
The Mind's New Science

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THE MIND'S

NEW

SCIENCE

A History of the
Cognitive Revolution

HOWARD GARDNER

Basic Books, Inc., Publishers / New York

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Library of Congress Cataloging in Publication Data

Gardner, Howard.

The mind's new science.

Bibliography: p. 393.

Includes index.

1. Cognition—History. 2. Cognition—Research—Methodology—History. 3. Artificial intelligence—History. I. Title.

BF311.G339 1985 153 85-47555

ISBN 0-465-04634-7

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Printed in the United States of America

Designed by Vincent Torre

85 86 87 88 HC 9 8 7 6 5 4 3 2 1

**For my parents,
Hilde Weilheimer Gardner and Ralph Gardner**

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PREFACE

In the mid-1970s, I began to hear the term *cognitive science*. As a psychologist interested in cognitive matters, I naturally became curious about the methods and scope of this new science. When I was unable to find anything systematic written on the subject, and inquiries to colleagues left me confused, I decided to probe further. Some immersion in the writings of self-proclaimed cognitive scientists convinced me that cognitive science was deeply rooted in philosophy and therefore, in a sense, had a long history. At the same time, the field was so new that its leading figures were all alive, and some of them were still quite young.

I decided that it would be useful and rewarding to undertake a study in which I would rely heavily on the testimony of those scholars who had founded the field as well as those who were at present its most active workers. But in lieu of an oral history or a journalistic account of current laboratory work (both of which subsequently were undertaken by other authors), I decided to make a comprehensive investigation of cognitive science in which I could include the long view—the philosophical origins, the histories of each of the respective fields, the current work that appears most central, and my own assessment of the prospects for this ambitious field.

It had not escaped my attention that the Alfred P. Sloan Foundation was a major supporter of work in the cognitive sciences. I therefore approached its program officer Kenneth Klivington about the possibility of writing a history of cognitive science. To my delight, the Foundation proved receptive, and I began my formal study at the beginning of 1981. I want to express my gratitude to the entire administration of the Sloan Foundation, and to its two responsible program officers, Kenneth Klivington and Eric Wanner, who were totally supportive of my efforts to carry through this somewhat risky undertaking.

In the course of my study, I interviewed formally, or conducted informal discussions with, dozens of cognitive scientists in this country and

abroad. As far as I can recall, no scientist whom I approached denied me an interview, and most—even those who expressed skepticism about cognitive science—were gracious and informative. I regret that I had to stop interviewing and begin writing after a time, and I regret even more that I ultimately was not able to discuss in print the work of many of those from whom I learned much. Unfortunately, if I had included even half of the work worthy of review, this book would be several times longer than it is.

I want to mention first and thank the many individuals who willingly discussed their work and the field of cognitive science with me. (I also must apologize to those whom I have inadvertently omitted from this list.) I am indebted to Jonathan Adler, Allan Allport, John Anderson, Dana Ballard, Jon Barwise, Elizabeth Bates, Brent Berlin, Ned Block, Daniel Bobrow, Margaret Boden, Stanley Brandes, Joan Bresnan, John Seely Brown, Roger Brown, Jerome Bruner, Peter Bryant, Alfonso Caramazza, Noam Chomsky, Gillian Cohen, Michael Cole, Roy D'Andrade, Daniel Dennett, Hubert Dreyfus, Jerome Feldman, Charles Fillmore, Jerry Fodor, Michael Gazzaniga, Clifford Geertz, my late and beloved mentor Norman Geschwind, Samuel Glucksberg, Nelson Goodman, Charles Gross, Patrick Hayes, Geoffrey Hinton, Stephen Isard, Philip Johnson-Laird, Ronald Kaplan, Paul Kay, Samuel Jay Keyser, Stephen Kosslyn, George Lakoff, Jean Lave, Jerome Lettvin, Robert LeVine, Claude Lévi-Strauss, Christopher Longuet-Higgins, John McCarthy, Jay McClelland, Jean Mandler, Alexander Marshack, John Marshall, Jacques Mehler, Susanna Millar, George Miller, Marvin Minsky, Julius Moravcsik, John Morton, Ulric Neisser, Freda Newcombe, Allen Newell, Donald Norman, Daniel Osherson, Domenico Parisi, Stanley Peters, Michael Posner, Karl Pribram, Hilary Putnam, Raj Reddy, Richard Rorty, Eleanor Rosch, David Rumelhart, Roger Schank, Israel Scheffler, John Searle, Robert Siegler, Herbert Simon, Aaron Sloman, Brian Cantwell Smith, Stuart Sutherland, Leonard Talmy, Sheldon Wagner, Terry Winograd, and Edgar Zurif.

Several friends and colleagues were good enough to read and comment critically on one or more of the drafts of this book. I am considerably in their debt. I wish to thank Margaret Boden, Hiram Brownell, Daniel Dennett, Martha Farah, Josef Grodzinsky, Jerome Kagan, Benny Shanon, Eric Wanner, my wife, Ellen Winner, and several anonymous reviewers for their useful comments, criticisms, and words of encouragement. I know that I benefited greatly from their feedback; I fear that remaining errors and infelicities are my own responsibility.

Over the several years in which this book was in preparation, I was fortunate enough to have the help of Linda Levine, Susan McConnell, Christine Meyer, and Claudia Strauss, who served as research assistants.

Preface

Mara Krechevsky, my current research assistant, has been invaluable in helping me to bring the manuscript to publication. In addition, she has made many substantive contributions to the manuscript. I thank Connie Wolf at Harvard and Carmella Loffredo at the Sloan Foundation for their help. The manuscript in its various guises was ably typed and word-processed by Dolly Appel, Damaris Chapin, Isabel Eccles, Nan Kortz, and Laura Stephens-Swannie. I am sure they would agree with the sentiment expressed by Samuel Johnson with respect to *Paradise Lost*: "No man could wish it longer."

As with my last three books, I have been fortunate to have the support of many individuals at Basic Books. On the editorial side I am tremendously grateful to Judith Greissman, Jane Isay, and Martin Kessler for their thoughtful reactions to earlier versions of this manuscript. Linda Carbone performed ably as the project editor; and Phoebe Hoss, as development editor, helped me to deal with many expositional problems and also displayed an uncanny sense of where I (and, at times, where cognitive science) had fallen short. In another life, she is at risk of becoming a cognitivist herself.

My greatest pleasure is to have the opportunity to dedicate this book to my parents.

HOWARD GARDNER
Cambridge, Massachusetts
April 1985

PART I

THE COGNITIVE REVOLUTION

1

Introduction: What the *Meno* Wrought

One thing I would fight for to the end, both in word and deed if I were able—that if we believed that we must try to find out what is not known, we should be better and braver and less idle than if we believed that what we do not know it is impossible to find out and that we need not even try.

—SOCRATES, *The Meno*

The safest general characterization of the European philosophical tradition is that it consists in a series of footnotes to Plato.

—ALFRED NORTH WHITEHEAD

The Greek Agenda

In the *Meno*, a Platonic dialogue, Socrates persistently questions a young slave about his knowledge of geometry. At first the slave appears quite knowledgeable, readily asserting that a square composed of sides two feet in length contains four square feet. But when, in response to a problem posed by Socrates, the slave indicates that a figure of eight square feet contains sides four feet long, Socrates demonstrates that the boy is thoroughly confused and does not realize that the length of the side must be the square root of eight.

The centerpiece of the dialogue features many questions and responses in the approved Socratic manner. Through this interchange, the philosopher ultimately succeeds in drawing out from the boy the knowledge that a square with a four-foot side would actually be sixteen square feet—that is, twice as great an area than he had supposed; and the knowledge that one can, by geometric maneuvers, inscribe a square that is actually eight square feet within this larger square. In so doing, Socrates has demonstrated to his satisfaction, and to the satisfaction of the slave's master, Menon, that the youth possesses within him all of the knowledge necessary to compute the various geometrical relationships in question.

At issue in this Platonic dialogue was far more than an exploration of the extent of knowledge possessed by a single slave boy. Here, for perhaps the first time in human intellectual history, was an extended rumination on the nature of knowledge: where does it come from, what does it consist of, how is it represented in the human mind? And, for good measure, there was also proposed a specific—if ultimately highly controversial—theory of human knowledge.

According to Plato (and, presumably, Socrates as well), the domain of knowledge par excellence inhered in mathematics and the exact sciences it had spawned. Indeed, the purest forms of knowledge were idealized forms or archetypes which can merely be glimpsed in mundane reality. An understanding of geometrical matters—indeed, of all matters of genuine knowledge—was already implanted in the human soul at birth. The task in instruction, as demonstrated in the dialogue of the *Meno*, was simply to bring this innate knowledge to conscious awareness.

The Greeks' interest in the nature of knowledge, no less than their particular contentious theories and evocative images, continued to reverberate through the Western intellectual tradition. Aristotle's version was the principal cornerstone of the Middle Ages, when discussions about knowledge were principally the purview of theologians. Then, during the Renaissance and Enlightenment periods, philosophers continued the discussions and began to draw regularly on findings obtained in the newly emerging empirical sciences. Such thinkers as Descartes, Locke, and Kant dealt comfortably with theoretical and empirical issues concerning knowledge, and the Neapolitan scholar Giambattista Vico even christened a New Science (*Scienza Nuova*) to deal with these and related matters. By the end of the nineteenth century, there had been a proliferation of new sciences and philosophical specialties, several of which purported to deal with the nature of the human mind.

Today, armed with tools and concepts unimaginable even a century ago, a new cadre of thinkers called cognitive scientists has been investigating many of the same issues that first possessed the Greeks some twenty-

five hundred years ago. Like their earlier counterparts, cognitive scientists today ask what it means to know something and to have accurate beliefs, or to be ignorant or mistaken. They seek to understand what is known—the objects and subjects in the external world—and the person who knows—his* perceptual apparatus, mechanisms of learning, memory, and rationality. They ponder the sources of knowledge: where does it come from, how is it stored and tapped, how might it be lost? They are curious about the differences among individuals: who learns early or with difficulty; what can be known by the child, the inhabitant of a preliterate society, an individual who has suffered brain damage, or a mature scientist?

Further, cognitive scientists, again as did the Greeks, conjecture about the various vehicles of knowledge: what is a form, an image, a concept, a word; and how do these “modes of representation” relate to one another? They wonder about the priorities of specific sense organs as against a central “general understanding” or “common sense.” They reflect on language, noting the power and traps entailed in the use of words and their possible predominant influence over thoughts and beliefs. And they speculate at length on the nature of the very activity of knowing: why do we want to know, what are the constraints on knowing, and what are the limits of scientific knowledge about human knowing?

This “new science,” thus, reaches back to the Greeks in the commitment of its members to unraveling the nature of human knowledge. At the same time, however, it is radically new. Proceeding well beyond armchair speculation, cognitive scientists are fully wedded to the use of empirical methods for testing their theories and their hypotheses, of making them susceptible to disconfirmation. Their guiding questions are not just a rehash of the Greek agenda: new disciplines, like artificial intelligence, have arisen; and new questions, like the potential of man-made devices to think, stimulate research. Moreover, cognitive scientists embrace the most recent scientific and technological breakthroughs in a variety of disciplines. Most central to their undertaking is the computer—that creation of the mid-twentieth century that holds promise for changing our conceptions of the world in which we live and our picture of the human mind.

Definition and Scope of Cognitive Science

In the course of proposing and founding a new field of knowledge, many individuals will formulate their own definitions. Indeed, since the term *cognitive science* first began to be bandied about in the early 1970s, dozens of scientists have attempted to define the nature and scope of the

*For ease of exposition, the pronoun *he* is used in its generic sense throughout this book.

field (see, for example, Bruner 1983; Collins 1977; Mandler 1981; Miller 1979; Norman 1980; Rumelhart 1982). It therefore becomes important for me at the outset to state what I take cognitive science to be.

I define cognitive science as a contemporary, empirically based effort to answer long-standing epistemological questions—particularly those concerned with the nature of knowledge, its components, its sources, its development, and its deployment. Though the term *cognitive science* is sometimes extended to include all forms of knowledge—animate as well as inanimate, human as well as nonhuman—I apply the term chiefly to efforts to explain human knowledge. I am interested in whether questions that intrigued our philosophical ancestors can be decisively answered, instructively reformulated, or permanently scuttled. Today cognitive science holds the key to whether they can be.

Of the various features or aspects generally associated with cognitive-scientific efforts, I consider five to be of paramount importance. Not every cognitive scientist embraces every feature, of course; but these features can be considered symptomatic of the cognitive-scientific enterprise. When all or most are present, one can assume that one is dealing with cognitive science; when few, if any, are present, one has fallen outside my definition of cognitive science. These features will be introduced more formally at the end of chapter 3 and will be revisited repeatedly throughout the book, but it is important to make an initial acquaintance with them at this point.

First of all, there is the belief that, in talking about human cognitive activities, it is necessary to speak about mental representations and to posit a level of analysis wholly separate from the biological or neurological, on the one hand, and the sociological or cultural, on the other.

Second, there is the faith that central to any understanding of the human mind is the electronic computer. Not only are computers indispensable for carrying out studies of various sorts, but, more crucially, the computer also serves as the most viable model of how the human mind functions.

While the first two features incorporate the central beliefs of current cognitive science, the latter three concern methodological or strategic characteristics. The third feature of cognitive science is the deliberate decision to de-emphasize certain factors which may be important for cognitive functioning but whose inclusion at this point would unnecessarily complicate the cognitive-scientific enterprise. These factors include the influence of affective factors or emotions, the contribution of historical and cultural factors, and the role of the background context in which particular actions or thoughts occur.

As a fourth feature, cognitive scientists harbor the faith that much is to be gained from interdisciplinary studies. At present most cognitive

Introduction: What the Meno Wrought

scientists are drawn from the ranks of specific disciplines—in particular, philosophy, psychology, artificial intelligence, linguistics, anthropology, and neuroscience (I shall refer to these disciplines severally as the “cognitive sciences”). The hope is that some day the boundaries between these disciplines may become attenuated or perhaps disappear altogether, yielding a single, unified cognitive science.

A fifth and somewhat more controversial feature is the claim that a key ingredient in contemporary cognitive science is the agenda of issues, and the set of concerns, which have long exercised epistemologists in the Western philosophical tradition. To my mind, it is virtually unthinkable that cognitive science would exist, let alone assume its current form, had there not been a philosophical tradition dating back to the time of the Greeks.

Purpose and Plan of This Book

I have chosen to write a book on cognitive science because I consider this area to be the most exciting new line of inquiry undertaken by scientists in the past few decades. Whether it will ultimately achieve all of its objectives, no one can say at this point; but this seems an opportune time to present a history and a current assessment. For contemporaries present during the opening decades of cognitive science, I hope to convey something of the enthusiasm I have noted, the difficulties that are being confronted, and the nature of the research enterprises in which investigators are presently engaged.

My history has two components. The first consists of the various interdisciplinary conversations and projects that took place in this century—both those preceding and those surrounding the unofficial launching of cognitive science in the mid-1950s. I relate the founding of cognitive science in the next two chapters of the book. The second component—spanning chapters 4 through 9—consists of brief targeted histories of each of the six aforementioned fields of cognitive science. (Other disciplines, such as sociology or economics, might have been added; the “borderline” disciplines of anthropology and neuroscience might have been eliminated; but I believe that the major points about cognitive science are made effectively by these six fields.) In my view, a brief targeted history of each of the several cognitive sciences serves as an optimal introduction to the principal issues of today, to the ways in which they are currently approached and explored, and to the lines of work likely to be undertaken in the future.

I have built each historical chapter around one or two major themes, which have been selected to convey a feeling for the kinds of issues that

have recurred and the kinds of approaches that are especially central within a particular field. For example, in philosophy I trace the perennial dispute between those of a rationalist persuasion (who view the mind as actively organizing experiences on the basis of pre-existing schemes); and those of an empiricist bent (who treat mental processes as a reflection of information obtained from the environment). In anthropology I survey various attempts over the years to compare the thought of primitive peoples with that exhibited by typical individuals in modern Western society. Approaching these same fields from a methodological point of view, I raise the questions whether philosophy will eventually come to be supplanted by an empirically based cognitive science, and whether anthropology can (or even should) ever transcend the individual case study.

Of course, such organizing themes can only scratch the surface of the complex territory that underlies any scientific discipline. Still I hope that through such themes I can convey how a linguist views an issue, what a psychologist deems a problem (and a solution), which conceptions of process obtain in neuroscience and artificial intelligence. Only through such an immersion in the daily (and yearly) concerns of a cognitive scientist drawn from a particular discipline can one appreciate the possibilities—and the difficulties—that arise when workers from different fields collaborate in cognitive-scientific research. In the end I will in each case take stock and indicate where things stand with reference to the principal lines of contention in a particular cognitive science—a discussion that will, in turn, suggest some of the principal factors that have stimulated cognitive scientists to join forces.

While each of the histories stands on its own, their juxtaposition points up fascinating and difficult-to-anticipate parallels. Scientific fields hardly develop in a vacuum: such disparate factors as the dissemination of Darwin's pivotal writings, the outbreak of wars, the rise of great universities have had reverberations—and sometimes cataclysmic ones—across apparently remote fields, which may well have had little direct contact with one another. For the most part, I shall simply allow these parallels to emerge, but at the beginning of part III I shall specify certain historical forces that seem to have exerted influence across a range of cognitive sciences.

Having taken the measure of the individual cognitive sciences, I turn in the third part of the book to review ongoing work that is quintessentially cognitive-scientific. Thus, in chapters 10 to 13, the focus shifts from work within a traditional discipline to those lines of research that stand most squarely at the intersection of a number of disciplines and therefore can be considered prototypical of a single, unified cognitive science. I have sought to identify work that is of the highest quality: if cognitive science

is to be assessed as an intellectual enterprise, it ought to be judged by the most outstanding instances.

There is a common structure to these four essays on current cognitive-scientific work. Consistent with my claim that cognitive science seeks to elucidate basic philosophical questions, each chapter begins with a perennial epistemological issue. For example, in chapter 10, I describe work on how we perceive the world; in chapter 13, I review competing claims on the extent of human rationality. Across chapters 10 to 13, there is a progression from those issues that seem most circumscribed to those that are most global. Not surprisingly, the most confident answers exist for the delimited questions, while the global topics remain ringed by unresolved questions.

My personal reflections on cognitive science are reserved for the final chapter. There I revisit the major themes of cognitive science in light of the histories sketched and the interdisciplinary work reviewed. I also discuss two themes that emerge from the inquiry and that will be introduced at greater length in chapter 3: the computational paradox and the cognitive challenge. In my view, the future of cognitive science rests on how the computational paradox is resolved and on how the cognitive challenge is met.

One might say that cognitive science has a very long past but a relatively short history. The reason is that its roots go back to classical times, but it has emerged as a recognized pursuit only in the last few decades. Indeed, it seems fair to maintain that the various components that gave rise to cognitive science were all present in the early part of the century, and the actual birthdate occurred shortly after mid-century. Just why cognitive science arose when it did in the form it did will constitute my story in the remainder of part I.

2

Laying the Foundation for Cognitive Science

The Hixon Symposium and the Challenge to Behaviorism

In September of 1948 on the campus of the California Institute of Technology, a group of eminent scientists representing several disciplines met for a conference on "Cerebral Mechanisms in Behavior," sponsored by the Hixon Fund (Jeffress 1951). This conference had been designed to facilitate discussions about a classic issue: the way in which the nervous system controls behavior. And yet the discussions ranged far more widely than the official topic had implied. For example, the opening speaker, mathematician John von Neumann, forged a striking comparison between the electronic computer (then a discovery so new that it smacked of science fiction) and the brain (which had been around for a while). The next speaker, mathematician and neurophysiologist Warren McCulloch, used his provocative title ("Why the Mind Is in the Head") to launch a far-ranging discussion on how the brain processes information—like von Neumann, he wanted to exploit certain parallels between the nervous system and "logical devices" in order to figure out why we perceive the world the way we do.

Less steeped in the latest technological innovations but more versed in the problems of explaining human behavior, the next speaker, psy-

chologist Karl Lashley, gave the most iconoclastic and most memorable address. Speaking on "The Problem of Serial Order in Behavior," he challenged the doctrine (or dogma) that had dominated psychological analysis for the past several decades and laid out a whole new agenda for research. In the terms of my own discussion, Lashley identified some of the major components needed for a cognitive science, even as he castigated those forces that had prevented its emergence before this time.

In order to appreciate the importance of Lashley's remarks, it is necessary to consider the scientific climate in which he (and his numerous colleagues interested in human psychology) had been operating during the past few decades. At the turn of the century, in the wake of the founding of new human sciences, investigators had been addressing the key issues of mental life: thinking, problem solving, the nature of consciousness, the unique aspects of human language and culture. These discussions had linked up with the philosophical agenda of the West, but investigators had sought to go beyond sheer speculation through the use of rigorous experimental methods.

Unfortunately the scientific method favored by most researchers at that time was introspection: self-reflection on the part of a trained observer about the nature and course of his own thought patterns. Though suggestive (indeed, often too suggestive), such introspection did not lead to that accumulation of knowledge that is critical to science. Introspectionism might have collapsed of its own weight, but, in fact, it was toppled in a more aggressive manner by a group of mostly young, mostly American scientists who became known as the "behaviorists."

The behaviorists put forth two related propositions. First of all, those researchers interested in a science of behavior ought to restrict themselves strictly to public methods of observations, which any scientist could apply and quantify. No subjective ruminations or private introspection: if a discipline were to be science, its elements should be as observable as the physicist's cloud chamber or the chemist's flask. Second, those interested in a science of behavior ought to focus exclusively on *behavior*: researchers ought assiduously to eschew such topics as mind, thinking, or imagination and such concepts as plans, desires, or intentions. Nor ought they to countenance hypothetical mental constructs like symbols, ideas, schemas, or other possible forms of mental representation. Such constructs, never adequately clarified by earlier philosophers, had gotten the introspectionists into hot water. According to behaviorists, all psychological activity can be adequately explained without resorting to these mysterious mentalistic entities.

A strong component of the behaviorist canon was the belief in the supremacy and determining power of the environment. Rather than in-

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