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COGNITIVE SCIENCE

FOURTH EDITION

SAGE

JAY FRIEDENBERG / GORDON SILVERMAN / MICHAEL JAMES SPIVEY

COGNITIVE SCIENCE

AN INTRODUCTION TO THE STUDY OF MIND

FOURTH EDITION

Cognitive Science

Fourth Edition

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Cognitive Science

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PREFACE

One 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 for Exploring Cognitive Science Across Disciplines

Chapter No.	Name/Title	Chapter Summary	Primary Topic/ Issues	Secondary Topic/ Issues	Methodologies	Major Figures	Evaluation
1	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
2	The 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
3	The Psychological Approach	The scientific study of mind and behavior	• The scientific method • Voluntarism • Structuralism • Functionalism • Gestalt psychology • Psychoanalytic 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 • Koffka • Kohler • Freud • Watson • Pavlov • Skinner	• Multiple theoretical positions; first systematic and scientific study of mental phenomena; problems with introspection and phenomenology

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

Chapter No.	Name/Title	Chapter Summary	Primary Topic/ Issues	Secondary Topic/ Issues	Methodologies	Major Figures	Evaluation
7	The Network Approach	View of mind as an interconnected set of nodes or web; processing consists of the spread of activation through the web	• Serial and parallel processing • Artificial neural networks • Semantic networks • Network science	• Perceptrons • Back propagation • Stability and plasticity • Catastrophic interference • Spreading activation • Retrieval cues • Priming • Propositional networks • Small-world networks	• Software simulations of artificial neural networks • Comparison of results with theory and empirical data	• McCulloch • Pitts • Hopfield • Kohonen • Grossberg • Collins • Quillian • Rumelhart • McClelland • Watts • Strogatz • Buchanan	• Significant advantages to using networks for understanding learning and knowledge representation; challenges in building networks that rival the brain
8	The Evolutionary Approach	Mind as the adapted product of selection forces	• Natural selection • Evolved psychological mechanisms • Comparative cognition • Evolution and cognitive processes • Behavioral economics • Artificial life	• General-purpose versus domain-specific view of mind • Wason selection task • Heuristics and fallacies • Exaptation, molecular drive, and spandrels	• Experimentation • Cross-species comparison	• Darwin • Buss • Cosmides • Tooby • Edelman	• 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

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Chapter No.	Name/Title	Chapter Summary	Primary Topic/ Issues	Secondary Topic/ Issues	Methodologies	Major Figures	Evaluation
9	The Linguistic Approach	The multidisciplinary study of language	• The nature of language • Primate language use • Language acquisition • Language deprivation • Linguistic relativity hypothesis • Grammar • The Wernicke–Geschwind model • Natural language processing	• Phonology and morphology • Syntax and semantics • Animal language studies • Critical period • Second-language acquisition • Phrase structure, transformational and universal grammar • Aphasias • Speech recognition • Pragmatic analysis	• Case studies • Developmental studies • Experimentation	• Gardner • Premack • Savage-Rumbaugh • Sapir • Whorf • Chomsky • Broca • Wernicke • Tanenhaus • Clark • Lakoff • Marslen-Wilson • Saffran	• Multiple perspectives and techniques brought to bear on the complex cognitive topic of language; advances in computer-based language comprehension
10	The Emotional Approach	Emotions and moods influence all major cognitive processes and should be incorporated into cognitive theories and models of mind	• Emergence synthesis approach • Flashbulb and autobiographical memory • Mood-congruent and mood-dependent memory • Role of synapses in emotional processing • Affective computing	• Evolutionary accounts of psychological disorders • Analytical rumination hypothesis • The feel-good, do-good phenomenon • CogAff architecture • Social robots	• Experimentation • The Iowa Gambling Task	• Damasio • Fox • Minsky • Solomon	• Need for an understanding of information flow and neural circuits that underlie emotions and how these impact thought; more work needed on how cognitions affect emotions

Chapter No.	Name/Title	Chapter Summary	Primary Topic/ Issues	Secondary Topic/ Issues	Methodologies	Major Figures	Evaluation
11	The Social Approach	Thinking about people is different from thinking about objects; social cognitive neuroscience is a good example of the interdisciplinary approach	• Mirror neurons • Theory of mind • Attitudes • Cognitive dissonance • Impressions • Attributions • Stereotyping • Prejudice	• Anterior and posterior attention systems • Autism • Prisoner's dilemma	• Brain imaging • The ultimatum game • Social dilemmas	• Fiske • Ochsner and Lieberman • Rizzolatti • Siegal and Varley • Frith • Schacter	• Automatic versus effortful processing is a common theme; the historical focus on the individual is too narrow, cognitive science must embrace the social environment
12	The Artificial Intelligence Approach I	Defining the concept of artificial intelligence; machine representation of cognitive function	• Historical perspective • Influence of Turing • Predictive architectures • Artificial general intelligence • Agent-based architectures: Multiagent systems	• Universal computation • Chatbots • Evolutionary computing	• Cognitive models • Turing Test	• Turing • Minsky • Kurzweil • Craik • Hawkins • Russell • Norvig • McCarthy • Goertzel	• New computational technologies may lead to the densities required to achieve the requirements needed to implement 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."

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Chapter No.	Name/Title	Chapter Summary	Primary Topic/ Issues	Secondary Topic/ Issues	Methodologies	Major Figures	Evaluation
13	The Artificial Intelligence Approach II	The intelligent agent (IA) paradigm; applying the principles to the design of IAs; cognitive models of IAs; robotic embodiments; biological and social influences on robots	• Importance of biology • Embodiment and situational aspects of IA (structure) • Expert systems • Building a brain • Robotic architectures	• Hierarchical, reactive, hybrid robotic architectures • Emotion in IAs	• Cognitive modeling • Simulation	• Turing • Minsky • Brooks • Russell • Norvig • Breazeal • Arkin	• In some activities, machines already outperform humans; a great many problems need to be addressed in the future: perception, finely honed reasoning, and manipulative capabilities of adult humans; the more we try to replicate human intelligence, the more we may learn to appreciate and understand humans
14	The Embodied Ecological Approach	An evaluation of the embodiment approach to cognitive science and the ecological perception framework	• 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	• Predictability • Randomness • Constructivism	• Nonlinear modeling • Use of state space, trajectories, and attractors to describe cognitive phenomena	• Gibson • Dreyfus • Brooks • Barsalou • Pulvermüller • Borghi • Turvey • Spivey	• Benefits of cognitive science are many and widespread throughout engineering, medicine, education, and other fields; lack of a single unified theory

ABOUT THE AUTHORS

Jay Friedenberg is Professor of the Psychology Department at Manhattan College, where he directs the Cognitive Science Program. He is interested in both vision and the philosophy of mind. He teaches courses in physiological psychology, cognition and learning, sensation and perception, and artificial intelligence and robotics. He has published several articles on visual estimation of center of mass. His current research projects focus on the aesthetics of geometrical shapes. He has published books on artificial intelligence, dynamical systems theory, and psychology. He is a member of the International Association of Empirical Aesthetics, the Eastern Psychological Association, the Vision Science Society, the Psychonomic Society, and Phi Beta Kappa. He obtained his PhD in cognitive psychology in 1995 at the University of Virginia.

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CHAPTER ONE

INTRODUCTION

Exploring Mental Space

Learning Objectives

After reading this chapter, you will be able to:

1. 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.

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.