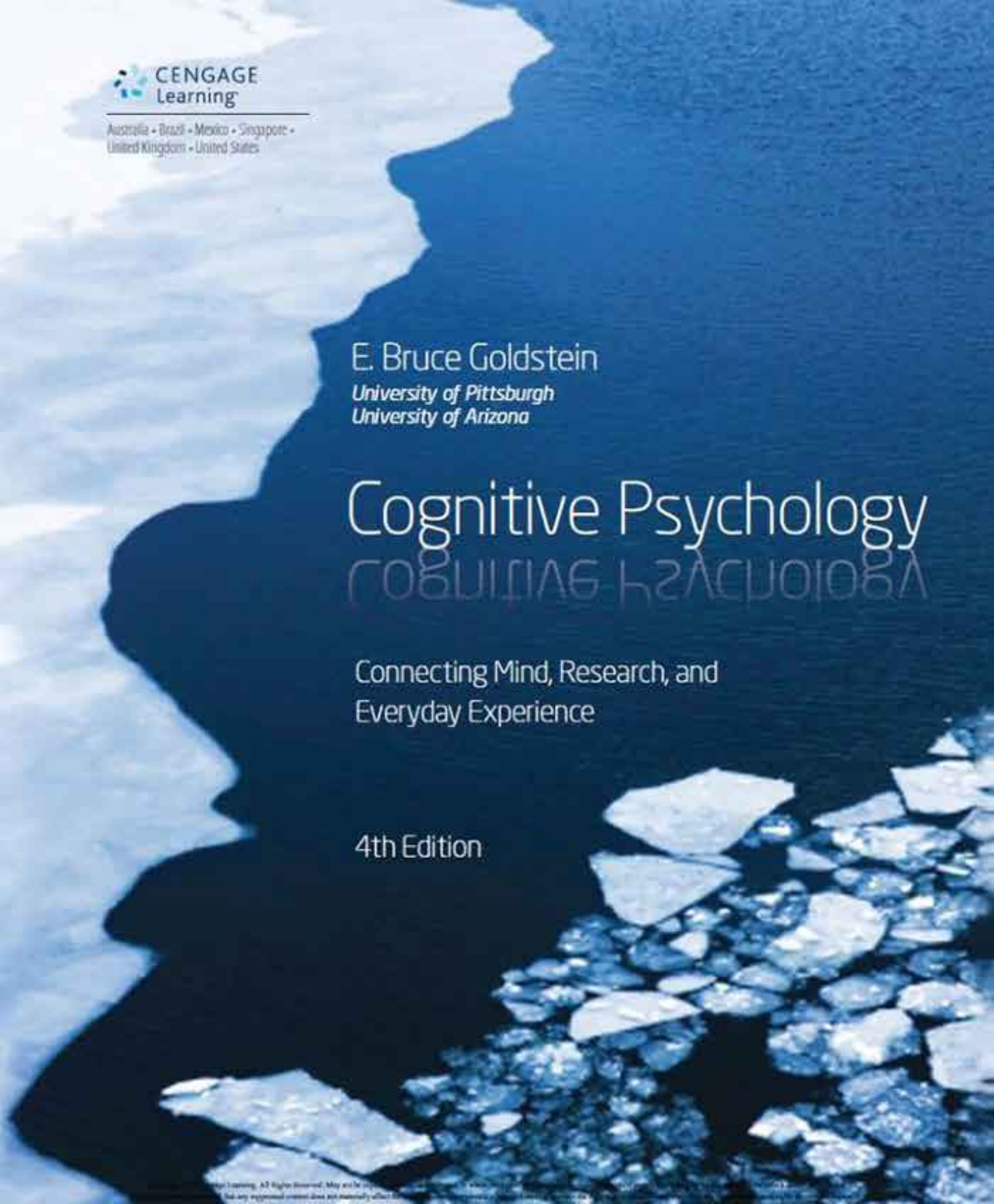
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Cognitive Psychology
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4th Edition

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To Barbara

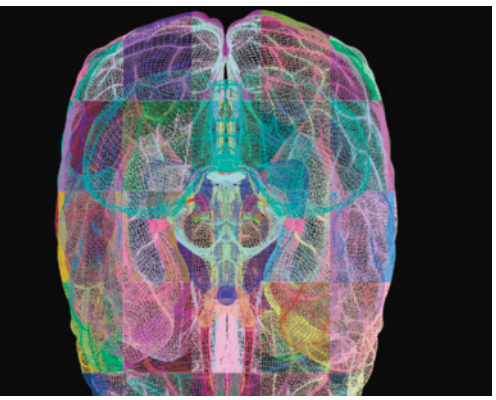
About the Author

E. BRUCE GOLDSTEIN is Associate Professor Emeritus of Psychology at the University of Pittsburgh and Adjunct Professor of Psychology at the University of Arizona. He has received the Chancellor's Distinguished Teaching Award from the University of Pittsburgh for his classroom teaching and textbook writing. He received his bachelor's degree in chemical engineering from Tufts University and his PhD in experimental psychology from Brown University. He was a postdoctoral fellow in the Biology Department at Harvard University before joining the faculty at the University of Pittsburgh. Bruce has published papers on a wide variety of topics, including retinal and cortical physiology, visual attention, and the perception of pictures. He is the author of *Sensation and Perception*, 9th edition (Wadsworth/Cengage, 2014) and is the editor of the *Blackwell Handbook of Perception* (Blackwell, 2001) and the two-volume *Sage Encyclopedia of Perception* (Sage, 2010).

Brief Contents

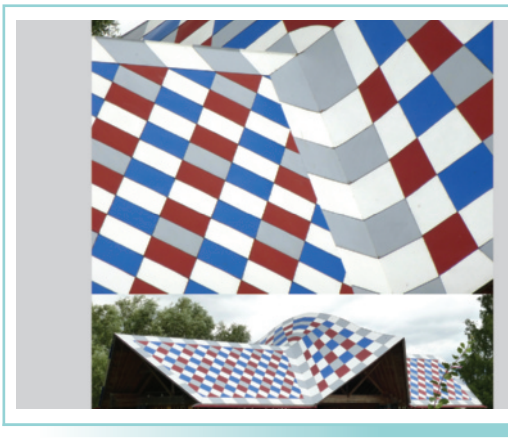
Contents

CHAPTER 1



CHAPTER 2

CHAPTER 3



CHAPTER 4

CHAPTER 5

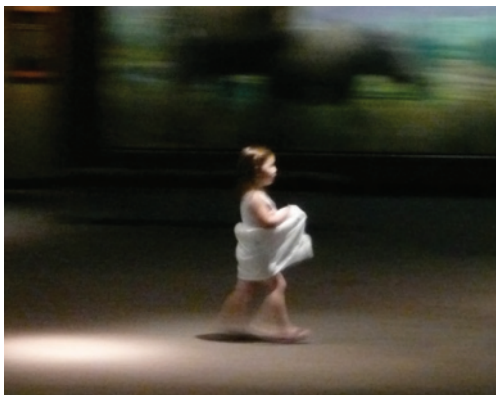
CHAPTER 6

CHAPTER 7

CHAPTER 8

CHAPTER 9

CHAPTER 10



CHAPTER 11

CHAPTER 12

CHAPTER 13

Numbers in parentheses refer to the experiment numbers in CogLab 5.0.

The first experiments in each chapter are "primary experiments." These experiments are directly or closely related to discussion in the text.

Asterisks (*) indicate "related experiments." These experiments are relevant to the topic of the chapter but are not directly related to the discussion in the text.

CHAPTER 1

Simple Detection (2) A simple reaction time task that measures how fast you react to the appearance of a dot.

CHAPTER 2

Brain Asymmetry (15)* How speed of processing for shapes and words may be different in the left and right hemispheres.

CHAPTER 3

Apparent Motion (3) Determining how fast two dots have to be flashed, one after the other, to achieve an illusion of movement.

Statistical Learning (47) How learning can occur in response to exposure to sequences of forms.

Signal Detection (1)* Collecting data that demonstrate the principle behind the theory of signal detection, which explains the processes behind detecting hard-to-detect stimuli.

Garner Interference: Integral Dimensions (4)* Making light/dark judgments for a square. A one-dimensional task.

Garner Interference: Separable Dimensions (5)* Making light/dark judgments for squares of different sizes. A second dimension is added.

Müller-Lyer Illusion (6)* Measuring the size of a visual illusion.

Blind Spot (14)* Mapping the blind spot in your visual field that is caused by the fact that there are no receptors where the optic nerve leaves the eye.

Metacontrast Masking (16)* How presentation of a masking stimulus can impair perception of another stimulus.

Categorical Perception: Discrimination (39)* Demonstration of categorical perception based on the ability to discriminate between sounds.

Categorical Perception: Identification (40)* Demonstration of categorical perception based on the identification of different sound categories.

CHAPTER 4

Visual Search (7) Feature search experiment. Searching for a green circle among blue lines, with different numbers of blue lines.

Change Detection (9) A task involving detecting changes in alternating scenes.

Inhibition of Return (10) How presentation of a target away from fixation can cause a slowing of responding.

Spatial Cueing (12) How cueing attention affects reaction time to the cued area. Evidence for the spotlight model of attention.

Stroop Effect (13) How reaction time to naming font colors is affected by the presence of conflicting information from words.

Attentional Blink (8)* Testing your ability to detect stimuli that are presented in rapid succession.

Simon Effect (11)* How speed and accuracy of responding is affected by the location of the response to a stimulus.

Von Restorff Effect (32)* How the distinctiveness of a stimulus can influence memory.

CHAPTER 5

Partial Report (18) The partial report condition of Sperling's iconic memory experiment.

Brown-Peterson Task (20) How memory for trigrams fades.

Irrelevant Speech Effect (23) How recall for items on a list is affected by the presence of irrelevant speech.

Memory Span (24) Measuring memory span for numbers, letters, and words.

Operation Span (25) Measuring the operation-word span, a measure of working memory.

Phonological Similarity Effect (26) How recall for items on a list is affected by how similar the items sound.

Word Length Effect (27) Measurement of the word length effect.

Modality Effect (17)* How memory for the last one or two items in a list depends on whether the list is heard or read.

Position Error (21)* Memory errors when trying to remember the order of a series of letters.

Sternberg Search (22)* A method to determine how information is retrieved from short-term memory.

Von Restorff Effect (32)* How the distinctiveness of a stimulus can influence memory.

Neighborhood Size Effect (42)* How recall in a short-term memory task is affected by the size of a word's "neighborhood" (how many words can be created by changing a letter or phoneme).

CHAPTER 6

Serial Position (31) How memory for a list depends on an item's position on the list.

Remember-Know (36) Distinguishing between remembered items in which there is memory for learning the item and items that just seem familiar.

Implicit Learning (45) How we can learn something without being aware of the learning.

Suffix Effect (19)* How adding an irrelevant item to the end of a list affects recall for the final items on a list in a serial position experiment.

CHAPTER 7

Encoding Specificity (28) How memory is affected by conditions at both encoding and retrieval, and the relation between them

Levels of Processing (29) How memory is influenced by depth of processing.

Production Effect (30)* How memory depends on whether words are read out loud or silently.

Von Restorff Effect (32)* How the distinctiveness of a stimulus can influence memory.

CHAPTER 8

False Memory (33) How memory for words on a list sometimes occurs for words that were not presented.

Forgot It All Along (34) How it is possible to remember something and also have the experience of having previously forgotten it.

Memory Judgment (35) A test of how accurate people are at predicting their memory performance.

CHAPTER 9

Lexical Decision (41) Demonstration of the lexical decision task, which has been used to provide evidence for the concept of spreading activation.

Prototypes (46) A method for studying the effect of concepts on responding.

Absolute Identification (44)* Remembering levels that have been associated with a stimulus.

CHAPTER 10

Link Word (37) A demonstration of how imagery can be used to help learn foreign vocabulary.

Mental Rotation (38) How a stimulus can be rotated in the mind to determine whether its shape matches another stimulus.

CHAPTER 11

Lexical Decision (41) Demonstration of the lexical decision task.

Word Superiority (43) Comparing speed of identifying a letter when the letter is isolated or in a word.

Categorical Perception: Discrimination (39)* Demonstration of categorical perception based on the ability to discriminate between sounds.

Categorical Perception: Identification (40)* Demonstration of categorical perception based on the identification of different sound categories.

Neighborhood Size Effect (42)* How recall in a short-term memory task is affected by the size of a word's "neighborhood" (how many words can be created by changing a letter or phoneme).

CHAPTER 13

Decision Making (48) How decisions can be affected by the context within which the decision is made.

Risky Decisions (50) How decision making is influenced by framing effects.

Typical Reasoning (51) How the representativeness heuristic can lead to errors of judgment.

Wason Selection (52) Two versions of the Wason four-card problem.

Monty Hall (49)* A simulation of the Monty Hall three-door problem, which involves an understanding of probability.

Demonstrations

Methods

Preface to Instructors

The Evolution of a Cognitive Psychology Textbook

This book is the culmination of a process that began in 2002, when I decided to write the first edition. From a survey of more than 500 instructors and my conversations with colleagues, it became apparent that many teachers were looking for a text that not only covers the field of cognitive psychology but is also accessible to students. From my teaching of cognitive psychology, it also became apparent that many students perceive cognitive psychology as being abstract, too theoretical, and not connected to everyday experience. With this information in hand, I set out to write a book that would tell the story of cognitive psychology in a concrete way that would help students appreciate the connections between empirical research, the principles of cognitive psychology, and everyday experience.

I did a number of things to achieve this result. I started by including numerous **real-life examples** in each chapter, and **neuropsychological case studies** where appropriate. To provide students with firsthand experience with the phenomena of cognitive psychology, I included more than 40 **Demonstrations**—easy-to-do mini-experiments that were contained within the narrative of the text—as well as 20 additional suggestions of things to try, throughout the chapters. The Demonstrations in this edition are listed on page xix.

One thing I avoided was simply presenting the results of experiments. Instead, whenever possible, I described **how experiments were designed** and what the subjects were doing, so students would understand how results were obtained. In addition, most of these descriptions were supported by illustrations such as pictures of stimuli, diagrams of the experimental design, or graphs of the results.

Students with instructors who adopted CogLab also received access to more than 45 online **CogLab experiments** (now more than 50) that they could run themselves and then compare their data to the class average and to the results of the original experiments from the literature.

The first edition (2005) therefore combined many elements designed to achieve the goal of covering the basic principles of cognitive psychology in a way that students would find interesting and easy to understand. My goal was for students to come away feeling excited about the field of cognitive psychology.

The acceptance of the first edition was gratifying, but one thing I've learned from years of teaching and textbook writing is that there are always explanations that can be clarified, new pedagogical techniques to try, and new research and ideas to describe. With this in mind as I began preparing the second edition (2008), I elicited feedback from students in my classes and received more than 1,500 written responses indicating areas in the first edition that could be improved. In addition, I also received feedback from instructors who had used the first edition. This feedback was the starting point for the second edition, and I repeated this process of eliciting student and instructor feedback for the third and fourth editions as well. Thus, in addition to updating the science, I revised many sections that students and instructors had flagged as needing clarification.

Retained Features

All of the features described above were well received by students and instructors, and so are continued in this new fourth edition. Additional pedagogical features that have been retained from previous editions include **Test Yourself** sections, which help students review

the material, and end-of-chapter **Think About It** questions, which ask students to consider questions that go beyond the material.

Methods sections, which were introduced in the second edition, highlight the ingenious methods cognitive psychologists have devised to study the mind. The 29 Methods sections, which are integrated into the text, describe methods such as brain imaging, the lexical decision task, and think-aloud protocols. This not only highlights the importance of the method, but makes it easier to return to its description when it is referred to later in the text. See page xx for a list of Methods.

The end-of-chapter **Something to Consider** sections describe cutting-edge research, important issues, or applied research. A few examples of topics covered in this section are *What Neuroscience Tells Us About Cognition* (Chapter 2); *Math Performance and Working Memory* (Chapter 5); and *The Dual Systems Approach to Thinking* (Chapter 13). **Chapter Summaries** provide succinct outlines of the chapters, without serving as a substitute for reading the chapters.

What Is New in the Fourth Edition

As with previous editions of this book, this edition features updates to material throughout, and in a few cases chapters have been rewritten or reorganized to improve clarity and pedagogy.

One indication of changes to this edition is over 80 new key terms, such as the following: attentional capture; Bayesian inference; belief bias; change detection; common ground; conceptual knowledge; corpus; diffusion tensor imaging; dual systems approach to thinking; embodied approach; group brainstorming; hierarchical processing; hub and spoke model; inverse projection problem; meaning dominance; mental model; myside bias; neural mind reading; neural network; personal semantic memory; processing capacity; remember/know procedure; semantic dementia; sensory-functional hypothesis; sparse coding; syntactic coordination; visual world paradigm.

Following is a chapter-by-chapter list that highlights a few of the key changes in this edition. Text in *italics* indicates section headings new to this edition.

CHAPTER 1 Introduction to Cognitive Psychology

- *Modern Research in Cognitive Psychology* includes Beilock's research on "choking under pressure" to illustrate how research progresses from one question to another.
- Treatment of the role of models in cognitive psychology has been expanded.

CHAPTER 2 Cognitive Neuroscience

- *Why Study Cognitive Neuroscience?* introduces the idea of levels of analysis and an expanded discussion of the rationale for the physiological study of the mind.
- The use of fMRI while subjects are viewing movies to determine semantic brain maps (Huth et al., 2012) is described.
- *All Together Now: Neural Networks* includes new methods such as diffusion tensor imaging.
- *Something to Consider: What Neuroscience Tells Us About Cognition* follows up on *Why Study Cognitive Neuroscience?* by providing examples of how neuroscience can contribute to our understanding of mechanisms suggested by behavioral research.

CHAPTER 3 Perception

- Chapter has been rewritten to focus on the idea that although perception appears easy, it is based on invisible underlying processes. It opens with a discussion of why it is so difficult to design robotic vision systems.

- Pain is used to illustrate the effect of top-down processing.
- *Bayesian Inference* has been added to accompany Helmholtz's theory of unconscious inference.
- *Something to Consider: Where Perception Meets Memory* describes how neurons in the hippocampus fire to remembered perceptions (Gelbard-Sagiv et al., 2008).

CHAPTER 4 Attention

- New opening emphasizes the idea that there are a number of different aspects of attention.
- Description of Schneider and Shiffrin's (1977) experiments on automatic processing has been streamlined.
- Treatment of distractions while driving has been updated to include texting and Internet use (Strayer et al., 2013).
- *Something to Consider: Taking Possession by the Brain* is a new discussion of the physiology of attention that reflects William James's idea of attention "taking possession" of the mind (Datta & DeYoe, 2009).

CHAPTER 5 Short-Term and Working Memory

- New opening introduces the different types of memory that will be discussed in Chapters 5–8.
- Discussion of the capacity of short-term memory has been updated to add the idea of defining capacity in terms of the amount of information (Alvarez & Cavanagh, 2004).
- *Method: Change Detection* (Luck & Vogel, 1997) follows up on the Change Detection demonstration in Chapter 4.
- fMRI study showing that the visual cortex is involved in holding information during a delay (Harrison & Tong, 2009) has been added.
- *Something to Consider: Math Performance and Working Memory* describes how writing can prevent choking under pressure (Ramirez & Beilock, 2011). This follows up on the "choking under pressure" discussion in Chapter 1.

CHAPTER 6 Long-Term Memory: Structure

- New opening describes chapter theme, "Division and Interaction," reflecting that there are different types of memory mechanisms that interact with each other.
- *What Happens to Episodic and Semantic Memories as Time Passes?* is an updated discussion of the semanticization of remote memories (Petrican et al., 2010).
- *Method: Remember/Know Procedure* accompanies Petrican et al. research.
- *Imagining the Future* outlines the connection between episodic memory and the ability to imagine the future (Addis et al., 2007; Schacter, 2012).

CHAPTER 7 Long-Term Memory: Encoding and Retrieval

- *Consolidation: The Life History of Memories* is an updated section on memory and the brain with expanded treatment of the physiology of consolidation, including new research on the multiple trace hypothesis (Viskentas et al., 2009) and consolidation and sleep (Wilhelm et al., 2011).
- *Something to Consider: Effective Studying* previously appeared earlier in the text.

CHAPTER 8 Everyday Memory and Memory Errors

- Discussion of memory and emotion has been updated to include how emotion can enhance consolidation (Cahill et al., 2003; Roozendaal & McGaugh, 2011) and how emotion can interfere with memory (Mather & Sutherland, 2011).

- Discussion of flashbulb memory includes the idea that emotion can increase recollection but decrease memory for details (Rimmele et al., 2011).
- *Something to Consider: The Power of Pictures* describes how pictures can create false memories (Nash & Wade, 2009).

CHAPTER 9 Knowledge

- Discussion of connectionist networks has been simplified.
- *The Representation of Concepts in the Brain* includes an expanded discussion of categories in the brain to more accurately reflect the varied approaches proposed to explain how concepts are represented (Hoffman & Lambon Ralph, 2012; Mahon & Caramazza, 2011; Pulvermüller, 2013; Warrington & Shallice, 1985).
- *Something to Consider: The Hub and Spoke Model* has been added (Jeffries, 2013; Pobric et al., 2010; Pulvermüller, 2013).
- *Method: Sentence Verification Technique* has been added. *Method: Transcranial Magnetic Stimulation (TMS)* has been introduced in conjunction with research on the hub and spoke model.

CHAPTER 10 Visual Imagery

- *Something to Consider: Imagery and Food Craving* describes using visual imagery to decrease food cravings (Harvey et al., 2005).

CHAPTER 11 Language

- Treatment of lexical ambiguity has been updated to include a discussion of how accessing a word's meaning is affected by meaning dominance (Rayner & Fraizer, 1989).
- Material on Broca and Wernicke has been moved from Chapter 2 to this chapter.
- In discussion of sentence processing, material has been added on making predictions based on knowledge of the environment (Federmeier & Kustas, 1999) and on knowledge of language constructions (Fine et al., 2013).
- Situation models have been updated with new material on predictions based on knowledge about situations (Metusalem et al., 2012).
- Section on conversations has been revised to include material on common ground (Clark, 1996).

CHAPTER 12 Problem Solving

- Treatment of creative problem solving has been expanded with added examples, a section on practical creativity, and a discussion of problem solving as a process.
- Discussion of how too much knowledge can be a bad thing has been revised (Smith et al., 1993).
- *Something to Consider: Creativity, Mental Illness, and the Open Mind* considers whether there is a link between mental illness and creativity (Carson, 2011; Chi & Snyder, 2012).

CHAPTER 13 Judgment, Decisions, and Reasoning

- Chapter now opens with material on judgment and heuristics. Deductive reasoning, which students find more difficult, has been moved to the end of the chapter.
- Further examples have been added to illustrate how decision making is influenced by the number of alternatives available (Shen et al., 2010) and whether the person making the decision is hungry or tired (Danzinger et al., 2011).
- Discussion of deductive reasoning uses new examples to make syllogisms, and the distinction between validity and truth, easier to understand.

- *Mental Models of Deductive Reasoning* describes a way to determine the validity of a syllogism (Johnson-Laird, 1999).
- *Something to Consider: The Dual Systems Approach to Thinking* describes research based on the idea of two systems for thinking, one fast and the other slow (Evans & Stanovich, 2013; Kahneman, 2011).

Ancillaries to Support Your Teaching

All of these supplements are available online for download. Go to **login.cengage.com** to create an account and log in.

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Preface to Students

As you begin reading this book, you probably have some ideas about how the mind works from things you have read, from other media, and from your own experiences. In this book, you will learn what we actually do and do not know about the mind, as determined from the results of controlled scientific research. Thus, if you think that there is a system called "short-term memory" that can hold information for short periods of time, then you are right; when you read the chapters on memory, you will learn more about this system and how it interacts with other parts of your memory system. If you think that some people can accurately remember things that happened to them as very young infants, you will see that there is a good chance that these reports are inaccurate. In fact, you may be surprised to learn that even more recent memories that seem extremely clear and vivid may not be entirely accurate due to basic characteristics of the way the memory system works.

But what you will learn from this book goes much deeper than simply adding more accurate information to what you already know about the mind. You will learn that there is much more going on in your mind than you are conscious of. You are aware of experiences such as seeing something, remembering a past event, or thinking about how to solve a problem—but behind each of these experiences are a myriad of complex and largely invisible processes. Reading this book will help you appreciate some of the "behind the scenes" activity in your mind that is responsible for everyday experiences such as perceiving, remembering, and thinking.

Another thing you will become aware of as you read this book is that there are many practical connections between the results of cognitive psychology research and everyday life. You will see examples of these connections throughout the book. For now I want to focus on one especially important connection—what research in cognitive psychology can contribute to improving your studying. This discussion appears on pages 202–203 of Chapter 7, but you might want to look at this material now rather than waiting until later in the course. I invite you to also consider the following two principles, which are designed to help you get more out of this book.

Principle 1: It is important to know what you know.

Professors often hear students lament, "I came to the lecture, read the chapters a number of times, and still didn't do well on the exam." Sometimes this statement is followed by "... and when I walked out of the exam, I thought I had done pretty well." If this is something that you have experienced, the problem may be that you didn't have a good awareness of what you knew about the material and what you didn't know. If you think you know the material but actually don't, you might stop studying or might continue studying in an ineffective way, with the net result being a poor understanding of the material and an inability to remember it accurately come exam time. Thus, it is important to test yourself on the material you have read by writing or saying the answers to the Test Yourself questions in the chapter and also by taking advantage of the sample test questions that are available on Psychology CourseMate. To access these questions and other valuable learning aids, go to *www.cengagebrain.com*.

Principle 2: Don't mistake ease and familiarity for knowing.

One of the main reasons that students may think they know the material, even when they don't, is that they mistake familiarity for understanding. Here is how it works: You read the chapter once, perhaps highlighting as you go. Later, you read the chapter again, perhaps focusing on the highlighted material. As you read it over, the material is familiar because you remember it from before, and this familiarity might lead you to think, "Okay, I know

that." The problem is that this feeling of familiarity is not necessarily equivalent to knowing the material and may be of no help when you have to come up with an answer on the exam. In fact, familiarity can often lead to errors on multiple-choice exams because you might pick a choice that looks familiar, only to find out later that although it was something you had read, it wasn't really the best answer to the question.

This brings us back again to the idea of testing yourself. One finding of cognitive psychology research is that the very act of *trying* to answer a question increases the chances that you will be able to answer it when you try again later. Another related finding is that testing yourself on the material is a more effective way of learning it than simply rereading the material. The reason testing yourself works is that *generating* material is a more effective way of getting information into memory than simply *reviewing* it. Thus, you may find it effective to test yourself before rereading the chapter or going over your highlighted text.

Whichever study tactic you find works best for you, keep in mind that an effective strategy is to rest (take a break or study something else) before studying more and then retesting yourself. Research has shown that memory is better when studying is spaced out over time, rather than being done all at once. Repeating this process a number of times—testing yourself, checking back to see whether you were right, waiting, testing yourself again, and so on—is a more effective way of learning the material than simply looking at it and getting that warm, fuzzy feeling of familiarity, which may not translate into actually knowing the material when you are faced with questions about it on the exam.

I hope you will find this book to be clear and interesting and that you will sometimes be fascinated or perhaps even surprised by some of the things you read. I also hope that your introduction to cognitive psychology extends beyond just "learning the material." Cognitive psychology is endlessly interesting because it is about one of the most fascinating of all topics—the human mind. Thus, once your course is over, I hope you will take away an appreciation for what cognitive psychologists have discovered about the mind and what still remains to be learned. I also hope that you will become a more critical consumer of information about the mind that you may encounter on the Internet or in movies, magazines, or other media.

Acknowledgments

The starting point for a textbook like this one is an author who has an idea for a book, but other people soon become part of the process. Writing is guided by feedback from editors and reviewers on writing and content. When the manuscript is completed, the production process begins, and a new group of people take over to turn the manuscript into a book. This means that this book has been a group effort and that I had lots of help, both during the process of writing and after submitting the final manuscript. I would therefore like to thank the following people for their extraordinary efforts in support of this book.

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CHAPTER 5 Short-Term and Working Memory

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Geoffrey Woodman
Vanderbilt University

CHAPTER 6 Long-Term Memory: Structure

Shayna Rosenbaum
York University

CHAPTER 7 Long-Term Memory: Encoding and Retrieval

Almut Hupbach
Lehigh University

Jeffrey Karpicke
Purdue University

CHAPTER 8 Everyday Memory and Memory Errors

Steve Lindsay
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Karen Mitchell
Yale University

CHAPTER 9 Knowledge

Gregory Murphy
New York University

Timothy Rogers
University of Wisconsin

CHAPTER 10 Visual Imagery

Giorgio Ganis
University of Plymouth

CHAPTER 11 Language

Sarah Brown-Schmidt
University of Illinois

Tessa Warren
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Keith Rayner
University of California at San Diego

CHAPTER 12 Problem Solving

Miriam Bassok
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CHAPTER 13 Judgment, Decisions, and Reasoning

Ruth Byrne
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The following reviewers read parts of chapters to check for accuracy in their areas of expertise, or took the time to answer questions that I posed.

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Deon Benton
Carnegie-Mellon University

Jason C. K. Chan
Iowa State University

Marlene Cohen
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University of California, Berkeley

Tim Nokes
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Mary Peterson
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Christopher Schunn
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Karl G.D. Bailey
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Christine Feeley
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Stephani Foraker
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Ralf Greenwald
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Cognitive Psychology

A hiker steps out of a cave into the sunlight and anticipates his journey through an amazing and varied landscape. Now you, the reader of this book, are about to embark on an intellectual journey that will take you through the remarkable inner workings of the mind. This chapter sets the stage for this journey, by tracing the history of the scientific study of the mind from its beginnings in a few laboratories in Europe in the late 19th century, to today's widespread scientific study of what the mind is and what it does.

Introduction to Cognitive Psychology

CHAPTER

1

SOME QUESTIONS WE WILL CONSIDER

- How is cognitive psychology relevant to everyday experience? (4)
- Are there practical applications of cognitive psychology? (4)
- How is it possible to study the inner workings of the mind when we can't really see the mind directly? (7)
- How are models used in cognitive psychology? (17)

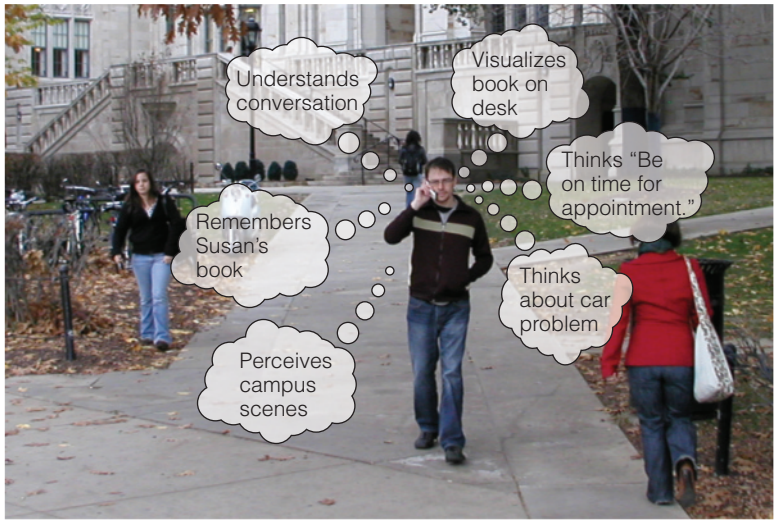
As Raphael is walking across campus, talking to Susan on his cell phone about meeting at the student union later this afternoon, he remembers that he left the book she had lent him at home (Figure 1.1). "I can't believe it," he thinks, "I can see it sitting there on my desk, where I left it. I should have put it in my backpack last night when I was thinking about it."

As he finishes his call with Susan and makes a mental note to be on time for their appointment, his thoughts shift to how he is going to survive after Wednesday when his car is scheduled to go into the shop. Renting a car offers the most mobility, but is expensive. Depending on his roommate for rides is cheap, but limiting. "Maybe I'll pick up a bus schedule at the student union," he thinks, as he puts his cell phone in his pocket.

Entering his anthropology class, he remembers that an exam is coming up soon. Unfortunately, he still has a lot of reading to do, so he decides that he won't be able to go to the movies with Susan tonight as they had planned. As the lecture begins, Raphael is anticipating, with some anxiety, his meeting with Susan.

This brief slice of Raphael's life is noteworthy because it is ordinary, while at the same time so much is happening. Within a short span of time, Raphael does the following things that are related to material covered in chapters in this book:

- *Perceives* his environment—seeing people on campus and hearing Susan talking on the phone (Chapter 3: Perception)
- *Pays attention* to one thing after another—the person approaching on his left, what Susan is saying, how much time he has to get to his class (Chapter 4: Attention)



Bruce Goldstein

Figure 1.1 What's happening in Raphael's mind as he walks across campus? Each of the thought bubbles corresponds to something in the story in the text.

- *Remembers* something from the past—that he had told Susan he was going to return her book today (Chapters 5–8: Memory)
- *Distinguishes items in a category*, when he thinks about different possible forms of transportation—rental car, roommate's car, bus (Chapter 9: Knowledge)
- *Visualizes* the book on his desk the night before (Chapter 10: Visual Imagery)
- *Understands and produces language* as he talks to Susan (Chapter 11: Language)
- Works to *solve a problem*, as he thinks about how to get places while his car is in the shop (Chapter 12: Problem Solving)
- *Makes a decision*, when he decides to postpone going to the movies with Susan so he can study (Chapter 13: Judgment, Decisions, and Reasoning)

The things Raphael is doing not only are covered in this book but also have something very important in common: They all involve the mind. **Cognitive psychology** is *the branch of psychology concerned with the scientific study of the mind.* As you read the story told in this book, about the quest to understand the mind, you will learn what the mind is, how it has been studied, and what researchers have discovered about how the mind works. In this chapter we will first describe the mind in more detail, then consider some of the history behind the field of cognitive psychology, and finally begin considering how modern cognitive psychologists have gone about studying the mind.

Cognitive Psychology: Studying the Mind

You may have noticed that we have been using the term **mind** without precisely defining it. As we will see, mind, like other concepts in psychology, such as intelligence or emotion, can be thought of in a number of different ways.

WHAT IS THE MIND?

One way to approach the question "What is the mind?" is to consider how "mind" is used in everyday conversation. Here are a few examples:

1. "He was able to call to mind what he was doing on the day of the accident." (The mind as involved in memory)
2. "If you put your mind to it, I'm sure you can solve that math problem." (The mind as problem-solver)
3. "I haven't made up my mind yet" or "I'm of two minds about this." (The mind as used to make decisions or consider possibilities)
4. "He is of sound mind and body" or "When he talks about his encounter with aliens, it sounds like he is out of his mind." (A healthy mind being associated with normal functioning, a nonfunctioning mind with abnormal functioning)
5. "A mind is a terrible thing to waste." (The mind as valuable, something that should be used)
6. "He has a brilliant mind." (Used to describe people who are particularly intelligent or creative)

These statements tell us some important things about what the mind is. Statements 1, 2, and 3, which highlight the mind's role in memory, problem solving, and making decisions, are related to the following definition of the mind: *The mind creates and controls mental functions such as perception, attention, memory, emotions, language, deciding, thinking, and reasoning.* This definition reflects the mind's central role in determining our various mental abilities, which are reflected in the titles of the chapters in this book.

Another definition, which focuses on how the mind operates, is: *The mind is a system that creates representations of the world so that we can act within it to achieve our goals.* This definition reflects the mind's importance for functioning and survival, and also provides the beginnings of a description of how the mind achieves these ends. The idea of creating representations is something we will return to throughout this book.

These two definitions of the mind are not incompatible. The first one indicates different types of **cognition**—the mental processes, such as perception, attention, and memory, that are what the mind does. The second definition indicates something about how the mind operates (it creates representations) and its function (it enables us to act and to achieve goals). It is no coincidence that all of the cognitions in the first definition play important roles in acting to achieve goals.

Statements 4, 5, and 6 emphasize the mind's importance for normal functioning, and the amazing abilities of the mind. The mind is something to be used, and the products of some people's minds are considered extraordinary. But one of the messages of this book is that the idea that the mind is amazing is not reserved for "extraordinary" minds, because even the most "routine" things—recognizing a person, having a conversation, or deciding what courses to take next semester—become amazing in themselves when we consider the properties of the mind that enable us to achieve these familiar activities.

What exactly are the properties of the mind? What are its characteristics? How does it operate? Saying that the mind creates cognition and is important for functioning and survival tells us *what the mind does*, but not *how it achieves what it does*. The question of how the mind achieves what it does is what cognitive psychology is about. Our goals in the rest of this chapter are to describe how the field of cognitive psychology evolved from its early beginnings to where it is today, and to begin describing how cognitive psychologists approach the scientific study of the mind.

STUDYING THE MIND: EARLY WORK IN COGNITIVE PSYCHOLOGY

In the 1800s, ideas about the mind were dominated by the belief that it is not possible to study the mind. One reason given was that it is not possible for the mind to study itself, but there were other reasons as well, including the idea that the properties of the mind

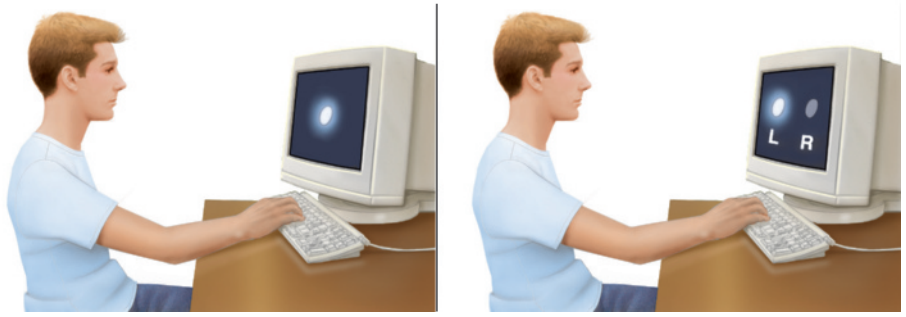
simply cannot be measured. Nonetheless, some researchers defied the common wisdom and decided to study the mind anyway. One of these people was the Dutch physiologist Franciscus Donders, who in 1868, 11 years before the founding of the first laboratory of scientific psychology, did one of the first experiments that today would be called a cognitive psychology experiment. (It is important to note that the term "cognitive psychology" was not coined until 1967, but the early experiments we are going to describe qualify as cognitive psychology experiments.)

DONDERS'S PIONEERING EXPERIMENT: HOW LONG DOES IT TAKE TO MAKE A DECISION? Donders was interested in determining how long it takes for a person to make a decision. He determined this by measuring **reaction time**—how long it takes to respond to presentation of a stimulus. He used two measures of reaction time. He measured **simple reaction time** by asking his subjects to push a button as rapidly as possible when they saw a light go on (**Figure 1.2a**). He measured **choice reaction time** by using two lights and asking his subjects to push the left button when they saw the left light go on and the right button when they saw the right light go on (**Figure 1.2b**).

The steps that occur in the simple reaction time task are shown in **Figure 1.3a**. Presenting the stimulus (the light) causes a mental response (perceiving the light), which leads to a behavioral response (pushing the button). The reaction time (dashed line) is the time between the presentation of the stimulus and the behavioral response.

But remember that Donders was interested in determining how long it took for a person to make a decision. The choice reaction time task added decisions by requiring subjects to decide whether the left or right light was illuminated and then which button to push. The diagram for this task, in **Figure 1.3b**, adds deciding which light was illuminated and which button to push to the mental response. Donders reasoned that the difference in reaction time between the simple and choice conditions would indicate how long it took to make the decision that led to pushing the correct button. Because the choice reaction time took one-tenth of a second longer than simple reaction time, Donders concluded that the decision-making process took one-tenth of a second.

Donders's experiment is important, both because it was one of the first cognitive psychology experiments and because it illustrates something extremely significant about studying the mind: Mental responses (perceiving the light and deciding which button to push, in this example) cannot be measured directly, but must be *inferred*



(a) Press J when light goes on. (b) Press J for left light, K for right.

Figure 1.2 A modern version of Donders's (1868) reaction time experiment: (a) the simple reaction time task and (b) the choice reaction time task. In the simple reaction time task, the subject pushes the J key when the light goes on. In the choice reaction time task, the subject pushes the J key if the left light goes on and the K key if the right light goes on. The purpose of Donders's experiment was to determine how much time it took to decide which key to press in the choice reaction time task. © Cengage Learning

from behavior. We can see why this is so by noting the dashed lines in **Figure 1.3**. These lines indicate that when Donders measured reaction time, he was measuring the relationship between presentation of the stimulus and the subject's response. He did not measure mental responses directly, but *inferred* how long they took from the reaction times. The fact that mental responses cannot be measured directly, but must be inferred from observing behavior, is a principle that holds not only for Donders's experiment but for all research in cognitive psychology.

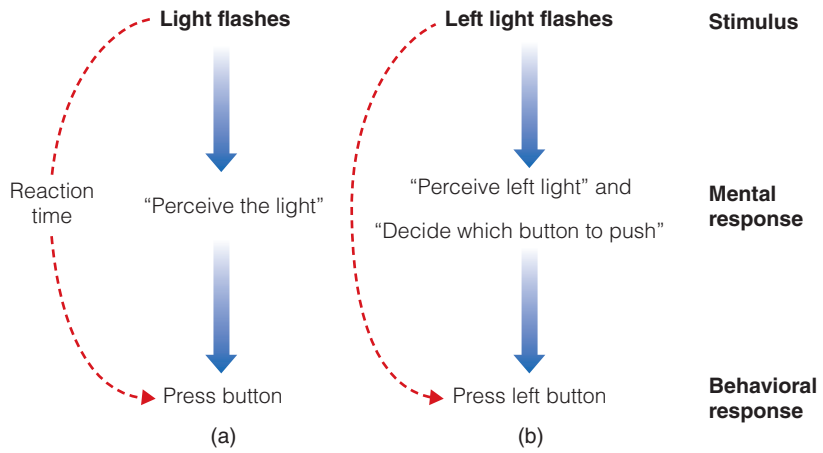


Figure 1.3 Sequence of events between presentation of the stimulus and the behavioral response in Donders's experiments: (a) simple reaction time task and (b) choice reaction time task. The dashed line indicates that Donders measured reaction time—the time between presentation of the light and the participant's response.

WUNDT'S PSYCHOLOGY LABORATORY: STRUCTURALISM AND ANALYTIC INTROSPECTION In 1879, 11 years after Donders's reaction time experiment, Wilhelm Wundt founded the first laboratory of scientific psychology at the University of Leipzig in Germany. Wundt's approach, which dominated psychology in the late 1800s and early 1900s, was called **structuralism**. According to structuralism, our overall experience is determined by combining basic elements of experience the structuralists called *sensations*. Thus, just as chemistry developed a periodic table of the elements, which combine to create molecules, Wundt wanted to create a "periodic table of the mind," which would include all of the basic sensations involved in creating experience.

Wundt thought he could achieve this scientific description of the components of experience by using **analytic introspection**, a technique in which trained subjects described their experiences and thought processes in response to stimuli. Analytic introspection required extensive training because the subjects' goal was to describe their experience in terms of elementary mental elements. For example, in one experiment, Wundt asked participants to describe their experience of hearing a five-note chord played on the piano. One of the questions Wundt hoped to answer was whether his subjects were able to hear each of the individual notes that made up the chord. As we will see when we consider perception in Chapter 3, structuralism was not a fruitful approach and so was abandoned in the early 1900s. Nonetheless, Wundt made a substantial contribution to psychology by his commitment to studying behavior and the mind under controlled conditions. In addition, he trained many PhDs who established psychology departments at other universities, including many in the United States.

EBBINGHAUS'S MEMORY EXPERIMENT: WHAT IS THE TIME COURSE OF FORGETTING? Meanwhile, 120 miles from Leipzig, at the University of Berlin, German psychologist Hermann Ebbinghaus (1885/1913) was using another approach to measuring the properties of the mind. Ebbinghaus was interested in determining the nature of memory and forgetting—specifically, how rapidly information that is learned is lost over time. Rather than using Wundt's method of analytic introspection, Ebbinghaus used a quantitative method for measuring memory. Using himself as the subject, he repeated lists of 13 nonsense syllables such as DAX, QEH, LUH, and ZIF to himself one at a time at a constant rate. He used nonsense syllables so that his memory would not be influenced by the meaning of a particular word.

Ebbinghaus determined how long it took to learn a list for the first time. He then waited for a specific amount of time (the *delay*) and then determined how long it took to relearn the list. Because forgetting had occurred during the delay, Ebbinghaus made

Figure 1.4 Calculating the savings score in Ebbinghaus's experiment. In this example, it took 1,000 seconds to learn the list of nonsense syllables for the first time. This is indicated by the lines at 0. The time needed to relearn the list at delays of (a) 19 minutes, (b) 1 day, and (c) 6 days are indicated by the line to the right of the 0 line. The red line indicates the savings score for each delay. Notice that savings decrease for longer delays. This decrease in savings provides a measure of forgetting.

errors when he first tried to remember the list. But because he had retained something from his original learning, he relearned the list more rapidly than when he had learned it for the first time.

Ebbinghaus used a measure called **savings**, calculated as follows, to determine how much was forgotten after a particular delay: Savings = (Original time to learn the list) − (Time to relearn the list after the delay). Thus, if it took 1,000 seconds to learn the list the first time and 400 seconds to relearn the list after the delay, the savings would be 1,000 − 400 = 600 seconds. **Figure 1.4**, which represents original learning and relearning after three different delays, shows that longer delays result in smaller savings.

According to Ebbinghaus, this reduction in savings provided a measure of forgetting, with smaller savings meaning more forgetting. Thus, the plot of percent savings versus time in **Figure 1.5**, called a **savings curve**, shows that memory drops rapidly for the first 2 days after the initial learning and then levels off. This curve was important because it demonstrated that memory could be quantified and that functions like the savings curve could be used to describe a property of the mind—in this case, the ability to retain information. Notice that although Ebbinghaus's savings method was very different from Donders's reaction time method, both measured *behavior* to determine a property of the *mind*.

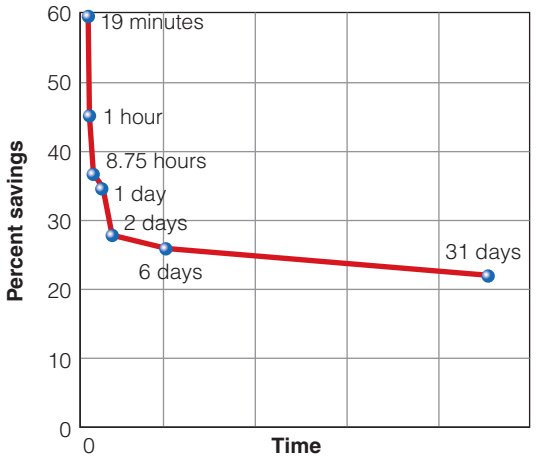


Figure 1.5 Ebbinghaus's savings curve. Ebbinghaus considered the percent savings to be a measure of the amount remembered, so he plotted this versus the time between initial learning and testing. The decrease in savings (remembering) with increasing delays indicates that forgetting occurs rapidly over the first 2 days and then occurs more slowly after that. *(Source: Based on H. Ebbinghaus,* Memory: A contribution to experimental psychology, *H. A. Ruger & C. E. Bussenius, Trans., New York: Teachers College, Columbia University, 1885/1913.)*

WILLIAM JAMES'S *PRINCIPLES OF PSYCHOLOGY* William James, one of the early American psychologists (although not a student of Wundt's), taught Harvard's first psychology course and made significant observations about the mind in his textbook, *Principles of Psychology* (1890). James's observations were based not on the results of experiments but on observations about the operation of his own mind. One of the best known of James's observations is the following, on the nature of attention:

> Millions of items … are present to my senses which never properly enter my experience. Why? Because they have no interest for me. My experience is what I agree to attend to. … Everyone knows what attention is. It is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. … It implies withdrawal from some things in order to deal effectively with others.

The observation that paying attention to one thing involves withdrawing from other things still rings true today and has been the topic of many modern studies of attention. As impressive as the accuracy of James's observations, so too was the range of cognitive topics he considered, which included thinking, consciousness, attention, memory, perception, imagination, and reasoning.

The founding of the first laboratory of psychology by Wundt, the quantitative experiments of Donders and Ebbinghaus, and the perceptive observations of James provided what seemed to be a promising start to the study of the mind (**Table 1.1**). However, research on the mind was soon to be curtailed, largely because of events early in the 20th century that shifted the focus of psychology away from the study of the mind and mental processes. One of the major forces that caused psychology to reject the study of mental processes was a negative reaction to Wundt's technique of analytic introspection.

Table 1.1: Early Pioneers in Cognitive Psychology

PERSON	PROCEDURE	RESULTS AND CONCLUSIONS	CONTRIBUTION
Donders (1868)	Simple reaction time vs. choice reaction time	Choice reaction time takes 1/10 seconds longer; therefore, it takes 1/10 second to make a decision	First cognitive psychology experiment
Wundt (1879)	Analytic introspection	No reliable results	Established the first laboratory of scientific psychology
Ebbinghaus (1885)	Savings method to measure forgetting	Forgetting occurs rapidly in the first 1 to 2 days after original learning	Quantitative measurement of mental processes
James (1890)	No experiments; reported observations of his own experience	Descriptions of a wide range of experiences	First psychology textbook; some of his observations are still valid today

Abandoning the Study of the Mind

Many early departments of psychology conducted research in the tradition of Wundt's laboratory, using analytic introspection to analyze mental processes. This emphasis on studying the mind was to change, however, because of the efforts of John Watson, who received his PhD in psychology in 1904 from the University of Chicago.

WATSON FOUNDS BEHAVIORISM

The story of how John Watson founded an approach to psychology called behaviorism is well known to introductory psychology students. We will briefly review it here because of its importance to the history of cognitive psychology.

As a graduate student at the University of Chicago, Watson became dissatisfied with the method of analytic introspection. His problems with this method were (1) it produced extremely variable results from person to person, and (2) these results were difficult to verify because they were interpreted in terms of invisible inner mental processes. In response to what he perceived to be deficiencies in analytic introspection, Watson proposed a new approach called **behaviorism**. One of Watson's papers, "Psychology As the Behaviorist Views It," set forth the goals of this approach to psychology in this famous quote:

> Psychology as the Behaviorist sees it is a purely objective, experimental branch of 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.... What we need to do is start work upon psychology making *behavior, not consciousness,* the objective point of our attack. (Watson, 1913, pp. 158, 176; emphasis added)