

# Cognitive Science

## FOURTH EDITION

The fourth edition of this popular text has been significantly rewritten to make it more accessible to students and easier for instructors to use. It remains distinctive in presenting a unified narrative of cognitive science as a field of inquiry in its own right. Thematically organized, *Cognitive Science* underscores the problems and solutions of cognitive science as an interdisciplinary enterprise rather than more narrowly examining individually the subjects that contribute to it—psychology, neuroscience, linguistics, and so on. The generous use of examples, illustrations, and applications demonstrates how theory and experiment can be applied to unlock the mysteries of the human mind. Drawing upon cutting-edge research, the text has been updated and enhanced with a new chapter on emotions and the emerging field of affective science. An extensive online set of resources is available to aid both instructors and students.

**José Luis Bermúdez's** research interests are interdisciplinary in nature at the intersection of philosophy, psychology, and neuroscience. His many books include *The Paradox of Self-Consciousness* (MIT Press, 1998), which analyzes the nature of self-awareness; *Thinking without Words* (Oxford University Press, 2003), which offers a model for thinking about the cognitive achievements and abilities of prelinguistic infants and nonlinguistic humans; and *Decision Theory and Rationality* (Oxford University Press, 2009), which explores tensions in how the concept of rationality is defined and formalized in different academic disciplines. Recent books include *Understanding "I": Language and Thought* (Oxford University Press, 2017) and *The Bodily Self: Selected Essays* (MIT Press, 2018). His most recent book, *The Power of Frames* (Cambridge University Press, 2020), was supported by an American Council of Learned Societies (ACLS) fellowship for 2018–2019 and a National Endowment for the Humanities (NEH) Summer Stipend for 2018. A target article with peer commentary based on *The Power of Frames* appeared in *Behavioral and Brain Sciences* (2022).

# Cognitive Science

## An Introduction to the Science of the Mind

FOURTH EDITION

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# Preface

## ABOUT THIS BOOK

Few things are more fascinating than the human mind—and few are more difficult to understand. Cognitive science is the enterprise of trying to make sense of this most complex and baffling natural phenomenon.

The very things that make cognitive science so fascinating make it very difficult to study and to teach. Many different disciplines study the mind. Neuroscientists study the mind's biological machinery. Psychologists directly study mental processes, such as perception and decision-making. Computer scientists explore how those processes can be simulated and modeled in computers. Evolutionary biologists and anthropologists speculate about how the mind evolved. In fact, very few academic areas are not relevant to the study of the mind in some way. The job of cognitive science is to provide a framework for bringing all these different perspectives together.

The enormous range of information out there about the mind can be overwhelming, both for students and for instructors. Different textbooks have approached this challenge in different ways.

Some textbooks have concentrated on being as comprehensive as possible, with a chapter covering key ideas in each of the relevant disciplines—a chapter on psychology, a chapter on neuroscience, and so on. These books are often written by committees—with each chapter written by an expert in the relevant field. These books can be very valuable, but they really give an introduction to the cognitive sciences (in the plural) rather than to cognitive science as an interdisciplinary enterprise.

Other textbook writers take a much more selective approach, introducing cognitive science from the perspective of the disciplines that they know best—from the perspective of philosophy, for example, or of computer science. Again, I have learned much from these books, and they can be very helpful. But I am convinced that students and instructors need something more general.

This book aims for a balance between these two extremes. Cognitive science has its own problems and its own theories. The book is organized around these. They are all ways of working out the fundamental idea at the heart of cognitive science—which is that the mind is an information processor. What makes cognitive science so rich is that this single basic idea can be (and has been) worked out in many different ways. In presenting these different models of the mind as an information processor, I have tried to select as wide a range of examples as possible to give students a sense of cognitive science's breadth and range.

## ABOUT THE FOURTH EDITION

This fourth edition of *Cognitive Science: An Introduction to the Science of the Mind* has been significantly revised in response to suggestions from users of the three previous editions and other experts commissioned by Cambridge University Press.

The major addition is Chapter 16, coauthored with Dong An, formerly a PhD student at Texas A&M and now on the faculty at Zhejiang University in China. This new chapter introduces the

emerging area of affective science. Affective science studies the emotions and other affective states. It uses some of the techniques and tools discussed in Part II, but it has also provided fertile ground for applying new techniques, particularly in the realm of genetics. Chapter 16 on affective science complements Chapter 15 on consciousness: both chapters explore aspects of the mind that traditional cognitive science has neglected. Chapter 15 has itself been reorganized for this edition. I have, at the instigation of David Rosenthal, introduced discussion of the higher-order theory of consciousness.

I have consolidated what previously, in the third edition, was two separate chapters on mind-reading (“Exploring Mindreading” and “Mindreading: Advanced Topics”) into what is now Chapter 13. Most of the main points from the early chapters have been preserved, but the presentation is now smoother, and some of the intricacies have gone.

Every chapter has been reviewed for concision and readability, and all the annotated bibliographies have been updated to incorporate significant new publications through 2021. The end result is a book that is slightly shorter than its predecessor, which I anticipate will allow Cambridge University Press to continue to offer competitive pricing.

## HOW THE BOOK IS ORGANIZED

This book is organized into three parts.

### Part I: Historical Landmarks

Cognitive science has evolved considerably in its short life. Priorities have changed as new methods have emerged—and some fundamental theoretical assumptions have changed with them. The three chapters in Part I introduce students to some of the highlights in the history of cognitive science. Each chapter is organized around key discoveries and/or theoretical advances.

### Part II: Models and Tools

Part II sets out the main models and tools that cognitive scientists can bring to bear to understand cognition and the mind.

The first model, discussed in Chapter 4, is associated with the physical symbol system hypothesis originally developed by computer scientists Allen Newell and Herbert Simon. According to the physical symbol system hypothesis, all information processing involves the manipulation of physical structures that function as symbols. For the first decades of cognitive science, the physical symbol systems hypothesis was, as the late Jerry Fodor famously put it, the “only game in town.” In the 1980s and 1990s, connectionist and neural network modelers developed an alternative, derived from models of artificial neurons in computational neuroscience and connectionist artificial intelligence. Chapter 5 explores the motivation for this approach and introduces some of the key concepts.

Another set of models and tools that can be used to study the mind derives from dynamical systems theory and is introduced and discussed in Chapter 6. Bayesian approaches to modeling the mind have also gained currency. As explained in Chapter 7, these approaches treat the mind as a predictive, hypothesis-testing machine and have been used both to study the mind as a whole and to model the activity of individual brain areas and populations of neurons.

One of the key ideas of cognitive science is that the mind is modular (that some, or all, information processing is carried out by specialized modules). Chapter 8 explores different ways of developing this basic idea, including the radical claim, proposed by evolutionary psychologists, that the mind is simply a collection of specialized modules, with no nonspecialized processing at all. Theoretical discussions of modularity are complemented by experimental techniques for

studying the organization of the mind. Chapter 9 surveys the cognitive scientist's toolkit in this regard, focusing in particular on different types of brain mapping.

### Part III: Applications

The eight chapters in this part are more applied than those in Part II. They explore different ways in which the models and tools introduced in Part II can be used to give accounts of particular cognitive phenomena.

Chapter 10 considers language learning. Many cognitive scientists have thought that language learning is a process of learning explicit rules with a significant innate component. But we explore both neural network and Bayesian models that illustrate alternative ways of thinking about how children can learn languages. In Chapter 11, we turn to models of how children learn about the basic structure of the physical world (how they acquire what is often called a *folk physics*). Here, too, we see the power of neural network models.

One of the most significant recent developments of neural network models has been the explosive growth of deep-learning algorithms, which have made possible impressive advances in areas long thought to be major challenges for artificial intelligence, such as image recognition, machine translation, and games of strategy, such as Go. These are covered in Chapter 12.

Chapters 13 and 14 illustrate how theoretical, methodological, and experimental issues can come together. Chapter 13 works through an issue that has received much attention in contemporary cognitive science—the issue of whether there is a dedicated cognitive-system response for our understanding of other people (the so-called *mindreading system*). Chapter 14 explores the situated cognition movement and related developments in robotics, particularly behavior-based robotics and biologically inspired robotics.

In Chapter 15, we look at recent developments in the cognitive science of consciousness—a fast-moving and exciting area that raises fundamental questions about possible limits to what can be understood through the tools and techniques of cognitive science. And then finally, in Chapter 16, we examine the emerging area of affective science, which uses multiple techniques to study emotions and other affective states in human and nonhuman animals. The book ends with Chapter 17, which briefly sketches out a selection of exciting new directions in cognitive science.

## USING THIS BOOK IN COURSES

This book has been designed to serve as a self-contained text for a single-semester (twelve to fifteen weeks) introductory course on cognitive science. Students taking this course may have taken introductory courses in psychology and/or philosophy, but no particular prerequisites are assumed. All the necessary background is provided for a course at the freshman or sophomore level (first or second year). The book could also be used for a more advanced introductory course at the junior or senior level (third or fourth year). In this case, the instructor would most likely want to supplement the book with additional readings. There are suggestions on the instructor website (see “Course Website” section).

## TEXT FEATURES

I have tried to make this book as user-friendly as possible. Key text features include the following:

- **Chapter overviews.** Each chapter begins with an overview to orient the reader.
- **Exercises.** These have been inserted at various points within each chapter. They are placed in the flow of the text to encourage the reader to take a break from reading and engage with

the material. They are typically straightforward, but for a few, I have placed suggested solutions on the instructor website (see “Course Website” section).

- **Boxes.** Boxes have been included to provide further information about the theories and research discussed in the text. Readers are encouraged to work through these, but the material is not essential to the flow of the text.
- **Summaries, checklists, and further reading.** These can be found at the end of each chapter. The summary provides a short overview of the chapter. The checklists allow students to review the key points of the chapter and also serve as a reference point for instructors. Suggestions of additional books and articles are provided to guide students’ further reading on the topics covered in the chapter.

## COURSE WEBSITE

A course website accompanies the book. It can be found at [www.cambridge.org/bermudez4e](http://www.cambridge.org/bermudez4e). The **publicly accessible section of the website** contains the following:

- Discussion questions for each chapter that students can use to check their understanding
- Sample syllabi for courses of different lengths and different levels
- Links to useful learning resources, videos, and experimental demonstrations
- Links to online versions of relevant papers and online discussions for each chapter

Instructors and other authorized users can access a **password-protected section of the website**. This contains the following:

- PowerPoint slides for each chapter
- Electronic versions of figures from the text
- Suggested solutions for the more challenging exercises and problems
- Student review questions
- A bank of questions that instructors can use for assessment (the questions are formatted to be uploaded into Respondus 4.0 for compatibility with many learning management systems or imported directly into Blackboard)

The website is a work in progress. Students and instructors are welcome to contact me with suggestions, revisions, and comments. Contact details are on the website.

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Drafts of this textbook have been used four times to teach PNP 200 Introduction to Cognitive Science here at Washington University in St. Louis—twice by me and once each by David Kaplan and Jake Beck. Feedback from students both inside and outside the classroom was extremely useful. I hope that other instructors who use this text have equally motivated and enthusiastic classes. I would like to record my thanks to the teaching assistants who have worked with me on this course: Juan Montaña, Tim Oakberg, Adam Shriver, and Isaac Wiegman. And also to Kimberly Mount, the PNP administrative assistant, whose help with the figures and preparing the manuscript is greatly appreciated.

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As I was completing work on the new edition, I found myself unexpectedly taking on heavy administrative duties at Texas A&M. I am very grateful to provost Tim Scott for providing funding for a graduate research assistant to keep the project on track. Dong Yu (David) Yang greatly assisted me in updating the annotated bibliographies and online resources.

Finally, I am delighted that Dong An, who assisted me with the third edition while still a PhD student at A&M, signed up as a coauthor for the new Chapter 16 on emotions. Dong is now on the faculty at Zhejiang University, one of the leading universities in China, and I am grateful for her expert guidance on a topic that she knows much better than I do.

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