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COGNITIVE PSYCHOLOGY AND INFORMATION PROCESSING:

An Introduction

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Preface

PREMISE

Basic research, at its essence, is exploration of the unknown. When it is successful, isolated pieces of reality are deciphered and described. Most of the history of an empirical discipline consists of probes into this darkness—some bold, others careful and systematic. Most of these efforts are initially incorrect. At best, they are distant approximations to a reality that may not be correctly specified for centuries. How, then, can we describe the fragmented knowledge that characterizes a scientific discipline for most of its history?

The knowledge that a field claims at any point in its development cannot be unified, at that time, by a correct account of the phenomenon it studies; for that only becomes available much later. Throughout most of the history of a research science, reality does not unify its literature. What, then, does? It is our premise that the data, experiments, and theory of a developing field can only be fully understood by reference to the paradigmatic commitments of its practitioners. A dynamic field of science is held together by its *paradigm*.

Thomas Kuhn developed the concept of a scientific paradigm as part of a fundamental reformulation of views on the scientific enterprise. The paradigm, representing tacit commitments to a conception of reality that cannot be defended on rational or canonical grounds, stood in contrast to then-prevailing views of how science is done. Kuhn challenged the idea that scientific investigation is absolutely rational, thoroughly cumulative, and unequivocally objective. He highlighted the role of consensual judgments in determining what appears rational, objective, and worth cumulating. His most vociferous critics, philosophers of science by profession, have by now

largely conceded his major points. Although some have relabeled the concepts and denied their source, the astute reader cannot fail to discern Kuhn's thesis lurking in such alternative formulations as research programs, scientific disciplines, and scientific domains.

As psychologists, we may ask whether these diverting echoes from philosophy of science have much to do with us. Does psychology have a paradigm? We suggest that, in fact, it has several; and a grasp of this reality and its significance is essential to an understanding of psychological research at either the graduate or undergraduate level. In the first chapter, we suggest a way to define and analyze psychological paradigms. The psychological research literature speaks effectively to the existence of something like paradigms in our discipline. In 1970, for example, Mostofsky edited a book on attention, containing 18 articles. One of these was authored by Donald Broadbent. It was entitled "Stimulus Set and Response Set: Two Kinds of Selective Attention," and it contained 34 citations. In the same book appeared another paper by Werner Honig, entitled "Attention and the Modulation of Stimulus Control," and it carried 38 citations. Of the 72 articles cited by Broadbent and Honig, *not one* appeared in both citation lists. Obviously, if two psychological researchers could write about attention without citing a single common paper, there must be two distinct psychological literatures on the subject. This is anomalous for a cumulative enterprise, but comprehensible in paradigmatic terms. Our example from the study of attention is not unique. Anyone who has considered the treatments of early childhood autism in the *Journal of Applied Behavioral Analysis* and childhood schizophrenia in the *Psychoanalytic Review* must conclude that the psychologists differ more than the children about whom they write.

How can a student approach this kind of discontinuity in the literature? One approach, sometimes tried by undergraduates, is to suppose that the apparently different views can be reconciled. This leads to tortured logic and bizarre reference lists in term papers, as well as unrelenting frustration for their writers and graders. One can only speculate on what these students think we are doing by the time they have completed the B.A. Another approach is more typical of graduate training. It involves mastering one of the literatures and rejecting several others. Unfortunately, the student may often be encouraged to believe that the chosen approach represents the only correct and defensible—even the only scientific—way to study the topic at hand. This is the purchase of coherence at a high price.

We do not claim, or even know, that a student can effectively bridge several paradigms in the course of graduate training; and mastery of one is essential to the practice of scientific research. What we do claim is that, if a scientist is to remain viable, he or she must be prepared in the course of a 40-year professional career to reject at least one paradigm in favor of another. This cannot be accomplished by one who equates the consensual judgments of his

or her reference group with the rational methods of science. A paradigm change in mid-career is less dislocating for one whose graduate education has placed those consensual paradigmatic judgments in the broader epistemological context—in short, for one whose graduate training has included explicit accounts of paradigmatic commitments.

For the undergraduate student, the literature of a developing science often seems fractured and chaotic. Apparently important issues go completely unresearched; seemingly trivial issues fill chapters. Negative evidence is given heavy weight in one case and lightly dismissed elsewhere. These patterns are understandable if, and only if, one understands the pretheoretical commitments of the practitioners of the science—in short, their paradigm. Undergraduate readers have found this treatment of the literature highly congenial and comprehensible.

We think it is essential to adequate scientific education to teach paradigms, and we believe that there is an effective method. The method emphasizes the integral nature, rather than the objective correctness, of a given set of consensual commitments. Moreover, we believe that paradigmatic content can be effectively combined with the technical research literature commonly presented in scientific texts. This book represents the culmination of those beliefs. You, the reader, will make the final judgment of their validity.

CONTRIBUTIONS

A major problem we faced as authors is that the field of cognitive psychology has become exceedingly large. No one, today, can seriously claim expert knowledge of the entire range of cognitive literature. Indeed, it is increasingly difficult to keep up with the data accumulating in a subfield such as memory or perception. The field of cognitive psychology seems to have exploded in the middle 1960s and has not touched ground since.

Our strategy in dealing with this situation was twofold. To organize and interrelate the rather disjunctive literatures in the various subfields of cognition, we adopted the notion of consensual validation and an elaboration of the Kuhnian concept of a scientific paradigm. The idea and its development are the contribution of Roy Lachman, who conceived this book at a time when the field was much smaller than it is today. Second, we attempted to set up a division of labor so that significant aspects of the cognitive literature could be covered in a nonsuperficial way. We started with Roy Lachman, Janet L. Lachman, and D. James Dooling. As each of us completed a first draft, the other two criticized it for later revision. We soon added Earl Butterfield; his job was to evaluate the first drafts and their critiques, to resolve any inconsistencies between them, and, most important, to rewrite all material in a language that would be readable by nonspecialists. The objective

was to ensure that the book did not assume professional expertise by our student readers, and to give the writing a coherence not always present in multi-authored texts. There were eventually some departures from this scheme, especially as the magnitude of the task became apparent. The final division of labor is represented in the following table:

Chapter	*Short Title*	*Original Conception and First Draft*	*First Revision*	*Final Revision*
1	Science and Paradigms	Roy Lachman Janet Lachman	Earl Butterfield	Roy Lachman Janet Lachman
2	Contributions from Psychology	Roy Lachman Janet Lachman	Earl Butterfield	Roy Lachman Janet Lachman
3	Contributions from Other Disciplines	Roy Lachman Janet Lachman	Earl Butterfield	Roy Lachman Janet Lachman
4	The Information-Processing Paradigm	Roy Lachman Janet Lachman	Roy Lachman Janet Lachman	Roy Lachman Janet Lachman
5	Reaction Time	D. J. Dooling	Earl Butterfield	Earl Butterfield
6	Consciousness and Attention	D. J. Dooling	Earl Butterfield	Earl Butterfield
7	Structure of Episodic Memory	D. J. Dooling	Earl Butterfield	Earl Butterfield
8	Episodic Memory Flexibility	Roy Lachman Janet Lachman	Earl Butterfield	Roy Lachman Janet Lachman
9	Semantic Memory	Roy Lachman Janet Lachman	Earl Butterfield	Roy Lachman Janet Lachman
10	Psycholinguistics	Janet Lachman	Earl Butterfield	Janet Lachman
11	Comprehension	Janet Lachman Roy Lachman	Earl Butterfield	Janet Lachman Roy Lachman
12	Global Models	Roy Lachman Janet Lachman	Earl Butterfield	Roy Lachman Janet Lachman
13	Pattern Recognition	Janes F. Juola	Earl Butterfield	James F. Juola
14	Epilogue	Roy Lachman	Janet Lachman	Roy Lachman Janet Lachman

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thanks to E. E. Smith, F. I. M. Craik, Irving Biederman, and one anonymous reviewer; all provided extensive feedback on many of the chapters. They are only to be credited with making the product better; if errors remain they are the responsibility of the authors.

The production of the book was especially facilitated by our graduate student Carroll Thronesbery, who worked with us on the innumerable last-minute details. We also could not have dispensed with those who helped with the typing and bibliography. Especial thanks for her competent and loyal assistance in typing go to our secretary Fern Tombaugh.

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Contents

1 Science and Paradigms: The Premises of This Book

ABSTRACT

I. *Introduction*
Technical competence in a science is possible without perspective, and perspective is possible without technical skill.

A. *Perspective and Content are Both Important to Science Education.*

B. *Beginning Definitions of Cognitive Psychology and Information Processing* A scientific field can be defined by its content, general approach, and specific approach. The content of cognitive psychology is the human higher mental processes, and the general method is the same as other sciences. The specific approach covered in this book is the information-processing paradigm.

C. *Some Preliminary Examples of Cognitive Behavior* Automobile driving is the kind of activity that cognitive psychologists believe involves many important cognitive capabilities. We use this activity to introduce some of the emphases and assumptions of information-processing psychology.

D. *The Significance of Information Processing and Cognitive Psychology* Paradigmatic views often find their way into the larger society, and we think the information-processing approach will have such an impact. Presently, it is most visible in cognitive science; but it is being extended. We advocate learning it along with other approaches.

II. *Cognitive Psychology as an Experimental Science*

A. *Psychology Is a Research Science, Not a Mature System* This means that many psychological questions have not been clearly asked, let alone answered. The student should not approach an active research science seeking only established facts and agreed-upon theories. Learning about an unsettled research science involves learning the current questions, approaches, and controversies. These have their source in aspects of scientific practice that are often ignored in traditional descriptions of scientific method.

B. *A Fundamental Premise: The Rational and Conventional Rules of Science* Every scientist operates within two sets of rules. One is the rational rule system of the scientific method, which has been widely described. The other is conventional and paradigmatic; it results from consensus among a group of scientists that a particular approach is worthy.
   1. *The Rational Rules* While other human institutions make statements about mankind, scientific statements are unique. The rational rules of science are designed to obtain knowledge for its own sake. They are morally neutral and constructed to verify theoretical statements by observational methods.
   2. *The Conventional Rules* The rational rules supply more guidance in how to make observations than in what to observe. Intelligent, well-trained, and honest scientists can disagree about what to observe and what a particular observation means. Groups of scientists tend to form, however, within which there is considerable consensus on what observations are worth making and how they should be interpreted. The tacit rules followed by these subgroups constitute the conventional component of their science, their paradigm.

C. *Normal and Revolutionary Science* Thomas Kuhn (1962) suggested that advanced sciences cycle between "normal" and "revolutionary" science. During periods of normal science, there is a sense of progress within the context of a particular paradigm, and little questioning of its premises. However, as experiments are done, anomalies arise that cannot be handled within the existing paradigm. When there is sufficient weight of these anomalies, the discipline may go into crisis and alter some of its most fundamental paradigmatic commitments. Although Kuhn's contribution has been criticized, we think it is an excellent descriptive account of scientific activity and, with some modification, is highly appropriate to psychology.

D. *Paradigms in Psychology* Psychology has always been, and still is, multiparadigmatic. However, at one time the dominant view was behavioristic. This has changed, partly due to the arrival of the information-processing approach. In cognitive psychology, the information-processing view was once revolutionary. It is now the dominant paradigm in cognition, and cognitive psychology now appears to be in a state of normal science.

III. *Characteristics of Paradigms*

Paradigms are not the same as theories. We suggest six dimensions along which paradigms may be defined and differentiated.

A. *Intellectual Antecedents* These are the prior sources of the ideas and concepts that a scientist brings to his work.

B. *Pretheoretical Ideas* The working scientist draws on assumptions and tacit beliefs about the nature of the reality he is studying. These guide research and aid in the formulation of experimental questions.

C. *Subject Matter* The decision to study one facet of behavior and not another amounts to a judgment about which questions should be answered and which deferred.

D. *Analogies* When a scientist is studying a poorly understood system, it is useful to borrow concepts and ideas from better-understood systems. This borrowing is tantamount to analogizing the two systems and can be used to develop theories and formulate research questions.

E. *Concepts and Language* The terms in a paradigmatic language can be imported from the paradigm's intellectual antecedents, or from a discipline which is the source of an important analogy, or invented within the paradigm. The language used within a paradigm reflects the pretheoretical ideas of its users.

F. *Research Methods* Whereas the rational rules dictate observational methods, paradigms tend to develop preferences for particular kinds of observations, experimental designs, and variables.

IV. *Paradigms, Information Processing, Psychology, and Society*
It usually takes a long time for a paradigm to have an impact on the wider society outside the discipline in which it is used. We think that the information-processing view of human capacities will eventually permeate institutions outside cognitive psychology. Therefore, we have taken considerable trouble to present as explicitly as possible the pretheoretical ideas, intellectual antecedents, subject matter, concepts and language, analogies, and research methods of the information-processing paradigm.

The Lesson of the Copernican Revolution. In the Ptolemaic system, as in the cosmogony of the Bible, man was assigned a central position in the universe, from which position he was ousted by Copernicus. Ever since, writers eager to drive the lesson home have urged us, resolutely and repeatedly, to abandon all sentimental egoism, and to see ourselves objectively in the true perspective of time and space. What precisely does this mean? In a full "main feature" film, recapitulating faithfully the complete history of the universe, the rise of human beings from the first beginnings of man to the achievements of the twentieth century would flash by in a single second. Alternatively, if we decided to examine the universe objectively in the sense of paying equal attention to portions of equal mass, this would result in a lifelong preoccupation with interstellar dust, relieved only at brief intervals by a survey of incandescent masses of hydrogen—not in a thousand million lifetimes would the turn come to give man even a second's notice. It goes without saying that no one—scientists included—looks at the universe this way, whatever lip-service is given to "objectivity". Nor should this surprise us. For, as human beings, we must inevitably see the universe from a centre lying within ourselves and speak about it in terms of a human language shaped by the exigencies of human intercourse. Any attempt rigorously to eliminate our human perspective from our picture of the world must lead to absurdity.

—From the opening paragraph of
Personal Knowledge (Polanyi, 1962)

I. INTRODUCTION

Science is an organized human activity having much in common with other human institutions. People can function effectively in a complex institution without necessarily understanding its history, social purpose, or properties. A businessman may know little of his nation's economy, yet earn great wealth. A general may not understand the causes of war, yet still win battles. A lawyer may know nothing of the history and social function of law, yet still win court cases. Beginning students sometimes do excellent technical work without necessarily knowing its importance. Scientists are human beings working within human institutions, just as are businesspeople, generals, and lawyers. Some of them can and do produce competent research without knowing its value, nor its place in the mosaic of knowledge, nor even the forces that directed them to the problems solved by their own findings. The point is that technical competence is not the same as perspective, in science or other human institutions. It is possible to have one without the other. The objective of this book is to provide both: a knowledge of the content of cognitive psychology, along with a perspective on that content.

Just as technical competence is possible without perspective, so perspective is possible without technical skill. People can grasp unifying views without practicing a specialty. They can understand war without fighting. They can understand law without trying cases. They can understand the economy without investing a dollar. Similarly, a student can gain a broad perspective on the sciences, or on a particular science, without earning a Ph.D. and setting to work in a laboratory.

A. Perspective and Content Are Both Important to Science Education

A few students intend to earn a Ph.D. in cognitive psychology and earn their living working in a laboratory; but the vast majority have no such intention. In this book, we hope to present the science of cognitive psychology so it can be grasped equally well by students who aspire to scientific specialization and those who do not. This requires that theories and data be analyzed relative to their place in the overall pattern of knowledge. Presenting technical facts, laws, and scientific theories is not enough, even though that is sometimes all one finds in science books and courses. We believe it is essential to bring broad perspectives to the teaching of science. Science and the student would benefit if more effort were spent on the pattern of knowledge to which theories and the data relate.

Science would benefit in two ways. Scientific research would be of better quality if all researchers understood where their work fit in the scheme of