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Volume 1

edited by Lila R. Gleitman and Mark Liberman

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Foreword

The book you are holding is the first of a four-volume introduction to contemporary cognitive science. The work includes more than forty chapters, written by linguists, psychologists, philosophers, computer scientists, biologists, and engineers. The topics range from muscle movement to human rationality, from acoustic phonetics to mental imagery, from the cerebral locus of language to the categories that people use to organize experience. Topics as diverse as these require distinctive kinds of theories, tested against distinctive kinds of data, and this diversity is reflected in the style and content of the chapters.

The authors of these volumes are united by their fascination with the mechanisms and structure of biological intelligence, especially human intelligence. Indeed, the principal goal of this introductory work is to reveal the vitality of cognitive science, to share the excitement of its pursuit, and to help you reflect upon its interest and importance. You may therefore think of these volumes as an invitationnamely, the authors' invitation to join the ongoing adventure of research into human cognition.

The topics we explore fall into four parts, each corresponding to a separate volume. The parts are: language, visual cognition, thinking, and conceptual foundations. Each volume is self-contained, so they can be read in any order. On the other hand, it is easiest to read the chapters of a given volume in the order indicated. Each chapter concludes with suggestions for further reading and a set of problems to test your understanding.

It remains only to wish you a pleasant and invigorating journey through cognitive science. May it lead to a life-long interest!

Istituto San Raffaele
July 1995

Daniel N. Osherson
Series Editor

The Study of Cognition

Daniel N. Osherson

Cognitive science is the study of human intelligence in all of its forms, from perception and action to language and reasoning. The exercise of intelligence is called cognition. Under the rubric of cognition fall such diverse activities as recognizing a friend's voice over the telephone, reading a novel, jumping from stone to stone in a creek, explaining an idea to a classmate, remembering the way home from work, and choosing a profession. Cognitive processes are essential to each of these activities; indeed, they are essential to everything we do.

Research on cognition has historical roots in antiquity and was already flourishing in the 1800s. The field drew new impetus in the 1950s from theoretical innovations in linguistics (Chomsky 1956, 1957) and computer science (Minsky 1956, 1961; Newell and Simon 1956). The rapid development of these fields raised the possibility of genuine insight into the structure of human cognition and exerted a magnetic attraction on other disciplines concerned with intelligence, both human and artificial. These disciplines included parts of neurophysiology, psychology, philosophy, anthropology, mathematics, and economics. The result has been a vigorous dialogue among scientists working within diverse traditions, employing different methodologies, and starting from different assumptions. By the mid-1970s it was becoming clear that the different approaches were complementary and that the next generation of scientists would need to have a distinctive kind of training, drawing from several established disciplines. In response, undergraduate and postgraduate programs in cognitive science were started in many universities in North America, Europe, and Japan.

The new programs have created a need for new textbooks, especially introductory textbooks that open cognitive science to the beginning student. Such is the purpose of these four volumes. They provide a glimpse of the topics treated within the discipline, the methods used, and the theories produced so far.

Why Study Human Cognition?

Before looking at the contents of the volumes in more detail, let us consider some reasons for the scientific investigation of human cognition.

The Fascination of Cognitive Science

Think about your last conversation with a friend. From a certain point of view it went this way. Your friend had an idea or thought that she wanted to convey to you. For this purpose she sent volleys of commands to scores of muscles in her abdomen, chest, throat, tongue, and lips. The resulting oral gymnastics had the effect of vibrating the air molecules around her. Ultimately, the vibrations in the air caused corresponding vibrations at your eardrum. These vibrations were passed along in attenuated form through bones, fluids, and tissues in your ear until they resulted in a volley of sensory discharges along the auditory nerve to your brain. The sensory discharges then acted in such a way as to cause some counterpart of your friend's idea to be formed in your brain. This idea gave rise to an idea of your own, so you sent volleys of commands to scores of muscles in your abdomen, chest, throat, tongue, and lips that had the effect and so forth. The intricacy of this process is astonishing. It allows the communication of ideas and thoughts of great originality and subtlety, yet operates at remarkable speed (producing comprehensible speech at several words per second) and requires no noticeable mental effort by the speaker and listener. This point is worth stressing. Speech and understanding are effortless and unconscious activities that go on while we think about the topic of the conversation (instead of having to think about the mechanism of communication). How does this marvelous communication system work? Such is the subject of volume I, *Language*.

Almost any human competence arouses the same sense of curiosity and wonder. Consider visual recognition. For you to know that it is your friend across the room, it suffices for light reflected from his face to flash across the retinas of your eyes for a fraction of a second. Within broad limits, it does not matter how much ambient light there is in the room, or whether the light reflected to the retinas comes from a profile or frontal view of your friend's face. Typically, the central area of only one retina is enough for the job, which amounts to no more than 10 square millimeters of retinal surface (about 3 percent the size of a fingernail). As in the case of language, the nervous system relies on unconscious processes to transform successive flashes of light on the retina (which typically jumps from position to position several times per second) into the seamless visual scenery we experience. These processes are the subject of volume 2, *Visual Cognition*.

In addition to the fascination engendered by their sheer intricacy and efficiency, human cognitive processes are of interest for another reason. To a large extent a person just *is* the ensemble of cognitive processes she harbors; the thoughts, perceptions, utterances, and actions created by these processes help define her as a person. As a result, cognitive science focuses on a fundamental question both for the individual and for the species, namely, What does it mean, from the cognitive point of view, to be human?

Technological Development

It is a commonplace that Western societies are being transformed by the introduction of computer technology. Every month brings news of faster computers and the development of software for new domains of modern life. It is easy to be dazzled by the pace of progress.

For this reason, it is important not to lose sight of a sobering fact about modern computers and the programs that make them run. Years of effort have not succeeded in endowing computerized systems with even rudimentary abilities in areas where humans excel. An example is tool use. No computer-driven, mechanical hand approaches the multipurpose dexterity of the human carpenter's hand, and no breakthroughs are in sight that will close the gap. The human advantage is even more pronounced with respect to perceptual-motor coordination. No existing computerized system rivals the effortless partnership between visual processing and motor planning that underlies the carpenter's ability to drive a nail just where it is needed.

The same can be said for other human competences. In the case of language, computerized translation lags far behind the skill of bilingual humans. Even within a single language, although automatic comprehension continues to improve, there is as yet nothing close to a computer program that can discuss airline reservations, for example, in normal speech. Even the elementary task of transcribing the continuous speech of an arbitrarily chosen, native speaker of English remains beyond current technology, whereas this ability amounts to little more than basic literacy in the human case.

These considerations suggest that the investigation of human intelligence can play a useful role in the search for artificially intelligent systems. Study of the human case might suggest new design principles to be incorporated into computerized systems. For example, investigating how the human visual system processes and interprets light might aid computer scientists in attempting to build automated systems with similar powers. Of course, there is no guarantee that investigating the human case will shed light on the artificial case. The human system might prove so difficult to understand that computer scientists would do better to look elsewhere for guidance. In addition, Nature may not have invented the only way to process visual information efficiently, to move a hand, to speak, and so on. Analogously, bird and insect flightinvolving the deformation and agitation of wingsdid not turn out to be the only mechanism available for air travel. Nonetheless, the tremendous powers of the human system provide good reason to study it, and collaboration between cognitive scientists and computer scientists has increased steadily over the years.

Preparation and Repair of the Cognitive System

The human cognitive apparatus may be thought of as a tool for interacting successfully with the environment. Like any complex instrument, this tool must be fine-tuned to the specific circumstances of its use and repaired if damaged. These activities correspond to education and medical treatment, respectively. Research in cognitive science can contribute to both domains.

Education. Designing a successful curriculum for a given field of knowledge (say, one of the sciences) requires two kinds of expertise on the part of the designer. First, she must be solidly competent in the field. Second, she must understand (if only implicitly) how the learner's cognitive apparatus is structured. The second kind of expertise guides the way lessons are built and organized, so as to maximize learning. It is reasonable to expect that progress in cognitive science will illuminate the cognitive structure of children and adults in such a way as to aid in the design of effective curricula. Research relevant to this theme is presented in chapter 4 of volume 3, *Thinking*.

Another kind of learning consists in better appreciating the strengths and weaknesses of one's cognitive apparatus. To illustrate the point, consider your ability to assign probabilities to chance outcomes. In what kinds of situations do you do this correctly, and in what kinds of situations are you subject to illusions and systematic error? Research in cognitive science raises and analyzes questions of this nature. It thus alerts us to potential pitfalls in our reasoning, and can ultimately aid our judgment. Some aspects of human judgment are discussed in these terms in chapters 23 of volume 3.

Medical treatment. The brain may lose its remarkable cognitive powers through traumatic injury, stroke, or diseases like schizophrenia or Alzheimer's syndrome. Advances in tissue grafts and in brain chemistry have brought treatment of such conditions into the realm of possibility. If, however, new treatments are to be effective in restoring lost or threatened functions, much information will be needed about the cognitive role played by different neural structures. This is a primary area of research in cognitive science, discussed in several of the chapters that follow.

Cognitive science is also central to advances in the diagnosis of neural disease and damage. In light of detailed knowledge of the relation between brain and cognition, the fine grain of a patient's perceptual, linguistic, or motor behavior may assume diagnostic significance. The attempt to correlate such behavior with the onset of neural disease is another area of active research in cognitive science (see Kosslyn 1988; Posner et al. 1988).

Social Choices

How people decide to organize themselves when they are free to choose, as well as what social structures they find tolerable when their choices are constrained, is determined in part by their conception of themselves as human beings. Consider the following opposing views:

> *View 1:* People are basically lazy, moved to activity and inquiry only under the pressure of organic need.

> *View 2:* People are innately curious and industrious, becoming lazy only from stifled ambition and training for passivity.

A community that shared view 1 might well be led to different political choices than would a community that shared view 2.

A scientifically sound theory of human cognition can be expected to throw light on questions such as these. It is not to be expected (or desired) that, by itself, information of this sort determines social choices; they are also governed by the values and aspirations of those concerned. Nonetheless, it may be hoped that greater understanding about this one component of human nature, namely, human cognition, can lead to more adaptive reflection on some of the choices that face contemporary society.

Organization

Let us now consider some of the principles that underlie the organization of the four volumes.