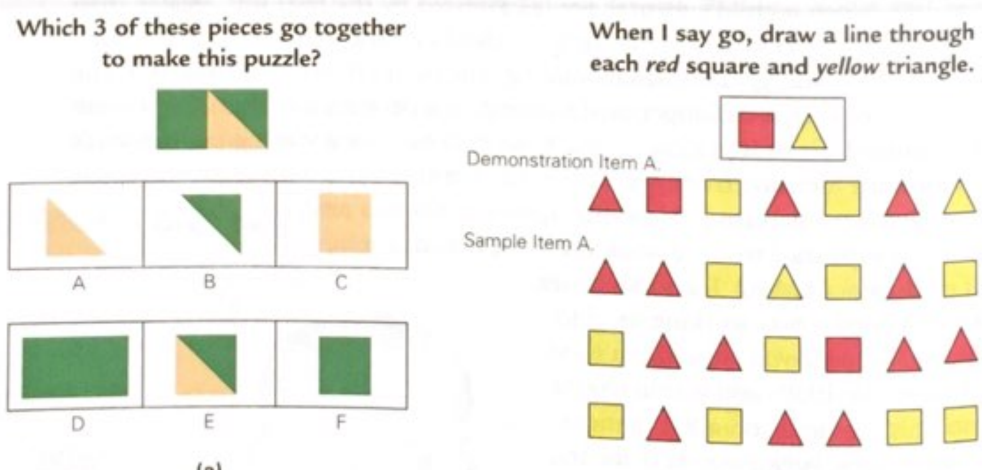


Figure 6.3 | **Sample Performance (Nonverbal) Test Items on the WAIS** | (a) This is a nonverbal test item similar to those on the WAIS Visual Puzzles subtest that assesses perceptual reasoning ability. (b) These are nonverbal test items similar to those on the WAIS Cancellation subtest that assess perceptual processing speed. (a) Wechsler Adult Intelligence Scale, Fourth Edition (WAIS-IV). Copyright © 2008 NCS Pearson, Inc. Reproduced with permission. All rights reserved. (b) "Wechsler Adult Intelligence Scale®, Fourth Edition" and "WAIS" are trademarks, in the United States and other countries, of Pearson Education, Inc. or its affiliate(s).)

score fell 1 standard deviation above the mean for his or her age group, he or she would have a deviation IQ score of 100 plus (15×1), or 115. The deviation IQ scale for the WAIS is illustrated in Figure 6.4. The same scale is used for the WISC but with standardization data for various child age groups; a similar deviation IQ scale with the standard deviation set at 15 is now used for scoring the Stanford-Binet intelligence test.

Reliability and validity. In addition to being standardized, a good test must also be reliable and valid. **Reliability** is the extent to which the scores for a test are consistent. This may be assessed in various ways. In the test–retest method, the test is given twice to the same sample, and the correlation coefficient for the two sets of scores is computed. If the test is reliable, this coefficient should be strongly positive. Remember from Chapter 1 that a strong correlation coefficient approaches 1.0, hence acceptable reliability coefficients should be around +0.90 or higher. The reliability coefficients for the major intelligence tests, the WAIS, WISC, and Stanford-Binet, are at this level (Kaufman, 2000).

If multiple forms of the test are available, then alternate-form reliability can be assessed. Alternate-form reliability is determined by giving different forms of the test to the same sample at different times and computing the correlation coefficient for performance on the two forms. A third type of reliability assessment involves consistency within the test. If the test is internally consistent, then performance on the two halves of the test (odd versus even items) should be strongly positively correlated. This type of reliability is called split-half reliability because performance on half of the test items (the odd-numbered items) is compared to performance on the other half (the even-numbered items).

In addition to reliability, a test should have validity. **Validity** is the extent to which a test measures what it is supposed to measure or predicts what it is supposed to predict. The former type of validity is called content validity, and the latter, predictive validity. Content validity means that the test covers the content that it is supposed to cover. Experts decide this. All course exams should have content validity (be on the content that was assigned). Predictive validity means that the test predicts behavior that is related to what is being measured by the test; for example, an intelligence test should predict how well a child does in school. Children and teenagers higher in intelligence should do better on average than children and teenagers lower in intelligence, and this is the case for the intelligence tests that we have discussed. These tests all have good predictive validity. It is important to note that if a test is valid, then it will also be reliable. However, the reverse is not true. A test may be reliable, but not valid. A good example is measuring the circumference of the head as an indicator of intelligence. This number would be consistent across two measurements and therefore reliable, but it does not predict intelligent behavior (does not have predictive validity).

Intelligence test scores are among the most valid predictors of academic performance and job performance across

reliability The extent to which the scores for a test are consistent.

validity The extent to which a test measures what it is supposed to measure or predicts what it is supposed to predict.

and Keith Stanovich (2009a, b) extend this definition to include other types of abilities. We'll consider Gardner's first. According to Gardner's theory of multiple intelligences, there are eight independent intelligences—linguistic, logical-mathematical, spatial, musical, bodily-kinesthetic, intrapersonal, interpersonal, and naturalistic. Brief descriptions of each of these intelligences are given in Table 6.1. The linguistic and logical-mathematical intelligences seem to fit with other definitions of intelligence in terms of mental abilities, but the other six are controversial; many psychologists see these as talents or skills instead of types of intelligence. In addition, many of these intelligences are difficult to quantify (such as intrapersonal intelligence) and present measurement problems.

According to Sternberg's triarchic theory of intelligence, there are three types of intelligence—analytical, practical, and creative. Analytical intelligence is essentially what is measured by standard intelligence tests, the skills necessary for good academic performance. However, the other two types of intelligence are not really measured by standard intelligence tests. Practical intelligence could be equated with good common sense or "street smarts." Creative intelligence is concerned with the ability to solve novel problems and deal with unusual situations. Sternberg's intelligences are all types of mental ability, but the inclusion of practical and creative intelligences broadens our conception of intelligence by including mental abilities that seem to have more applicability in the nonacademic world.

Cognitive researcher Keith Stanovich (2009a, 2009b) argues that intelligence is a meaningful, useful construct and, unlike Gardner and Sternberg, is not interested in expanding the definition of intelligence. Rather he argues that intelligence is only one component of good thinking and thus by itself is not sufficient to explain such thinking. The other critical component is our ability to think and act rationally, which is not assessed by standard intelligence tests. Further, these two components are independent so you can be intelligent and not act rationally and vice versa. This is why smart people sometimes do foolish things. Stanovich

Table 6.1 Brief Descriptions of Gardner's Eight Intelligences

Linguistic	Language ability as in reading, writing, and speaking
Logical-mathematical	Mathematical problem solving and scientific analysis
Spatial	Reasoning about visual spatial relationships
Musical	Musical skills such as the ability to compose and understand music
Bodily-kinesthetic	Skill in body movement and handling objects
Intrapersonal	Understanding oneself
Interpersonal	Understanding other people
Naturalist	Ability to discern patterns in nature

Mike Twohy/The New Yorker Collection/The Cartoon Bank

"Big deal, an A in math. That would be a D in any other country."

Thus, for a given population, 50% to 70% of the variation in their intelligence test scores is estimated to be due to heredity. However, because heritability is not 100%, this means that heredity and environment work together to determine intelligence (though heredity may make a larger contribution). Given this fact, recent research focuses on how heredity and environment interact to determine a person's intelligence score. The assumption is that heredity determines a **reaction range,** genetically determined limits for an individual's intelligence. Heredity places upper and lower limits on a person's intelligence, but the quality of the person's environment determines where the individual falls within this range. The principle is simple—the higher the environmental quality, the higher the person's intelligence within the reaction range.

Two points about heritability should be made clear. First, it is a group statistic and is not relevant to individual cases. For example, if the heritability estimate for intelligence for a population were 50%, this does not mean that 50% of the intelligence of an individual in the group is determined by genetics and the other 50% by environmental experiences. It means that 50% of the variation in intelligence among people in the population is due to genetics and 50% of the variation is due to environmental experiences. Second, it is important to understand that heritability has nothing to do with the differences that have been observed between populations, such as the difference in scores for Asian schoolchildren versus American schoolchildren. Heritability only applies to the variation within a given population or group, not to variation between groups. Observed group differences must be analyzed individually and in a different way.

Let's examine the gap between Asian and American schoolchildren to see one way such analyses are done (Stevenson, Chen, & Lee, 1993; Stevenson & Stigler, 1992). In this case, researchers examined the group difference for children of different ages and concluded that the gap is likely due to the priority placed on education in Asian countries. Why? There doesn't seem to be a gap before the children enter school. The gap begins and increases as the children proceed through school. The Asian cultures place higher value on education, and so the children spend more time studying and work harder, achieving more in school and higher test scores. There seem to be clear environmental factors operating to explain this particular group difference.

reaction range The genetically determined limits for an individual's intelligence.

As if there are not enough unanswered questions and debates about intelligence, a recent curious finding has led to yet another. It is called the "Flynn effect" because intelligence researcher James Flynn popularized it. The "Flynn effect" label was coined by Herrnstein and Murray in their book *The Bell Curve* (1994). Actually Flynn (2007) says that if he had thought to name it, he would have called it the "Tuddenham effect" because Tuddenham (1948) was the first to present convincing evidence of the effect using the intelligence test scores of U.S. soldiers in World Wars I and II. The **Flynn effect** refers to the fact that in the United States and other Western developed nations, average intelligence scores have improved steadily over the past century (Flynn, 1987, 1999, 2007, 2012). For example, the average score in 1918 would be equivalent to a score of 76 when compared to recent standardization norms. This translates to a gain on average of about 3 points per decade on both the Stanford-Binet and Wechsler intelligence scales. A recent meta-analysis (Trahan, Stuebing, Hiscock, & Fletcher, 2014) of 285 studies (N = 14,031) with test score data for a wider range of intelligence tests than Flynn used in his analyses supported Flynn's estimate of about 3 points per decade. Another recent, even larger meta-analysis of the intelligence test score data for almost 4 million participants from 31 countries across more than one century (1909–2013) also found an average of about 3 points per decade in intelligence test scores (Pietschnig & Voracek, 2015).

Flynn effect The finding that the average intelligence test score in the United States and other industrialized nations has improved steadily over the last century.

Proposed explanations for the Flynn effect involve a broad range of environmental factors, from improved nutrition, hygiene, and availability of medical services to better education and smaller average family size, but the explanation of the effect still remains a source of debate, with multiple factors likely contributing to it (Neisser, 1998; Mingroni, 2014; Williams, 2013). Joining this debate, Flynn has recently proposed that the effect is not due to people getting smarter overall but rather to the fact that they are getting smarter at skills that have become more important in our society over the past century, especially abstract, scientific thinking (Flynn, 2007, 2012). Our society has changed from agriculture-based to industry-based to information-based. Thus, the need to develop abstract, scientific thinking has grown as the nature of our society has changed. Flynn's hypothesis is supported by the finding that large intelligence increases have not been observed for all types of cognitive functioning. For example, the largest intelligence gains have come on intelligence subtests that involve abstract, scientific thinking, and the gains on subtests that are related to traditional academic subjects, such as vocabulary, general knowledge, and arithmetic, have been smaller. In agreement with Flynn's proposal, Pietschnig and Voracek (2015) found that the gains for fluid intelligence (abilities such as abstract reasoning that are independent of acquired knowledge) over the past century have been greater than for crystallized intelligence (acquired knowledge and verbal and numerical skills).

James Flynn

Bill Anderson/Science Source

Jean Piaget interacting with a child attempting to solve a problem in one of Piaget's loosely structured studies.

interviews he instead posed problems for children to solve (he used his own three children in his early research), observed their actions carefully, and questioned them about their solutions. He was particularly interested in children's errors, which he thought provided insight into the child's thinking, especially into how it differed from adult thinking. He found that children of roughly the same age often gave the same wrong answers. From such data, he developed a theory of cognitive development that revolutionized our understanding of children's thinking and its development (Piaget, 1926/1929, 1936/1952, 1983).

Piaget's cognitive theory incorporated two of his interests, biology and philosophy. He assumed that cognitive development stems from a child's adaptation to the environment, and that children attempt to promote their survival by trying to learn about their environment. This means that a child is an active seeker of knowledge and gains an understanding of the world by operating in it. The child organizes this knowledge into what Piaget called schemes (now called schemas), which are frameworks for our knowledge about people, objects, events, and actions. Remember, we discussed these in Chapter 5. Schemas are the basic units of our knowledge that allow us to organize and interpret information about our world. In our long-term memories, we have schemas for concepts (such as books or dogs), events (such as going to a restaurant or to the dentist's office), and actions (such as riding a bicycle).

According to Piaget, cognitive adaptation involves two processes, assimilation and accommodation, both of which impact the development of schemas and thus learning. **Assimilation** is the interpretation of new experiences in terms of our existing schemas; **accommodation** is the modification of current schemas to allow for new experiences. Our earlier example of overextension—when infants call all men "dada"—would represent a child's attempt to assimilate. Children learn, however, that they need to accommodate and change their schemas. A child has only one father, but there are many men in the world. It is through accommodation that the number and complexity of a child's schemas increase and learning occurs. In accommodation, either new schemas are created for information that doesn't fit into one's present schemas or existing schemas are modified to include the new information (such as for father and men).

assimilation Piaget's term for the interpretation of new experiences in terms of present schemas.

accommodation Piaget's term for the modification of present schemas to fit with new experiences.

Piaget also proposed that major changes in children's thinking occur in stages. Each stage permits only certain kinds of thinking and involves qualitatively different

THE FAMILY CIRCUS By Bil Keane

"Look what I can do, Grandma!"

The child in this cartoon is demonstrating egocentric behavior, so he would be in Piaget's preoperational stage of cognitive development. Given his egocentrism, he thinks that everybody sees what he sees regardless of where they are.

speech, which represents continuing development of symbolic representation.

The preoperational stage. In the **preoperational stage**, from age 2 to age 6, children's thinking becomes more symbolic and language-based, but remains egocentric and lacks the mental operations that allow logical thinking. Preoperational children can pretend, imagine, and engage in make-believe play. They have the ability to use one thing to represent another. Preoperational children might pretend that a broom is a horse to ride, or that their finger is a toothbrush. They no longer need to be interacting with an object to think about it. For example, they now can point to a picture of a dog and say "doggie" or crawl around and pretend to be a dog by barking like a dog. Word learning also continues at a rapid pace, and children have learned thousands of words by the end of the preoperational stage. Children also learn to produce narratives, descriptions of past events that have the structure of a story. However, preoperational children's thinking still has major limitations. Let's first consider what it means that their thinking is egocentric.

Egocentrism is the inability to distinguish one's own perceptions, thoughts, and feelings from those of others. This means that a preoperational child cannot perceive the world from another person's perspective. For example, preoperational children don't realize what they are doing when they block the view of the television. They assume that another's view is the same as their view. Egocentric behavior does not stem from selfishness or a lack of consideration. Preoperational children just have not developed the cognitive ability to see another person's view. It is important for parents to realize this cognitive limitation in their preoperational children. If not, they may misinterpret their children's behavior in a negative way, leading to unjust punishment of the child.

preoperational stage The second stage in Piaget's theory of cognitive development, from age 2 to 6, during which the child's thinking becomes more symbolic and language-based, but remains egocentric and lacks the mental operations that allow logical thinking.

egocentrism The inability to distinguish one's own perceptions, thoughts, and feelings from those of others.

conservation The knowledge that the quantitative properties of objects (such as mass and number) remain the same despite changes in appearance.

Next, to understand what Piaget meant by the lack of mental operations that allow a child to think logically, let's consider conservation. Some grasp of conservation marks the end of the preoperational stage and the beginning of the concrete operational stage. **Conservation** is the knowledge that the quantitative properties of an object (such as mass and number) remain the same despite changes in appearance. Simply put, the quantitative properties of an object do not change with a change in appearance. There are many Piagetian conservation tests, but a well-known one is the liquid/beakers problem (see Figure 7.2). In this test, the child is first shown two identical short, fat beakers

Germinal - Embryo - Fetus - sensorimotor - pre operational -
0-10 day 10-8 weeks 2mar -birt birth - 2 2-6

Concrete operational 6-12

Formal operational 12+

in systematic deduction and tests of hypotheses, what could easily be referred to as scientific thinking. To understand the difference in thinking between concrete and formal operational children, Piaget used several scientific thinking tasks (Inhelder & Piaget, 1958).

In one of these tasks, children or adolescents are shown several flasks of what appear to be the same clear liquid and are told that one combination of two of these liquids would produce a blue liquid. The task is to determine the combination that would produce the blue liquid. The concrete operational children just start mixing different clear liquids together haphazardly. The formal operational children, however, proceed very differently. They develop a systematic plan for deducing what the correct combination must be by determining all of the possible combinations (hypotheses for the correct combination) and then systematically evaluating each one. To accomplish this plan, they systematically mix the liquid in one beaker with each of the other liquids. If none of these combinations produced the blue liquid, they deduce that the liquid in that beaker is not relevant to the sought-after combination and then proceed to test each of the other clear liquids in the same manner until they find the correct combination.

Formal operational adolescents can also evaluate the logic of verbal statements without referring to concrete situations; the concrete operational child can only do so with concrete evidence. For example, in one formal operational study, the experimenter asked whether a statement about some colored poker chips was true, false, or uncertain (Osherson & Markman, 1975). When the experimenter hid a chip in his hand and asked about the statement, "Either the chip is red or it is not red," the formal operational children realized that the statement was true regardless of the color of the hidden chip, but the concrete operational children were uncertain of the statement's truth status. The formal operational children understood the disjunctive logic of the statement, and the concrete operational children did not. Concrete operational children also have difficulty with propositional logic that contradicts reality (Moshman & Franks, 1986). For example, concrete operational children would judge the following reasoning to be faulty, "If cats are bigger than horses and horses are bigger than mice, then cats are bigger than mice," because the first relationship does not hold in real life. Concrete operational children are tied to the realistic truth of the content (what is) in their logical reasoning, but formal operational children are not.

Evaluation of Piaget's theory. Recent research has shown that cognitive development seems to proceed in the general sequence of stages that Piaget proposed (Lourenco & Machado, 1996). This means that Piaget's theory seems to have captured the general nature of cognitive development accurately. However, there are many issues with the specifics of Piaget's stage theory. For example, recent research has demonstrated that rudiments of many of Piaget's key concepts (such as object permanence) may begin to appear at earlier ages than Piaget proposed. Infants and young children may be more cognitively competent than Piaget in the next section when we examine the work of Russian psychologist Lev Vygotsky, whose theory did emphasize the sociocultural aspects of cognitive development. The second issue will be addressed in the section after that when we examine the question of what happens to intelligence from adolescence to old age. Does it decline as we age, especially in late adulthood? This discussion will allow us to examine two major research methods used by developmental psychologists, cross-sectional studies and longitudinal studies.

zone of proximal development According to Vygotsky, the difference between what a child can actually do and what the child could do with the help of others.

scaffolding According to Vygotsky, a style of teaching in which the teacher adjusts the level of help in relation to the child's level of performance while orienting the child's learning toward the upper level of his or her zone of proximal development.

Vygotsky's Sociocultural Approach to Development

Lev Vygotsky was a Russian developmental psychologist who was a contemporary of Piaget. Both were born in 1896, but Vygotsky died of tuberculosis at a very young age, 37, and did not have the opportunity to finish developing his theory. As with Piaget's work, there was little interest in the Western world in Vygotsky's work until the 1960s. Vygotsky's approach has become especially popular recently, however, because of its sociocultural emphasis on development.

Vygotsky (1930, 1933, 1935/1978, 1934/1986) stressed that cognitive abilities develop through interactions with others and represent the shared knowledge of one's culture. The social aspects of Vygotsky's approach are straightforward. We are social animals, and therefore much of our learning occurs within social interactions. In brief, we learn from other people—our parents, siblings, friends, teachers, and others. Vygotsky proposed that culture impacts both the content and the processes of the child's cognitive development, because a child's cognitive development occurs within this cultural context. Now that we have a general idea of Vygotsky's theory, let's take a look at two of his major theoretical concepts—the zone of proximal development and scaffolding.

In Vygotsky's theory, the **zone of proximal development** is the difference between what a child can actually do and what the child could do with the help of others. In Vygotsky's terms, this is the difference between the levels of actual development and potential development. It means that there are thinking skills that the child can display with the help of others but cannot perform independently. It also leads to a style of teaching called **scaffolding.** In scaffolding, the teacher adjusts the level of help in relation to the child's level of performance, while directing the child's learning progress toward the upper level of the child's zone of proximal development. The teacher gauges the amount of assistance necessary based on the learner's needs. The learning is structured in steps so that the child learns to achieve each step independently, but is guided and supported by the teacher throughout the learning process.


Sovfoto/UIG via Getty Images

Lev Vygotsky

To illustrate these two concepts and Vygotsky's theory, let's consider the example of a child trying to solve a jigsaw puzzle (Berger, 2006). A child may appear not to be able to solve the puzzle. However, Vygotsky would say that this particular problem-solving task could be within the child's zone of proximal development, but that she could not achieve it on her own. She needs a teacher to scaffold the task for her. How might this scaffolding proceed? The teacher would break the task down into manageable units; for example, the teacher might ask the child just to look for pieces for a particular section of the puzzle with specific suggestions about the size, shape, and colors of the relevant pieces. If this doesn't work, the teacher might actually place a few pieces in their proper places or move a few relevant pieces to their correct orientations, so their relevance is more obvious to the child. Throughout this scaffolding process, the teacher must be totally supportive of the child's progress and sensitive to how much help the child needs to progress toward solving the puzzle and how best to direct her to succeed in the next step of the solution process. After solving the puzzle, the teacher might have the child do it again, but this time with less guidance. Soon the child will be able to complete the puzzle independently. The teacher builds a scaffold to enable the child's learning. Once the learning is achieved, the scaffold is no longer necessary.

As recommended with Piaget's tests for the various types of conservation, find a young child and try to teach her how to solve a jigsaw puzzle using Vygotsky's scaffolding method. It will not only give you a better understanding of this approach but will also lead you to understand the social aspects of learning that Vygotsky stressed in his theory.

How Intelligence Changes in Adulthood

Piaget's description of intellectual development stops in adolescence with the onset of formal operations (hypothetical thought and systematic deduction), but it is important to examine what happens to intelligence across the various stages of adulthood from youth to old age. Do our cognitive abilities severely decrease across adulthood, especially in old age? The attempt to answer this question illustrates the differences between two major research methods in developmental psychology, cross-sectional studies versus longitudinal studies. In a **cross-sectional study,** people of different ages are studied and compared with one another at a single point in time. In a **longitudinal study,** the same people are studied over a long period of time. This involves collecting data periodically on the same people as they age. Longitudinal studies assess changes in people over time, whereas cross-sectional studies assess differences among age groups at a particular point in time. We will examine the use of both of these developmental research methods to answer the question about intelligence across the life span, learning the advantages and disadvantages of each.

cross-sectional study A study in which the performances of groups of participants of different ages are compared with one another.

longitudinal study A study in which performance of the same group of participants is examined at different ages.