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COGNITIVE SCIENCE FOURTH EDITION

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COGNITIVE SCENCE AN INTRODUCTION T THE STUDY OF MIND FOURTH EDITION

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Cognitive Science

Fourth Edition

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Cognitive Science

An Introduction to the Study of Mind

Fourth Edition

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SAGE Publications, Inc. 2455 Teller Road Thousand Oaks, California 91320 E-mail: order@sagepub.com

SAGE Publications Ltd. 1 Oliver's Yard 55 City Road London EC1Y 1SP United Kingdom

SAGE Publications India Pvt. Ltd. B 1/I 1 Mohan Cooperative Industrial Area Mathura Road, New Delhi 110 044 India

SAGE Publications Asia-Pacific Pte. Ltd. 18 Cross Street #10-10/11/12 China Square Central Singapore 048423

Sponsoring Editor: Jessica Miller Project Associate: Ivey Mellem Production Editor: Astha Jaiswal Copy Editor: Gillian Dickens Typesetter: C&M Digitals (P) Ltd. Cover Designer: Candice Harman Marketing Manager: Victoria Velasquez Copyright © 2022 by SAGE Publications, Inc.

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Printed in the United States of America

ISBN 9781544380155

This book is printed on acid-free paper.

21 22 23 24 25 10 9 8 7 6 5 4 3 2 1

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PREFACE

O ne of the most challenging mysteries remaining to science is the human mind. The brain, which serves as the core engine of the mind, is the most complex object in the universe. It is made up of billions of cells sending signals back and forth to each other over trillions of connections. How can we make sense of all this? Recent years have seen great strides in our understanding, and this has been due in part to developments in technology. In this book, we provide an up-to-date introduction to the study of the mind, examining it from an interdisciplinary perspective. We attempt to understand the mind from the perspective of different fields. Among these are philosophy, psychology, neuroscience, networks, evolution, emotional and social cognition, linguistics, artificial intelligence, robotics, and the new framework of embodied cognition. Beyond this, we make attempts to bridge some of these fields, showing what research at the intersection of these disciplines is like. Each chapter in this text is devoted to a particular disciplinary approach and examines the methodologies, theories, and empirical findings unique to each. Come with us as we explore the next great frontier—our inner world.

WHAT'S NEW IN THIS EDITION

For this fourth edition, new content has been added throughout. In Chapter 1 (Introduction), the treatment of formal logic and production systems has been more richly elaborated with concrete examples. Also, a summary of the new Embodied Ecological Approach in Chapter 14 has been included. In Chapter 2 (The Philosophical Approach), a more in-depth exploration of syllogistic reasoning has been added, along with a more detailed discussion of reductionism and how it contrasts with emergence. Also, the discussion of Searle's Chinese room thought experiment has been expanded. In Chapter 3 (The Psychological Approach), a discussion of intelligence tests has been added. In Chapter 4 (The Cognitive Approach I), the description of Anne Treisman's feature integration theory of visual attention was expanded, along with some discussion of Desimone and Duncan's biased competition account. In Chapter 5 (The Cognitive Approach II), a section on conceptual representation has been added. In Chapter 6 (The Neuroscience Approach), the descriptions of various brain-recording methods have been expanded, and discussions of the somatosensory homunculus and of sparse distributed coding were added. In Chapter 7 (The Network Approach), treatments of Elman's simple recurrent network and McClelland and Rogers's connectionist model of category knowledge have been added, along with an expanded discussion of pattern completion. In Chapter 8 (The Evolutionary Approach), a discussion of foraging skills in animals has been included, and the treatment of gender differences in spatial abilities has been expanded. Chapter 9 (The Linguistic Approach) has been substantially rearranged. The role of linguistics (and Chomsky in particular) in the formation of cognitive science is emphasized early on. The treatment of phonology, morphology, syntax, semantics, and language acquisition has been expanded significantly. Also, sections on spoken word recognition and cognitive linguistics have been added. In Chapter 10 (The Emotional Approach), Lisa Feldman Barrett's proposal that emotions are not discrete but can partially overlap one another has been added, as well as a discussion of how color perception can influence affect. In Chapter 11 (The Social Approach), the discussions of the mirror neuron system, autism, the prisoner's dilemma, and stereotype formation have been slightly expanded. Chapter 12 (The Artificial Intelligence Approach I) has been substantially rearranged in its treatment of Alan Turing and Lotfi Zadeh, with a new focus on intelligent agents, Bayesian probability, deep learning, and brain-computer interfaces. In Chapter 13 (The Artificial Intelligence Approach II), the discussion of reactive and deliberative architectures has been expanded and sections have been added on robotic embodied intelligence, evolutionary algorithms, and swarming robotics. Chapter 14 (The Embodied Ecological Approach) was converted from a "future-looking conclusion" chapter into a "state-of-the-art dynamical, embodied, ecological" chapter. The discussions of dynamical systems theory and ecological perception have been significantly expanded, and a section on embodied cognition has been added.

A Matrix							
Na	Name/Title	Chapter Summary	Primary Topic/ Issues	Secondary Topic/ Issues	Methodologies	Major Figures	Evaluation
<u> </u>	Introduction	An introduction to cognitive science and summary overview of different perspectives	 Interdisciplinary study Representation and computation Interdisciplinary perspective Categories of mental representation 	 Concepts Propositions Production rules Declarative and procedural knowledge Analogies 	No methodologies discussed	Thagard Harnish Pylyshyn Marr	 Cognitive science is unique in that it binds together different perspectives and methodologies in the study of mind
$\vdash \Box \triangleleft$	Philosophical Approach	The search for wisdom and knowledge; frames broad questions about mind	 The mind-body problem Functionalism Knowledge acquisition Consciousness 	 Monism Dualism Nature-nurture debate Reductionism Emergence 	• Deductive and inductive reasoning	Aristotle Plato Berkeley Democritus Descartes Ryle Clark Hume Locke Chalmers Nagel Jackson Searle Churchland Dennett	 Provides a broad perspective; asks fundamental questions; not an empirical approach
⊢∟∢	The Psychological Approach	The scientific study of mind and behavior	 The scientific method Voluntarism Structuralism Gestalt psychology Psychology Behaviorism 	 Theory and hypothesis Independent and dependent variables Experimental and control groups Stream of consciousness Levels of consciousness 	 Scientific method Introspection Phenomenology 	Wundt Titchener James Wertheimer Kohler Kohler Freud Watson Pavlov Skinner	 Multiple theoretical positions; first systematic and scientific study of mental phenomena; problems with introspection and phenomenology

(Continued)

	Evaluation	 Fruitful synergistic use of experimentation and model building 	 Common set of assumptions underlying information processing and modularity; concepts of representation and computation need to be reconciled with connectionism 	 The marriage of cognitive and neuroscience perspectives in cognitive neuroscience is a good neuroscience approach; specification of biological structures and processes of cognitive abilities
	Major Figures	Neisser Fodor Selfridge Norman Marr Treisman Deutch Posner Snyder Kahneman Biederman	Sperling Baddeley Atkinson Shiffrin Anderson Kosslyn Block Newell Sternberg	Sperry Sacks Humphreys Posner Lashley Hebb Shallice Engel Singer
	Methodologies	Experimentation Modeling	 Experimentation Modeling Same as Cognitive Approach I chapter 	Case studies Lesion studies Cell-recording techniques EEG, ERP, CAT, PET, and †MRI MEG and TMS
	Secondary Topic/ Issues	Template matching Feature detection vision reature integration theory Models of attention	Memory types: sensory, working, and long term The modal, and working memory models The Kosslyn- Schwartz theory of visual imagery Heuristics Means-ends analysis The GPS and SOAR models	The split brain Dorsal and ventral pathways Agnosias Plasticity Hippocampal function Action schemas and scripts Metacognition Binding and neural synchrony
	Primary Topic/ Issues	 Information- processing perspective Modularity Pattern recognition Attention 	 Memory Models of memory Visual imagery Problem solving 	 Neuroscience methodology Neuron anatomy and physiology Brain anatomy Neuroscience of visual object recognition, attention, memory, executive function, and problem solving
	Chapter Summary	The information- processing view of mind; use of a computer as a metaphor for mind; use of process models and assumption of modularity	The information- processing view of mind; use of a computer as a metaphor for mind; use of process models and assumption of modularity (Same as Cognitive Approach I chapter)	The study of nervous system anatomy and physiology that underlies and gives rise to cognitive function
(p	Name/Title	Approach I	Approach II Approach II	The Neuroscience Approach
(Continued)	Chapter No.	4	cu	۵

Evaluation	 Significant advantages to using networks for understanding learning and knowledge representation; challenges in building networks that rival the brain 	 Powerful theoretical framework, but not all mental processes may be adaptive; good integration with neuroscience; domain- specific processing view clashes with general-purpose processor view 	(Continued)
Major Figures	 McCulloch Pitts Hopfield Kohonen Kohonen Grossberg Gollins Quillian Rumelhart McClelland Watts Strogatz Buchanan 	 Darwin Buss Cosmides Tooby Edelman 	
Methodologies	 Software simulations of artificial neural networks Comparison of results with theory and empirical data 	 Experimentation Cross-species comparison 	
Secondary Topic/ Issues	Perceptrons Back propagation Stability and plasticity Catastrophic interference Spreading activation Retrieval cues Priming Propositional networks Small-world networks	 General-purpose versus domain- specific view of mind Wason selection task Heuristics and fallacies Exaptation, molecular drive, and spandrels 	
Primary Topic/ Issues	 Serial and parallel processing Artificial neural networks Semantic networks Network science 	 Natural selection Evolved psychological mechanisms Comparative cognition Evolution and cognitive processes Behavioral economics 	
Chapter Summary	View of mind as an interconnected set of nodes or web; processing consists of the spread of activation through the web	Mind as the adapted product of selection forces	
Name/Title	Approach	The Evolutionary Approach	
Chapter No.	7	ω	

Chapter Summary The multidisciplinary study of language
Emotions and moods influence all major cognitive processes and should be incorporated into cognitive theories and models of mind

Evaluation	Automatic versus effortful processing is a common theme; the historical focus on the individual is too narrow, cognitive science must embrace the social environment	 New computational technologies may lead to the densities required to achieve the requirements needed to implement an intelligence that an intelligence that is beyond the human level; a fundamental dilemma persists: "Brains must have programs yet at the same time must not be programmed."
Major Figures	 Fiske Ochsner and Uleberman Rizzolatti Siegal and Varley Frith Schacter 	 Turing Minsky Kurzweil Craik Hawkins Hawkins Russell Norvig McCarthy Goertzel
Methodologies	 Brain imaging The ultimatum game Social dilemmas 	 Cognitive models Turing Test
Secondary Topic/ Issues	 Anterior and posterior attention systems Autism Prisoner's dilemma 	 Universal computation Chatbots Evolutionary computing
Primary Topic/ Issues	Mirror neurons Theory of mind Attitudes Cognitive dissonance Impressions Attributions Stereotyping Prejudice	 Historical perspective Influence of Turing Predictive architectures Artificial general intelligence Agent-based architectures: Multiagent systems
Chapter Summary	Thinking about people is different from thinking about objects; social cognitive neuroscience is a good example of the interdisciplinary approach	Defining the concept of artificial intelligence; machine representation of cognitive function
Name/Title	Approach	The Artificial Intelligence Approach I
Chapter No.	7	5

	Evaluation	 In some activities, machines already outperform humans; a great many problems need to be addressed in the future: perception, finely honed reasoning, and manjulative capabilities of adult humans; the more we try to replicate human intelligence, the more we may learn to appreciate and understand humans 	 Benefits of cognitive science are many and widespread throughout engineering, medicine, education, and other fields; lack of a single unified theory
	Major Figures	 Turing Minsky Brooks Russell Norvig Breazeal Arkin 	 Gibson Dreyfus Brooks Barsalou Pulvermüller Borghi Turvey Spivey
	Methodologies	 Cognitive modeling Simulation 	 Nonlinear modeling Use of state space, trajectories, and attractors to describe cognitive phenomena
	Secondary Topic/ Issues	 Hierarchical, reactive, hybrid robotic architectures Emotion in IAs 	 Predictability Randomness Constructivism
	Chapter SummaryPrimary Topic/ IssuesSummaryIssuesThe intelligent agent (IA)Importance of biologyThe intelligent agent (IA)Importance of biologyThe intelligent agent (IA)Importance of biologyThe intelligent agent (IA)Importance of biologyThe intelligent agent (IA)Embodiment and situational aspects of IA (structure)of IAs; robotic biological and biological and biological and biological and architectures		 Cognitive science needs to do a better job explaining the role of the body and of physical environments in cognition, as well as individual and cultural differences The dynamical systems approach
			An evaluation of the embodiment approach to cognitive science and the ecological perception framework
(p	Name/Title	The Artificial Intelligence Approach II	The Ecological Approach
(Continued)	Chapter No.	α	4

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ABOUT THE AUTHORS

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Gordon Silverman is Professor Emeritus of Electrical and Computer Engineering at Manhattan College. His professional career spans more than 55 years of corporate, teaching, consulting, and research experience, during which he has developed a range of scientific instruments, particularly for use in physiological psychology research environments. He is the holder of eight patents, some related to behavior modification. The author of more than 20 journal articles and books, he has also served on the faculties of The Rockefeller University and Fairleigh Dickinson University. His current research interests include telemedicine, rehabilitation medicine, artificial intelligence, and biomedical instrumentation and modeling. He holds engineering degrees from Columbia University and received a PhD in system science from New York University Polytechnic School of Engineering in 1972.

Michael J. Spivey is Professor of Cognitive Science at the University of California, Merced. He earned his BA in Psychology at the University of California, Santa Cruz, and his PhD in Brain and Cognitive Sciences at the University of Rochester. After 12 years as a psychology professor at Cornell University, Spivey moved to UC Merced to help build their Department of Cognitive and Information Sciences. He has published over 100 journal articles and book chapters on the embodiment of cognition and interactions between language, vision, memory, syntax, semantics, and motor movement. His research uses eye tracking, computer-mouse tracking, and dynamical systems theory to explore how brain, body, and environment work together to make a mind what it is. In 2010, Spivey received the William Procter Prize for Scientific Achievement from the Sigma Xi Scientific Research Honor Society.



INTRODUCTION Exploring Mental Space

A BRAVE NEW WORLD

We are in the midst of a scientific revolution. For centuries, science has made great strides in our understanding of the external observable world. Physics revealed the motion of the planets, chemistry discovered the fundamental elements of matter, and biology has told us how to understand and treat disease. But during much of this time, there were still many unanswered questions about something perhaps even more important to us—the human mind.

What makes mind so difficult to study is that, unlike the phenomena described above, it is not something we can easily observe, measure, or manipulate. In addition, the mind is the most complex entity in the known universe. To give you a sense of this complexity, consider the following. The human brain is estimated to contain 10 billion to 100 billion individual nerve cells or neurons. Each of these neurons can have as many as 10,000 connections to other neurons. This vast web of neural tissue is the core engine of the mind and helps generate a wide range of amazing and difficult-to-understand mental phenomena, such as perception, memory, language, emotion, and social interaction.

The past several decades have seen the introduction of new technologies and methodologies for studying this intriguing organ, and its relationship to the body, and to the environment. We have learned more about the mind in the past half-century than in all the time that came before that. This period of rapid discovery has coincided with an increase in the number of different disciplines—many of them entirely new—that study mind. Since then, a coordinated effort among the practitioners of these disciplines has come to pass. This diversely interdisciplinary approach has since become known as cognitive science. Unlike the sciences that came before, which were focused solely on the world of physical events in physical space, this new endeavor now turns its full attention to discovering the fascinating mental events that take place in mental space.

Learning Objectives

After reading this chapter, you will be able to:

 List at least five disciplines that participate in the field of cognitive science.

2. Describe what a mental representation is.

3. Describe what mental computation is.

4. Define what interdisciplinary means.