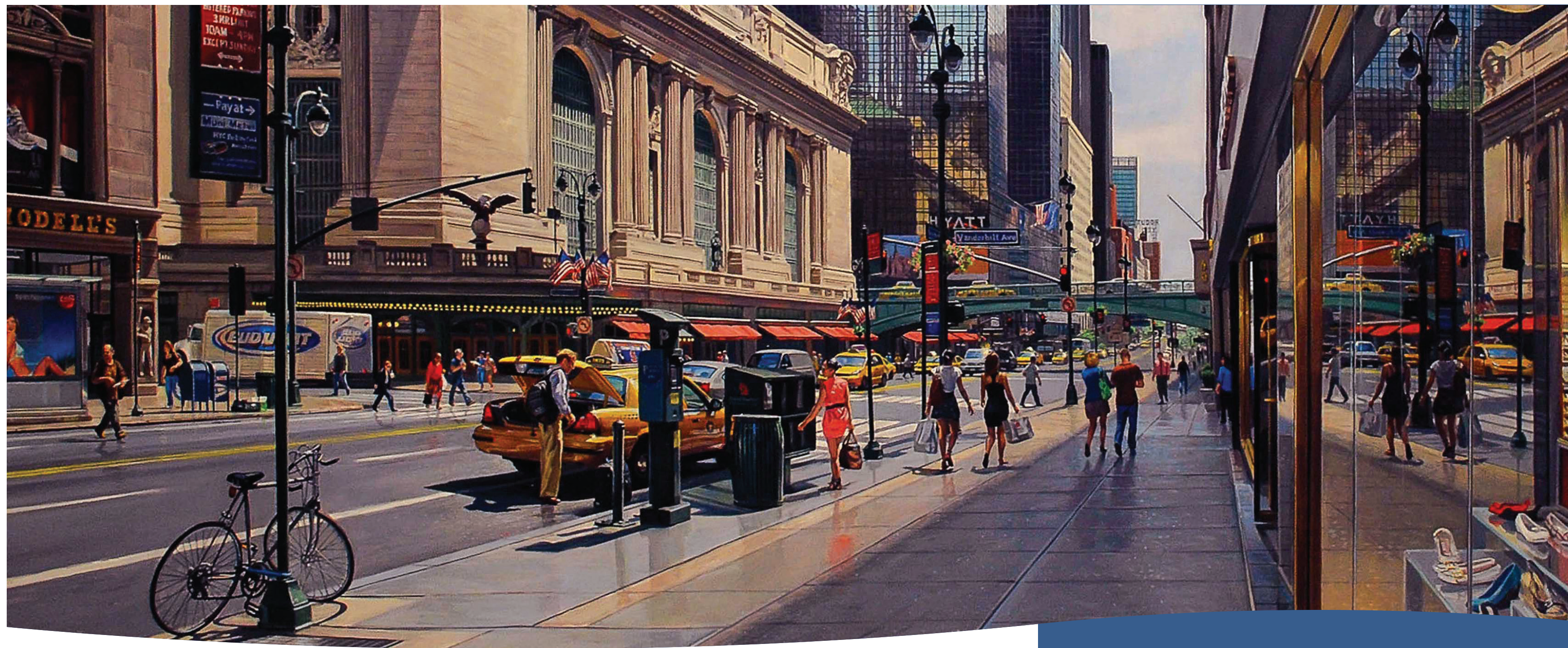

Cognitive Psychology In and Out of the Laboratory presents balanced, up-to-date coverage of cognitive psychology and shows readers that research conducted in the lab truly does have an impact in the real world. Using her signature, accessible writing style, author Kathleen M. Galotti masterfully connects cognitive psychology to students' everyday lives through current, relevant examples. The **Sixth Edition** has been updated to reflect the rapidly changing field of cognitive psychology with new references, streamlined content that gives more attention to key topics like memory, and material on advances in research that enhance our understanding of how people acquire and use information.

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"Galotti has gathered the most important topics in modern cognitive psychology and approaches them with a conversational writing style, supplemented with examples and figures, bringing abstract concepts to life."

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Shawnee State University

"I strongly agree with Galotti's sentiment. Cognitive psychology is so much more than the rigorous experimental research that dominates most textbooks in the field. While it is important to facilitate an appreciation for experimental design and behavioral testing methodologies, I feel it is equally important to highlight the application of research in cognitive psychology to our everyday, real-world problems."

—Dunja L. Trunk
Bloomfield College

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GALOTTI COGNITIVE PSYCHOLOGY IN AND OUT OF THE LABORATORY Edition Six

SAGE

KATHLEEN M. GALOTTI

edition 6

COGNITIVE PSYCHOLOGY
In and Out of the Laboratory

COGNITIVE PSYCHOLOGY
In and Out of the Laboratory

edition 6

To my kids, Tim and Kimmie, for giving meaning and purpose to my life; to my dogs, Tandy, Bussey, Eskie, Flit, Tackle, Lizzy, Tryker, and Nimo, for leavening that life with lightheartedness; and to my fabulous Carleton students, past, present, and future, for consistently keeping me on my toes.

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COGNITIVE PSYCHOLOGY
In and Out of the Laboratory

edition 6

KATHLEEN M. GALOTTI
CARLETON COLLEGE

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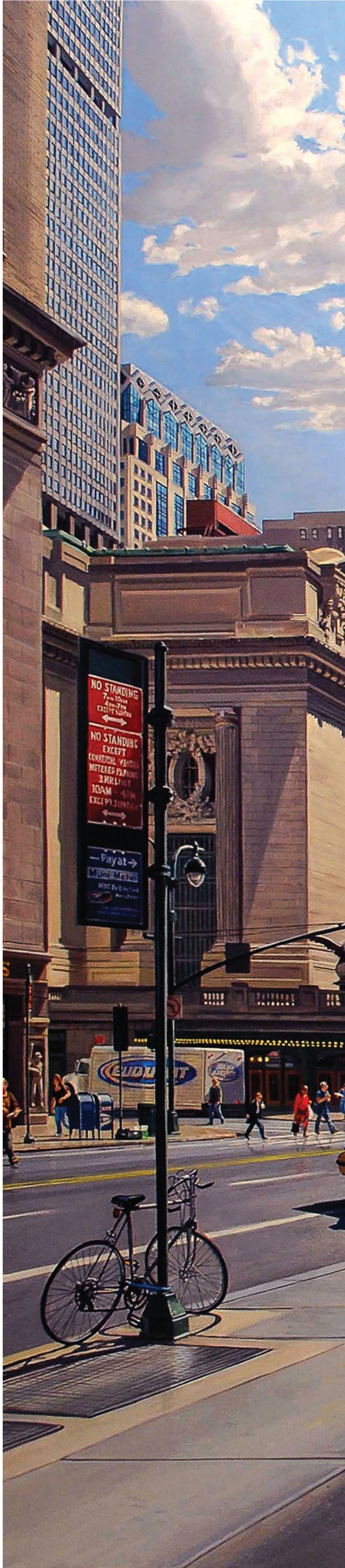

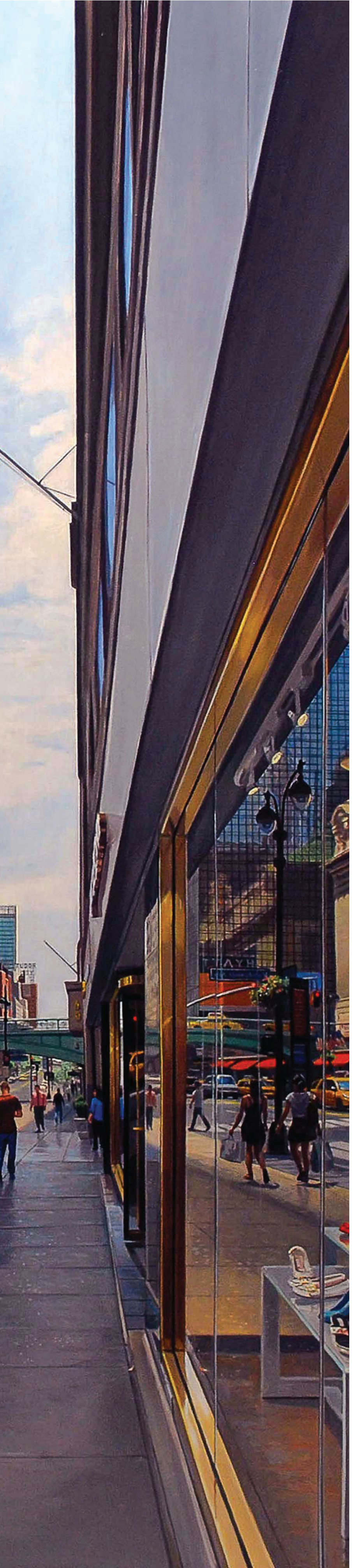

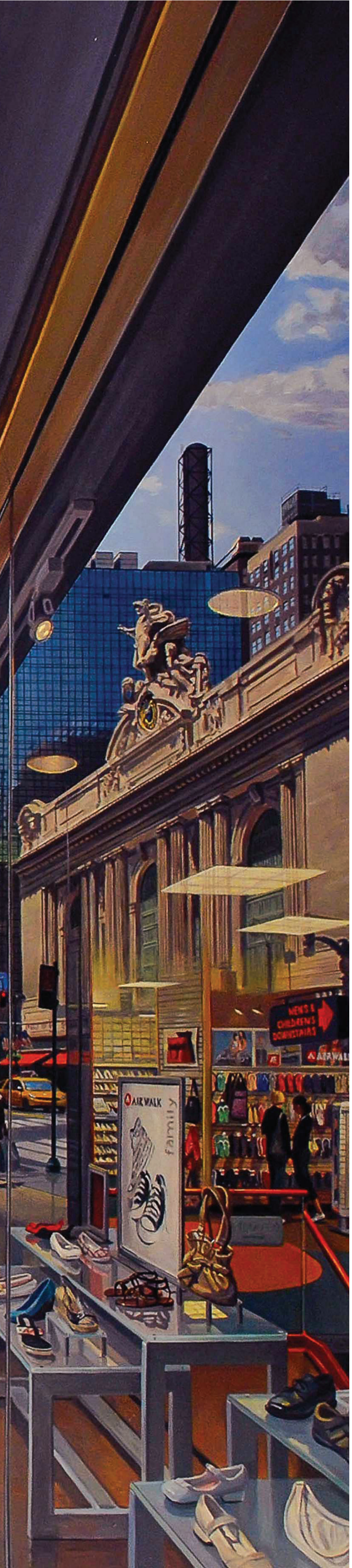

PREFACE

When I wrote the first edition of this book about 25 years ago, I had yet to become a mother and had just been tenured at Carleton College. I was still excited to get paid for doing a job that I loved enough to do for free. I still feel that way about what I do for a living—there is nothing better than teaching, and there are no better students than the Carleton kids I've grown so fond of. Many of them have influenced this edition and previous editions—in the examples I use to illustrate concepts, in their own independent projects that extend our understanding of those concepts, and in their feedback to me on previous editions. (They particularly enjoy finding my mistakes.)

Still, much has changed since 1992. I've birthed one son (now a college graduate and married) and adopted an infant daughter from Vietnam (she's now 15 years old and has started driving!). The students and campus have changed as well—we've all become much more adept with and dependent on technology, for example. And the field of cognitive psychology has changed a lot, placing much more emphasis on both neuroscience and situated cognition as well as making advances in the basic research that informs our understanding of how people acquire and use information. These changes certainly merit periodic revisions of the book, and voilà!—we have the sixth edition.

Undergraduate students studying psychology have different reactions to the field of cognitive psychology. Some find it exciting and elegant, covering topics essential to understanding the human mind. Cognitive psychology, after all, raises questions about how the mind works—how we perceive people, events, and things; how and what we remember; how we mentally organize information; how we call on our mental resources to make important decisions. Other students find the field of cognitive psychology technical and "geeky"—filled with complicated models of phenomena far removed from everyday life.

My goal throughout the writing of all editions of this book has been to bridge that gap—to try to reach out to students who are in the latter camp to show them what this field offers to be excited about. I think much of the problem is due to the disconnection of laboratory phenomena from everyday life. Too often, cognition texts focus exclusively on the laboratory research without showing students how that work bears on important real-world issues of consequence. I hope when students finish reading this book, they see why cognitive psychologists are so passionate about their topic and their research.

A textbook author can choose either to be comprehensive and strive for encyclopedic coverage or to be selective and omit many worthwhile topics and studies. I hope I've struck a balance between these extremes but must confess I prefer the latter. This reflects my own teaching goals; I like to supplement textbook chapters with primary literature from journals. I have tried to keep chapters relatively short in the hope that instructors will supplement the text with other readings. My firm belief is that the best courses are those in which instructors are enthusiastic about the material; the relative brevity of the text is intended to encourage instructors to supplement and customize it with added coverage on topics they find especially interesting.

My further hope is to encourage instructors and students alike to consider cognitive phenomena as having contexts that both foster and constrain their occurrence. Universals assumed or generalized from the laboratory do not always translate to every person in every situation. Too often, topics in cognitive psychology are presented as absolute unchanging aspects of everyone's experience. Recent work in developmental psychology, cross-cultural psychology, and individual differences strongly suggests that this presentation is, at best, oversimplification and, at worst, fiction. I hope newer work in cognitive psychology can retain its rigor and elegance but can frame questions and issues more inclusively, reflecting a recognition of the ways people and situations differ as well as share similarities.

ORGANIZATION OF THIS BOOK

Cognitive Psychology In and Out of the Laboratory is intended for a one-semester or one-term course for students who have already completed an introductory psychology course. We begin with a chapter that surveys the field and describes its research methods and paradigms. A chapter reviewing the structure and function of the brain comes next. These two introductory chapters are followed by chapters covering topics that would generally be regarded as core aspects of cognition: perception, attention, and memory. The emphasis in these chapters is on reviewing both the "classic" studies that define the field and the newer approaches that challenge long-standing assumptions. Next come chapters on knowledge representation and organization. These chapters center on questions of how we mentally represent and store the vast amounts of information we acquire throughout our lives. The next few chapters, covering topics in "higher-order" cognition, include discussions of language, problem solving, reasoning, and decision making.

It is in the last three chapters where this book departs most from a "prototypical" cognitive psychology textbook. Chapter 13 gives an overview of the development of cognition from infancy through adolescence. The last two chapters, on individual differences and cross-cultural approaches, include material not often covered in cognitive psychology courses. I feel strongly that these topics belong in a thorough examination of cognitive phenomena. Although traditional cognitive psychologists don't always consider these issues in their work, I believe they ought to and, in the future, will.

Almost all important material is integrated into the text rather than pulled out into boxes, asides, or extras that students might skip. This choice reflects my own experience as a student as well as feedback from my students who say they find boxed material distracting and often treat it as optional. I hope that omitting these extras reinforces the message to students that their learning and mastery will be best enhanced through their own careful reading and note taking rather than more superficial approaches such as highlighting and skimming.

NEW TO THIS EDITION

In the fifth edition, there was much streamlining, with sections and chapters combined to improve the organization and to shorten the text. In this edition, we have expanded slightly, dividing the former chapter on long-term memory into two different chapters.

Throughout the book, discussion of recent work has been incorporated. To take just a few examples, there is now exposition of brain training programs in Chapter 2 as well as coverage of face perception in Chapter 3, mindfulness meditation in Chapter 4, and consolidation in memory in Chapter 7. Newer research is incorporated throughout all the chapters.

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ACKNOWLEDGMENTS

The actual writing of the first edition of this book was a 5-year project. However, the groundwork for the book evolved over 15 years, stretching back to my own undergraduate and graduate education. I was fortunate to have benefited from the rigorous and dynamic teaching of Blythe Clinchy at Wellesley College and of Jonathan Baron, John Sabini, and Henry and Lila Gleitman at the University of Pennsylvania. My education and thinking about cognitive and developmental issues continued to profit from interactions with colleagues at Carleton College. Colleagues in Carleton's Cognitive Science Program—especially Roy Elveton, Susan Singer, and Jason Decker—as well as colleagues from other disciplines, including Deanna Haunsperger, Steven Kennedy, Marion Cass, Martha Paas, and Steven Kozberg, have sharpened my pedagogical philosophy and helped me to maintain a sense of humor and balance about the craziness that periodically invades Carleton.

One of the real joys of working at Carleton has been the privilege of teaching some incredibly talented, motivated, and energetic students. Students in my Cognitive Processes courses over the past 34 years have been kind enough to give me feedback on which chapters worked well and which ones didn't, and I thank them for their candor. Other current and former Carleton students have helped me with the mundane but necessary tasks of checking references and writing for permissions throughout all of the editions; they include April Anderson, Stephanie Aubry, Julie Greene, Andy Hebrank, Simin Ho, Allison Logeman, Matt Maas, Diane Mistele, Kitty Nolan, Emily Snyder, Scott Staupe, Jennifer Tourjé, Valerie Umscheid, Elizabeth White, and James Whitney. My former administrative assistants, Marianne Elofson, Ruby Hagberg, and Lorie Tuma, all helped with previous editions and just generally made the workplace much more inviting than it otherwise would have been. Pamela Gaggioli has now taken on that role and continues to be an invaluable assistant in every aspect of the work I do.

Several current and former students posed for some of the photographs in this edition, including Zoe Cohen, Zack Delpier, Chris Leppink-Shands, Hope Altenbaumer Molaizay, Zach Montes, Jonathan Rowe, Anna Smith, Laura Soter, Jane Tandler, and Jessa Youso. Because my students have contributed so much to my thinking and professional development, it is special to me to be able to make them a tangible part of the book! Other friends, neighbors, and colleagues who "modeled" for various photographs include Audrey and Susannah Battiste, Jason and Micah Decker, and Julia Kallestad. My own children (Timothy Komatsu and Kimmie Galotti) and my daughter in-law (Julia Mandsager Komatsu) are also depicted in one or more photos (sometimes to their chagrin).

Carleton College has supported this book through various sabbaticals and faculty development grants. Then dean of the college, Roy Elveton, enthusiastically endorsed and funded this endeavor from the start. A dean can really make a difference in a faculty member's professional development, and Roy often went above and beyond the call of duty for me and several of my talented colleagues at Carleton during his brief administrative tenure. His belief in my ability to write this book is something I will always be grateful for. As an emeritus colleague in our Cognitive Science Program and the Department of Philosophy, Roy remains a most trusted mentor and inspirer of our program. Steve Poskanzer, current president, and Bev Nagel, current dean of the college, have made the milieu at Carleton an inviting and vibrant one in which to work.

I owe a special debt to Vicki Knight, editor of the first and third editions. Her wise counsel, sharp sense of humor, love of animals, and excellent taste in restaurants made our collaboration a very engaging one. I never would have been able to finish the first edition without her encouragement, and without the first edition there would not have been any subsequent ones! For the fourth edition, Michele Sordi took the reins, passing the job along to Reid Hester for the

fifth edition. Reid once again served as my editor for this sixth edition and once again offered sage (!) advice throughout the revision process. He was ably assisted by Eve Oettinger and Abbie Rickard.

The cover designer, Janet Kiesel, worked with my plea to use another Robert Neffson painting, integrating text and elements beautifully. D. J. Peck has been a delightful copyeditor to work with—eagle-eyed and with an impressive insistence on consistency. I am delighted to be lucky enough to work once again with Jane Haenel, the production editor, as she is so on top of myriad details and so sane in her approach to the whole process. When I heard she would be the production editor for this edition, my heart was filled with joy!

Reviewers of past editions of the book, who also made important contributions, include for the first edition Sharon Armstrong, Central College (Pella, IA); Terry Au, University of California, Los Angeles; Ira Fischler, University of Florida; John H. Flowers, University of Nebraska–Lincoln; Margery Lucas, Wellesley College; Robert Seibel; Steven M. Smith, Texas A&M University; and Margaret Thomas, University of Central Florida; and for the second edition Brenda J. Byers, Arkansas State University; Robert Campbell, Clemson University; L. Mark Carrier, Florida State University; David G. Elmes, Washington and Lee University; Ira Fischler, University of Florida; John H. Flowers, University of Nebraska–Lincoln; Nancy Franklin, State University of New York at Stony Brook; Peter Graf, University of British Columbia; Morton A. Heller, Winston–Salem State University; Lorna Jarvis, Hope College–Peale Science Center; Douglas Johnson, Colgate University; James Juola, University of Kansas; Richard Metzger, University of Tennessee; John Pani, University of Louisville; Aimee M. Surprenant, Purdue University; Joseph Thompson, Washington and Lee University; and Lori R. Van Wallendael, University of North Carolina. For the third edition, I received many very constructive and helpful suggestions and insights for strengthening the book from Lisa Abrams, University of Florida; Nancy Alvarado, California State Polytechnic University, Pomona; Jeffrey Anastasi, Arizona State University; Krystine Batcho, Le Moyne College; Stephanie Buchert, Kent State University; Walt Chromiak, Dickinson College; John Flowers, University of Nebraska–Lincoln; Allen Keniston, University of Wisconsin–Eau Claire; Kristy Nielson, Marquette University; Evelyn Schaefer, University of Winnipeg; Elizabeth Spievak, Hanover College; Mark Stewart, Willamette University; Brian Sundermeier, University of Minnesota–Minneapolis; and Lori Van Wallendael, University of North Carolina at Charlotte.

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Fifth edition reviewers included Michael Dodd, University of Nebraska–Lincoln; Stephen Dopkins, The George Washington University; Kendall J. Eskine, Loyola University New Orleans; Rhiannon E. Hart, Rochester Institute of Technology; Conor T. McLennan, Cleveland State University; Rolf Nelson, Wheaton College; and Ruth Tincoff, Bucknell University.

Once again, for the sixth edition I received a really helpful and substantive set of reviews, this time from Kristen Weede Alexander, California State University, Sacramento; Mary A. Dolan, California State University, San Bernardino; Marissa Greif-Hackett, Florida Atlantic University; Ben Hinnant, Catholic University of America; Elaine M. Justice, Old Dominion University; Darcy B. Mitchell, Colby-Sawyer College; Monica Riordan, Chatham University; Joni N. Saby, Temple University; and Harriet S. Waters, Stony Brook University.

I would also like to thank artist Robert Neffson for allowing us to use another one of his wonderful paintings for the cover and interior design art. It's beautiful!

ABOUT THE AUTHOR

Kathleen M. Galotti holds a B.A. in psychology and economics from Wellesley College as well as an M.A. and Ph.D. in psychology and an M.S.E. in computer and information sciences from the University of Pennsylvania. At Carleton College, she holds an endowed chair as the W. H. Laird Professor of Cognitive Science and serves as the director of that interdisciplinary program, which she helped to establish in 1989. She also is a former chair of the Department of Psychology. She teaches courses in cognitive and developmental psychology and cognitive science and has also taught courses in statistics and introductory psychology.

Dr. Galotti's research centers on the development of reasoning and decision-making skills from the preschool period through adulthood and on the styles with which adolescents and adults plan for the future, make important life commitments, and learn new information. Her research has been funded through the National Science Foundation, the Spencer Foundation, and the National Institutes of Health. She is the author of *Making Decisions That Matter: How People Face Important Life Choices* (Lawrence Erlbaum, 2002) as well as the second edition of the textbook *Cognitive Development: Infancy Through Adolescence* (Sage, 2017). She has also authored or co-authored dozens of articles in peer-reviewed journals.

Dr. Galotti is the parent of two children, Timothy and Kimberlynn, and spends much of her time enjoying their exuberance, energy, and all of their many activities and performances. In her spare time, she raises and trains Bernese Mountain dogs and a Cavalier King Charles spaniel and shows them in competition in licensed obedience, rally, and agility trials. She is an approved obedience and rally judge for the American Kennel Club.


NO STANDING
NO STANDING
EXCEPT
MODELL'S

1

COGNITIVE PSYCHOLOGY

History, Methods, and Paradigms

CHAPTER OUTLINE

SETTING THE STAGE

This book is about cognitive psychology—that branch of psychology concerned with how people acquire, store, transform, use, and communicate information (Neisser, 1967). Put differently, cognitive psychology deals with our mental life: what goes on inside our heads when we perceive, attend, remember, think, categorize, reason, decide, and so forth.

To get a better feel for the domain of cognitive psychology, let's consider an example of cognitive activity:

You're walking along a dark, unfamiliar city street. It's raining and foggy, and you are cold and a bit apprehensive. As you walk past a small alley, you catch some movement out of the corner of your eye. You turn to look down the alley and start to make out a shape coming toward you. As the shape draws nearer, you are able to make out more and more features, and you suddenly realize that it's . . .

What cognitive processes are going on in this admittedly melodramatic example? In general, this example illustrates the initial acquisition and processing of information. In particular, the cognitive processes depicted include **attention**, mentally focusing on some stimulus (the mysterious shape); **perception**, interpreting sensory information to yield meaningful information; and **pattern recognition**, classifying a stimulus into a known category. In recognizing the shape as something familiar, you no doubt called on **memory**, the storage facilities and retrieval processes of cognition. All this processing occurred rapidly, probably within a few seconds or less. Most of the cognitive processing in this example appears so effortless and automatic that we usually take it for granted.

Here's another example:

You're in a crowded public place such as a shopping mall during the holiday season. Throngs of people push past you, and you're hot and tired. You head for a nearby bench, aiming to combine some rest with some people watching. As you make your way, a young woman about your age jostles up against you. You both offer polite apologies ("Oh, excuse me!" "Sorry!"), glancing at each other as you do. She immediately exclaims, "Oh, it's you! How are you? I never thought I'd run into anyone I know here—can you believe it?" You immediately paste a friendly but vague smile on your face to cover your frantic mental search. Who is this woman? She looks familiar, but why? Is she a former classmate? Did you and she attend camp together? Is she saying anything that you can use as a clue to place her?

This example illustrates your use of memory processes, including **recognition** (you see the woman as familiar) and **recall** (you try to determine where you know her from). Other cognitive processes are involved here too, although they play a lesser role. For instance, you perceive the entity talking to you as a person, specifically a woman, more specifically a vaguely familiar woman. You pay attention to her. You may be using various strategies or techniques of **reasoning** and **problem solving** to try to figure out who she is.

Photo by Meaguell Gaines

■ Photo 1.1: An ordinary activity, such as reading a map, involves a great deal of cognitive processing.

Your success or failure at this task may also depend on your mental organization of the knowledge you have accumulated in your lifetime—your **knowledge representation**. To communicate with her, you use **language** as well as nonverbal cues or signals. Eventually, you'll need to use **decision making** to determine how to deal with the situation: Will you admit your forgetfulness, or will you try to cover it up?

As these two examples demonstrate, our everyday lives involve a great deal of cognition. Furthermore, this everyday cognition is complex, often involving several cognitive processes. We tend to remain unaware of this complexity, however, because much of our cognitive processing occurs so often, so rapidly, and with so little effort that we might not even know it is taking place.

In both of the preceding examples, several cognitive processes were occurring either simultaneously or very closely in time. In fact, it is nearly impossible to specify, in either of these examples, exactly how many cognitive processes occurred or in what sequence. This uncertainty typifies everyday situations: So much is going on so quickly that we can't even be sure of what information is being received or used. How, then, can cognition be studied with any precision?

This kind of problem is one all scientists face: how to study a naturally occurring phenomenon with sufficient experimental rigor to draw firm conclusions. The answer, for many, is to try to isolate the phenomenon and bring it (or some stripped-down version of it) into the laboratory. With this approach, the challenge is to decide what is essential and what is inessential about the phenomenon under study.

For example, in studying how memory works, psychologists have often used experiments in which people are presented with lists of words or nonsense syllables. The experimenters then control or systematically vary variables such as the complexity, length, frequency, meaningfulness, relatedness, and rate of presentation of items on the list along with the state of alertness, expertise, practice, and interest of the research participants. The experimenters assume that factors that increase or decrease performance in the laboratory will also increase or decrease performance under less controlled conditions. Furthermore, the researchers assume that although in everyday life people do not encounter material to be remembered in this manner, the processes of memory work in essentially the same ways in laboratory experiments as in everyday life. So if increasing the number of items to be remembered decreases memory performance in a laboratory, then we can expect that needing to remember more information is more difficult than remembering less in an everyday situation.

The key challenge for all scientists, however, is to make sure the laboratory tasks they develop preserve the essential workings of the processes under study. The most rigorously controlled experiment is of, at best, limited value if the phenomenon being studied does not occur or occurs in significantly different ways outside the laboratory. Unfortunately, there is no simple or guaranteed way to ensure that laboratory tasks model everyday tasks. Therefore, students and other "consumers" of science must take a critical stance when considering how experimental situations apply to everyday ones. Throughout this book, we will look at how laboratory models do or don't accurately describe, explain, and predict cognitive processing in real life. We will also consider how situational and personal factors, such as people's level of development, personality variables, degree of expertise, gender, and cultural background, affect cognitive processing.

Before we discuss specific cognitive processes, however, an overview of the field of cognitive psychology will provide a useful framework within which to consider specific topics, experiments, and findings in the field. We will first examine the historical roots of cognitive psychology to see how the field has developed. Next, we will look at traditional and common research methods used in cognitive psychology. Finally, we will consider four paradigms, or schools of thought, that represent the current streams of thought in the field.

INFLUENCES ON THE STUDY OF COGNITION

A complete treatise on how modern cognitive psychology has evolved over the course of human history could fill several volumes and would obviously be beyond our scope. Worth noting, however, is that several ideas about certain mental abilities date back to at least the Greek philosophers Aristotle and Plato (Murray, 1988). Both of these philosophers wrote extensively on the nature of memory. Plato, for instance, likened storing something in memory to writing on a wax tablet. In other writings, he compared the mind to an aviary in which many birds are flying and compared memory retrieval to trying to catch a specific bird: Sometimes you can, but other times you can grab only a nearby bird. Similarly, when I try to recall the name of the girl who sat behind me in third grade, I have trouble latching on to exactly the right one (was it Joan? Joanne? Anne?), but my choices are probably pretty close.

Other historians of psychology trace the field's roots to the philosophers of the 17th to 19th centuries, including John Locke, David Hume, John Stuart Mill, René Descartes, George Berkeley, and Immanuel Kant. These philosophers also debated the nature of mind and knowledge, with Locke, Hume, Berkeley, and Mill following Aristotle and a more empiricist position and Descartes and Kant aligning with Plato and a nativist position.

Briefly, **empiricism** rests on the tenet that knowledge comes from an individual's own experience—that is, from the empirical information that people collect from their senses and experiences. Empiricists recognize individual differences in genetics but emphasize human nature's malleable, or changeable, aspects. Empiricists believe people are the way they are, and have the capabilities they have, largely because of previous learning. One mechanism by which such learning is thought to take place is through the mental **association** of two ideas. Locke (1690/1964) argued that two distinct ideas or experiences, having nothing to do with each other, could become joined in the mind simply because they happened to occur or be presented to the individual at the same time. Empiricists accordingly believe the environment plays a powerful role in determining one's intellectual (and other) abilities.

Nativism, by contrast, emphasizes the role of constitutional factors—of native ability—over the role of learning in the acquisition of abilities and tendencies. Nativists attribute differences in individuals' abilities less to differences in learning than to differences in original, biologically endowed capacities and abilities. Nativism is an important idea in cognitive psychology, as we will see. Nativists often suggest that some cognitive functions come built in as part of our legacy as humans. "Hard-wired" functions such as working memory, for example, are attributed to innate structures of the human mind that are present in at least rudimentary form at birth and are not learned, formed, or created as a result of experience.

Interestingly, only during the last 120 years have central cognitive issues, such as the nature of the mind and the nature of information in the mind, been seen as amenable to scientific psychological investigation. Indeed, until the 1870s, no one really thought to ask whether actual data could help to resolve any of these questions. When people began doing so, experimental psychology was born. However, the nativist–empiricist debate is still a controversial one in the 21st century (Pinker, 2002). We will look next at the different schools of experimental psychology that laid the foundations for cognitive psychology today.

STRUCTURALISM

Many students are surprised to find out that psychology as a formal discipline has been around for little more than a century. Historians often date the "founding" of the field of psychology back to 1879, when Wilhelm Wundt converted a laboratory into the first institute for research in experimental psychology (Fancher, 1979). Wundt wanted to establish a "science of mind" to discover the laws and principles that explained our immediate conscious experience. In particular, Wundt wanted to identify the simplest essential units of the mind. In essence, he wanted to create a table of "mental elements," much like a chemist's periodic chart. Once the set of elements was identified, Wundt believed, psychologists could determine how these units combine to produce complex mental phenomena. Wundt (1904) foresaw an entire field devoted to the study of how systematically varying stimuli would affect or produce different mental states; he described this field in a volume titled *Principles of Physiological Psychology*.

Wundt and his students carried out hundreds of studies, many involving a technique of investigation called **introspection**. Although this term today connotes "soul searching," Wundt's technique was much more focused. It consisted of presenting highly trained observers (usually graduate students) with various stimuli and asking them to describe their conscious experiences. Wundt assumed that the raw materials of consciousness were sensory and thus "below" the level of meaning. In particular, Wundt thought any conscious thought or idea resulted from a combination of sensations that could be defined in terms of exactly four properties: *mode* (e.g., visual, auditory, tactile, olfactory), *quality* (e.g., color, shape, texture), *intensity*, and *duration*.

Wundt's goal was to "cut through the learned categories and concepts that define our everyday experience of the world" (Fancher, 1979, p. 140). Wundt believed strongly that with proper training people could detect and report the workings of their own minds. A student of Wundt, Edward B. Titchener, applied the term **structuralism** to his own endeavors as well as to Wundt's (Hillner, 1984). The term was meant to convey Wundt's focus on what the elemental components of the mind are rather than on the question of *why* the mind works as it does.

The method of introspection, unfortunately, proved to be problematic, as we will see shortly. Nonetheless, modern cognitive psychologists owe Wundt more than a historical debt. A pioneer in the study of many cognitive phenomena, he was the first to approach cognitive questions scientifically and the first to design experiments to test cognitive theories.

FUNCTIONALISM

While Wundt was working in Leipzig, Germany, an American named William James was working to establish the new discipline of psychology in the United States. In many ways, Wundt and James were opposites. A prolific researcher who personally carried out or supervised hundreds of rigorous experiments, Wundt was not known for his interpersonal style. James (the brother of the writer Henry James), in contrast, carried out little original research but wrote eloquently about psychological findings and their relevance to everyday life (Fancher, 1979). His textbook *The Principles of Psychology* (James, 1890/1983) is still highly regarded and widely cited today.

James regarded psychology's mission to be the explanation of our experience. Like Wundt, James was interested in conscious experience. Unlike Wundt, however, James was not interested in the elementary units of consciousness. Instead, he asked *why* the mind works the way it does. He assumed that the way the mind works has a great deal to do with its *function*—the purposes of its various operations. Hence, the term **functionalism** was applied to his approach.

James's writings, which introduced psychological questions to American academics, still offer food for thought to students and teachers of psychology, perhaps because they so directly address everyday life. Consider one of the best-known chapters in his textbook on "habit." James (1890/1983) saw habit as the "flywheel of society" (Vol. 1, p. 125), a mechanism basic to keeping our behavior within bounds. He saw habits as inevitable and powerful and drew from this a practical conclusion:

> Every smallest stroke of virtue or of vice leaves its ever so little scar. The drunken Rip Van Winkle, in Jefferson's play, excuses himself for every fresh dereliction by saying, "I won't count this time!" Well! He may not count it, and a kind Heaven may not count it; but it is being counted none the less. Down among his nerve-cells and fibres the molecules are counting it, registering and storing it up to be used against him when the next temptation comes. (p. 131)

James's point, of course, is that people should take great care to avoid bad habits and establish good ones. He offered advice about how to do so, urging people to never allow an exception when trying to establish a good habit, to seize opportunities to act on resolutions, and to engage in a "little gratuitous effort" every day to keep the "faculty of effort" alive (James, 1890/1983, Vol. 1, p. 130). Other American psychologists shared James's assumptions and approaches. Fellow functionalists such as John Dewey and Edward L. Thorndike, for example, shared James's conviction that the most important thing the mind did was to let the individual adapt to her or his environment.

Functionalists drew heavily on Darwinian evolutionary theory and tried to extend biological conceptions of adaptation to psychological phenomena (Hillner, 1984). Structuralists and functionalists differed in their methods as well as their focus. The structuralists were convinced that the proper setting for experimental psychology was the laboratory, where experimental stimuli could be stripped of their everyday meanings to determine the true nature of mind. The functionalists disagreed sharply with this approach, attempting instead to study mental phenomena in real-life situations. Their basic belief was that psychologists should study whole organisms doing whole real-life tasks.

BEHAVIORISM

You probably learned the terms *classical conditioning* and *instrumental conditioning* in your introductory psychology class. The Russian psychologist Ivan Pavlov used the first term, and psychologists such as Edward Thorndike used the second term, to explain psychological phenomena strictly in terms of observable stimuli and responses.

In the United States, a school of psychology known as **behaviorism** took root during the 1930s and dominated academic psychology until well into the 1960s. Many regard it as a branch of functionalism (Amsel, 1989). One of the general doctrines of behaviorism is that references to unobservable subjective mental states (such as consciousness), as well as to unobservable subjective processes (such as expecting, believing, understanding, remembering, hoping for, deciding, and perceiving), are to be banished from psychology proper, which behaviorists took to be the scientific study of behavior.

Behaviorists rejected such techniques of study as introspection, which they found in principle to be untestable. In an article published in 1913, John Watson most directly described his view of what psychology is and isn't:

> Psychology as the behaviorist views it is a purely objective natural science. Its theoretical goal is the prediction and control of behavior. Introspection forms no essential part of its methods, nor is the scientific value of its data dependent upon the readiness with which they lend themselves to interpretation in terms of consciousness. The behaviorist, in his efforts to get a unitary scheme of animal response, recognizes no dividing line between man and brute. The behavior of man, with all of its refinement and complexity, forms only a part of the behaviorist's total scheme of investigation. (p. 158)

Why did behaviorists so disdain the technique of introspection? Their disdain was mainly because of its obviously subjective nature and its inability to resolve disagreements about theory. Suppose two observers are presented with the same stimulus, and one reports an experience of "greenness" and the other an experience of "green-yellowness." Which one is correct? Is one misrepresenting or misinterpreting his or her experience? If no physiological cause (e.g., color blindness) explains the different reports, then the scientist is left with an unresolvable dispute. Titchener restricted his research participants to graduate students trained to introspect "properly" (advising those who couldn't learn to do this to find another career). This, however, created more problems than it solved. The reasoning was circular. How do we know that a particular sensation is a true building block of cognition? Because trained observers report it to be so. How do we know the observers are trained? Because they consistently report that certain sensations and not others are the true elements of consciousness.

Watson, in fact, regarded all "mental" phenomena as reducible to behavioral and physiological responses. Such things as "images" and "thoughts," he believed, resulted from low-level activity of glands or small muscles. In his first textbook, Watson cited evidence showing that when people report they are "thinking," muscles in the tongue and larynx are actually moving slightly. Thought, for Watson, simply amounted to perception of these muscle movements (Fancher, 1979).

Watson's contribution to cognitive psychology—banishing all "mental language" from use—was largely negative insofar as he believed the scientific study of mental phenomena was simply not possible. Watson and his followers did, however, encourage psychologists to think in terms of measures and research methods that moved beyond subjective introspection, thereby challenging later psychologists to develop more rigorous and more testable hypotheses and theories as well as stricter research protocols.

B. F. Skinner (1963/1984), psychology's best-known behaviorist, took a different tack with regard to mental events and the issue of **mental representations**. Skinner argued that such "mentalistic" entities as images, sensations, and thoughts should *not* be excluded simply because they are difficult to study. Skinner believed in the existence of images, thoughts, and the like and agreed they were proper objects of study, but he objected to treating mental events and activities as fundamentally different from behavioral events and activities. In particular, he objected to hypothesizing the existence of mental representations (internal depictions of information), which he took to be internal copies of external stimuli. Skinner believed images and thoughts were likely to be no more or less than verbal labels for bodily processes. But even if mental events *were* real and separate entities, Skinner believed, they were triggered by external environmental stimuli and gave rise to behaviors. Therefore, he held, a simple functional analysis of the relationship between the stimuli and behaviors would avoid the well-known problems of studying mental events (Hergenhahn, 1986).

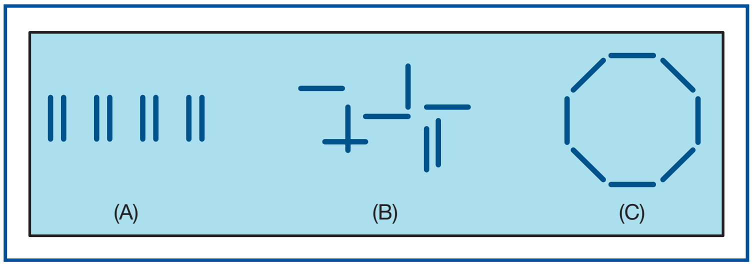
Other behaviorists were more accepting of the idea of mental representations. Edward Tolman, for example, believed that even rats have goals and expectations. As he explained it, a rat learning to run a maze must have the goal of attaining food and must acquire an internal representation—some cognitive map or other means of depicting information "in the head"—to locate the food at the maze's end. Tolman's work centered on demonstrating that animals had both expectations and internal representations that guided their behavior.

GESTALT PSYCHOLOGY

The school of **Gestalt psychology** began in 1911 in Frankfurt, Germany, in a meeting of three psychologists: Max Wertheimer, Kurt Koffka, and Wolfgang Köhler (Murray, 1988). As the name *Gestalt* (a German word that loosely translates to "configuration" or "shape") suggests, these psychologists' central assumption was that psychological phenomena could not be reduced to simple elements but rather needed to be analyzed and studied in their entirety. Gestalt psychologists, who studied mainly perception and problem solving, believed an observer did not construct a coherent perception from simple, elementary sensory aspects of an experience but instead apprehended the total structure of an experience as a whole.

As a concrete example, consider Figure 1.1. Notice that (A), (B), and (C) contain the same elements—namely, eight equal line segments. However, most people experience the three arrays quite differently, seeing (A) as four pairs of line segments, (B) as eight line segments haphazardly arranged, and (C) as a circle or, more precisely, an octagon made up of eight line segments. The arrangement of lines—that is, the relationships among the elements as a whole—plays an important role in determining our experience.

The Gestalt psychologists thus rejected structuralism, functionalism, and behaviorism as offering incomplete accounts of psychological and, in particular, cognitive experiences. They chose to study people's subjective experience of stimuli and to focus on how people use or impose structure and order on their experiences. They believed that the mind imposes its own structure and organization on stimuli and, in particular, organizes perceptions into *wholes* rather than discrete parts. These wholes tend to simplify stimuli. Thus, when we hear a melody, we experience not a collection of individual sounds but rather larger and more organized units—melodic lines.



■ Figure 1.1: Examples of Gestalt figures. Although (A), (B), and (C) all contain eight equal lines, most people experience them differently, seeing (A) as four pairs of lines, (B) as eight unrelated lines, and (C) as a circle made up of eight line segments.

THE STUDY OF INDIVIDUAL DIFFERENCES

Yet another strand of the history of psychology is important to mention here, even though no particular "school" is associated with it: the investigations into individual differences in human cognitive abilities by Sir Francis Galton and his followers. Galton, a half-cousin of Charles Darwin, inherited a substantial sum of money during his early 20s that afforded him the time and resources to pursue his interests. A child prodigy himself (he read and wrote by the age of 2½ years), Galton trained in medicine and mathematics at Cambridge University in England. Like many of his fellow students (and many of today's college students), Galton felt a great deal of academic pressure and competitiveness and "was constantly preoccupied with his standing relative to his fellow students" (Fancher, 1979, p. 257). This strong preoccupation (which may have contributed to a breakdown he suffered at Cambridge) developed into a lifelong interest in measuring intellectual ability.

Galton's interest in intellectual differences among people stemmed in part from his reading of his cousin Darwin's writings on evolution. Darwin believed animals (including humans) evolved through a process he called natural selection, by which certain inherited traits are perpetuated because individuals possessing those traits are more likely to survive and reproduce. Galton wondered whether intellectual talents could also be inherited. Galton noticed "intelligence," "smartness," or "eminence" seemed to run in families; that is, smart parents appeared to produce smart children. Of course, this could be explained in terms of either genetics or environment (e.g., intelligent parents may have greater resources to spend on their children's education and/or greater interest or motivation to do so). Thus, Galton's question of how large a role genetics plays in intelligence was difficult to answer. To address it, Galton put his mathematical training to use in analyzing data (usually family trees of "eminent" men) and, later, inventing statistical tests, some of which are still used today.

Galton (1883/1907) studied a variety of cognitive abilities, in each case focusing on ways of measuring the ability and then noting its variation among different individuals. Among the abilities he studied (in both laboratory and "naturalistic" settings) was mental imagery. He developed a questionnaire instructing respondents to "think of some definite object—suppose it is your breakfast-table as you sat down this morning—and consider carefully the picture that rises before your mind's eye" (p. 58). He then asked a few questions. Is the image dim or clear? Are all of the objects in the image well defined? Does part of the image seem to be better defined? Are the colors of the objects in the image distinct and natural? Galton was surprised to discover much variability in this capacity: Some respondents reported almost no imagery; others experienced images so vividly they could hardly tell they *were* images.

Galton left a large legacy to psychology and to cognitive psychology in particular. His invention of tests and questionnaires to assess mental abilities inspired later cognitive psychologists to develop similar measures. His statistical analyses, later refined by other statisticians, allowed hypotheses to be rigorously tested. His work on mental imagery is still cited by current investigators. Most broadly, Galton's work challenged psychologists, both those who believed genetic influences are crucially important and those who were strongly opposed to the idea, to think about the nature of mental—that is, cognitive—abilities and capacities.

THE "COGNITIVE REVOLUTION" AND THE BIRTH OF COGNITIVE SCIENCE

Despite the early attempts to define and study mental life, psychology, especially American psychology, came to embrace the behaviorist tradition during the first five decades of the 1900s. A number of historical trends, both within and outside academia, came together in the years during and following World War II to produce what many psychologists think of as a "revolution" in the field of cognitive psychology. This **cognitive revolution**, a new series of psychological investigations, was mainly a rejection of the behaviorist assumption that mental events and states were beyond the realm of scientific study or that mental representations did not exist. In particular, the "revolutionaries" came to believe no complete explanation of a person's functioning could exist that did not refer to the person's mental representations of the world. This directly challenged the fundamental tenet of radical behaviorism that concepts such as mental representation were not needed to explain behavior.

One of the first of these historical trends was a product of the war itself: the establishment of the field of **human factors engineering**. During the war, military personnel needed to be trained to operate complicated pieces of equipment. Engineers quickly found they needed to design equipment (such as instrument operating panels, radar screens, and communication devices) to suit the capacities of the people operating it.

Lachman, Lachman, and Butterfield (1979) offered an anecdote about why such problems were important to solve:

> One type of plane often crashed while landing. It turned out that the lever that the pilot had to use for braking was near the lever that retracted the landing gear. During landing, the pilot could not take his eyes off the runway: He had to work by touch alone. Sometimes pilots retracted their landing gear instead of putting on their brakes; they touched the ground with the belly of the plane at top speed. The best way to keep them from crashing was not to exhort them to be careful; they were already highly motivated to avoid crashing and getting killed. Improving training procedures was also an inefficient approach; pilots with many safe landings behind them committed this error as well as rookie pilots.
>
> The most reasonable approach was to redesign the craft's controls so that completely different arm movements were required for braking and for retracting the landing gear. (p. 57)

Psychologists and engineers thus developed the concept of the man–machine system, now more accurately referred to as the **person–machine system**: the idea that machinery operated by a person must be designed to interact with the operator's physical, cognitive, and motivational capacities and limitations.

Psychologists during World War II also borrowed concepts, terminology, and analogies from communications engineering. Engineers concerned with the design of such things as telephones and telegraph systems talked about the exchange of information through various "channels" (such as telegraph wires and telephone lines). Different kinds of channels differ in how much information they can transmit per unit of time and how accurately. Humans were quickly seen to be a particular kind of communication channel, sharing properties with better-known *inanimate communications channels*. Thus, people came to be described as limited-capacity processors of information.

What is a **limited-capacity processor**? As the name suggests, it means that people can do only so many things at once. When I'm typing, I find it difficult (actually, impossible) to simultaneously keep up my end of a conversation, read an editorial, or follow a television news broadcast. Similarly, when I concentrate on balancing my checkbook, I can't also recite multiplication tables or remember all the teachers I've had from kindergarten onward. Although I can do some tasks at the same time (I can fold the laundry while I watch television), the number and kinds of things I can do at the same time are limited.

A classic article focusing on capacity limitations was authored by George Miller in 1956. This article, titled "The Magical Number Seven, Plus or Minus Two," observed that (a) the number of unrelated things we can perceive distinctly without counting, (b) the number of unrelated things on a list we can immediately remember, and (c) the number of stimuli we can make absolute discriminations among are, for most normal adults, between five and nine. Miller's work exemplified how the limits of people's cognitive capacities could be measured and tested.

At about the same time, developments in the field of **linguistics**, the study of language, made clear that people routinely process enormously complex information. Work by linguist Noam Chomsky revolutionized the field of linguistics, and both linguists and psychologists began to see the central importance of studying how people acquire, understand, and produce language.

In addition, Chomsky's (1957, 1959, 1965) early work showed that behaviorism cannot adequately explain language. Consider the question of how language is acquired. A behaviorist might explain language acquisition as the result of parents' reinforcing a child's grammatical utterances and punishing (or at least not reinforcing) ungrammatical utterances. However, both linguists and psychologists soon realized such an account must be wrong. For one thing, psychologists and linguists who observed young children with their parents found that parents typically respond to the *content* rather than to the *form* of the children's language utterances (Brown & Hanlon, 1970). For another, even when parents (or teachers) explicitly tried to correct children's grammar, they could not. Children seemed simply not to "hear" the problems, as is evident in the following dialogue (McNeill, 1966, p. 69):

CHILD: Nobody don't like me.

MOTHER: No, say, "Nobody likes me." [eight repetitions of this dialogue]

MOTHER: No, now listen carefully; say, "Nobody likes me."

CHILD: Oh! Nobody don't likes me.

(Clearly, this mother was more focused on the child's linguistic development than emotional development!)

Chomsky's work thus posed a fundamental challenge to psychologists: Here were humans, already shown to be limited-capacity processors, quickly acquiring what seemed to be an enormously complicated body of knowledge—language—and using it easily. How could this be?

Reversing engineers' arguments that machines must be designed to fit people's capabilities, many linguists tried to describe structures complex enough to process language. Chomsky (1957, 1965) argued that underlying people's language abilities is an implicit system of rules, collectively known as a *generative grammar*. These rules allow speakers to construct, and listeners to understand, sentences that are "legal" in the language. For example, "Did you eat all the oat bran cereal?" is a legal, well-formed sentence, but "Bran the did all oat eat you cereal?" is not. Our generative grammar, a mentally represented system of rules, tells us so because it can produce (generate) the first sentence but not the second.

Chomsky (1957, 1965) did not believe all the rules of a language are consciously accessible to speakers of that language. Instead, he believed the rules operate implicitly: We don't necessarily know exactly what all the rules are, but we use them rather easily to produce understandable sentences and to avoid producing gobbledygook.

Another strand of the cognitive revolution came from developments in **neuroscience**, the study of the brain-based underpinnings of psychological and behavioral functions. A major debate in the neuroscience community had been going on for centuries, all the way back to Descartes, over the issue of **localization of function**. To say a function is "localized" in a particular region is, roughly, to claim that the neural structures supporting that function reside in a specific brain area. In a major work published in 1929, a very influential neuroscientist, Karl Lashley, claimed there was no reason to believe that major functions (such as language and memory) are localized (H. Gardner, 1985).

However, research during the late 1940s and 1950s accumulated to challenge that view. Work by Donald Hebb (1949) suggested that some kinds of functions, such as visual perceptions, were constructed over time by the building of *cell assemblies*—connections of sets of cells in the brain. During the 1950s and 1960s, Nobel Prize–winning neurophysiologists David Hubel and Torsten Wiesel discovered that specific cells in the visual cortex of cats were in fact specialized to respond to specific kinds of stimuli (such as orientation of lines and particular shapes). Equally important, Hubel and Wiesel (1959) demonstrated the importance of early experience on nervous system development. Kittens that were experimentally restricted to an environment with only horizontal lines would fail to develop the ability to perceive vertical lines. This work suggested that at least some functions are localized in the brain (H. Gardner, 1985).

There is yet one more thread to the cognitive revolution, also dating from about World War II: the development of computers and artificially intelligent systems. In 1936, a mathematician named Alan Turing wrote an article describing "universal machines," mathematical entities that are simple in nature but capable in principle of solving logical or mathematical problems. This article ultimately led to what some psychologists and computer scientists call the **computer metaphor**: the comparison of people's cognitive activities to an operating computer. Just as computers need to be fed data, people need to acquire information.

Both computers and people often store information and therefore must have structures and processes that allow such storage. People and computers often need to recode information—that is, to change the way it is recorded or presented. People and computers must also manipulate information in other ways—transform it, for example, by rearranging it, adding to or subtracting from it, deducing from it, and so on. Computer scientists working on the problem of **artificial intelligence** study how to program computers to solve the same kinds of problems humans can and to try to determine whether computers can use the same methods that people apparently use to solve such problems.

During the 1970s, researchers in different fields started to notice they were investigating common questions: the nature of mind and of cognition; how information is acquired, processed, stored, and transmitted; and how knowledge is represented. Scholars from fields such as cognitive psychology, computer science, philosophy, linguistics, neuroscience, and anthropology, recognizing their mutual interests, came together to found an interdisciplinary field known as **cognitive science**. H. Gardner (1985) even gave this field a birth date—September 11, 1956—when several founders of the field attended a symposium on information theory at the Massachusetts Institute of Technology.

H. Gardner (1985) pointed out that the field of cognitive science rests on certain common assumptions. Most important among these is the assumption that cognition must be analyzed at what is called the *level of representation*. This means cognitive scientists agree that cognitive theories incorporate such constructs as symbols, rules, images, and ideas—in Gardner's words, "the stuff . . . found between input and output" (p. 38). Thus, cognitive scientists focus on representations of information rather than on how nerve cells in the brain work or on historical or cultural influences.

GENERAL POINTS

Each school of psychology described so far has left a visible legacy to modern cognitive psychology. Structuralists asked the question, what are the elementary units and processes of the mind? Functionalists reminded psychologists to focus on the larger purposes and contexts that cognitive processes serve. Behaviorists challenged psychologists to develop testable hypotheses and to avoid unresolvable debates. Gestalt psychologists pointed out that an understanding of individual units would not automatically lead to an understanding of whole processes and systems. Galton demonstrated that individuals can differ in their cognitive processing. Developments in engineering, computer science, linguistics, and neuroscience have uncovered processes by which information can be efficiently represented, stored, and transformed, providing analogies and metaphors for cognitive psychologists to use in constructing and testing models of cognition. As we take up particular topics, we will see more of how cognitive psychology's different roots have shaped the field.

Keep in mind that cognitive psychology shares in the discoveries made in other fields, just as other fields share in the discoveries made by cognitive psychology. This sharing and borrowing of research methods, terminology, and analyses gives many investigators a sense of common purpose. It also all but requires cognitive psychologists to keep abreast of new developments in fields related to cognition.

RESEARCH METHODS IN COGNITIVE PSYCHOLOGY

Throughout this book, we will review different empirical studies of cognition. Before we plunge into those studies, however, we will look at some of the different kinds of studies that cognitive psychologists conduct. The following descriptions do not exhaust all the studies a cognitive psychologist *could* conduct but should acquaint you with the major methodological approaches to cognitive psychology.

EXPERIMENTS AND QUASI-EXPERIMENTS

The most frequently adopted approach to cognitive investigations is the psychological experiment. A true **experiment** is one in which the experimenter manipulates one or more independent variables (the experimental conditions) and observes how the recorded measures (dependent variables) change as a result. A major distinction between experiments and observational methods (which we will examine in just a bit) is the investigator's degree of experimental control. Having experimental control means the experimenter can assign participants to different experimental conditions so as to minimize preexisting differences between them. Ideally, the experimenter can control all variables that might affect the performance of research participants *other than* the variables on which the study is focusing.

For example, an experiment in cognitive psychology might proceed as follows. An experimenter recruits a number of people for a study of memory, randomly assigns them to one of two groups, and presents each group with exactly the same stimuli, using exactly the same procedures and settings and varying only the instructions (the independent variable) for the two groups of participants. The experimenter then observes the overall performance of the participants on a later memory test (the dependent variable).

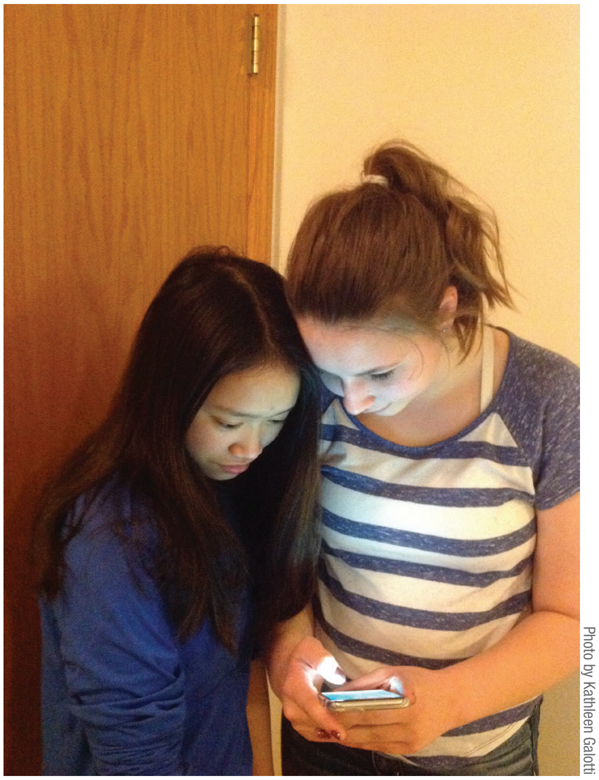
This example illustrates a **between-subjects design**, where different experimental participants are assigned to different experimental conditions and the researcher looks for differences in performance between the two groups. In contrast, a **within-subjects design** exposes the same experimental participants to more than one condition. For example, participants might perform several memory tasks but receive a different set of instructions for each task. The investigator then compares the performance of the participants in the first condition with the performance of the *same* participants in another condition.

Some independent variables preclude random assignment (i.e., having the experimenter assign a research participant to a particular condition in an experiment). For example, experimenters cannot reassign participants to a different gender, ethnicity, age, or educational background. Studies that appear in other ways to be experiments but that have one or more of these factors as independent variables (or fail to be true experiments in other ways) are called **quasi-experiments** (D. T. Campbell & Stanley, 1963).

Scientists value experiments and quasi-experiments because they enable researchers to isolate causal factors and make better-supported claims about causality than is possible using observational methods alone. However, many experiments fail to fully capture real-world phenomena in the experimental task or research design. The laboratory setting or the artificiality or formality of the task may prevent research participants from behaving normally, for example. Furthermore, the kinds of tasks amenable to experimental study might not be those most important or most common in everyday life. As a result, experimenters sometimes risk studying phenomena that relate only weakly to people's real-world experience.

NATURALISTIC OBSERVATION

As the name suggests, **naturalistic observation** consists of an observer watching people in familiar everyday contexts going about their cognitive business. For example, an investigator might watch as people try to figure out how to work a new smartphone. Ideally, the observer remains as unobtrusive as possible so as to disrupt or alter the behaviors being observed as little as possible. In this example, the investigator might stand nearby and surreptitiously note what people who use the smartphone do and say. Being unobtrusive is much harder than it might sound. The observer needs to make sure the people being observed are comfortable and do not feel as though they are "under a microscope." At the same time, the observer wants to avoid causing the people being observed to "perform" for the observer. In any case, the observer can hardly fully assess his or her own effects on the observation. After all, how can one know what people would have done had they not been observed?



■ Photo 1.2: Recording people engaged in everyday behaviors in typical settings uses the naturalistic observation method of investigation.

Observational studies have the advantage that the things studied occur in the real world and not just in an experimental laboratory. Psychologists call this property **ecological validity**. Furthermore, the observer has a chance to see just how cognitive processes work in natural settings: how flexible they are, how they are affected by environmental changes, and how rich and complex actual behavior is. Naturalistic observation is relatively easy to do, doesn't typically require a lot of resources to carry out, and doesn't require other people to formally volunteer for study.

The disadvantage of naturalistic observation is a lack of **experimental control**. The observer has no means of isolating the causes of different behaviors or reactions. All the observer can do is collect observations and try to infer relationships among them. However plausible different hypotheses may seem, the observer has no way to verify them. Some psychologists believe that naturalistic observation is most appropriately used to identify problems, issues, or phenomena of interest to then be investigated with other research methods.

A second problem, which all scientists face, is that an observer's recordings are only as good as her or his initial plan for what is important to record. The settings and people the observer chooses to observe, the behaviors and reactions she or he chooses to record, the manner of recording, and the duration and frequency of observation all influence the results and conclusions the observer can later draw. Moreover, whatever biases the observer brings to the study (and, as we will see in Chapter 12, all of us are subject to a large number of biases) limit and possibly distort the recordings made.

CONTROLLED OBSERVATION AND CLINICAL INTERVIEWS

As the term **controlled observation** suggests, this method gives researchers some degree of influence over the setting in which observations are conducted. Investigators using this research method try to standardize the setting for all participants, in many cases manipulating specific conditions to see how participants will be affected. In the smartphone example, for instance, the investigator might arrange for the smartphone to display different instructions to different people. The study would still be observational (because the researcher would not control who used the machine or when), but the researcher would be trying to channel the observed behavior in certain ways.

In **clinical interviews**, the investigator tries to channel the process even more. The investigator begins by asking each participant a series of open-ended questions. The interviewer might ask the participant to think about a problem and describe his or her approaches to it. With the clinical interview method, however, instead of allowing the participant to respond freely, the interviewer follows up with another set of questions. Depending on the participant's responses, the interviewer may pursue one or another of many possible lines of questioning, trying to follow the participant's own thinking and experience while focusing on specific issues or questions.

INTROSPECTION

We have already seen one special kind of observation dating back to the laboratory of Wundt. In the technique of introspection, the observer observes his or her own mental processes. For example, participants might be asked to solve complicated arithmetic problems without paper or pencil and to "think aloud" as they do so.

Introspection has all the benefits and drawbacks of other observational studies plus a few more. One additional benefit is that observing one's own reactions and behavior may give one better insight into an experience and the factors that influenced it, thereby yielding a richer, more complete picture than an outsider could observe. But observing yourself is a double-edged sword. Although perhaps a better observer in some ways than an outsider, you may also be more biased in regard to your own cognition. People observing their own mental processes may be more concerned with their level of performance and may be motivated to subtly and unconsciously distort their observations. They may try to make their mental processes appear more organized, logical, thorough, and so forth than they actually are, and they may be unwilling to admit when their cognitive processes seem flawed or random. Moreover, with some cognitive tasks (especially demanding ones), observers may have few resources left with which to observe and record while they work on the task.

INVESTIGATIONS OF NEURAL UNDERPINNINGS

Much work in cognitive neuroscience involves examining people's brains. Before the second half of the 20th century, this kind of examination could be conducted only during an autopsy after a patient died. However, since the 1970s, various techniques of **brain imaging,** the construction of pictures of the anatomy and functioning of intact brains, have been developed. We will discuss many of these techniques in Chapter 2.

GENERAL POINTS

This brief outline of different research designs barely scratches the surface of all the important things we could look at. There are a few general points to note, however. First, cognitive psychologists use a variety of approaches to study cognitive phenomena. In part, these approaches reflect philosophical differences among psychologists over what is important to study and how trade-offs should be made between certain drawbacks and benefits. In part, they reflect the intellectual framework or paradigms (examples to be discussed very shortly) within which researchers work. They may also reflect how amenable different areas of cognition are to different research approaches.

Second, no research design is perfect. Each has certain potential benefits and limitations that researchers must weigh in designing studies. Students, professors, and other researchers must also carefully think, both critically and appreciatively, about how the research design answers the research question posed. I hope you'll keep these thoughts in mind as you discover in the rest of this book examples of the wide variety of research studies that cognitive psychologists have carried out.

PARADIGMS OF COGNITIVE PSYCHOLOGY

Having looked at cognitive psychology's historical roots and research methods, we can now focus on modern cognitive psychology. In this section, we will examine the four major paradigms that cognitive psychologists use in planning and executing their research.

First of all, what is a **paradigm**? The word has several related meanings, but you can think of it as a body of knowledge structured according to what its proponents consider important and what they do not. Paradigms include the assumptions investigators make in studying a phenomenon. Paradigms also specify what kinds of experimental methods and measures are appropriate for an investigation. Thus, paradigms are intellectual frameworks that guide investigators in studying and understanding phenomena.

In learning about each paradigm, ask yourself the following questions. What assumptions underlie the paradigm? What questions or issues does the paradigm emphasize? What analogies (such as the analogy between the computer and the mind) does the paradigm use? What research methods and measures does the paradigm favor?

THE INFORMATION-PROCESSING APPROACH

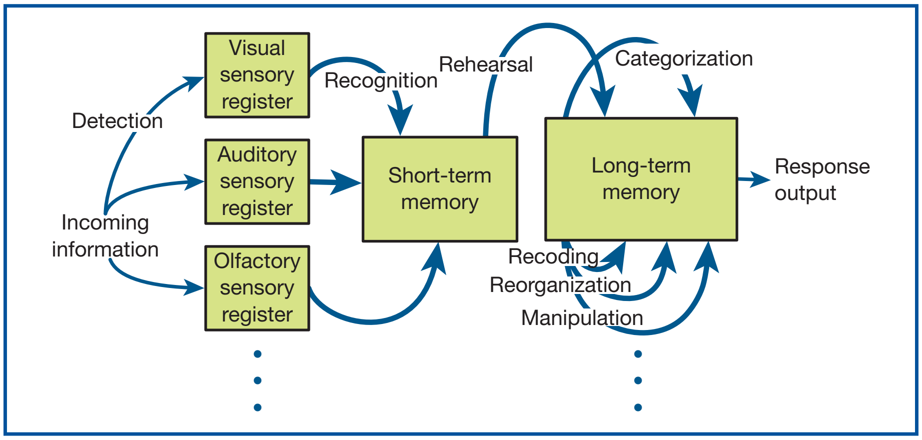
The **information-processing approach** dominated cognitive psychology during the 1960s and 1970s and remains influential today (Atkinson & Shiffrin, 1968). As its name implies, the information-processing approach draws an analogy between human cognition and computerized processing of information. Central to the information-processing approach is the idea that cognition can be thought of as information (what we see, hear, read about, and think about) passing through a system (us or, more specifically, our minds).

Researchers following an information-processing approach often assume that information is processed (received, stored, recoded, transformed, retrieved, and transmitted) in stages and that it is stored in specific places while being processed. One goal within this framework, then, is to determine what these stages and storage places are and how they work.

Other assumptions underlie the information-processing approach as well. One is that people's cognitive abilities can be thought of as "systems" of interrelated capacities. We know different individuals have different cognitive capacities—different attention spans, memory capacities, and language skills, to name a few. Information-processing theorists try to find the relationships between these capacities to explain how individuals go about performing specific cognitive tasks.

In accordance with the computer metaphor, information-processing theorists assume that people, like computers, are general-purpose symbol manipulators. In other words, people, like computers, can perform astonishing cognitive feats by applying only a few mental operations to symbols (such as letters, numbers, propositions, and scenes). Information is then stored symbolically, and the way it is coded and stored greatly affects how easy it is to use it later (as when we want to recall information or manipulate it in some way).

A general-purpose information-processing system is shown in Figure 1.2. Note the various memory stores where information is held for possible later use and the different processes that operate on the information at different points or that transfer it from store to store. Certain processes, such as detection and recognition, are used at the beginning of information processing; others, such as recoding and retrieval, have to do with memory storage; still others, such as reasoning and concept formation, have to do with putting information together in new ways. In this model, boxes represent stores and arrows represent processes (leading some to refer to information-processing models as "boxes-and-arrows" models of cognition). Altogether, information-processing models are depicted best by something computer scientists call *flowcharts*, which illustrate the sequential flow of information through a system.



■ Figure 1.2: A typical information-processing model.

The information-processing tradition is rooted in structuralism in that its followers attempt to identify the basic capacities and processes we use in cognition. The computer metaphor used in this approach also shows indebtedness to the fields of engineering and communications. Psychologists working in the information-processing tradition are interested in relating individual and developmental differences to differences in basic capacities and processes. Typically, information-processing psychologists use experimental and quasi-experimental techniques in their investigations.

THE CONNECTIONIST APPROACH

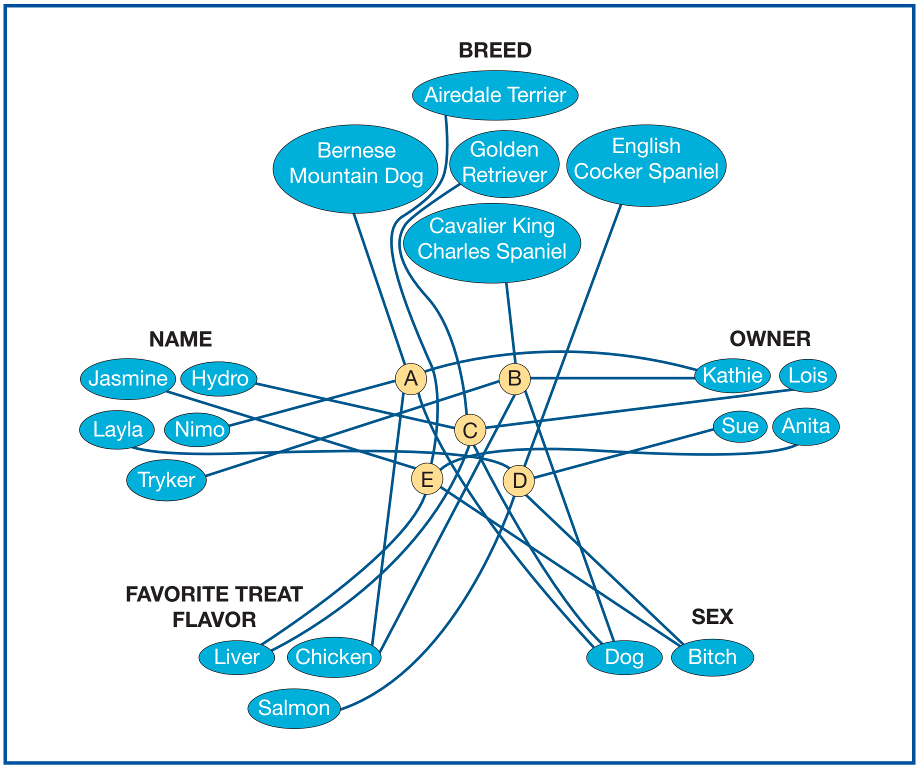
Early in the 1980s, researchers from a variety of disciplines began to explore alternatives to the information-processing approach that could explain cognition. The framework they established is known as **connectionism** (sometimes also called *parallel-distributed processing*, or *PDP*). Its name is derived from models depicting cognition as a network of connections among simple (and usually numerous) processing units (McClelland, 1988). Because these units are sometimes compared to *neurons*, the cells that transmit electrical impulses and underlie all sensation and muscle movement, connectionist models are sometimes called **neural networks** (technically speaking, there are distinctions between connectionist and neural network models, but we will not review them here).

Each unit is connected to other units in a large network. Each unit has some level of activation at any particular moment in time. The exact level of activation depends on the input to that unit from both the environment and the other units to which it is connected. Connections between two units have weights, which can be positive or negative. A positively weighted connection causes one unit to excite, or raise the level of activation of, units to which it is connected; a negatively weighted connection has the opposite effect, inhibiting or lowering the activation of connected units.

Figure 1.3 depicts a (very partial) connectionist representation of the dogs that showed up to my training class the other night. To reduce complexity, it shows only positively weighted connections. To "unpack" this figure, look at the node in the center circle labeled "A." This node doesn't have particular meaning by itself, just as, for example, any individual neuron in your body doesn't have any one particular function. But if node A were to become activated, that activation would spread to all the other nodes with which it is connected—the "Kathie" node in the "Owner" group, the "Nimo" node in the "Name" group, the "Bernese Mountain Dog" node in the "Breed" group, the "Dog" node in the "Sex" group, and the "Chicken" node in the "Favorite Treat Flavor" group of nodes. The "representation" of Nimo in this network is the simultaneous activation of these nodes.

One major difference between the information-processing and connectionist approaches is the manner in which cognitive processes are assumed to occur. In information-processing models, cognition is typically assumed to occur *serially*—that is, in discrete stages (first one process occurs, which feeds information into the next process, which feeds information into the next process, etc.). In contrast, most (but not all) connectionist models assume that cognitive processes occur in *parallel*, many at the same time.

The connectionist framework allows for a wide variety of models, which can vary in the number of units hypothesized, number and pattern of connections among units, and connection of units to the environment. All connectionist models share the



■ Figure 1.3: A depiction of a connectionist model.

assumption, however, that there is no need to hypothesize a central processor that directs the flow of information from one process or storage area to another. Instead, different patterns of activation account for the various cognitive processes (Dawson, 1998). Knowledge is not stored in various storehouses (such as the boxes depicted in Figure 1.2) but rather is stored within connections between units. Learning occurs when new connective patterns are established that change the weights of connections between units.

Feldman and Ballard (1982), in an early description of connectionism, argued that this approach is more consistent with the way the brain functions than an information-processing approach. The brain, they argued, is made up of many neurons connected to one another in various complex ways. The authors asserted that

> the fundamental premise of connectionism is that individual neurons *do not transmit large amounts of symbolic information*. Instead they compute by being *appropriately connected* to large numbers of similar units. This is in sharp contrast to the conventional computer model of intelligence prevalent in computer science and cognitive psychology. (p. 208)

Rumelhart (1989) put the issue more simply: "Connectionism seeks to replace the computer metaphor of the information-processing framework with a brain metaphor" (p. 134).

Like the information-processing approach, connectionism draws from structuralism an interest in the elements of cognitive functioning. However, whereas information processors look to computer science, connectionists look to cognitive neuropsychology (the study of people with damaged or otherwise unusual brain structures) and cognitive neuroscience for information to help them construct their theories and models. Information-processing accounts of cognition try to provide explanations at a more abstract symbolic level than do connectionist accounts. Connectionist models are more concerned with the "subsymbolic" level: how cognitive processes actually could be carried out by a brain. Connectionism, being much newer than information processing, is just beginning to map out explanations for individual and developmental differences. Most connectionist work seeks to replicate the findings of experimental and quasi-experimental research using computer programs based on a neural network model.

THE EVOLUTIONARY APPROACH

Some of our most remarkable cognitive abilities and achievements are ones we typically take for granted. Two that come immediately to mind are the ability to perceive three-dimensional objects correctly and the ability to understand and produce language. These abilities may seem rather trivial and mundane—after all, a 3-year-old can do quite a bit of both. However, researchers in the field of artificial intelligence quickly found that it is not easy to program computers to carry out even rudimentary versions of these tasks (Winston, 1992).

So why can young children do these tasks? In fact, how can a wide range of people, even people who don't seem particularly gifted intellectually, carry them out with seemingly little effort? Some psychologists search for an answer in evolutionary theory (Cosmides & Tooby, 2002; Richerson & Boyd, 2000). The argument goes something like this. Like other animal minds, the human mind is a biological system, one that has evolved over generations. Like other animal minds, it too is subject to the laws of natural selection. Therefore, the human mind has responded to evolutionary pressures to adapt in certain ways rather than others in response to the environments encountered by our predecessors. Evolutionary psychologist Leda Cosmides (1989) noted that the environments our ancestors experienced were not simply physical but ecological and social as well.

The idea here is that humans have specialized areas of competence produced by our evolutionary heritage. Cosmides and Tooby (2002) argued that people have "a large and heterogeneous set of evolved, reliably developing, dedicated problem-solving programs, each of which is specialized to solve a particular domain or class of adaptive problems (e.g., grammar acquisition, mate acquisition, food aversion, way-finding)" (p. 147). In other words, people have special-purpose mechanisms (including cognitive mechanisms) specific to a certain context or class of problems.

Cosmides and Tooby (2000, 2002) believed that some of the most significant issues our ancestors faced involved social issues such as creating and enforcing social contracts. To do this, people must be especially good at reasoning about costs and benefits, and they must be able to detect cheating in a social exchange. Therefore, evolutionary psychologists predict that people's reasoning will be especially enhanced when they are reasoning about cheating, a topic we will examine in much greater detail in Chapter 12.

In general, evolutionary psychologists believe we understand a system best if we understand the evolutionary pressures on our ancestors. Explaining how a system of reasoning works, they believe, is much easier if we understand how evolutionary forces shaped the system in certain directions rather than other, equally plausible ones.

THE ECOLOGICAL APPROACH AND EMBODIED COGNITION

A fourth major approach to the study of cognition comes from philosophers, psychologists, and anthropologists and overlaps much more with the evolutionary approach than it does with either the information-processing or connectionist approach. The central tenet of this approach is that cognition does not occur in isolation from larger cultural contexts; all cognitive activities are shaped by the culture and context in which they occur.

Jean Lave, a current theorist in this tradition, has conducted some fascinating work that illustrates the **ecological approach**. Lave (1988) described the results of the Adult Math Project as "an observational and experimental investigation of everyday arithmetic practices" (p. 1). Lave, Murtaugh, and de la Rocha (1984) studied how people used arithmetic in their everyday lives. In one study, they followed people on grocery-shopping trips to analyze how and when people calculate "best buys." They found that people's methods of calculation varied with the context. This was somewhat surprising because students in our culture are taught to use the same specified formulas on all problems of a given type to yield one definite numerical answer. To illustrate, compare a typical third-grade arithmetic problem presented by teachers to students—"Brandi had eight seashells. Nikki had five more. How many seashells did the two of them have together?"—with the following problem, posed and solved by one of the grocery shoppers, regarding the number of apples she should purchase for her family for the week:

> There's only about three or four [apples] at home, and I have four kids, so you figure at least two apiece in the next three days. These are the kinds of things I have to resupply. I only have a certain amount of storage space in the refrigerator, so I can't load it up totally. . . . Now that I'm home in the summertime, this is a good snack food. And I like an apple sometimes at lunchtime when I come home. (Murtaugh, 1985, p. 188)

Photo by Kathleen Galotti

■ Photo 1.3: Research in the ecological tradition uses everyday settings, such as a grocery store expedition, to study cognitive processing.

Lave (1988) pointed out a number of contrasts between this arithmetic problem solving and the kind used in solving school problems. First, the second example has many possible answers (e.g., 5, 6, 9), unlike the first problem, which has one (13). Second, the first problem is given to the problem solver to solve; the second is constructed by the problem solver herself. Third, the first problem is somewhat disconnected from personal experience, goals, and interests, whereas the second comes out of practical daily living.

Although there has been much recent interest in the ecological approach, the idea of studying cognition in everyday contexts actually arose several years earlier. A major proponent of this viewpoint was J. J. Gibson, whose work on perception will be discussed at length in Chapter 3. Ulric Neisser, a friend and colleague of Gibson, wrote a book in 1976 aimed at redirecting the field of psychology toward studying more "realistic" cognitive phenomena.

We can see the influences of both the functionalist and Gestalt schools on the ecological approach. The functionalists focus on the purposes served by cognitive processes, certainly an ecological question. Gestalt psychology's emphasis on the context surrounding any experience is likewise compatible with the ecological approach. The ecological approach would deny the usefulness (and perhaps even the possibility) of studying cognitive phenomena in artificial circumstances divorced from larger contexts. Thus, this tradition relies less on laboratory experiments or computer simulations and more on naturalistic observation and field studies to explore cognition.

A current viewpoint in cognitive science is one known generally as the **embodied cognition** view (Chemero, 2011; Wilson, 2002), and it can be seen as a particular version of the ecological paradigm. As Wilson (2002) put it, "Proponents of embodied cognition take as their theoretical starting point not a mind working on abstract problems, but a body that requires a mind to make it function" (p. 625). That is, the way cognition works is held to be inextricably linked to the fact that minds are typically encased in bodies, and those bodies influence how we perceive, navigate, and behave. Those processes of perceiving, navigating, and behaving are not simply ancillary processes to the pure cognitive ones (such as thinking and deducing) but instead are important components that define the way we do cognition. Wilson explained further,

> There is a growing commitment to the idea that the mind must be understood in the context of its relationship to a physical body that interacts with the world. It is argued that we have evolved from creatures whose neural resources were devoted primarily to perceptual and motoric processing, and whose cognitive activity consisted largely of immediate, on-line interaction with the environment. (p. 625)

Indeed, a school of *radical embodied cognitive science* (Chemero, 2011) holds that theories of cognition do not need to posit the existence of mental representations at all. We will come back to the topic of embodied cognition in Chapter 3.

COGNITIVE NEUROSCIENCE

The idea that the brain shapes, directs, enables, and constrains human cognition is the view held by the field of **cognitive neuroscience**. We will take up this view in greater depth in Chapter 2 after we review ideas about the structure and function of the brain. Cognitive neuroscientists seek to understand the ways cognitive processes and activities are processed by the brain.

GENERAL POINTS

Each of these paradigms makes an important contribution to cognitive psychology, and in some ways the paradigms offer complementary perspectives on how the underlying principles of cognition ought to be investigated and understood. The information-processing paradigm, for example, focuses researchers on the functional aspects of cognition—what kinds of processes are used toward what ends. The connectionist approach, in contrast, focuses on the underlying "hardware"—how the global cognitive processes described by an information-processing model are implemented in the human brain. The evolutionary approach centers on questions of how a cognitive system or function has evolved over generations. The ecological approach stresses the need to consider the context of any cognitive process to understand more completely how that process functions in the real world. And the cognitive neuroscience paradigm looks to see how the brain instantiates cognitive processing of information.

Not all cognitive research fits neatly into one of these paradigms. Some research incorporates parts of different paradigms; some fits no paradigm neatly. However, I hope these paradigms will provide a useful backdrop against which to consider individual studies.

This framework offers a sense of where we are headed in the rest of the book as we take up specific cognitive topics in more detail. Throughout, you should examine how the research studies discussed bear on cognitive activities in your everyday life. Are the questions posed, and the research approaches used to answer them, appropriate? How do the theoretical assumptions shape the way the questions are posed? What do the research findings mean, and what new questions do they raise?

Cognitive psychology is my field. Not surprisingly, I've found it to be full of fascinating, deeply rooted questions, complex as well as elegant and relevant to many real-world issues. I hope that you too, after reading this book, will find this field to be an important one—a field worth knowing about.

Summary

1. Cognition plays a large role in our everyday existence. We take much of our cognitive experience for granted because the ways we function cognitively are so routine that we simply don't pay attention to them. Nonetheless, on closer inspection, we see that many cognitive activities are astonishingly complex.
2. We have examined different traditions in the study of cognition, tracing the history of the field back at least as far as Wilhelm Wundt's Leipzig laboratory. We have seen how major schools of thought—structuralism, functionalism, behaviorism, and Gestalt approaches—have framed cognitive questions.
3. Structuralism, a school of psychology associated with Wundt, seeks to discover the laws and principles that explain our immediate conscious experience. In particular, structuralists want to identify the simplest essential units of the mind and to determine how these units combine to produce complex mental phenomena.
4. Functionalism, a school of psychology associated with William James, takes as the basic aim of psychology understanding the function of the mind—the ways mental functions let individuals adapt to their environment.
5. Behaviorism, regarded by some as a branch of functionalism, takes as the central aim of psychology the scientific study of behavior, an observable consequence of psychological experience. Radical behaviorists insist that references to unobservable, subjective mental states (such as consciousness) as well as to unobservable subjective processes (such as expecting, believing, understanding, remembering, hoping for, deciding, and perceiving) should be banished from psychology proper.
6. The school of Gestalt psychology holds as its central assumption that psychological phenomena cannot be reduced to simple elements but rather must be analyzed and studied in their entirety. Gestalt psychologists believe that observers do not construct a coherent perception from simple, elementary sensory aspects of an experience but instead apprehend the total structure of an experience as a whole.
7. Sir Francis Galton emphasized the idea that individuals differ, even as adults, in their cognitive capacities, abilities, and preferences.
8. The current study of cognitive psychology grows out of, and contributes to, innovations in other fields such as computer science, communications, engineering, linguistics, evolution, and anthropology.
9. Cognitive psychology draws on many different research methods, including experiments, quasi-experiments, controlled observation, and naturalistic observation.
10. We have reviewed different paradigms, or intellectual frameworks of the study of cognition. Paradigms specify the assumptions, guiding questions, and research methods that investigators adopt.
11. The information-processing paradigm emphasizes stage-like processing of information and specific storage of that information during processing.
12. The connectionist approach depicts cognitive processing as a pattern of excitation and inhibition within a network of connections among simple (and usually numerous) processing units that operate in parallel.
13. The evolutionary paradigm examines how a cognitive process has been shaped by environmental pressure over long periods of time.

14. The ecological paradigm stresses the ways the environment and the context shape the way cognitive processing occurs. Embodied cognition asserts that cognition is shaped and constrained by the context of the body of the organism experiencing the processing.

15. The cognitive neuroscience paradigm, which we will explore in greater detail in Chapter 2, links the way cognitive processing is carried out to the way the brain is structured and functions.

Review Questions

1. What roles do laboratory experiments and naturalistic observation play in cognitive research?
2. What similarities and differences exist among the following three "schools" of psychology: structuralism, functionalism, and behaviorism?
3. What is a mental representation, and how is this concept viewed by Gestalt psychologists, information-processing psychologists, behaviorist psychologists, and connectionists?
4. Describe how research on individual differences might bear on cognitive psychology.
5. What was the "cognitive revolution"? What resulted from it?
6. Describe and critique the major research methods of cognitive psychology.
7. Compare and contrast the major paradigms of cognitive psychology reviewed in this chapter. Which pair of paradigms shares the deepest similarities? Which pair is the most dissimilar? Defend your views.

Key Terms

artificial intelligence
association
attention
behaviorism
between-subjects design
brain imaging
clinical interview
cognitive neuroscience
cognitive revolution
cognitive science
computer metaphor
connectionism
controlled observation
decision making
ecological approach
ecological validity
embodied cognition
empiricism
experiment
experimental control
functionalism
Gestalt psychology
human factors engineering
information-processing approach
introspection
knowledge representation
language
limited-capacity processor
linguistics
localization of function
memory
mental representation
nativism
naturalistic observation
neural network
neuroscience
paradigm
pattern recognition
perception
person–machine system
problem solving
quasi-experiment
reasoning
recall
recognition
structuralism
within-subjects design

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Setting the Stage	What Is Cognitive Psychology?
Influences on the Study of Cognition	The Quest to Understand Consciousness Generative Theories Cognitive Perspective of Learning and Information Processing Gestalt, Psychoanalysis, and Behaviorism
Research Methods in Cognitive Psychology	Cognitive Rehabilitation in Parkinson's Disease
Paradigms of Cognitive Psychology	Neural Portrait of the Human Mind

2

THE BRAIN
An Overview of Structure and Function

CHAPTER OUTLINE

SETTING THE STAGE

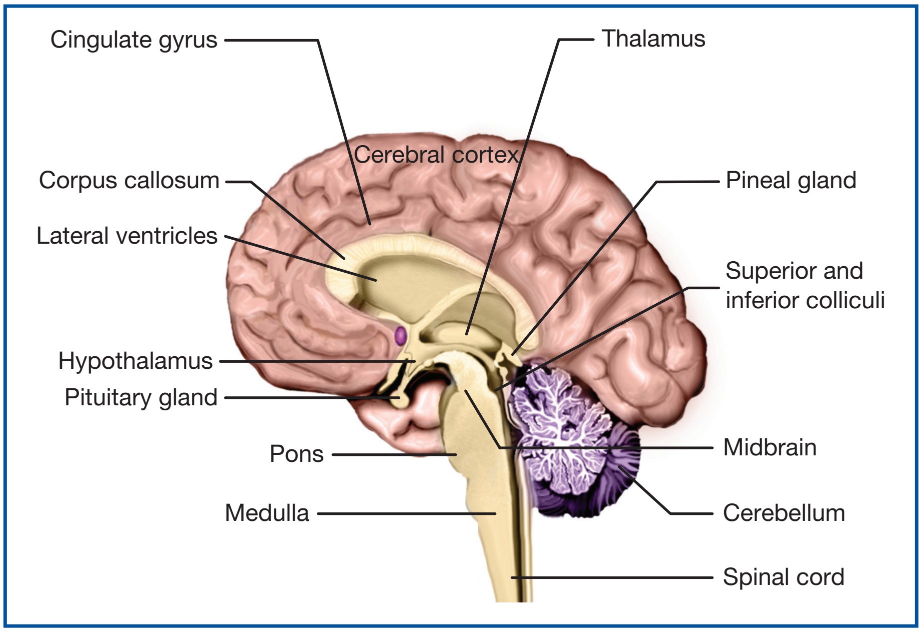
When the field of cognitive psychology began (during the 1950s and 1960s), cognitive psychologists found the workings of the brain to be quite interesting but not necessarily relevant to their understanding of how cognitive processes worked. The idea was that description of cognitive processes and structures was best done at a level of abstraction above the neural level, which was thought to be too inordinately complicated. Many feared that a description of how each neuron in the brain worked would not yield a comprehensible explanation of, say, how one's learning of French verb endings takes place. The level of detail of the neurons in your brain would simply not provide a very useful explanation, whereas one couched in terms of theoretical ideas such as memory storage areas (which might not physically exist) would. Theorists began to distinguish between different "levels" of explanation—a symbolic and abstract level for cognition as opposed to a neural level for the actual functioning of cognitive processes in real time.

There is still strong argument among psychologists, biologists, philosophers, and computer scientists over which level of explanation is most useful for different kinds of understanding. However, increasing numbers of cognitive psychologists have become interested in the functioning of the brain as an underpinning for cognitive activity. Although the question of which level provides the most useful explanation remains, many cognitive psychologists feel they cannot investigate cognition without a working knowledge of how the brain develops and functions.

Of course, the topic of brain functioning and its relationship to cognition is itself a vast and complex one, and only brief highlights are given here. The interested student is referred to other in-depth treatments of the topic (e.g., Gazzaniga, 2009; Reuter-Lorenz, Baynes, Mangun, & Phelps, 2010). First, consider some growth statistics. The brain grows from 0 to 350 grams (about three-quarters of a pound) during the prenatal period, but this growth doesn't stop at birth. The maximum brain weight of 1,350 grams (about three pounds) is achieved when the individual is about 20 years old (Nowakowski & Hayes, 2002). Most postbirth growth takes place before the child's fourth birthday, but some changes continue through adulthood.

STRUCTURE OF THE BRAIN

There are obviously a lot of different structures to talk about when we talk about the brain. We will need to discuss first the different divisions of the brain, and we will begin with a phylogenetic division. Figure 2.1 shows various structures of the adult brain, including the midbrain. All of the structures above the midbrain are part of the forebrain (including the cerebral lobes, which we will discuss in detail momentarily). All of the structures below the midbrain are part of the hindbrain. In our brief discussion, we will focus specifically on the cerebral cortex, a part of the forebrain. However, it is worth talking briefly about the hindbrain and midbrain first.



■ Figure 2.1: Lateral view of the interior features of the human brain.

Adapted from Garrett, B. (2011). *Brain & behavior: An introduction to biological psychology*, p. 65.

THE HINDBRAIN AND MIDBRAIN

The **hindbrain** contains the pons, the medulla, and the cerebellum (B. Garrett, 2015). The **medulla** (sometimes called the *medulla oblongata*) transmits information from the spinal cord to the brain and regulates life support functions such as respiration, blood pressure, coughing, sneezing, vomiting, and heart rate (Pritchard & Alloway, 1999). The **pons** (the name derives from the Latin word for *bridge*) also acts as a neural relay center, facilitating the "crossover" of information between the left side of the body and the right side of the brain and vice versa. It is also involved in balance, sleep, and arousal and in the processing of both visual and auditory information.

The **cerebellum** contains neurons that coordinate muscular activity (Purvis et al., 2012). It is one of the most primitive brain structures. It also governs balance and is involved in general motor behavior and coordination. Brain lesions in the cerebellum can cause irregular and jerky movements, tremors, and impairment of balance and gait. The cerebellum has also been implicated in people's ability to shift attention between visual and auditory stimuli and to deal with temporal stimuli such as rhythm (Akshoomoff & Courchesne, 1994).

The **midbrain** is located (unsurprisingly) in the middle of the brain. Many of the structures contained in the midbrain (such as the inferior and superior colliculi) are involved in relaying information between other brain regions such as the cerebellum and forebrain. Another midbrain structure, the reticular formation, helps to keep us awake and alert and is involved in arousal (B. Garrett, 2015).

THE FOREBRAIN

Because of our interest in cognitive issues, we will focus the remainder of our discussion of the brain on the **forebrain**. Some of the structures of the forebrain are also presented in Figure 2.1. The **thalamus**, for example, is yet another structure for relaying information, especially to the cerebral cortex (Pritchard & Alloway, 1999), which we will talk about shortly. The **hypothalamus** controls the pituitary gland by releasing hormones, specialized chemicals that help to regulate other glands in the body. The hypothalamus also controls so-called homeostatic behaviors such as eating, drinking, temperature control, sleeping, sexual behaviors, and emotional reactions.

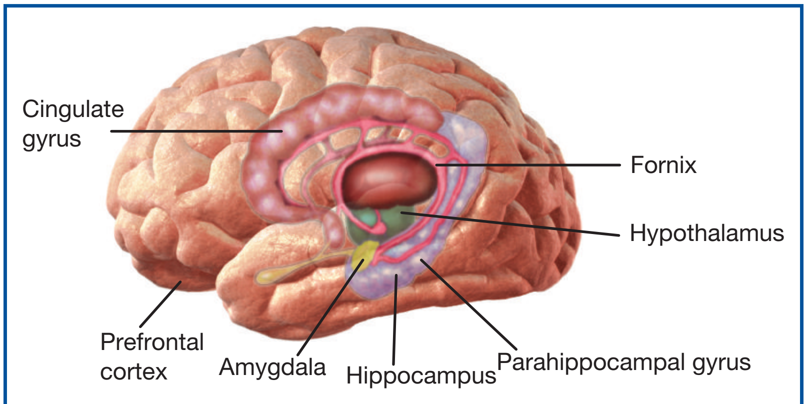
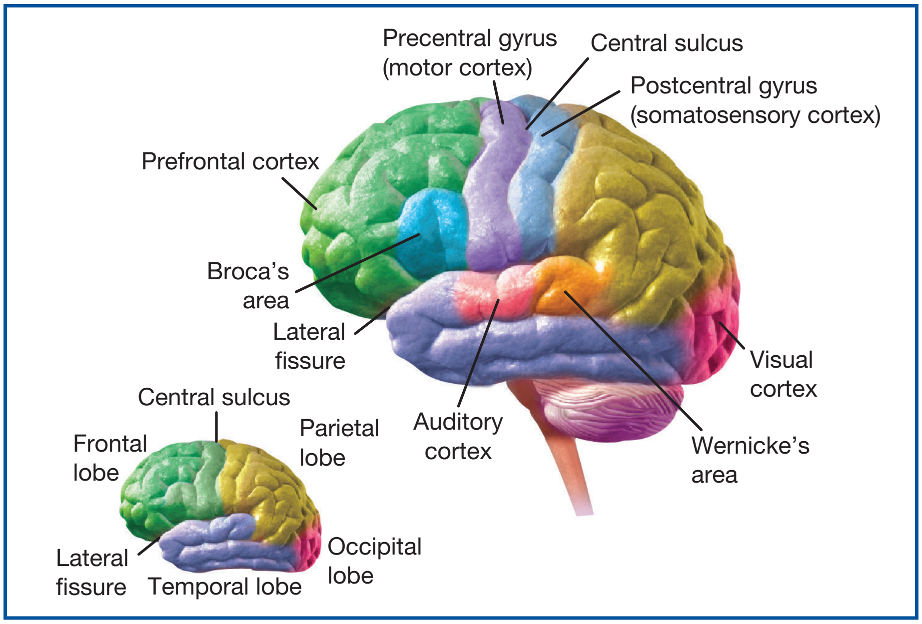


Figure 2.2: Structures of the limbic system.

Adapted from Garrett, B. (2011). *Brain & behavior: An introduction to biological psychology,* Figure 8.4, p. 227.

Other structures in the forebrain are shown in Figure 2.2. The **hippocampus**, which is involved in the formation of long-term memories, and the **amygdala**, which modulates the strength of emotional memories and is involved in emotional learning, are located in the forebrain (actually, inside the medial temporal lobes, which are described below), as are the basal ganglia, which are involved in the production of motor behavior.

We will discuss many of these structures, including the hippocampus and amygdala, in the chapters to come. For now, we will focus on the cerebrum (from the Latin word for *brain*), the largest structure in the brain. It consists of a layer called the **cerebral cortex**, consisting



■ Figure 2.3: Lobes and functional areas on the surface of the cerebral hemispheres.

Adapted from Garrett, B. (2011). *Brain & behavior: An introduction to biological psychology*, p. 58.

of about a half-dozen layers of neurons with white matter beneath, which carries information between the cortex and the thalamus or between different parts of the cortex.

Figure 2.3 presents a more detailed diagram of the cerebral cortex, which neurologists divide into four lobes: **frontal** (underneath the forehead), **parietal** (underneath the top rear part of the skull), **occipital** (at the back of the head), and **temporal** (on the side of the head). The left and right hemispheres are connected by either the corpus callosum (in the case of the frontal, parietal, and occipital lobes) or the anterior commissure (in the case of the temporal lobe). A structure known as the central sulcus (a prominent shallow groove on the surface of the brain) divides the frontal and parietal lobes; another sulcus, the lateral fissure, helps to define the temporal lobe. Actually, because our heads have two sides, right and left, we have two lobes of each kind—the right frontal, left frontal, right parietal, left parietal, and so forth.

The parietal lobes contain the somatosensory cortex, which is contained in the postcentral gyrus (a gyrus is a convolution or ridge of the brain), the area just behind the central sulcus. The somatosensory cortex is involved in the processing of sensory information from the body—for example, sensations of pain, pressure, touch, and temperature (Pritchard & Alloway, 1999). The occipital lobes process visual information, and the temporal lobes process auditory information and enable the recognition of certain stimuli such as faces. Because the temporal lobes are just above structures such as the amygdala and hippocampus, both of which are involved in memory, damage to the temporal lobes can result in memory disruption as well.

The frontal lobes have three separate regions. The **motor cortex** (located in the precentral gyrus) directs fine motor movement; the premotor cortex seems to be involved in planning such movements. The **prefrontal cortex** is involved with what neuroscientists call **executive functioning**—planning, making decisions, implementing strategies, inhibiting inappropriate behaviors, and using working memory to process information. Damage to certain parts of the prefrontal cortex can result in marked changes in personality, mood, affect, and the ability to control inappropriate behavior (Pritchard & Alloway, 1999).

■ Photo 2.1: Phrenology head. Specific locations on the skull were thought to correspond to different specific abilities.

The prefrontal cortex shows the longest period of maturation; it appears to be one of the last brain regions to mature (Casey, Giedd, & Thomas, 2000). Interestingly, this region may also be one of the "first to go" as aging affects the brain toward the end of life. It has been hypothesized that brain regions that show the most plasticity over the longest periods may be the most sensitive to environmental toxins or stressors.

LOCALIZATION OF FUNCTION

When I describe a particular brain region or structure as having a particular role to play (as in memory or attention), you may wonder what the basis of such a claim is. That is, how do neuroscientists *know* what brain region does what? The answer lies in studies of localization of function, a means of mapping the brain.

FACULTY PSYCHOLOGY AND PHRENOLOGY

The original idea of localization of function traces back to an Austrian anatomist named Franz Gall (1758–1828), who proposed an early localization theory. Gall believed in something called **faculty psychology**, a term that has nothing to do with why your college instructors are or are not crazy! Faculty psychology was the theory that different mental abilities, such as reading and computation, were independent and autonomous functions carried out in different parts of the brain (Fodor, 1983). Gall believed that different locations in the brain were associated with such faculties as parental love, combativeness, acquisitiveness, and secretiveness, to name a few. Later, Gall's student Johan Spurzheim carried on Gall's teachings, developing the study of **phrenology**, a now discredited idea that psychological strengths and weaknesses could be precisely correlated to the relative sizes of different brain areas. Photo 2.1 depicts a sculpture showing where the different faculties were supposedly located in the brain.

The major problem with phrenology is not the assumption that different parts of the brain control different functions but rather two subsidiary assumptions: (a) that the size of a portion of the brain corresponds to its relative power and (b) that different faculties are absolutely independent. We now know that different mental activities—for example, perception and attention—are not wholly distinct and independent but rather interact in many different ways. We also know that the overall size of a brain or brain area is not indicative of the functioning of that area. Therefore, having a different configuration of bumps and indentations in a brain does not determine or even predict how an individual will function cognitively or socially.

STUDIES OF APHASIA AND OTHER MAPPING TECHNIQUES

More modern approaches to localizing function in the brain date back to Paul Broca (1824–1880), who during the early 1860s presented findings at a medical conference that injury to a particular part of the left frontal lobe (the dark blue region shown in Figure 2.3) resulted in a particular kind of aphasia, or disruption of expressive language (Springer & Deutsch, 1998). This brain region has become known as Broca's area; injury to this area leads to a kind of aphasia known as Broca's or nonfluent aphasia, in which the person is unable to produce many words or to speak very fluently.

A decade after Broca's discovery, Carl Wernicke (1848–1904) announced the discovery of a second "language center" in the brain, this one thought to control language understanding (as opposed to language production). This region, which has come to be known as Wernicke's area, is located in the superior posterior region of the temporal lobe, also typically in the left hemisphere, and is also shown in Figure 2.3 (in orange). Patients with so-called Wernicke's aphasia (also called fluent aphasia) are able to produce speech with seemingly fluent contours of pitch and rhythm. However, the speech often makes no sense and contains gibberish. Moreover, these patients show impairments in their ability to understand speech (Pritchard & Alloway, 1999).

Work by other neuropsychologists began to establish connections between lesions in particular brain regions and loss of specific motor control or sensory reception. Using research performed either on animals or as part of neurosurgical procedures intended to address problems such as epilepsy, scientists began to "map out" the portion of the frontal lobe known as the motor cortex, as shown in Figure 2.3.

In addition, neuropsychologists have mapped out a second area of the brain, located in the parietal lobe just behind the motor cortex, known as the **primary somatosensory cortex** (see Figure 2.3). Like the motor cortex, the primary somatosensory cortex is organized such that each part of it receives information from a specific part of the body. As with the motor cortex, the total amount of "brain real estate" devoted to a particular part of the body is not proportional to the size of that body part. In other words, a large region of the body, such as a leg, corresponds to only a small portion of the primary somatosensory cortex. A more sensitive body part, such as the fingers or lips, has a correspondingly larger amount of cortex devoted to it.

The previous discussion may have given you the idea that every part of the brain can be mapped to some specific sensation, behavior, idea, thought, memory, or cognitive process. This idea, however, is false. Although motor reception and sensory reception have the kinds of mapping depicted in Figure 2.3, most so-called higher-order cognitive processes, such as thinking and remembering, do not.

Many neuroscientists subscribe to the principle that higher-order cognitive processes are too complicated and interconnected to be localized to any one region (Pritchard & Alloway, 1999). This view drew support from the work of Karl Lashley (1890–1958), who performed several landmark studies in neuroscience measuring the effects of brain **ablation** (removal of parts of the brain) on the maze-running ability of rats. Lashley (1929) reported that impairment in maze running was related to the *total amount* of cortex removed, not to which specific area was removed.

Complicating this already involved picture is the notion of the **plasticity** of the brain (Black, 2004). Some brain regions can adapt to "take over" functions of damaged regions, depending on the injury and the function involved. In general, the younger the patient and the less extensive the injury, the better the chance of regaining function.

LATERALIZATION OF FUNCTION

Broca's report of a "language center" in his patients did more than argue for localization of function. Broca and many neuropsychologists since have been able to show that the two cerebral hemispheres seem to play different roles when it comes to some cognitive functions, especially language. We call this phenomenon **lateralization**.

Most individuals (about 95%) show a specialization for language in the left hemisphere. In these individuals, the left hemisphere is likely to be larger in size, especially in the areas where language is localized (Springer & Deutsch, 1998). We say that these individuals have a left hemisphere dominance in language. A small percentage of people do not show such specialization, having language function in both hemispheres (these are called *bilateralized* individuals), and an even smaller percentage of people have language centers located in the right hemisphere.

If the left hemisphere is dominant for language, then what role does the right hemisphere play? Structurally, the right hemisphere often has larger parietal and temporal areas, and it is speculated that this leads to better integration of visual and auditory information and better spatial processing by the right hemisphere than by the left hemisphere. The right hemisphere is associated with working on geometric puzzles, navigation around familiar spaces, and even musical ability (Springer & Deutsch, 1998).

Some describe the difference in function between the two hemispheres by labeling the left hemisphere as the analytical one and the right hemisphere as the synthetic one (N. R. Carlson, 2013). The idea here is that the left hemisphere is particularly good at processing information serially—that is, information with events occurring one after another. If you think about processing a sentence, the events would be the individual words that are spoken or read in sequence. By contrast, the right hemisphere is thought to be more synthetic, putting individual elements together to make up a whole. Cognitive processes here might include constructing maps or other spatial structures, drawing sketches, and navigating through mazes.

Popular press articles have made much of the difference between the two cerebral hemispheres, going so far in some cases as to classify people as either right-brained or left-brained. It's very important to remember that this is a gross oversimplification. The vast majority of individuals have two quite functional cerebral hemispheres that continually interact to process information and carry out cognitive functions. The odds that only one hemisphere would be active in a normal person during any everyday task are remote. Moreover, the two hemispheres are connected by a large neural structure known as the **corpus callosum** (shown in Figure 2.1), which sends information from one hemisphere to another very quickly. (A second, smaller brain structure, known as the anterior commissure, also connects the two hemispheres; it is not depicted in Figure 2.3.)

STUDIES OF SPLIT-BRAINED PATIENTS

What happens when the corpus callosum is not able to transfer information from one hemisphere to another? As it turns out, scientists have some answers to this originally hypothetical question. Beginning in the late 1950s, researchers and neurologists were looking for ways of treating severe and intractable epilepsy in which seizures that began in one hemisphere of the brain spread to the other, often several times a day (N. R. Carlson, 2013). Surgeons took the dramatic step of severing the corpus callosum in these patients in an effort to stop the spread of the seizures. Neuropsychologists Roger Sperry, Michael Gazzaniga, and their associates began to study these patients to see what effects having a severed corpus callosum brought about (Gazzaniga & Sperry, 1967).

If you look carefully at Figure 2.1 again, focusing on the size of the corpus callosum, you might expect that severing it would have dramatic effects. But quite the opposite was true. As Gazzaniga and Sperry (1967) noted, "The disruption of interhemispheric integration produces remarkably little disturbance in ordinary daily behavior, temperament, or intellect" (p. 131). Indeed, to detect any differences in cognition between so-called **split-brained patients** and those of us with an intact corpus callosum, the investigators needed to resort to designing special tasks.

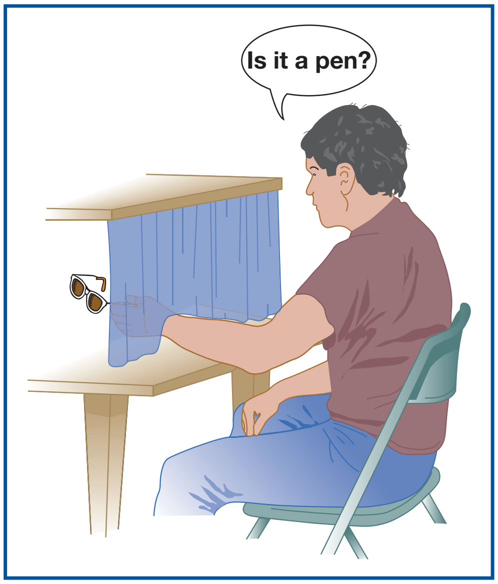


Figure 2.4: A patient with severed corpus callosum identifying objects by touch.

Adapted from Garrett, B. (2011). *Brain & behavior: An introduction to biological psychology,* p. 66.

In one of these tasks, depicted in Figure 2.4, the patient reached through a curtain to grasp a familiar object, in this case a pair of sunglasses. It was already known from previous animal and human work that sensory information received from one side of the body projects to the *opposite* cerebral hemisphere (B. Garrett, 2015). Thus, in Figure 2.4, the patient grasps the sunglasses in his left hand, projecting the information to the right hemisphere. But, in most (especially right-handed) individuals, language centers are located in the left hemisphere. Thus, the patient would be unable to describe the object he was holding, even though if he was asked to "pick out" sunglasses from a set of familiar objects, he had no problem doing so. Further experiments showed that if special equipment (called a tachistoscope) was used, information could be (very briefly) projected to either the right or left hemisphere of the patient. Gazzaniga and Sperry (1967) described some of the results as follows:

> The same sort of result was obtained in tasks that required intermodal integration going from vision to touch and vice versa. When a sample word such as pencil, tack, knife, sock, comb, etc., was presented in the left visual half field, the left hand, *but not the right*, could be used to search out the described correct matching object by touch from among an array of others, all shielded from vision. In such instances, when the stimulus and the matching answer were both presented exclusively to the right hemisphere, the subjects remained completely unaware of the given stimulus and response selection. . . . After making a correct manual response . . . they would commonly describe the selected object as some totally unrelated item that was obviously a pure guess. (pp. 139–140)

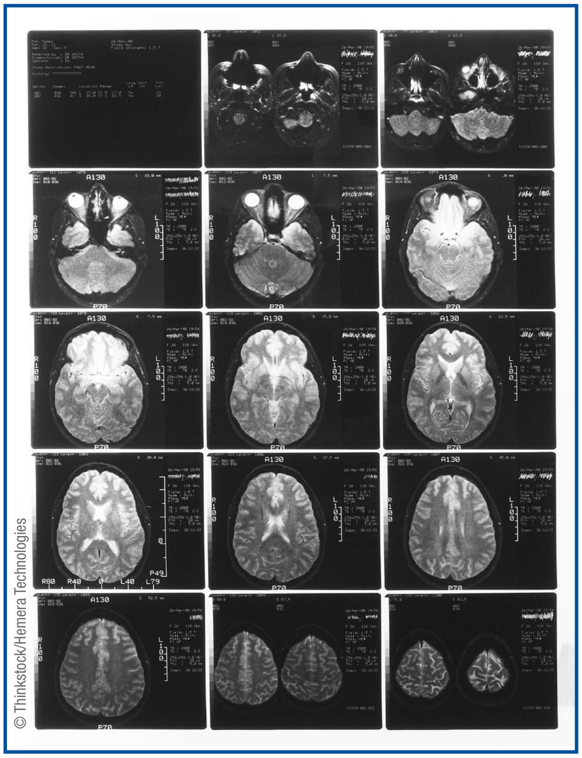
Clearly, the results from split-brained patients are intriguing and raise many more questions than they answer. The important point for now is to recognize that the two cerebral hemispheres appear to play very different roles for some cognitive processes, especially those concerning language.

BRAIN-IMAGING TECHNIQUES

In Broca's day, neurologists needed to wait until a patient died to really investigate the structural features of his or her brain. During the early part of the 20th century, more information came from studies performed as patients underwent brain surgery—to remove a tumor or stop the spread of epilepsy, most commonly. Fortunately for people but unfortunately for science, ethical considerations precluded doing brain surgery on healthy people, which limited our understanding of how "normal" brains functioned.

However, during the last five decades, technology has advanced to the point where neurologists and neuropsychologists can examine the functioning of normal brains using noninvasive means. We will briefly review some of these methods, known collectively as brain-imaging techniques.

■ Photo 2.2: A person undergoing a CAT (or CT) scan.



■ Photo 2.3: An MRI scan. The different images are of different "slices" through the brain.

CAT (CT) SCANS

Some of these methods give us information about neuroanatomy—the structures of the brain. One of the earliest such brain-imaging techniques, developed during the 1970s, was X-ray computed tomography—also called X-ray CT or **computerized axial tomography (CAT)** scan—a technique in which a highly focused beam of X-rays is passed through the body from many different angles. Differing densities of body organs (including the brain) deflect the X-rays differently, allowing visualization of the organ. Photo 2.2 depicts a person undergoing a CAT scan.

Typically, CAT scans of a person's brain result in 9 to 12 different "slices" of the brain, each one taken at a different level of depth. CAT scans depend on the fact that structures of different density show up differently. Bone, for example, is denser than blood, which is denser than brain tissue, which in turn is denser than cerebrospinal fluid (Banich, 2004). Recent brain hemorrhages are typically indicated by the presence of blood; older brain damage is typically indicated by areas of cerebrospinal fluid. Thus, clinicians and researchers can use CAT scans to pinpoint areas of brain damage and to make inferences about the relative age of the injury.

MAGNETIC RESONANCE IMAGING (MRI)

Although CAT scans are an important diagnostic tool in neuropsychology, they are used less often than a newer brain-imaging technique, **magnetic resonance imaging (MRI)**. Like CAT scans, MRI provides information about neuroanatomy. Unlike CAT scans, however, MRI requires no exposure to radiation and often permits clearer pictures. Photo 2.3 presents an MRI scan.

Someone undergoing an MRI typically lies inside a tunnel-like structure that surrounds the person with a strong magnetic field. Radio waves are directed at the head (or whatever body structure is being scanned), causing the centers of hydrogen atoms in those structures to align themselves in predictable ways. Computers collate information about how the atoms are aligning and produce a composite three-dimensional image from which any desired cross section can be examined further.

MRI scans are often the technique of choice because they now produce some of the clearest images of a brain. However, not everyone can undergo an MRI scan. The magnetic fields generated in an MRI scan interfere with electrical fields, so people with pacemakers are not candidates for an MRI (pacemakers generate electric signals). Neither are people with metal in their bodies such as a surgical clip on an artery or a metal shaving in the eye. The magnetic field could dislodge the metal in the body, causing trauma. (Metal anchored to