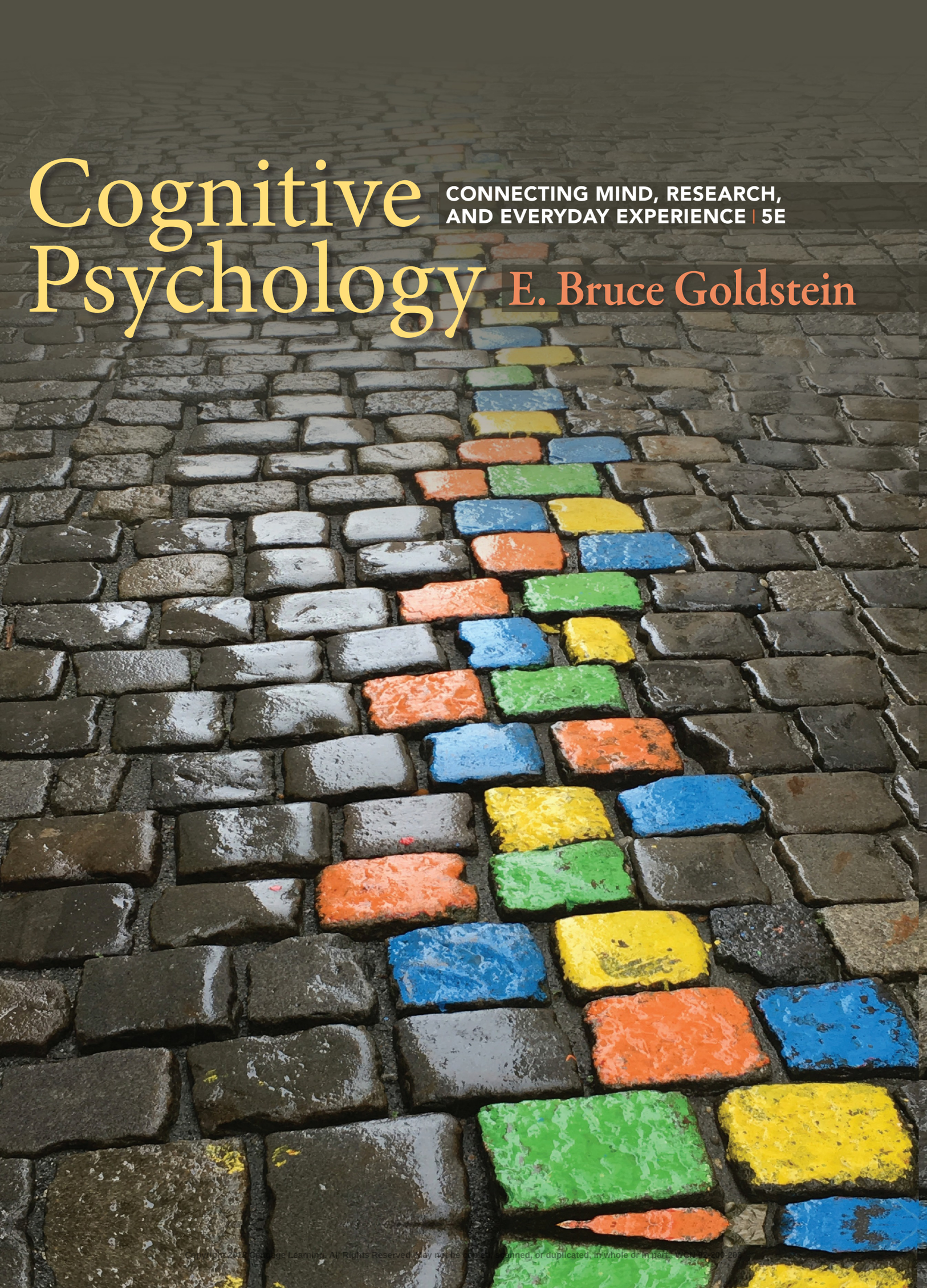
Cognitive Psychology

CONNECTING MIND, RESEARCH, AND EVERYDAY EXPERIENCE | 5E

E. Bruce Goldstein



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COGNITIVE PSYCHOLOGY

Connecting Mind, Research, and Everyday Experience | 5E

E. Bruce Goldstein

University of Pittsburgh

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Cognitive Psychology: Connecting Mind, Research, and Everyday Experience,
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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 received the Chancellor's Distinguished Teaching Award from the University of Pittsburgh for his classroom teaching and textbook writing. After receiving his bachelor's degree in chemical engineering from Tufts University, he had a revelation that he wanted to go to graduate school in psychology, rather than engineering, and so received his PhD in psychology, specializing in visual physiology, from Brown University. He continued his research in vision as a post-doctoral fellow in the Biology Department at Harvard University and then joined the faculty at the University of Pittsburgh. He continued his research at Pitt, publishing papers on retinal and cortical physiology, visual attention, and the perception of pictures, before focusing exclusively on teaching (Sensation & Perception, Cognitive Psychology, Psychology of Art, Introductory Psychology) and writing textbooks. He is the author of *Sensation and Perception,* 10th edition (Cengage, 2017), and edited the *Blackwell Handbook of Perception* (Blackwell, 2001) and the two-volume *Sage Encyclopedia of Perception* (Sage, 2010). In 2016, he won "The Flame Challenge" competition, sponsored by the Alan Alda Center for Communicating Science, for his essay, written for 11-year-olds, on *What Is Sound?*

Brief Contents

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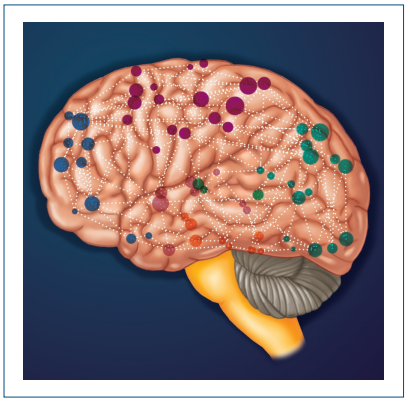

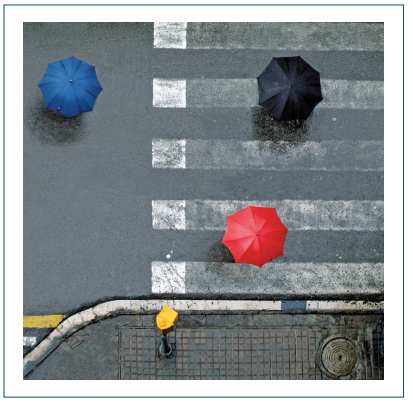

CHAPTER 7

CHAPTER 11

Language 321

CogLab Experiments

Numbers in parentheses refer to the experiment number in CogLab.

The first experiments in each chapter are "Primary Experiments" that 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

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

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

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. An additional dimension is added.

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

Blind Spot (14)* Map 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.

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

Chapter 4

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

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

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

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

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

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.

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

Chapter 5

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

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

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

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.

Irrelevant Speech Effect (22) 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.

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

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.

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.

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.

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

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

Chapter 8

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

Forgot it All Along Effect (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.

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

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

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

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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

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

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

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

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).

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

Chapter 12

None

Chapter 13

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

Decision Making (48) An experiment that demonstrates 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 Task (52) Two versions of the Wason four-card problem.

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Preface to Instructors

The Evolution of a Cognitive Psychology Textbook

This edition is the culmination of a process that began in 2002, when I decided to write the first edition of this book. 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 too abstract and 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 xxi.

One thing I avoided was simply presenting the results of experiments. Instead, whenever possible, I **described how experiments were designed**, and what participants 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 also received access to more than 45 online **CogLab experiments** that they could run themselves and could 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 they are continued in this new fifth 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. Over two dozen 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 xxiv for a list of Methods.

The end-of-chapter **Something to Consider** sections describe cutting-edge research, important principles, or applied research. A few examples of topics covered in this section are *Technology Determines What Questions We Can Ask* (Chapter 2); *Autobiographical Memories Determined by Odors and Music* (Chapter 8); 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 Fifth 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 the updating of this edition is the inclusion of 96 new boldfaced terms in the text, which also appear in the Glossary. Following is a list that highlights a few of the new or updated topics in this edition. *Italicized* items are new section headings.

CHAPTER 1 Introduction to Cognitive Psychology

- What is consciousness? fMRI study of a comatose person.
- *Paradigms and Paradigm Shifts*
- *The Evolution of Cognitive Psychology*

CHAPTER 2 Cognitive Neuroscience

- *Structural Connectivity*
- *Functional Connectivity*
- *Method: Resting State Functional Connectivity*
- *The Default Mode Network*
- *The Dynamics of Cognition*
- *Technology Determines What Questions We Can Ask*

CHAPTER 3 Perception

- *Knowledge, Inference, and Prediction.*

CHAPTER 4 Attention

- *Method: Experience Sampling*
- *Distraction Caused by Mind Wandering*
- Prediction controlling eye movements
- *Attentional Networks*
- Effective connectivity

CHAPTER 5 Short-Term and Working Memory

- *Why Is More Working Memory Better?*

CHAPTER 6 Long-Term Memory: Structure

- *Interactions Between Episodic and Semantic Memory*
- *Loss of Semantic Memory Can Affect Episodic Memories*
- *Back to the Future* (Episodic memory and imagining the future, updated)
- *Procedural Memory and Attention*
- *A Connection Between Procedural Memory and Semantic Memory*

CHAPTER 7 Long-Term Memory: Encoding and Retrieval

- The involvement of hippocampus in remote memory—fMRI evidence.
- *Alternative Explanations in Cognitive Psychology*

CHAPTER 8 Everyday Memory and Memory Errors

- *Music and Odor-Elicited Autobiographical Memories*

CHAPTER 10 Visual Imagery

- *Individual Differences in Imagery*
- Contrasting object imagery and spatial imagery

CHAPTER 11 Language

- Major revision: 25 references deleted; 30 new references added; 11 figures replaced by 8 new figures; 17 new key terms
- Updated: Garden path sentences; multiple meanings of words; common ground in conversation.
- *Language and Music*

CHAPTER 12 Problem Solving and Creativity

- *Brain "Preparation" for Insight and Analytical Problem Solutions*
- *Opening the Mind to Think "Outside the Box"*
- *Networks Associated With Creativity*
- *Wired to Create: Things Creative People Do Differently*
- *Method: Transcranial Direct Current Stimulation*

CHAPTER 13 Judgment, Decisions, and Reasoning

- Poor decision making in the NBA draft.
- Evaluating false evidence, linking to idea of fake news
- Illusory truth, backfire effect
- Neuroeconomics, updated

Ancillaries to Support Your Teaching

Instructor Ancillaries

Online Instructor's Manual: The manual includes key terms, a detailed chapter outline, lesson plans, discussion topics, student activities, video links, and an expanded test bank.

Online PowerPoints: Helping you make your lectures more engaging while effectively reaching your visually oriented students, these handy Microsoft PowerPoint® slides outline the chapters of the main text in a classroom-ready presentation. The PowerPoint slides are updated to reflect the content and organization of the new edition of the text.

Cengage Learning Testing, powered by Cognero®: Cengage Learning Testing, Powered by Cognero®, is a flexible online system that allows you to author, edit, and manage test bank content. You can create multiple test versions in an instant and deliver tests from your LMS in your classroom.

CogLab

CogLab Online is a series of virtual lab demonstrations designed to help students understand cognition through interactive participation in cognitive experiments. Students with instructors that adopt CogLab also receive access to more than 50 online CogLab experiments that they can run themselves, then compare their data to the class average and to the results of the original experiments from the literature. To view a demo, visit coglab.cengage.com.

MindTap

MindTap® Psychology: *MindTap® for Cognitive Psychology,* 5th edition, is the digital learning solution that helps instructors engage and transform today's students into critical thinkers. Through paths of dynamic assignments and applications that you can personalize, real-time course analytics, and an accessible reader, MindTap helps you turn cookie cutter into cutting edge, apathy into engagement, and memorizers into higher-level thinkers. As an instructor using MindTap, you have at your fingertips the right content and unique set of tools curated specifically for your course, all in an interface designed to improve workflow and save time when planning lessons and course structure. The control to build and personalize your course is all yours, focusing on the most relevant material while also lowering costs for your students. Stay connected and informed in your course through real-time student tracking that provides the opportunity to adjust the course as needed based on analytics of interactivity in the course.

Animated and experiential demonstrations are available in the MindTap. The purpose of these activities is to extend the students' experience beyond simply reading a description of an experiment, a principle, or a phenomenon, by giving them the opportunity to experience these things more fully and actively. This is achieved in a number of ways. Students may observe something unfolding on the screen or respond in some way, such as participating in a mini-experiment.

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 thought 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 thought 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 199–202 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.

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. Then 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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Specialist Reviewers

A number of experts were commissioned to read one of the chapters from the fourth edition and provide suggestions on updating the content for the fifth edition. What made many of these reviews especially helpful were suggestions that combined the reviewers' expertise with their experience of presenting the material in their classes.

CHAPTER 4 **Attention**

Michael Hout
New Mexico State University

CHAPTER 5 **Short-Term and Working Memory**

Brad Wyble
Penn State University

Daryl Fougnie
New York University

CHAPTER 6 **Long-Term Memory: Structure**

Megan Papesh
Louisiana State University

CHAPTER 7 **Long-Term Memory: Encoding and Retrieval**

Andrew Yonelinas
University of California, Davis

Barbara Knowlton
University of California, Los Angeles

CHAPTER 8 **Everyday Memory and Memory Errors**

Jason Chan
Iowa State University

Jennifer Talarico
Lafayette College

CHAPTER 9 **Conceptual Knowledge**

Brad Mahon
University of Rochester

Jamie Reily
Temple University

CHAPTER 10 **Visual Imagery**

Frank Tong
Vanderbilt University

CHAPTER 11 **Language**

Bob Slevc
University of Maryland

Adrian Staub
University of Massachusetts

Tessa Warren
University of Pittsburgh

CHAPTER 12 **Problem Solving**

Evangelia Chrysikou
University of Kansas

CHAPTER 13 **Judgment, Decisions, and Reasoning**

Sandra Schneider
University of South Florida

In addition, 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.

Jessica Andrews-Hanna
University of Arizona

Ying-Hui Chou
University of Arizona

Marc Coutanche
University of Pittsburgh

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Lehigh University

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University of Arizona

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University of California, Berkeley

Alex Huth
University of California, Berkeley

Bruce Goldstein

These floating umbrellas, besides being pretty, symbolize many of the cognitive processes we will be describing in this book: Perception (Seeing colors and shapes); Attention (Where your eyes move when observing this scene); Memory (Seeing umbrellas might stimulate memories); Knowledge (You know what umbrellas are used for, and that they usually don't float); and Problem Solving (Floating umbrellas! What's that all about?). What unfolds, as you read this book, is a fascinating story about how the mind works to create these cognitions and more. This chapter begins by describing the history of cognitive psychology.

Introduction to Cognitive Psychology

1

SOME QUESTIONS WE WILL CONSIDER

- How is cognitive psychology relevant to everyday experience? (5)
- How is it possible to study the inner workings of the mind when we can't really see the mind directly? (7)
- What was the cognitive revolution? (13)

It's been 16 years since the accident. Sam, lying in the long-term care facility, has been in a coma ever since. Observing Sam, who shows no signs of awareness or ability to communicate, it seems reasonable to conclude that "there's nobody in there." But is that true? Does the fact that Sam hasn't moved or responded to stimulation mean he doesn't have a mind? Is there any probability that his eyes, which appear to be vacantly staring into space, could be perceiving, and that these perceptions might be accompanied by thoughts?

These are the questions Lorina Naci and coworkers (2014, 2015) were asking when they placed Sam in a brain scanner that measured increases and decreases in electrical activity throughout his brain, and then showed him an 8-minute excerpt from an Alfred Hitchcock television program called "Bang. You're Dead." At the beginning, a 5-year-old boy is playing with his toy gun. But then he discovers a real gun and some bullets in his uncle's suitcase. The boy loads one bullet into the gun, spins the chamber that contains the single bullet, and shoves the weapon into his toy-gun holster.

As the boy roams the neighborhood, pointing the gun at a number of different people, the tension mounts. He points the gun at someone! He pulls the trigger! The gun doesn't fire because the single bullet isn't in the firing chamber. But thoughts such as "Will the gun go off?" and "Will someone be killed?" are racing through the viewers' minds, knowing that the boy's "play" could, at any moment, turn tragic. (There was a reason Hitchcock was called "the master of suspense.") In the last scene, back at the boy's house, the boy's father, realizing that he is pointing a real gun, lunges toward the boy. The gun fires! A mirror shatters. Luckily, no one is hurt. The boy's father grabs the gun, and the audience breathes a sigh of relief.

When this film was shown to healthy participants in the scanner, their brain activity increased and decreased at the same time for all of the participants, with changes in brain activity being linked to what was happening in the movie. Activity was highest at suspenseful moments in the film, such as when the child was loading the gun or pointing it at someone. So the viewer's brains weren't just responding to the images on the screen; their brain activity was being driven both by the images *and* by the movie's plot. And—here's the important point—to understand the plot, it is necessary to understand things that weren't specifically presented in the movie, like "guns are dangerous when loaded," "guns can kill people," and "a 5-year-old boy may not be aware that he could accidentally kill someone."

So, how did Sam's brain respond to the movie? Amazingly, his response was the same as the healthy participants' responses: brain activity increased during periods of tension and decreased when danger wasn't imminent. This indicates that Sam was not only seeing the images and hearing the soundtrack, but that he was reacting to the movie's plot! His brain activity therefore indicated that Sam was consciously aware; that "someone was in there."

This story about Sam, who appears to have a mental life despite appearances to the contrary, has an important message as we embark on the adventure of understanding the mind. Perhaps the most important message is that the mind is hidden from view. Sam is an extreme case because he can't move or talk, but you will see that the "normal" mind also holds many secrets. Just as we can't know exactly what Sam is experiencing, we don't know exactly what other people are experiencing, even though they are able to tell us about their thoughts and observations.

And although you may be aware of your own thoughts and observations, you are unaware of most of what's happening in your mind. This means that as you understand what you are reading right now, there are hidden processes operating within your mind, beneath your awareness, that make this understanding possible.

As you read this book, you will see how research has revealed many of these secret aspects of the mind's operation. This is no trivial thing, because your mind not only makes it possible for you to read this text and understand the plots of movies, but it is responsible for who you are and what you do. It creates your thoughts, perceptions, desires, emotions, memories, language, and physical actions. It guides your decision making and problem solving. It has been compared to a computer, although your brain outperforms your smartphone, laptop, or even a powerful supercomputer on many tasks. And, of course, your mind does something else that computers can't even dream of (if only they could dream!): it creates your consciousness of what's out there, what's going on with your body, and, simply, what it's like to be you!

In this book, we will be describing what the mind is, what it does, and how it does it. The first step in doing this is to look at some of the things the mind does. As we do this, we will see that the mind is multifaceted, involving multiple functions and mechanisms. We begin this chapter by looking at the multifaceted nature of the mind and then describing some of the history behind the field of cognitive psychology.

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 chapter titles in this book.

Another definition, which focuses on how the mind operates, is this: *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, which is what the mind creates. 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.

Cognitive psychology is the study of mental processes, which includes determining the characteristics and properties of the mind and how it operates. 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.

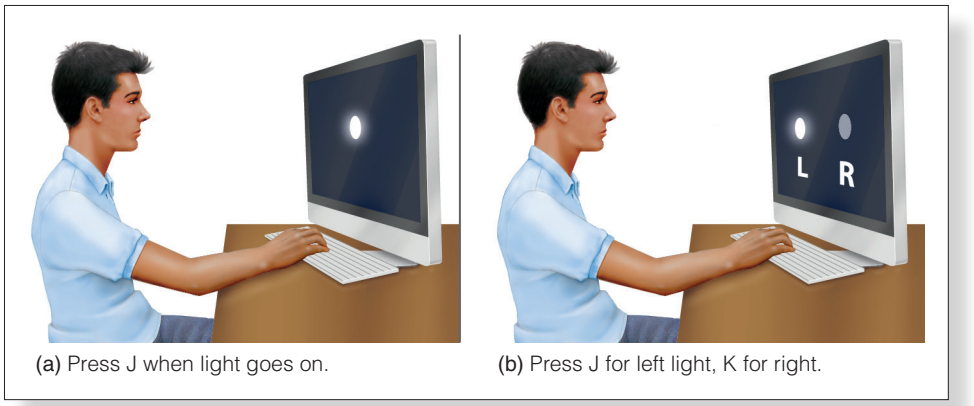
Studying the Mind: Early Work in Cognitive Psychology

In the 1800s, ideas about the mind were dominated by the belief that it is not possible to study the mind. One reason given for this belief 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 participants to push a button as rapidly as possible when they saw a light go on (**Figure 1.1a**). He measured **choice reaction time** by using two lights and asking his participants 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 1.1b**).

The steps that occur in the simple reaction time task are shown in **Figure 1.2a**. Presenting the stimulus (the light flashes) 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.

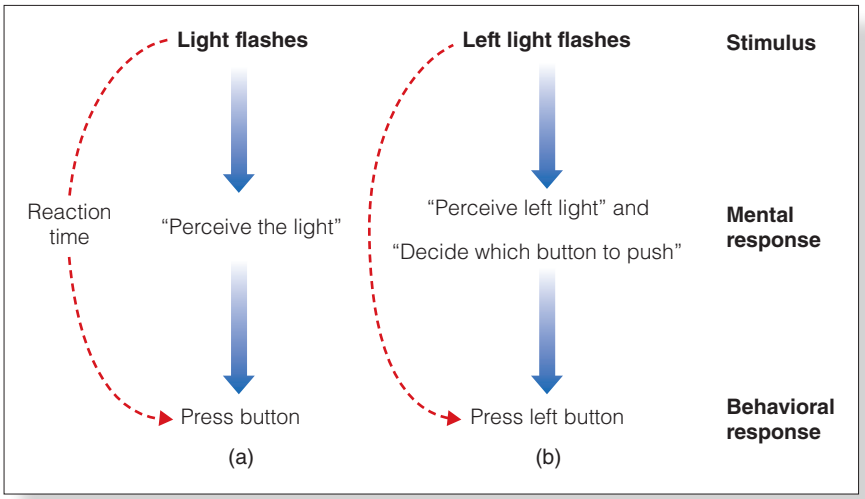


(a) Press J when light goes on. (b) Press J for left light, K for right.

➤ **Figure 1.1** 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 participant pushes the J key when the light goes on. In the choice reaction time task, the participant 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.

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 participants to first decide whether the left or right light was illuminated and then which button to push. The diagram for this task, in **Figure 1.2b**, changes the mental response to "Perceive left light" and "Decide which button to push." 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 from behavior. We can see why this is so by noting the dashed lines in Figure 1.2. These lines indicate that when Donders measured reaction time, he was measuring the relationship between presentation of the stimulus and the participant'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 1.2** 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 participants described their experiences and thought processes in response to stimuli. Analytic introspection required extensive training because the participants' 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 participants 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 participant, 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.

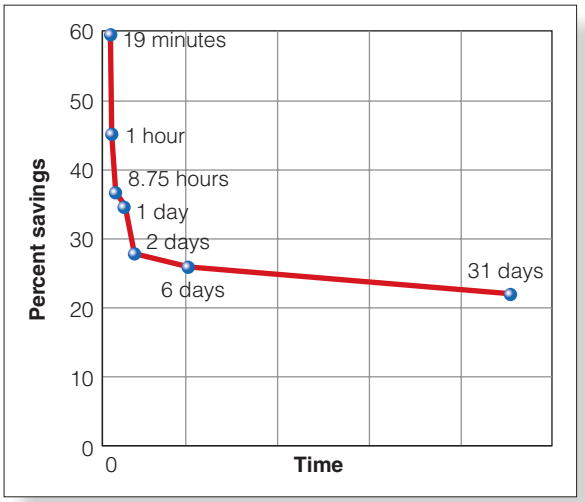
Ebbinghaus determined how long it took to learn a list for the first time. He then waited for a specific amount of time (the delay) and then determined how long it took to relearn the list. Because forgetting had occurred during the delay, Ebbinghaus made errors when he first tried to remember the list.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

➤ **Figure 1.3** 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 arrows indicate the savings score for each delay. Notice that savings decrease for longer delays. This decrease in savings provides a measure of forgetting.

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 1.3**, 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 1.4**, 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 1.4** 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 data from Ebbinghaus, 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 versus 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