COGNITIVE PSYCHOLOGY AND INFORMATION PROCESSING: An Introduction

ROY LACHMAN
JANET L. LACHMAN
University of Houston

EARL C. BUTTERFIELD
University of Kansas Medical Center

Psychology Press

COGNITIVE PSYCHOLOGY AND INFORMATION PROCESSING:
An Introduction

Page Intentionally Left Blank

COGNITIVE PSYCHOLOGY AND INFORMATION PROCESSING:
An Introduction

ROY LACHMAN
JANET L. LACHMAN
University of Houston

EARL C. BUTTERFIELD
University of Kansas
Medical Center

Psychology Press
Taylor & Francis Group
LONDON AND NEW YORK

First published 1979 by Lawrence Erlbaum Associates, Inc.

Published 2015 by Psychology Press
27 Church Road, Hove, East Sussex, BN3 2FA

and by Psychology Press
711 Third Avenue, New York, NY 10017

Psychology Press is an imprint of the Taylor & Francis Group, an informa business

Publisher's Note
The publisher has gone to great lengths to ensure the quality of this reprint but points out that some imperfections in the original may be apparent.

Library of Congress Catalog Card Number: 78-24744

ISBN-13: 978-1-315-79884-4 (eISBN)

Contents

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 Laehman 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

ACKNOWLEDGMENTS

Drafts of the chapters were read and evaluated by countless devoted students, and we cannot begin to thank them all individually. However, special mention is due to those graduate students who gave us detailed written feedback on various chapters: Eric Block, Cameron Camp, Wendy Moore, Bettye Thompson, Don Taylor, Carroll Thronesbery, and Marilyn G. Boltz. Their commentary was always astute—sometimes profound. We also owe a debt of thanks to our many colleagues who have field tested the book for us by using parts of it in their classes, and to the many others who have given us their comments and suggestions. In this connection, we wish to extend special 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.

We are also very grateful to Mr. Larry Erlbaum for his support and continued faith throughout a very long process of completion.

ROY LACHMAN
JANET L. LACHMAN
EARL C. BUTTERFIELD

Page Intentionally Left Blank

COGNITIVE PSYCHOLOGY AND INFORMATION PROCESSING:
An Introduction

Page Intentionally Left Blank

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 things, and the importance of science would be more widely understood and appreciated among the general public. Students would benefit by gaining greater enjoyment and understanding from a scientific education that imparted perspective. They would be excited by discovering adjoining pieces of the puzzle of knowledge, rather than bored by memorizing lists of experiments whose relations to one another sometimes seem obscure. Becoming educated should be intellectually exciting. It is science's big ideas and sense of discovery, not just its technical details, that carry its excitement. This is fortunate, because it is impossible in the 4 years of a diversified undergraduate education to master the details of even one scientific subdiscipline. On the other hand, it is quite possible to achieve a broad appreciation of a science on the way to a baccalaureate degree. But here is a dilemma: Most science courses are taught by specialists. A few of them may lack perspective on their own fields; for others, perspective has become so nearly second nature that they forget to teach it. Textbooks are also written by specialists. Only a rare textbook integrates a technical literature so that it is understandable and interesting to the general student and the aspiring scientist alike.

Our goal in this book is to present an overview and perspective that will bring coherence and significance to cognitive psychology and to the information-processing approach to cognition. In the process, we present many experiments and their results. As we describe these experiments, we explicitly address why they were done and how they reflect the basic commitments of the scientists who did them. Of course, we also cover what they seem to show about human beings—their properties and their nature. Together, the intellectual motivation for research and the interpretations of experiments render cognitive psychology coherent and exciting.

B. Beginning Definitions of Cognitive Psychology and Information Processing

Cognitive psychology is one branch of an extremely broad field. Many content areas fall within the field of psychology, such as brain physiology, social interaction, and intrapsychic dynamics. The topic area of cognition, then, is one way to distinguish cognitive psychology from other branches of the general discipline. Psychology also includes many different methods of study; there are literary psychologists, intuitive psychologists, humanistic psychologists, and scientific psychologists, among others. Different methods can be used to study what is apparently the same subject matter. For instance, social interaction is studied both by scientific psychologists in the experimental laboratory and by humanistic psychologists in the encounter group. In order to mark out an area of study such as "cognitive psychology," then, we must specify both the content and the general approach.

The subject matter of cognitive psychology could be broadly defined as "how the mind works," but as such it would be completely intractable. The cognitive psychologist, like any other student of nature, must limit the subject matter to keep it comprehensible and manageable. Therefore, those aspects that seem especially important to most cognitive psychologists are studied—the "higher mental processes," including memory, perception, learning, thinking, reasoning, language, and understanding. Most students of the higher mental processes, moreover, have made a commitment to the observational methods of science rather than to a literary, intuitive, or humanistic point of view. The typical cognitive psychologist is, therefore, a scientist motivated to understand a natural system consisting of the human higher mental processes.

The commitment to use the scientific method in studying the higher mental processes obviously sets limits on one's scholarly investigations. However, a multitude of further decisions must be made, implicitly or explicitly, before the first experiment is begun. What assumptions are reasonable? What ideas are relevant in creating hypotheses about the nature of mental processes? What hypotheses are plausible and worthy of study? What should be studied first, and what should be deferred until later? Scientific psychologists can legitimately differ in the way they resolve these questions. However, within scientific disciplines, there tend to form subgroups whose members adopt very similar resolutions. When a sufficiently large number of scientists in a field agree to a considerable extent on how such questions are to be resolved, they are said to share a *paradigm*. Information-processing psychology is one paradigm for studying cognitive psychology, and it happens that in recent years it has become the dominant paradigm in the study of adult cognitive processes.

As we shall use the term, *paradigm* refers to the common set of ideas a subgroup of scientists brings to their subject matter. We develop the concept of paradigm in considerable detail in the rest of this chapter, for it is a pivotal concept in our treatment of the literature on cognition. Although the same term has been used to refer to particular laboratory techniques, our usage is quite different. It is also different from "theory," but these differences are explored later.

Because of the enormous complexity of most natural and social systems, no scientist can study the totality of a major system. Research can begin only after manageable-sized subsystems have been defined. Significant research requires the knowledge, foresight, and luck to formulate the properties and states of a subsystem that corresponds reasonably well to the real world. The scientist's paradigm plays a central role in this very significant task. Cognitive psychologists within the information-processimg paradigm have a particular way of deciding which subsystems comprise the higher mental processes, some insights and intuitions about what they are like, and some commitments regarding how they should be studied. They have defined the area of study as the way man collects, stores, modifies, and interprets environmental information or information already stored internally. They are interested in knowing how he adds information to his permanent knowledge of the world, how he accesses it again, and how he uses his knowledge in every facet of human activity. Information-processing-oriented cognitive psychologists believe that such collection, storage, interpretation, understanding, and use of environmental or internal information *is* cognition. They believe understanding these processes is fundamental to understanding reading, speech production and comprehension, and creative thought. Indeed, many cognitive psychologists believe that this research will aid in understanding other human characteristics, such as emotion, personality, and social interaction. Some cognitive psychologists believe that the properties they study—speech, understanding, and thought—distinguish human beings from every other natural system on earth.

C. Some Preliminary Examples of Cognitive Behavior

So far, our discussion of information-processing psychology has been both brief and abstract. It is greatly extended in the next two chapters. Before that, however, it might be useful to concretize our brief description through a familiar activity, analyzed from the information-processing psychologist's point of view.

Most readers of this book probably know how to drive an automobile. Driving is the kind of activity that information-processing psychologists consider representative of tasks requiring many important cognitive processes. Although you are probably unaware of most of them, you perform countless internal acts as you drive your car. This is one characteristic of information-processing approaches to cognition: Many of the cognitive processes that interest information-processing psychologists occur without conscious awareness on the part of the individual who is performing them.

Consider your typical drive to your college or university. As you drive, you make various turns, each one signalled by some familiar landmark. These landmarks are so well known that you probably are not aware of "seeing" them each time. However, the information-processing psychologist is convinced that you must perceive each familiar landmark anew each time. You must recognize it as the same landmark that you have seen and used on previous occasions. How do you do this? From the information-processing viewpoint, you must have represented the landmark's appearance in your memory. When you see it again, you match up your current perception of the landmark to its stored representation; this is the process of *recognition.*

Recognition also makes available to you other stored information about the significance of the landmark. Thus, when you have recognized it you can know whether you should turn right or left, proceed straight ahead, get ready to turn, and so on. Information-processing psychology is fundamentally committed to the concept of representation: Everything you know is considered to be represented in your memory. How these representations are put to use is one of the central questions in many areas of cognitive psychology.

We have mentioned two kinds of information about the landmark: perceptual knowledge about its appearance and conceptual knowledge of its significance. Both kinds of information are presumably represented, and they are called into play whenever a driver correctly executes the actions necessary to get to his or her destination. Another question that intrigues information-processing psychologists is the *manner* in which different kinds of information are represented. The area of cognition is also characterized by an assumption that represented information is somehow *coded* for storage in the human nervous system. This means that external events are converted into an internal form according to some specifiable sets of rules. Perhaps there is a different code for perceptual and conceptual information; or perhaps there is a single code that can be reached on the basis of visual or conceptual stimuli. Many areas of cognitive psychology are concerned with the various forms in which content may be coded.

As you drive, you take in vast amounts of environmental data. You "see" dozens of other cars, many buildings and trees, signs and signals. Some of this material is almost immediately forgotten; for example, another driver who is behaving normally is unlikely to be remembered later. However, if a driver behaves erratically, you may subsequently recall his actions. Subjectively it seems as if you see only the erratic drivers. But the information-processing psychologist considers that you could not distinguish the erratic drivers from the others if you did not process information about them all. However, much of this processing activity did not result in memory for what was processed. This possibility indicates that there must be different *ways* of processing information—some that result in memory and some that do not. Cognitive psychologists are interested in what the different processing modes might be and how the human cognitive system sets one or another mode into operation.

As you drive you also make numerous decisions. Some are deliberate and conscious—for example, you decide to pass up a distant parking space in hopes of finding a better one. However, many are made without your attention or awareness. If your car has a stick shift, you decide repeatedly when to shift gears. You decide when to speed up and slow down, when to change lanes, when to pass and when to wait. When a green light changes to yellow, you decide whether to stop or proceed—incorporating into your decision an estimate of how long the yellow light will last, whether there are cars approaching from the other direction, whether someone is behind you, and the speed of your own vehicle and its distance from the intersection. Quite a bit of data goes into this decision making, although for the most part you can do it without thinking about it. What is more, the decision may depend in part on whether you are late for class, whether you have a new or an old car, or whether your insurance is paid up. Information-processing psychologists consider that much cognition depends on internal decision making. Some is conscious, some unconscious, and some is completely outside the control of the individual. Nevertheless, such decision making is an important part of the information-processing approach to cognitive psychology.

The conviction that cognitive processes occur over time, and that some take longer than others, is another feature of information-processing psychology. Many information-processing experiments are designed expressly to find out how long different activities take. Many conclusions are drawn from what the researcher discovers about how much time a cognitive operation consumes. Temporal measures are used to estimate how complex a particular task is or how many suboperations, such as decisions, recodings, and mental searches, may possibly be involved. Now that we have called attention to some of the things we do without thinking about them, you may be able to describe some of the internal activities involved in your own driving. In fact, rational and intuitive analyses are respectable tools in the information-processing paradigm. Scientists who work within this paradigm believe that they can gain important insights by informal analysis of cognitive activities. But information-processing psychologists know that they cannot rely on rational and intuitive tools alone, precisely because so many cognitive processes go on outside of people's awareness. To know how people's minds work, information-processing psychologists must also use experimental tools, and they do so extensively. Some of these techniques are elegant and yield unexpected insights into how people work. Herein lies part of the fun of studying the information-processing paradigm.

Like all paradigms, the information-processing approach to human cognition has an intellectual history, a set of research tools, and a language that sets it off from other paradigms. Without understanding these, it is impossible to understand the paradigm and, concomitantly, the experiments and theories the paradigm has stimulated. There is much more discussion of these matters in the next chapter and throughout the book. We have used the information-processing paradigm as our organizing theme. It has guided our choice of chapters and of what to include in them. We know that this is not the only approach to cognitive psychology, nor will it last forever. In fact, in our final chapter we briefly describe recent and potentially important changes in the approach. We simply believe that the scientific data on the higher mental processes are *currently* organized more comprehensibly by the information-processing paradigm than by any other view.

D. The Significance of Information Processing and Cognitive Psychology

For those who plan to obtain advanced degrees and become professional psychologists, the significance of cognitive psychology and the information-processing orientation lies in the fact that these are important parts of contemporary psychology. A professional education is incomplete without some mastery of them. But this book is also for psychology majors who plan to stop with a bachelor's degree and, indeed, for those who are not psychology majors. It is intended to give an appreciation and comprehension of mankind's finest faculties, his mental ones. In the process, it accounts for some of the most intriguing features of science: its paradigmatic conventions and its revolutions. The information-processing approach has been in the forefront of a scientific revolution; it has provided psychologists with a fundamentally new way of thinking about people. Past ways of characterizing the most central characteristics of humankind have been quite different. For example, Freudian psychology focused on the clash between rational and irrational forces in shaping the human personality. Conflict between the demands of civilized society and innate, instinctive forces, which occurred primarily during infancy and early childhood, was considered a fundamental determinant of later behaviors. More recently, psychologists have viewed the human being as a conditioned responder, waiting passively for stimuli to impinge on him before emitting the response he has been conditioned to make. Both these views have been invoked to explain emotional behavior and psychopathology. Information-processing psychology differs from both Freudian and conditioning psychology. Our paradigm focuses on normal and rational behavior, and views the human being as an active seeker and user of information.

No approach explains all behavior; certain approaches seem to work best for certain kinds of human activities. This will long be the case in a developing science such as psychology. At the moment, the information-processing view seems congenial mostly to scholars of intelligent human behavior—it seems to work best in accounting for people's ability to accomplish familiar, well-learned mental operations. For the time being, it has little to say about emotional behavior, mental illness, or individual differences. However, the number of scholars who share the information-processing view is increasing. Some have applied the paradigm to social psychology (Carroll & Payne, 1976; Hendrick, 1977), developmental psychology (Klahr & Wallace, 1976), and neuropsychology (Pribram, in press). Attempts have also been made to apply it to clinical psychology (Mahoney, 1974).

Freudian and behavioristic conceptions of man have been adopted by large segments of society. We anticipate that the information-processing conception will also work its way into social institutions outside of science. Information-processing conceptions are being used increasingly wherever survival depends on rapid and accurate dealings with changing and complex environments—for example, space travel and undersea exploration. The approach is also useful and will become increasingly important in school teaching, rehabilitation of perceptual and intellectual abnormalities, and in the communications fields.

Virtually every human activity is guided by a model of human nature. An implicit model of what people are like is responsible for the actions of police officers, salespersons, doctors, military officers, parents—in fact, everyone who interacts with other people. The use of some conception of man is universal and inescapable—whether the conception is valid or not. Insofar as the approach conveyed by this book is a valid picture of human capabilities, propensities, and behavior, learning it should improve one's effectiveness in many kinds of interactions with others.

We believe that an important piece of the truth is contained in the information-processing approach. It does not explain everything that humans do, but some human skills are explained more adequately in information-processing terms than in any other way. We advocate that a student learn this approach, and others as well. We believe that a complete education warrants learning a variety of approaches, such as dynamic, humanistic, and operant psychology, as well as information processing. A person who has mastered and understood several paradigms is in an excellent position to accomplish two important ends. First, he or she will be able to see the strengths and weaknesses of each approach as it applies to the aspects of human behavior that the person finds most interesting. The strengths of the information-processing view are most apparent to one who has tried to understand human intellectual capacities from behavioristic, psychoanalytic, and other viewpoints. Second, the person will be better able to deal with differences of approach, thus increasing receptivity to newer and more powerful conceptions as they are developed. Even the comprehension of established views will be facilitated. Each psychology course that is offered from a new vantage can increase a sense of disorder and chaos for the student who expects all of the facts collected by psychologists to fit into a coherent view. But for the student who has considered the similarities and differences between psychological paradigms, each new approach will fit a pattern and be easier to understand. Just as someone who knows two languages finds it easier to learn a third, so the student who understands scientific revolutions and how they evolve will not be dislocated each time he encounters another paradigm. Scientific perspective consists in large measure of understanding how paradigmatic conceptions change. Cognitive psychology provides an excellent opportunity to understand such change, because it has so recently undergone one.

II. COGNITIVE PSYCHOLOGY AS AN EXPERIMENTAL SCIENCE

A. Psychology Is a Research Science, Not a Mature System

When they hear the word "science," many people think of mature systems, such as planetary mechanics, thermodynamics, electromagnetism, or optics. They do not recognize the differences between these relatively advanced systems (Hanson, 1958) and very active research sciences, such as molecular biology, microphysics, and most areas of psychology. Mature systems were once wide-open research sciences; many experiments were done to answer questions about their subject matters. But today, many questions have been answered. The natural systems associated with these fields are now well understood, although they are sometimes subject to reinterpretation. Today, experiments are rarely conducted on fundamental issues. In fields like psychology, however, scientists are actively engaged in the most fundamental kinds of research. The answers to most of their questions are not known. No field of contemporary psychology has achieved the status of a mature science. Psychology is dynamic, changing, and unsettled, and it ranks among the most exciting of research sciences. This is one reason that psychology courses often do not seem to hang together—changes are first taught in the area that originated them, and other areas may not reflect the change for some time.

Learning a dynamic research science is different from learning an advanced system. An immature research science has a multitude of unanswered questions, and the student will find that many of them have not even been clearly asked. There is often substantial disagreement between scientists over how to frame the questions and about what evidence would answer them. You will be frustrated indeed if you approach an active research science like psychology as if it were made up primarily of finished systems of established facts and agreed-upon theories. Learning psychology consists as much in learning the current questions, controversies, and research approaches as it does in learning established facts. There is no single theoretical scheme to organize the facts and questions of a dynamic research science, as there is for more established fields. Moreover, the questions, controversies, and approaches within an immature and dynamic research science have hardly ever been selected by applying textbook rules of scientific procedure. The choice of research questions, the character of current controversies, and the kinds of research approaches in use are comprehensible and interesting only in view of their social-intellectual roots. Throughout this book, we have provided the relevant contemporary antecedents and recent history to help make cognitive psychology orderly.

The controversies between scientists in an active research field can be particularly disorganizing for students. The student's problem is to distinguish the controversies that are central to the field, or at its frontiers, from those that are peripheral. Methodological issues can and often do fascinate research scientists; there are occasional researchers who make whole careers pursuing them. George Miller, a leading cognitive psychologist, has argued that methodological issues are bread and butter to the working scientist but can be spinach to everyone else. We have tried to avoid this source of difficulty by not presenting issues whose resolution will have limited effects on cognitive psychology. We have not presented data about issues which we judge peripheral, even if there are numerous experiments on them in the technical literature of our field.

It is also true of a research science that seemingly well-established facts are sometimes called into question by single pieces of conflicting data or by novel interpretations of old results. The facts and theories of a research science are variously qualified, depending on which other facts and interpretations one acknowledges. When writing about research sciences, textbook writers often try to present all possible qualifications to every fact or interpretation they discuss. This thoroughness can ensure that they will not offend the scientists who have discovered the qualifications, but it can also obscure the major generalizations that a student strives to grasp. The main outlines and important features of a research science can sometimes be seen more easily by simply ignoring data that are endlessly qualified and requalified. In this book, we have omitted qualifications that seem to confuse rather than clarify fundamental issues. We have tried, in short, to strike a balance between oversimplification and overcomplication.

Science is a human institution, and as such it suffers from human frailties and shortcomings. It is important to distinguish the actual from the ideal conduct of science as a preliminary to understanding the activities within a particular scientific field, such as cognitive psychology. Much of the chaos that so often seems to characterize an active research discipline results from an incongruence between the way the discipline is said to be studied and the way it is actually carried out. One reason research sciences often seem incomprehensible to the beginner is that the published research report often does not correspond in a one-to-one fashion to the actual conduct of inquiry. Scientific research is sometimes portrayed as if it were a completely rational, progressive business that moves steadily forward. New questions are supposedly generated only by gaps in knowledge or by unexplained facts. Experiments are presumably conducted only to test deductions from scientific theory. Theories are wisely discarded if the experiments give results that do not conform to the deductions from them; and the best theory is adopted, though only tentatively, of course. Few working scientists actually accept this as an accurate account of how science is done. A careful examination of the theoretical and experimental activities of scientists suggests that scientific inquiry is considerably more complicated and much more interesting than this false stereotype (Kessel, 1969).

This stereotyped view of science might be the only way to teach a high school course or the most elementary college course, but it causes great grief to the serious student. It provides no way of understanding why obviously important issues go completely unresearched, while experiments on some minor topics fill whole journals and books and then disappear. Why do so many experiments sometimes produce so little progress in theory? How can well-established theories be completely discarded and replaced by new ones? The stereotyped view leaves questions like these completely unanswered, and science ends up seeming incomprehensible. It is not. Questions like these can be answered. The answer begins here: There is more than one set of rules by which science is done.

B. A Fundamental Premise: The Rational and Conventional Rules of Science

Every scientist has made a commitment to certain procedures that qualify his or her work as "science" rather than as something else. These rules are well known and publicized; they constitute the *scientific method.* The rational rules of science are quite similar from one discipline to another. They are shared by physicists, biologists, and social scientists. However, if you have ever tried to use your understanding of a physical science to understand psychological research, you have probably found that there were as many differences as commonalities. Understanding the rational rules is essential, but it is not enough to render the actual experiments and theories of a science obvious and comprehensible. The reason is that every scientist uses a second set of rules in addition to those of the scientific method. The second set of rules is *conventional*, in the sense that several or many scientists agree that they are appropriate. However, while every science has conventional rules, they are not the same from one scientific discipline to another. Even scholars within a single discipline may subscribe to different conventional rules. When a group of scientists share essentially the same conventional guidelines for formulating research questions and structuring experiments to answer them, they are members of the same scientific paradigm.

The *fundamental premise of this book* is that an active research science cannot be intelligently understood by reference to the rational rules of science alone. It is equally necessary to understanding the paradigm that guides the scientists who do the experiments. Without understanding the paradigm, a student may find the experiments unrelated to each other; or the answers the experiments are supposed to provide may seem incomprehensible. The questions the scientists have chosen to ask may seem trivial or exotic, and their controversies may resemble tempests in teapots. However, to the student who grasps the paradigm guiding the research, the relationship between theory and experiment will become clearer. The way in which experiments relate to each other will become more evident. The questions scholars in the field have chosen to ask will not seem so arbitrary, and their approach to answering the questions will look more reasonable. The field as a whole will have coherence and relevance to the student who understands the intellectual motives of the scientists who comprise it—include their rational rule system and their conventional, paradigmatic one.

1. The Rational Rules

Let us first consider the rational aspects of science, for it is these that distinguish science from other human institutions that make claims about human nature. Religion, art, poetry, political organizations, legal scholars, the military arts, encounter groups, and meditators are all sources of claims about people—their motives, essence, and actions. There are at least two fundamental differences between scientific methods for the study of mankind and nonscientific methods, such as religion and political ideology. The first concerns their objectives. Science may be unique, in that it is the only institution whose ultimate objective is obtaining knowledge for its own sake. The rational rules prescribe no prior commitment to what the truth is; the institution is designed to discover the truth and, when it is found, either to stop there or to transmit the findings to technology. Other institutions, such as religion and politico-legal systems, also make and defend claims about the way people actually are; but these claims are primarily in support of the institution's role in defining correct and incorrect action. The truth claims are not an end unto themselves, but are offered as foundations for prescribing moral rights and wrongs. The formal institutional rules of scientific method include no way to translate scientific discovery into prescriptions of the right thing to do; in fact, they preclude it. Science's rational component, for example, may be used to determine the number of deaths attributable to abortion or how to reduce this number, but it cannot render a judgment whether abortion is right or wrong. The rational rules can provide estimates of the incidence of premarital sex, but they cannot be invoked to judge the moral appropriateness of sex before marriage. It is true that scientists sometimes go on record for or against some moral principle, and this is legitimate if they are speaking as persons with moral views. However, the community of scientists does not accord universal adulation to a colleague who represents his moral conclusions as scientific discovery, however much they themselves may agree with the conclusions.

The second major difference between the rational rules for scientific conclusions and alternative methods resides in the scientific ideal for verification. The rational component of science demands that scientific beliefs at some point be tested against observable evidence. Science, in principle, has no axioms that are sacred and invulnerable to observational test. As we shall see, there are paradigmatic assumptions that may in fact never be tested, and that serve as a starting point for theory construction; but ideally even these assumptions are candidates for abandonment in the face of contrary observational evidence. As we shall also see, there is considerable latitude in the way observations relate to theoretical claims; but in the rational rules of scientific procedure, observational data provide the final criterion for determining the truth or falsity of such claims. Other sources of knowledge claims do no institutionalize observational data to this extent. In religion, for example, new claims are considered in light of their consistency with the axioms of the faith. Claims that are derived from the axioms are considered true; claims that are inconsistent with the axioms or their derivatives are false. The axioms are permanent, given, and unquestionable; their source is divine revelation. For example, Milne (1952) wondered whether Christian theology was threatened by the existence of countless planets in the universe, any one of which might contain intelligent beings. He noted that the Christian would either have to deny the existence of life on other planets or accept the possibility that the Incarnation of Christ was repeated countless times throughout the universe. A theologian (Mascall, 1956) considered this possibility from a theological point of view, and argued that Milne had a poor understanding of the fundamental Christian position on the Incarnation. Nothing in that position precluded the possibility that man might be one of a family of intelligent beings redeemed by Christ, or that man might be the only species that had fallen and needed redemption, or several other possibilities. The point here is that Mascall considered the findings of cosmology as they related to the axioms of Christianity. His theological judgment rested on consistency with these axioms rather than on observational test. Acceptability of truth claims, thus, rests on a different basis in religion and in the formal rules of science.

The test of truth in political ideologies is also consistency with a set of axioms, although these axioms may have a different source from those of religion. They may consist of truths held to be self-evident, as in the American Declaration of Independence. Or they may be rooted in divine will, as is the doctrine of the divine right of kings. They may rest on a particularly influential analysis of historical forces, as does Marxism. Whatever the source, however, the axioms that form the basis of political ideology are not open to question. New situations are analyzed in terms of the existing axioms and are not taken as potential evidence that the axioms are wrong. Political and religious institutions contain no mechanism for changing the axioms; such change is not part of the institution's internal structure. This is one difference between such systems and science. Even well-established beliefs in science are in principle open to question, and their occasional abandonment is considered an acceptable part of the way science is supposed to function.

Thus, the rational rules of science differentiate scientific claims from those of other institutions that also make assertions about nature. Perhaps for this reason, scientists are somewhat self-conscious about how they prove their claims. Many, many textbooks describe the rational procedures for scientific verification of truth. All scientists know these rules well, and there is no question that they guide scientists in their daily work. But they are not the only guide scientists use. There are also the conventional parts of scientific decision making.

2. *The Conventional Rules*

It has been known for a long time that scientific inquiry takes much of its direction from certain intellectual commitments that scientists have *not* clearly stated (cf. Polanyi, 1962; Popper, 1959). Still, until recently, most textbook accounts of the rational component of science presented it as if it were an essentially complete account of how science is done. The problem is that the rules are *prescriptive* and define how science should be done. To understand an actual science, a student really needs *descriptive* information about how the science is actually done. Otherwise, the student's position is analogous to trying to understand congressional action by reference to the U.S. Constitution and Robert's Rules of Order. Certainly, these codified rules place constraints on what senators and representatives do. However, much of what occurs in congressional sessions must be explained by reference to particular personalities and the characteristics of their constituencies, special relationships between individual members of Congress, temporary alliances, and a host of other factors that could not be codified in the Constitution or parliamentary procedural rules. This does not mean just covert violations of the rules, such as influence peddling or bribery. Many deals are made off the floor, with members of Congress agreeing to vote for each other's bills. This is a perfectly legitimate activity; it is not precluded by the Constitution, but neither is it explained by the Constitution. The length of filibusters, the function of party whips, and even the positions taken by members of opposite political parties can be understood only by reference to pragmatic factors outside the scope of the Constitution and Robert's Rules. It is not that these documents are wrong; but in accounting for the activites and votes of real senators and representatives, they are incomplete. So it is with the rational rules of science.

The canonical (rule-governed) component of scientific method requires that hypothetical accounts of natural-system properties be verified by observation. Empirical corroboration in science is a complex and controversial subject. However, even though it is an oversimplification, it is reasonable to say that the rules provide some guidance in how to make observations that will confirm or disconfirm proposed accounts of nature. There are prescribed methods, for example, of structuring an experiment so as to isolate the causal effects of a particular variable. However one views the current state of development of canonical methodology, the rules are of little help in choosing which variable to study. The rational component of science provides much more guidance in *how* to observe than in selecting *what* to observe. In selecting what to observe, a researcher must rely on other sources of ideas—and the source that most researchers use is the "collective wisdom"of other researchers in the field. Such collective wisdom results partly from previous observation and experimentation; but it is also the product of "working assumptions" that others have made and found useful in formulating previous research. The working assumptions may never have been directly validated by experiment. They may have been indirectly supported, in the sense that productive experimentation has resulted from making them; and many scientists in the field may be quite convinced of their validity. However, the fundamental status of such working assumptions is different from empirically validated fact. They are consensually validated by collective judgment, not confirmed by direct experimental test.

Interpretations that are made of experimental data are also influenced by "collective wisdom." The rational rules of science impose some constraints on how a researcher may interpret his observations; for example, he cannot ignore the requirements of logic. Nevertheless, logical requirements do not completely determine a researcher's interpretations. The behavior of a rat in a Skinner box has at various times been interpreted as verifying, or not verifying, claims about how animals learn; and "animals" has been taken to include people. But to invoke the data of rat experiments in theories of complex human learning, one must assume that human and rat learning is similar in essential respects. Is this assumption empirically justified? Are there experiments in the psychological literature that have directly tested it? The answer is no, although for many years the assumption was widely accepted among experimental psychologists. Today, very few cognitive psychologists are comfortable with the assumption that complex human learning can be understood by extrapolation from the behavior of rats. Psychologists of human learning once supported such an assumption by consensus; but now their collective judgment has changed. Is this because experiments have proved the assumption wrong? The answer, again, is no. No one can point to a single experimental outcome that changed nearly everybody's mind. The change resulted from informal judgments rather than the application of formal scientific methods. The judgments were made by intelligent and well-read people who know a great deal about the experimental data of psychology; but they were judgments nonetheless. If the assumption of essential comparability between human and rat learning had been directly rejected by experimental observation, every respectable behavioral scientist who knew his trade would by now have abandoned it. However, there are perfectly respectable scientific psychologists, whose sanity, honor, and intellect are not in question, who still feel that animal behavior can illustrate important aspects of complex human learning abilities. Among students of complex human learning they are a vanishing minority, but their very existence is evidence that the rules of scientific procedure leave considerable room for different strategic interpretations of data on the part of decent, intelligent scholars.

The *central premise* of this book is that the character of a science is shaped as much by paradigmatic judgments as by the canons of scientific method. Consequently, understanding the paradigm is as much a part of learning the field as studying the experiments themselves. Like all judgments, paradigmatic ones leave room for fundamental differences in approach. If the rational rules of science determined all aspects of scientific decision making, there would be no room for different approaches and no need to learn paradigms. When differences of opinion arose, we would simply do the necessary experiment, and everyone would draw the same conclusion from the outcome. *This ideal state of affairs does not obtain and never will.* Partisans of different paradigms do not agree on what the "necessary experiment" should look like. Typically, they do not usually communicate and therefore do not discuss the matter. If they did communicate, competent scholars would still disagree on what the outcome means if they did not share the same conventions for interpreting results. It is not the *data* about which they might disagree; it is the *meaning* of the data. While all competent observers might agree that an experimental rat turned left at a certain time under certain conditions, some may absolutely refuse to draw any conclusion about human activity from this fact. Does this mean that a set of consensually validated judgments is essential to make rationally derived scientific observations meaningful? We think precisely so.

Seeing that both conventional and rational systems guide what scientists do is particularly informative for psychology students. The key point is that one cannot completely make sense of a scientific literature containing only the rational component. One must also understand paradigmatic decision making in science. Psychology has had more than its share of paradigmatic shake-ups in its short history, and these are best explained by reference to the tacit, conventional component of scientific psychology. The shake-ups are completely incomprehensible to the student who believes that a good scientist follows the data wherever they lead and that only incompetent or dishonest scientists let their preconceptions determine the experiments they do and how they do them. Actually, all scientists regularly let their preconceptions dictate what they will do next. They fall back on their conventional wisdom whenever the rational rules fail them, which is often. The scientist makes many decisions by reference to an inexplicit ideology acquired through years of professional training. This ideology—the researcher's scientific paradigm—should not be viewed as an irrational character flaw that detracts from the rationality of science. Rather, it is an essential supplement to the rational aspects of scientific procedure. The paradigm forms the context in which the rationally derived procedures of science can be meaningful and interpretable. Learning the paradigm of a scientific discipline is a large part of becoming an expert in the field. It is just as important to absorb the conventions for motivating experiments and interpreting experimental data as it is to become familiar with the facts. As our opening quote from Polanyi (1962) illustrates, the facts really do not "speak for themselves."

Thomas Kuhn (1962) was the first to introduce a systematic treatment of paradigms in science; and he did so in the context of a distinction he wished to make between "normal" and "revolutionary" science. The impact of paradigms on the practitioners of science is quite different in periods of normal and revolutionary science, but it is present in both.

C. Normal and Revolutionary Science

Since Thomas Kuhn published his book on comprehensive scientific paradigms in 1962, there have been several important reactions. Kuhn's book has become the most widely read interpretation of the nature of science. His original viewpoint has been the subject of a variety of criticisms in the literature on the philosophy of science. In response to his critics, Kuhn has changed various details of his position (1962, 1970a, 1970b, 1970c, 1974). Before publication of the original treatise, an "accumulation model" of scientific knowledge was the dominant conception. According to this view, progress in science consisted of the cumulative growth of factual discoveries, improvements in methods, and theoretical generalizations. Kuhn challenged this pervasive view. He argued that, in advanced and mature sciences, progress is not linear but alternating. He suggested that theoretical sciences cycle between a state he called *normal science* and a state of extraordinary or *revolutionary science.* Normal science consists of coherent traditions of day-to-day research activities. These activities are theoretical, methodological, and experimental; and they are justified and unified by the paradigm from which they emerge. The paradigm includes the intellectual commitments and beliefs of a community of like-minded scientists; it provides model problems to the community and defines the domain of acceptable solutions. The paradigm is not necessarily identified with a particular scientific theory, law, or method. It is more global, taking in the full range of implicit and explicit communal assumptions. Normal science is guided and structured by the paradigm. It produces research that extends and elucidates those facts that the paradigm suggests are most revealing. The paradigm sanctions methods known to, and accepted by, the paradigmatic community. In the course of normal science, the methods may also be extended, modified, and refined. As normal science proceeds under the auspices of a given paradigm, Kuhn describes two things that happen in advanced, mature disciplines such as physics: A stable body of knowledge grows and develops, and a small number of unsolved—perhaps insoluble—problems accumulate. The unsolved problems are called *anomalies.* One kind of anomaly is the failure of well-established theories, sanctioned by the paradigm, to predict experimental outcomes. Another is the failure of experiments to replicate. Whenever experimentation persistently fails to produce results consistent with the way the science has integrated and interpreted broad areas of prevailing knowledge, an anomaly exists. When enough anomalies arise, or when a particularly striking anomaly is reported, the discipline may go into crisis and change in character from normal to extraordinary science. If an alternative paradigm is put forth that can resolve the anomalies and shortcomings of the dominant one, a scientific revolution takes place. Scientific revolutions, in Kuhn's view, are noncumulative episodes in which most practitioners reject a dominant paradigm and accept, in whole or in part, the new commitments of a new paradigm. The revolutionary change to a new paradigm may mean significant changes in the scientists' conception of what problems are important, what solutions are acceptable, and what theoretical language is appropriate to those solutions. This is a truly revolutionary state of affairs, much like an ideologically based political revolution. As a matter of fact, the term "revolution" in politics came from science. It originated in the title of Copernicus' book referring to the revolutions of heavenly bodies—a book that provoked the archetype of all revolutions, intellectual or political.

Kuhn's book accelerated the rejection of views about science that had been accepted for many generations. Not surprisingly, his thesis has been vociferously attacked, mainly by philosophers of science (Lakatos, 1970; Popper, 1970; Shapere, 1971; Scheffler, 1972). One major objection concerns the concept of "paradigm," and a second is Kuhn's alleged acceptance of "irrationality."

Kuhn uses the paradigm concept in two important ways. One usage is essentially sociological, and refers to a community of scientists who function rather like a culture or subculture. The other usage refers to the particular commitments of the scientific culture: the scientific beliefs and values of the paradigmatic community and the particular puzzles, problems, and solutions those values support. Because a paradigm develops conventionally, without explicit documentation of its rules, some philosophers of science have rejected the "paradigm" concept as too vague and intuitive. But of course many useful concepts, such as "culture" and "common law," are likewise vague and intuitive and require development; nevertheless, they refer to a coherent reality. As a matter of fact, even critics who reject Kuhn's conception of the paradigm concept concede the distinction between normal and revolutionary science (e.g., Popper, 1970; Shapere, 1971). Because the rational rules do not change during revolutions, the distinction implies the existence of some other source of the overriding commitments that do change when scientific revolutions occur.

Other critics charge that Kuhn essentially defends irrationality (Suppe, 1977). This charge stems from the way Kuhn developed the concept of paradigms. His thesis implies that choice among paradigms cannot be made on reasoned objective grounds. One paradigm can never be objectively proven to be better than another. The problem is less with Kuhn, in this case, than with the philosophical conception of "rationality." The concept is somewhat underdeveloped, and for some philosophers encompasses only those judgments and conclusions that can be supported by existing formal or mathematical reasoning. Human reason, including that of scientists, no doubt includes components that have not yet been formally characterized. Kuhn's thesis is not that scientific judgments are made irrationally. We understand him to mean only that many such judgments involve a kind of reasoning that philosophers have not yet formalized.

Kuhn's conceptions on the growth of scientific knowledge have helped replace a long-prevailing view of science. That view, which grew out of the earlier tenets of logical positivism, fostered an unnaturally static view of the methodology of science. All competent students of science agree on the dynamic, everchanging character of the scientific enterprise: Methods, assumptions, facts, and theories are all continually modified, updated, reinterpreted, and sometimes abandoned. The process of change is surely one of the universal features of the scientific enterprise. Kuhn's formulations will likewise be altered, refined, and reinterpreted to give a richer and more accurate picture of modern science. Other philosophers of science are attempting to formulate their own accounts of the underlying systems of working assumptions used by scientists. These accounts are not identical with Kuhn's, of course, and their authors use different terms to avoid conceptual confusion. For example, Lakatos (1970) uses the term "problem shifts" rather than "revolution," and "research programs" instead of "paradigm." Toulmin (1972) characterizes scientific "disciplines" and their "evolution," and

Shapere (1977) describes scientific "domains" and how they are affected by "radical new hypotheses." The particulars of these alternatives differ from each other and from Kuhn's work. But all are attempting to deal with the reality that there are systems of assumption in science larger than formal theories, and to document how the assumptions change over time. Our treatment of the information-processing paradigm and its properties does not require a choice among the formulations that presently exist or are currently under development.

Kuhn's original analysis was developed for advanced, mature sciences, primarily the physical sciences. It requires some adaptation and modification as applied to psychology. We have taken the concepts of paradigm, normal science, anomaly, and revolution and have reconceptualized them to provide a novel account of cognitive psychology (cf. Segal & Lachman, 1972; Weimer & Palermo, 1973). Let us now take some of these rather abstract considerations and illustrate them by recent psychological events, in particular the decline of behaviorism. You have doubtless encountered aspects of behaviorism in one or more of your psychology courses, and we later describe in detail its impact on contemporary views of cognition. At one time, behaviorism was the dominant paradigm in American experimental psychology. It is no longer so. Let us consider this transition, which parallels the concept of a scientific revolution that Kuhn developed for mature sciences.

For many years, the majority of psychologists conducted normal scientific research into learning. Their research was based on certain important paradigmatic assumptions. They believed that most behavior was the result of learning and that relatively little could be attributed to innate abilities. They assumed that many species learned in the same way. They regarded learning as the formation of conditioned associations between external stimulus events and responses. These beliefs were not based on data, they were the conventional component of the scientific psychology of the time. The beliefs seemed plausible, and they helped psychologists decide what experiments were likely to be important and which observations would validly test their theories. For years, the study of learning proceeded as normal psychological science: Several theories of learning were formulated and tested with many experiments, which were usually performed on animals, such as the white rat.

Psychology entered a revolutionary period when many scientists began to question the conventional commitments of the learning theorists. The possibility of innate abilities was seriously reconsidered. Many psychologists came to believe that different species have different ways of learning. They raised the possibility that the formation of associations between stimuli and responses was not the only kind of learning. They even suggested that humans often learn in other ways. These changes in what psychologists believed were sometimes based partly on data, and sometimes on no data at all; but many researchers found the new commitments more plausible and more useful as guides to important and successful experiments.

The new beliefs were a massive challenge to learning theorists, because they struck at the very reasons for their research. If there were important innate abilities, then the centrality of learning to human behavior had been overplayed, and the energy devoted to studying it had been altogether disproportionate. If different species have different learning mechanisms, then data and theory about how animals learn might say nothing important about humans. If learning was not primarily a matter of conditioning, then painstakingly constructed theories of how stimuli are associated with responses by conditioning would be a small and perhaps trivial part of the science of psychology, rather than its very core. Such changed conceptions were revolutionary; they challenged the foundations on which most psychological theories were built; they implied that learning theory explained little of central importance. According to the new conceptions, it made no difference whether a particular learning theory was right or wrong: They were all seen as irrelevant, and research done to test any of them was uninteresting. The data collected when learning theory dominated normal psychological science were either reinterpreted in light of newer paradigms or discarded as insignificant. Although these newer views are not universally accepted, they represent the judgment of a substantial number of cognitive psychologists.

Scientific progress is cumulative, but only during periods of normal science. During scientific revolutions the conventional part of a science is changed drastically, and some or all of the data and theory of the preceding normal-science paradigm may be thrown out, ignored, or reinterpreted. Why do new paradigms replace old ones in psychology? Because many psychologists find them more helpful in their daily decision making and in becoming a successful scientist. They help answer questions like these: What are the probable components of the system I am studying? What are the important scientific questions of today? What observations can I make to help answer those questions? What experiment should I do first? Which experiments should be done at all? What should I measure? What conclusions do my observations justify? Scientists must answer these questions, and they regularly do, without reference to the rational rules. They answer such questions by referring to their conventional, paradigmatic beliefs.

The concepts and idea systems that make up a scientist's paradigm are usually learned while he is a student. They are learned primarily in graduate school, where the beginning scientist picks up the tricks of his trade. Some examples of conventionally accepted psychological concepts are the stimulus–response association, secondary reinforcement, uncertainty, representation, and propositional meaning. You may not have encountered the last two in previous courses, but they occur frequently in this book. Individual researchers may differ in how they use such concepts; but during periods of normal science, certain concepts are familiar to many scientists and their status is seldom questioned.

If scientists acquire their paradigms as students, what maintains their conventional beliefs later? The opinions of their peers, largely. Research is not a private matter performed alone in a laboratory. Psychologists, like all scientists, must regularly interact with one another. Although the public character of science is universally acknowledged, the extent to which the opinion of colleagues dictates a scientist's career and determines success is less widely appreciated. Whether or not a researcher publishes his experimental findings depends on other scientists; they read the reports and decide whether the work merits publication. When promotion is due, other scientists evaluate their colleague's scholarship and decide whether he or she will advance academically. When the scientist seeks money to support ongoing work, his or her research proposals are rated by colleagues; and unless they approve, the researcher receives no funds. Other scientists decide whether one's students should be graduated. When those students seek jobs, other scientists decide whether to hire them. Scientists have a deep personal investment in publishing their findings, in being promoted, in having the money to conduct their research, in having their students pass their doctoral examinations and find good jobs. These are some of the reasons it is to the scientist's advantage to gain and keep the high regard of fellow colleagues. This is far easier if one conducts one's research and trains one's students in a generally accepted paradigm.

Revolutionary science is extremely hard on established researchers, and this, too, contributes to the maintenance of normal science. Paradigmatic shifts beckon the established scientist to change his conception of reality and his view of his field. If he is to keep up, he must abandon familiar, well-understood concepts and ways of thinking; he must become something of a student again. He must retrain himself in a paradigm in which others are more expert. He may have to learn new research techniques. He may even have to abandon costly laboratory equipment that was suited to the old paradigm's research, and buy new equipment suited to the methods of the new paradigm. A scientist who is eminent in the practice of an established paradigm may become an obscure practitioner of an ascending one.

All this may suggest that scientists are bludgeoned into submission. On the contrary, most operate very comfortably within their scientific paradigm. Scientists have usually been trained in their paradigm, and they have a comforting sense of its correctness. It frees them from pondering extremely complex questions, such as "Where is my field going and how can I contribute to changing it?" It allows them to get on with their work. The community of scientists who share a paradigm function much like a family: They support one another; they provide validation for one another's work; they understand in a way that others do not. And the paradigm provides convenient ways to discount the work of incompetents and maniacs. Remember, scientists are human too.

How, then, does a paradigm ever die or decline? What brings on a scientific revolution? Why doesn't normal psychological science run forever? Paradigms fall slowly, from the weight of repeated failure. Problems that all agree need to be solved go untouched by research within the paradigm. Or, a particular kind of experiment may consistently fail to come out according to paradigmatic expectations. The unexpected results may be impossible to interpret within the paradigm unless the scientist makes absurd assumptions. Such occurrences can produce great dissatisfaction with a prevailing paradigm. Frustration can also result from the failure of experimental results to hold across similar settings. Experimental changes that are trivial according to the paradigm may completely reverse the outcome of an experiment. There is nothing quite so frustrating in the everyday life of a research psychologist as losing his usual findings by virtue of seemingly insignificant procedural variations. Another contributor to the fall of a paradigm is a sense that theory is not developing. Facts about the same behavioral system seem to remain unrelated for long periods of time. Even though there are many social pressures to continue normal science as usual, circumstances like these lead scientists to seek new ways of viewing their field. For example, one factor leading to the information-processing revolution was the lack of progress in understanding how people learn to read. There was enormous dissatisfaction with progress—in fact, there was none. A book written in 1908 remained, in 1968, the best available work on human reading, and was reprinted that year (Huey, 1908/1968). For a psychology that had for years been deeply committed to understanding learning, this was intolerable. The importance of reading could not be denied, but research based on learning theory ran into repeated dead ends. Ultimately, psychologists sought new approaches, and the information-processing revolution began. It has turned out to be more congenial to the study of reading; but most important to its initial success was the fact that it was there and that it represented a viable alternative.

Most scientific revolutions affect only the scientists whose old paradigm is replaced. Occasionally, however, enough sources of dissatisfaction with prevailing views come together to produce a seismic change in the general orientation, ideology, and activities of many scientists. A rare and very special type of scientific revolution changes even society's conception of man and the universe he inhabits. During the Copernican revolution, people's conception of their universe changed so that the sun rather than the earth came to be regarded as the center of their planetary system. The Copernican revolution also changed our view of how theories are "proved"; it was *the* scientific revolution. By believing Copernicus, Western society first accepted the view that observation and logic, not religious authority, should validate accounts of reality. In biology, the rise of Darwinian theory during the last century and, more recently, the ascendence of molecular biology are other examples of encompassing scientific revolutions. Freud presided over one such revolution in psychology, as did John Watson over another. In all of these examples, revolutionary conceptions of man and his universe spread through society. They profoundly influenced institutions outside of science: the church, the law, the educational system, politics, child-rearing, and so on (Segal & Lachman, 1972).

D. Paradigms in Psychology

Thomas Kuhn's ideas about paradigms and different kinds of science is gradually developing an enormous impact on how scientists think about themselves and their institutional enterprise. His views have also been extended and clarified by others. Masterman (1970), for example, has argued compellingly that paradigms play somewhat different roles in different sciences. She implies that there is a kind of developmental sequence of scientific disciplines. In the early days of a discipline, there is nonparadigmatic science: All facts are equally relevant; there are no overriding commitments to a particular conception of subject matter, to a particular method of study, or to a particular set of concepts. As the discipline develops, it becomes multiparadigmatic. Many paradigms vie simultaneously for the attention of the scientific community. Sometimes the different paradigms interact and influence one another; sometimes they do not. But eventually, in Masterman's scenario, one paradigm comes to dominate the discipline. This sets the scene for a scientific revolution. A new paradigm comes to challenge the prevailing one, and "a rank outsider with rudimentary new techniques may succeed in easily solving the major problems of the old paradigm (Masterman, 1970)."

This account describes science in a general way, but the real world is a bit more complicated. Certain branches of science may remain permanently multiparadigmatic. Several relatively dominant paradigms may maintain large constituencies and control most of the journals and meetings of the science. All the while, a number of less influential paradigms will continue to exist. This is now the state of science in psychology, and it may always be this way. The very early history of psychology may have been nonparadigmatic, but there have been multiple psychological paradigms since at least the turn of the century (Weimer, 1974; Weimer & Palermo, 1973). In our field, some paradigms simply change their relative dominance. Until the rise of Watsonian behaviorism, several paradigms claimed the allegiance of different groups of psychologists. Behaviorism appealed to more and more researchers until, by 1940, a variant called neobehaviorism had become the most dominant and popular approach to psychology. The dominance of neobehaviorism lasted for roughly 30 years, but no single paradigm replaced it. Today, psychology encompasses many paradigms, each of which is popular with a large identifiable group of scientists. The information-processing approach to cognition is one of these, and its influence is substantial.

III. CHARACTERISTICS OF PARADIGMS

By now it may have occurred to you to ask whether paradigms are theories. They are not, even though major paradigms are often associated with particular theories. The Newtonian paradigm and Newton's theory of celestial and terrestrial mechanics illustrate the difference. The theory described and predicted the motions of the planets in our solar system and described the interaction of bodies on earth. Its subject matter was thus only a part of what concerned physicists. The Newtonian paradigm suggested, for the whole field of physics, which problems were important, how they should be studied, and what concepts would most advance knowledge. Its basic concepts of absolute space, absolute time, and absolute motion were not replaced until the Einsteinian revolution. The Newtonian paradigm far outlasted Newton's theory. Newton's theory of the motions of physical bodies had been revised and updated many times—for example, by William Rowan Hamilton and Carl A. Jacobi in the nineteenth century and by Joseph Louis Lagrange in the eighteenth. But the Newtonian paradigm continued to influence all physical sciences for over 200 years. By 1900, physicists had materially changed their factual statements about planetary motion, but their paradigm was what it had been for nearly three centuries. Shortly thereafter, the paradigm of physics changed as well.

How can one psychological paradigm be distinguished from another? Paradigms can differ in several ways, although they sometimes differ in only one or two. A psychological paradigm can be identified by its intellectual antecedents, by its pretheoretical ideas, by its subject matter, by the concepts and language that its adherents use, by their preferred analogies, or by the methods and procedures that its scientists employ. Paradigms are also sociological phenomena. They arise around groups of scientists who communicate mostly with one another. When a group of scientists communicate frequently and are aware of and cite one another's research, they very likely share a paradigm. Let us now look more closely at the characteristics of psychological paradigms. We use these characteristics in the next three chapters when we describe the information-processing paradigm.

A. Intellectual Antecedents

We said earlier that the nature of a science at any point in time is comprehensible and interesting largely in view of its intellectual antecedents. A scientist's beliefs about his work are frequently dictated by his intellectual predecessors. Paradigms, then, can be distinguished by the intellectual antecedents of their adherents. These antecedents can be historic or contemporary. They are the sources of concepts and views that the scientist applies to his work. Scientists often borrow ideas from mathematics, philosophy, and other sciences, and the disciplines from which a paradigm has borrowed are its intellectual ancestors. Freudian psychology borrowed heavily from medicine. Behaviorism was strongly influenced by British associationism and the philosophy of logical positivism. Information processing has drawn extensively on concepts from engineering, computer science, and communication science.

B. Pretheoretical Ideas

Because sciences have intellectual antecedents, the scientist does not approach his subject matter naively, even if it is a new subject matter about which very little is known. In formulating questions that he might answer scientifically, the scientist draws on notions about the reality underlying his subject. His notions may come from earlier observations, from knowledge about other phenomena that he thinks are similar to his area of study, from well-established beliefs passed on to him from his teachers, or perhaps from his own idiosyncratic insight. Every scientist depends on a network of notions, which Holton has called *themata* (Holton, 1973, 1975). We prefer the term *pretheoretical ideas* because that term has been employed previously in the psychological literature. Pretheoretical ideas guide research, motivate scientists, and sometimes constrain their efforts. Themata, or pretheoretical ideas, are present in most concepts, methods, and propositions of science. They manifest themselves in each of the other dimensions of paradigms: their subject matter, concepts, analogies, and so on.

The pretheoretical ideas of cognitive psychology make up much of the next two chapters. Perhaps the best way to provide a preliminary sense of what we mean by pretheoretical ideas is through an example. To make it easier to distinguish our sample idea from validated scientific theory (which many pretheoretical ideas ultimately become), we will use an idea that proved incorrect. The work of Johannes Kepler provides such an example. Kepler was an astronomer who lived when planetary mechanics was a new science. To the study of planetary movements, Kepler brought his concept of the way things really were:

> The perfection of the world consists in light, heat, movement, and the harmony of movements. These are analogous to the faculties of the soul: light, to the sensitive; heat to the vital and the natural; movement, to the animal; harmony, to the rational. And indeed the adornment of the world consists in light; its life and growth in heat; and, so to speak, its action, in movement; and its

contemplation. . . in harmonies. (From Johannes Kepler, *Epitome of Copernican Astronomy IV and V,* translated by Charles Glenn Wallis, Great Books of the Western World, Volume 16, 853–857)

This notion of a universe characterized by harmony served Kepler as a pretheoretical idea. It suggested to him that planets traveled in circles, since circles are more harmonious than ellipses. His data were Tycho Brahe's observations of planetary motion, which did not immediately support the idea of circular orbits. However, for 19 years Kepler sought combinations of circles that would give him an orbit for the planet Mars that could be reconciled with Brahe's actual observations. He worked for all those years without success, and eventually he gave up the pretheoretical idea of circularity. Ultimately, Kepler himself demonstrated that it was much simpler to suppose that the planets actually traveled in elliptical orbits.

Incorrect pretheoretical ideas are easier to identify as conventionally derived than correct ones. However, our illustration should not suggest that such ideas are always—or even usually—wrong. Even those that do not seem to fit the data may not be wrong. An example of an extremely influential pretheoretical idea was the unshakable commitment by R. A. Millikan to an atomistic conception of electricity. Millikan lived early in this century, and his belief that electrical phenomena were the result of the actions of discrete elements, which we now call electrons, predated any experimental verification and was maintained in the face of indifferent data (Holton, 1973). Ultimately, Millikan conducted confirming experiments that gave his pretheoretical ideas an enduring scientific acceptance, unlike Kepler's idea of circular orbits.

Pretheoretical ideas operate in all sciences, and each paradigm within a science can be identified by its pretheoretical ideas. In information-processing psychology, most researchers believe that new inputs and old knowledge are represented in some "format" within the system. This pretheoretical idea is reflected in many of our theories involving formulations about the nature of mental searches, recoding of input into different formats, and internal-comparison operations.

A scientist's pretheoretical ideas are his conception of the reality underlying his subject matter. These ideas guide his definition of his subject matter by suggesting what are, and what are not, instances of the phenomena he wishes to study. They suggest what questions should be answered: For information-processing psychology, proper questions concern how information is represented, the nature of its code, how searches proceed, how "matches" are determined, and so on. By suggesting the questions, pretheoretical ideas often also suggest an appropriate methodology for obtaining the answers. Pretheoretical ideas often derive from a preferred analogy—a notion that one's science involves a reality similar to some better understood phenomenon. This in turn often suggests that terminology borrowed from the better understood area will be appropriate to the borrowing science as well. As you can see, then, the elements of a paradigm are not independent of each other; they function together as an interrelated system of ideas and concepts that give a scientist a particular "slant" on his field of study. We separate these elements for analytical purposes, but keep in mind that they are component pieces of a picture, each of which involves the other.

C. Subject Matter

Choosing a subject matter amounts to deciding what questions should be answered—selecting those questions whose answers seem to promise the most complete account of the natural system under study. In psychology, the natural system is the behavior of living creatures, especially human beings. Some psychologists believe that the most important aspect of people is their personalities. These researchers are likely to study individual differences, or people whose personalities are deviant. Others believe that learning is the most fundamental characteristic of living organisms, and they are apt to study how people and other animals acquire new responses. These psychologists will tend to overlook individual differences, and are usually more interested in typical performance than in extraordinary circumstances. Still other psychologists are interested in how people use language. They also are less likely to study individual differences, and are usually more interested in normal performance than deviant linguistic behavior.

The same questions recur continually within a conventional or paradigmatic group. While its choice of subject matter does not always define a particular paradigm, different paradigms are often best suited to the study of different subjects and hence become closely associated with them. Cognitive psychology is coming to be identified with the information-processing paradigm, because it has proved more successful than others in advancing our understanding of the higher mental processes.

D. Analogies

When scientists turn to the study of things they know little about, they often borrow principles from better-understood areas to guide their new research. When physicists first began to study gases, they borrowed principles from mechanics, postulating that gases were composed of something that behaved much like billiard balls or planets. Consequently, long before we understood molecules, the molecular action of gases was characterized with the same principles that accounted for the motion of visible bodies. Physicists could have used an analogy to some other phenomenon, such as ocean waves, and it would have misled them.

Analogies are also used to develop psychological theories. In Freud's psychoanalytic theory, sexual energy is viewed as a hydraulic system. According to this view, a person is subject to internal pressures that require release; if one outlet is plugged, the pressure will find another. This analogy directly underlies the psychoanalytic view of symptom substitution: If a patient's symptom is removed, but his basic personality remains unchanged, another symptom will appear to take its place. Freud's use of such analogies probably resulted from his medical training, according to which bodily organs were considered analogous to mechanical devices, such as pumps and levers. A paradigm's preferred analogies influence its choice of research questions, suggest hypotheses for experimentation, and help in theory construction. Different paradigms typically rely on different analogies.

E. Concepts and Language

Adherents of a paradigm often borrow terms from other disciplines, but they also invent terms to handle the concepts and data peculiar to their paradigm. There is some overlap between the languages of different paradigmatic groups, but each usually has a set of terms unique to it. These terms include names for conceptual entities and processes. Some people argue that this difference in language is "just semantic." They believe that the language of one paradigm is interchangeable with the language of another. It has been argued that it makes no difference whether a scientist says *stimulus* or *input,* whether he says *response* or *output* when referring to the conditions under which people behave and what they do. According to this view, all of the terms are mere jargon. We disagree. It seems to us that the terms that scientists use reflect their beliefs about the basic properties of the system they are studying. A psychologist's terminology often reflects fundamental conceptions of people and their capacities. Referring to behaviors as outputs rather than as responses implies very different pretheoretical ideas about the mechanisms underlying behavior.

F. Research Methods

The adherents of different paradigms often use different research methods. The paradigmatic, conventional component of science often includes preferences for particular pieces of apparatus, for particular experimental designs, for particular independent and dependent variables. Information-processing psychologists show a preference for human subjects and temporal measures, often using tachistoscopes and reaction-time data. They vary such factors as stimulus complexity and task demands; they control such matters as grammatical complexity and stimulus probability. These preferences, and the reasons for them, are developed in the next two chapters. They are not the only methods one could use, but they reflect the influence of the information-processing paradigm. Such methodological preferences are not perfect clues; but they often distinguish one paradigmatic group from another.

IV. PARADIGMS, INFORMATION PROCESSING, PSYCHOLOGY, AND SOCIETY

A paradigm reflects the thinking of a community of scholars who talk largely to one another, cite one another's findings, and do similar work. Paradigms are basic intellectual commitments about how to do a science, about the importance of different problems, about what are "facts" and what are not, about language and concepts that are appropriate, and about the suitability of different kinds of theory to a subject matter. Many paradigms can exist simultaneously in a given science, and in psychology several do. There certainly are differences among psychologists adhering to a given paradigm, but the similarities of their commitments outweigh the differences among them. Differences among paradigms are sometimes cast as issues of which is more scientific, but paradigmatic variations are far more subtle and more complex than that. Consider the metaphor of driving from New York to California. Many routes will get you there; no single way is absolutely correct. Some ways are more efficient than others; some are more beautiful; some are safer. People impose order on their world in their efforts to understand it; and it is impossible to absolutely value any single ordering scheme above all others. Nature can be ordered in many ways.

We have written this book from the point of view of one particular paradigm—information processing. We do not argue that it is *the* right way to understand and explain human mental processes, but we believe that it is at the present time the most comprehensive and comprehensible way. The recent ascendancy of information processing is a significant change in the study of higher mental processes. The change was essentially paradigmatic; it concerned man's basic character as well as theories of how he thinks. The information-processing paradigm made new questions interesting; it applied a new language to man's mental processes; it suggested new analogies for research into cognition; and it used some basically new techniques. This paradigm has potential applications beyond cognitive psychology—in clinical, social, and educational psychology, for instance. We would not be surprised to see the information-processing paradigm influence all of psychology. If it extends to the larger society as well, many people's conception of human nature will be affected.

It usually takes years for a change within science to affect the larger society. By now, most people have heard of Freud, but his impact on specialized psychology came over 50 years ago. Popular novels, child-rearing guides, and other printed materials now incorporate Freudian ideas, as if they were highly regarded and very contemporary among today's scientists. They are not; not many people realize how few courses in Freudian psychology are offered in most psychology departments today. The principles of behaviorism have been taught much more extensively over the last 40 years, but the general public knows far less about them. Some well-educated people have a general understanding of conditioning, but most do not. Information processing, which has been academically significant for 15 or 20 years, is still virtually unknown even to educated lay people. Students may come to college with a layman's acquaintance of approaches that may be 50 years behind events in particular sciences. In studying the contemporary literature, they must often leap over many years of thought within the science to catch up with prevalent paradigms. It is important for students to do this, both for themselves and for society at large. If only practicing scientists understand them, the newest paradigmatic developments will have little influence on society in general.

Even if we are wrong, and information-processing views never affect nonscientific social institutions, cognitive psychology has been profoundly influenced by the information-processing approach. Cognitive psychology is now identified as strongly with information processing as it is with the study of higher mental processes. The best way to understand this book and the field it deals with is to grasp the essentials of the information-processing paradigm. That understanding will make it much clearer why many rsearchers chose to do the experiments they did, and why they chose to do them as they did instead of some other way.

This book is designed to provide a thorough introduction to information-processing psychology. Chapters 2, 3, and 4 present in detail the characteristics of the paradigm and how it attained these characteristics. Later chapters present theory and data. As with all research sciences, the data are fragmented. The experiments will not answer all of your questions, as they have not answered all of the questions of the scientists who did them. But the studies represent what the science knows, where it is going, and how it expects to get there. The reader is not left to grapple alone with the fragmentation. Each chapter answers several of these organizing questions: Why are the contents of the chapter important? What do they mean to cognitive psychologists? What do the contents of the chapter add to our picture of humankind? How has the information-processing paradigm influenced the experiments discussed? We are convinced that if you learn the concept of a paradigm and the properties of the information-processing paradigm, you will be better able to tie together research on man's higher mental processes. Many students have used these ideas to make sense out of their other science courses as well.

References

Aderman, D. , & Smith, E. E. Expectancy as a determinant of functional units in perceptual recognition. Cognitive Psychology, 1971, 117-129.

Anderson, J. R. FRAN: A simulation model of free recall. In G. H. Bower (Ed.), The psychology of learning and motivation. Vol. 5. New York: Academic Press, 1972.

Anderson, J. R. Language, memory, and thought. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1976.

Anderson, J. R. Arguments concerning representations for mental imagery. Psychological Review, 1978, 85, 249-277.

Anderson, J. R. , & Bower, G. H. Human associative memory. Washington, D.C.: Winston, 1973.

Anderson, J. R. , & Reder, L. M. Elaborative processing of prose material. In L. S. Cermak & F. I. M. Craik (Eds.), Levels of processing and human memory. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1978.

Anderson, J. , & Whitten, L. Oddsmaker makes Humphrey 7-6 favorite over Ford. Record-Courier (Kent-Ravenna, Ohio), November 24, 1975, p. 9.

Anderson, R. C. , & Ortony, A. On putting apples into bottles—A problem of polysemy. Cognitive Psychology, 1975, 7, 167-180.

Anderson, R. C. , Pichert, J. W. , Goetz, E. T. , Schallert, D. L. , Stevens, K. V. , & Trollip, S. R. Instantiation of general terms. Journal of Verbal Learning and Verbal Behavior, 1976,15, 667-679.

Angell, J. R. The province of functional psychology. Psychological Review, 1907, 14, 61-91.

Atkinson, R. C. , & Crothers, E. J. A comparison of paired-associate learning models having different learning and retention axioms. Journal of Mathematical Psychology, 1964, I, 285 315.

Atkinson, R. C. , Herrmann, D. J. , & Wescourt, K. T. Search processes in recognition memory. In R. L. Solso (Ed.), Theories in cognitive psychology: The Loyola Symposium. Potomac, Md,: Lawrence Erlbaum Associates, 1974.

Atkinson, R. C. „ & Juola, J. F. Factors influencing speed and accuracy of word recognition. In S. Kornblum (Ed.), Attention and performance IV. New York: Academic Press, 1973.

Atkinson, R. C. , & Juola, J. F. Search and decision processes in recognition memory. In D. H. Krantz , R. C. Atkinson , R. D. Luce , and P. Suppes (Eds.), Contemporary developments in mathematical psychology. San Francisco: Freeman, 1974.

Atkinson, R. C. , & Shiffrin, R. M. Human memory: A proposed system and its control processes. In K. W. Spence & J.T. Spence (Eds.), Advances in the psychology oflearning and motivation research and theory. Vol. 2. New York: Academic Press, 1968.

Averbach, I. , & Coriell, A. S. Short-term memory in vision. Bell System Technical Journal, 1961, 40, 309 -328.

Axelrod, S. , & Guzy, L. T. Underestimation of dichotic click rates: Results using methods of absolute estimation and constant stimuli. Psychonomic Science, 1968,12, 133-134.

Ayer, A. J. (Ed.). Logical positivism. New York: Free press, 1959.

Baddeley, A. D. The psychology of memory. New York: Basic Books, 1976.

Baddeley, A. D. , & Ecob, J. R. Reaction time and short term memory—Implications of repetition effects for the high speed exhaustive scan hypothesis. Quarterly Journal of Experimental Psychology, 1973, 25, 229-240.

Baddeley, A. D. , Grant, S. , Wight, E. , & Thompson, N. Imagery and visual working memory. In P. M. Rabbitt & S. Dornic (Eds.), Attention and performance *{Vol.* 5). New York : Academic Press, 1975.

Baddeley, A. D. , & Hitch, G. Working memory. In G. Bower (Ed.), Recent advances in learning and motivation (Vol. 8). New York: Academic Press, 1974.

Baggett, P. Memory for explicit and implicit information in picture stories. Journal of Verbal Learning and Verbal Behavior, 1975, 14, 538-548.

Baker, L. , & Santa, J. L. Semantic integration and context. Memory & Cognition, 1977,5, 151-154.

Bamber, D. , Reaction time and error rates for "same"-"different" judgments of multidimensional stimuli. Perception and Psychophvsics, 1969, 6, 169-174.

Barclay, J. R. The role of comprehension in remembering sentences. Cognitive Psychology, 1973, 4, 229-254.
Barclay, J. R. , Bransford, J. D. „ Franks, J. J. , McCarrell, N. S. , & Nitsch, K. Comprehension and semantic flexibility. Journal of Verbal Learning and Verbal Behavior, 1974,13, 471-481
Baron, J. , & Thurston, I. An analysis of the word-superiority effect. Cognitive Psychology, 1973, 4, 207-228.
Bartlett, F. C. Remembering: An experimental and social study. Cambridge: Cambridge University Press, 1932.
Battig, W. F. , & Montague, W. E. Category norms for verbal items in 56 categories: A replication and extension of the Connecticut category norms. Journal of Experimental Psychology Monograph, 1969,50, 1-46.
Begg, I. , & Paivio, A. U. Concreteness and imagery in sentence meaning. Journal of Verbal Learning and Verbal Behavior, 1969, 8, 821-827.
Bever, T. G. , Fodor, J. A. , & Garrett, M. A formal limitation of associationism. In T. R. Dixon & D. L. Horton (Eds.), Verbal behavior and general behavior theory. Englewood Cliffs, N.J.: Prentice-Hall, 1968.
Bever, T. G. , Fodor, J. A. , & Weksel, W. On the acquisition of syntax. Psychological Review, 1965, 72(6), 467-482. (a)
Bever, T. G. , Fodor, J. A. , & Weksel, W. Is linguistics empirical? Psychological Review, 1965, 72(6), 493-500. (b)
Bever, T. G. , Lackner, J. R. , & Kirk, R. The underlying structures of sentences are the primary units of immediate speech processing. Perception and Psychophysics, 1969, 5, 225-234.
Biederman, I. , Glass, A. L. , & Stacy, E. W. Searching for objects in real-world scenes. Journal of Experimental Psychology, 1973, 97, 22-27.
Biederman, I. , & Stacy, E. Stimulus probability and stimulus set size in memory scanning. Journal of Experimental Psychology, 1974, 102, 1100-1107.
Bjork, R. A. Theoretical implications of directed forgetting. In A. W. Melton & E. Martin (Eds.), Coding processes in human memory, Washington, D.C.: Winston, 1972.
Bloomfield, L. Language. New York: Henry Holt, 1933.
Blumenthal, A. Observations with self-embedded sentences. Psychonomic Science, 1966, 6, 453-454.
Blumenthal, A. L. Prompted recall of sentences. Journal of Verbal Learning and Verbal Behavior, 1967, 6, 203-206.
Blumenthal, A. L. , & Boakes, R. Prompted recall of sentences: A further study. Journal of VerbaI Learning and Verbal Behavior, 1967, 6, 674-676.
Bobrow, D. G. , & Collins, A. (Eds.). Representation and understanding studies in cognitive science. New York: Academic Press, 1975.
Bobrow, S. A. , & Bower, G. H. Comprehension and recall of sentences. Journal of Experimental Psychology, 1969, 80, 455-461.
Boring, E. G. History of experimental psychology. New York: Appleton-Century-Crofts, 1950.
Boring, E. G. A history of experimental psychology (2nd ed.). New York: Appleton-Century-Crofts, 1957.
Bousfield, W. A. The occurrence of clustering in the recall of randomly arranged associates. Journal of General Psychology, 1953, 49, 229-240.
Bower, G. H. Stimulus-sampling theory of encoding variability. In A. W. Melton & E. Martin (Eds.), Coding processes in human memory. Washington, D.C.: Winston & Sons, 1972.
Bower, G. H. Cognitive psychology: An introduction. In W. K. Estes (Ed.), Handbook of learning and cognitive processes. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1975.
Bower, G. H. , & Reitman, J. S. Mnemonic elaboration in multilist learning. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 478-485.
Braine, M. D. S. On learning the grammatical order of words. Psychological Review, 1963, 70(4), 323-348.
Braine, M. D. S. On the basis of phrase structure. Psychological Review, 1965, 72(6), 483-492.

Bransford, J. D. , Barclay, J. R. , & Franks, J. J. Sentence memory: A constructive versus interpretive approach. Cognitive Psychology, 1972, 3, 193-209.
Bransford, J. D. , & Franks, J. J. The abstraction of linguistic ideas. Cognitive Psychology, 1971, 2, 331-350.
Bransford, J. D. , Franks, J. J. , Morris, C. D. , & Stein, B. S. , An analysis of memory theories from the perspective of problems of learning. In L. S. Cermak & F. I. M. Craik (Eds.), Levels of processing and human memory. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1978.
Bransford, J. D. , & Johnson, M. K. Contextual prerequisites for understanding: Some investigations of comprehension and recall. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 717-726.
Brewer, W. F. , & Harris, R. J. Memory for deictic elements in sentences. Journal of Verbal Learning and Verbal Behavior, 1974, 13, 321-327.
Broadbent, D. E. The role of auditory localization in attention and memory span. Journal of Experimental Psychology, 1954, 47, 191-196.
Broadbent, D. E. Perception and Communication. London: Pergamon Press, 1958.
Broadbent, D. E. Decision and stress. New York: Academic Press, 1971.
Brooks, L. R. The suppression of visualization in reading. Quarterly Journal of Experimental Psychology, 1967, 19, 289-299.
Brooks, L. R. Spatial and verbal components in the act of recall. Canadian Journal of Psychology, 1968, 22, 349-368.
Brown, J. A. Some tests of the decay theory of immediate memory. Quarterly Journal of Experimental Psychology, 1958, 10, 12-21.
Brown, R. A brief account of microscopic observations. In J. J. Bennett (Ed.), The miscellaneous botanical works (Vol. 1). London: Robert Hardwicke, 1866.
Brown, R. , Cazden, C. B. , & Bellugi, U. The child's grammar from I to III. In J. P. Hill (Ed.), Minnesota symposia on child psychology (Vol. 2). Minneapolis: University of Minnesota Press, 1969.
Brown, R. , & Lenneberg, E. H. A study in language and cognition. Journal of Abnormal and Social Psychology, 1954, 49, 454 462.
Brown, R. , & McNeill, D. The "tip of the tongue" phenomenon. Journal of Verbal Learning and Verbal Behavior, 1966, 5, 325-337.
Bugelski, B. R. Presentation time, total time, and mediation in paired-associate learning. Journal of Experimental Psychology, 1962, 63, 409-412.
Bugelski, B. R. Images as mediators in one-trial paired-associate learning. II: Self-timing in successive lists. Journal of Experimental Psychology, 1968, 77, 328-334.
Burrows, D. , & Murdock, B. B. Effects of extended practice on high speed scanning. Journal of Experimental Psychology, 1969, 82, 231-237.
Butterfield, G. B. , & Butterfield, E. C. Lexical codability and age. Journal of Verbal Learning and Verbal Behavior, 1977, 16, 113-118.
Carpenter, P. A. , & Just, M. A. Sentence comprehension: A psycholinguistic processing model of verification. Psychological Review, 1975, 82, 45-73.
Carpenter, P. A. , & Just, M. A. Models of sentence verification and linguistic comprehension. Psychological Review, 1976, 83, 318-322.
Carr, H. A. Psychology: A study of mental activity. New York: Longmans, Green, 1925.
Carroll, J. , & Payne, J. (Eds.). Cognition and social behavior. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1976.
Carroll, J. B. , & White, M.N. Word frequency and age of acquisition as determiners of picture-naming latency. Quarterly Journal of Experimental Psychology, 1973, 25, 85-95.
Cermak, L. S. , & Craik, F. I. M. (Eds.). Levels of processing and human memory. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1978.
Charness, N. Memory for chess positions: Resistance to interference. Journal of Experimental Psychology: Human Learning and Memory, 1976, 2, 641-653.
Chase, W. G. (Ed.). Visual information processing. New York: Academic Press, 1973.
Chase, W. G. , & Clark, H. H. Mental operations in the comparison of sentences and pictures. In L. W. Gregg (Ed.), Cognition in learning and memory. New York: Wiley, 1972.

Cherry, E. C. Some experiments on the recognition of speech, with one and with two ears. Journal of the Acoustical Society of America, 1953, 25, 975-979.
Cherry, E. C. On human communication (2nd ed.). Cambridge: MIT Press, 1966.
Chi, M. T. H. The representation of knowledge (Review of *Explorations in cognition* by D. A. Norman , D. E. Rumelhart , and the LNR Research Group). Contemporary Psychology, 1976, 21, 784-785.
Chomsky, N. Syntactic structures. The Hague: Mouton, 1957.
Chomsky, N. A review of Skinner's *Verbal Behavior. Language* , 1959, 35, 26-58.
Chomsky, N. Aspects of the theory of syntax. Cambridge: MIT Press, 1965.
Church, A. An unsolvable problem of elementary number theory. American Journal of Mathematics, 1936, 58, 345-363.
Clark, H. H. Linguistic processes in deductive reasoning. Psychological Review, 1969, 76, 387-404.
Clark, H. H. On the evidence concerning J. Huttenlocher and E. T. Higgens' theory of reasoning: A second reply. *Psychological Review* , 1972, 79, 428-432.
Clark, H. H. The language-as-fixed-effect fallacy: A critique of language statistics in psychological research. Journal of Verbal Learning and Verbal Behavior, 1973, 12, 335-359.
Clark, H. H. Semantics and comprehension. In T. A. Sebeok (Ed.), Current trends in linguistics. Volume 12: Linguistics and adjacent arts and sciences. The Hague: Mouton, 1974.
Clark, H. H. Inferences in comprehension. In D. LaBerge & S. J. Samuels (Eds.), Perception and comprehension. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1976.
Clark, H. H. Bridging. Stanford University Working Paper, 1977.
Clark, H. H. Inferring what is meant. In a forthcoming book edited by W.J. M. Levelt & G. B. F. d'Arcais , 1978.
Clark, H. H. , & Chase, W. G. On the process of comparing sentences against pictures. Cognitive Psychology, 1972, 3, 472-517.
Clark, H. H. , & Clark, E. V. Psychology and language: An introduction to psycholinguistics. New York: Harcourt Brace Jovanovich, 1977.
Clark, H. H. , & Haviland, S. E. Comprehension and the given-new contract. In R. O. Freedle (Ed.), Discourse, production, and comprehension. Norwood, N.J.: Ablex Publishing, 1977.
Clark, H. H. , & Lucy, P. Understanding what is meant from what is said: A study in conversationally conveyed requests. Journal of Verbal Learning and Verbal Behavior, 1975, 14, 56-72.
Clifton, C., Jr. , Kurcz, I. , & Jenkins, J. J. Grammatical relations as determinants of sentence similarity. Journal of Verbal Learning and Verbal Behavior, 1965, 4, 112-117.
Cofer, C. N. On some factors in the organizational charateristics of free recall. *American Psychologist* , 1965, 20, 261-272.
Cofer, C. N. , Chmielewski, D. L. ,& Brockway, J. P. Constructive processes and the structure of human memory. In C. N. Cofer (Ed.), The structure of human memory. San Francisco: Freeman, 1976.
Cole, R. A. Listening for mispronounciations: A measure of what we hear during speech. Perception and Psychophysics, 1973, 13, 153-156.
Coleman, E. B. Approximations to English: Some comments on the method. American Journal of Psychology, 1963, 76, 239 247.
Collins, A. M. , & Loftus, E. F. A spreading activation theory of semantic processing. Psychological Review, 1975, 82, 407-428.
Collins, A. M. , & Quillian, M. R. Retrieval time from semantic memory. Journal of Verbal Learning and Verbal Behavior, 1969, 8, 240-247.
Collins, A. M. , & Quillian, M. R. Experiments on semantic memory and language comprehension. In L. W. Gregg (Ed), Cognition in learning and memory. New York: Wiley, 1972.
Conrad, C. Cognitive economy in semantic memory. Journal of Experimental Psychology, 1972, 92, 149-154.
Conrad, R. Acoustic confusions in immediate memory. British Journal of Psychology, 1964, 55, 75-84.

Cooper, L. A. Mental rotation of random two-dimensional shapes. Cognitive Psychology, 1975, 7, 20-43.
Cooper, L. A. , & Shepard, R. N. Chronometric studies of the rotation of mental images. In W. G. Chase (Ed.), Visual information processing. New York: Academic Press, 1973.
Cornsweet, T. N. Visual perception. New York: Academic Press, 1970.
Corteen, R. S. , & Wood, B. Autonomic responses to shock-associated words in an unattended channel. Journal of Experimental Psychology, 1972, 94, 308-313.
Craik, F. I. M. The fate of primary items in free recall. Journal of Verbal Learning and Verbal Behavior, 1970, 9, 143-148.
Craik, F. I. M. , & Jacoby, L. L. A process view of short-term retention. In F. Restle , R. M. Shiffrin , N. J. Castellan , H. R. Lindman , and D. B. Pisoni (Eds.), Cognitive theory (Vol. 1). Hillsdale, N.J.: Lawrence Erlbaum Associates, 1975.
Craik, F. I. M.,, & Lockhart, R. S. Levels of processing: A framework for memory research. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 671-684.
Craik, F. I. M. , & Tulving, E. Depth of processing and the retention of words in episodic memory. Journal of Experimental Psychology: General, 1975, 104, 268-294.
Dallett, K. M. Implicit mediators in paired-associate iearning. Journal of Verbal learning and Verbal Behavior, 1964, 3, 91-94.
D'Amato, M. R. Experimental psychology: Methodology, psychophysics, and learning. New York: McGraw-Hill, 1970.
Danks, J. H. , & Schwenk, M. A. Prenominal adjective order and communication context. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 183-187.
Danks, J. H. , & Schwenk, M. A. Comprehension of prenominal adjective orders. Memory & Cognition, 1974, 2, 1A, 34-38.
Danks, J. H. , & Sorce, P. A. Imagery and deep structure in the prompted recall of passive sentences. Journal of Verbal Learning and Verbal Behavior, 1973, 12, 114-117.
Darwin, C. J. , Turvey, M. T. , & Crowder, R. G. An auditory analogue of the Sperling partial report procedure. Cognitive Psychology, 1972, 5, 255-267.
Davies, D. , & Isard, S. D. Utterances as programs. In D. Michie (Ed.), Machine Intelligence 7. Edinburgh: Edinburgh University Press, 1972.
Deese, J. Serial organization in the recall of disconnected items. Psychology Reports, 1957, 3, 577-582.
Deese, J. The structure of associations in language and thought. Baltimore: Johns Hopkins Press, 1965.
Deininger, R. L. Human factors engineering studies of the design and use of push-button telephone sets. Bell System Technical Journal, 1960, 39, 995-1012.
Deutsch, J. A. , & Deutsch, D. Attention: Some theoretical considerations. Psychological Review, 1963, 70, 80-90.
deVilliers, P. A. Imagery and theme in recall of connected discourse. Journal of Experimental Psychology, 1974, 103, 263-268.
Dewar, K. M. , Cuddy, L. L. ,& Mewhort, D. J. K. Recogniton memory for single tones with and without context. Journal of Experimental Psychology: Human Learning and Memory, 1977, 3, 60-67.
Bonders, F. C. Over de snelheid van psychische processen. Onderzoekingen gedaan in het Psyiologish Laboratorium der Utrechtsche Hoogeschool: 1868-1869. Tweede Reeks, II, 92-120. Translated by W. G. Roster In W. G. Koster (Ed.), Attention and Performance II. Acta Psychologica, 1969, 30, 412-431.
Dooling, D. J. , & Lachman, R. Effects of comprehension on retention of prose. Journal of Experimental Psychology, 1971, 88, 216-222.
Dresher, E. , & Hornstein, N. On some supposed contributions of artificial intelligence to the scientific study of language. Cognition, 1976, 4, 321-398.
Dumas, J. Scanning memory for multidimensional stimuli with extended practice. Perception and Psychophysics, 1972, 11, 209-212.
Ebbinghaus, H. Uber das Gedachtnis, 1885. [Reprinted as *Memory* (H. A. Ruger & C. E., Busenius , trans.). New York: Teachers College, 1913.]

Efron, R. The relationship between the duration of a stimulus and the duration of a perception. Neuropsvchologia, 1970, 8, 37-55. (a)
Efron, R. , The minimum duration of a perception. Neuropsychologia, 1970, 8, 57-63. (b)
Efron, R. , Effect of stimulus duration on perceptual onset and offset latencies. Perception & Psychophysics, 1970, 8, 231-234. (c)
Egeth, H. Parallel versus serial processes in multidimensional stimulus discrimination. Perception and Psychophysics, 1966, 1, 245-252.
Egeth, H. , Jonides, J. , & Wall, S. Parallel processing of multielement displays. Cognitive Psychology, 1972, 3, 674-698.
Einstein, A. Ueber die von der molikular-kinetischen Theorie der Wärme geforderte Bewegung von in ruhenden Flüssigkeiten suspendierten Teilchen. Annalen der Physik, 1905, 17, 549-560. [Translation in Einstein Investigations on the theory of the Brownian motion (A. D. Cooper , trans.). With notes by R. Fürth . London: Methuen, 1926.]
Ekstrand, B. , & Underwood, B. J. Paced versus unpaced recall in free learning. Journal of Verbal Learning and Verbal Behavior, 1963, 2, 288-290.
Ellis, J. A. Transfer failure and proactive interference in short-term memory. Journal of Experimental Psychology: Human Learning arid Memory, 1977, 3, 211-221.
Epstein, W. The influence of syntactical structure on learning. American Journal of Psychology, 1961, 74, 80-85.
Eriksen, C. W. Temporal luminance summation effects in backward and forward masking. Perception and Psychophysics, 1966, 1, 87-92.
Estes, W. K. The statistical approach to learning theory. In S. Koch (Ed.), Psychology: A study of a science (Vol. 2). New York: McGraw-Hill, 1959.
Estes, W. K. Some targets for mathematical psychology. Journal of Mathematical Psychology, 1975, 12, 263-282. (a)
Estes, W. K. Memory, perception, and decision in letter identification. In R. L. Solso (Ed.), Information processing and cognition: The Loyola Symposium. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1975. (b)
Estes, W. , Koch, S. , MacCorquodale, K. , Meehl, P. , Mueller, C. , Schoenfield, W. , & Verplanck, W. (Eds.). Modern learning theory. New York: Appleton-Century-Crofts, 1954,
Fiksel, J. R. , & Bower, G. H. Question-answering by a semantic network of parallel automata. Journal of Mathematical Psychology, 1976, 13, 1-45.
Fillenbaum, S. Pragmatic normalization: Further results for some conjunctive and disjunctive sentences. Journal of Experimental Psychology, 1974, 102, 574-578.
Fillenbaum, S. , & Rapoport, A. , Verbs of judging, judged: A case study. Journal of Verbal Learning and Verbal Behavior, 1974, 13, 54-62.
Fillmore, C. J. The case for case. In E. Bach and R. T. Harms (Eds.), Universals in linguistic theory. New York: Holt, Rinehart *&* Winston, 1968.
Fillmore, C. J. Some problems for case grammar. In R. J. O'Brien (Ed.), Linguistics: Developments of the sixties—Viewpoints for the seventies. Monograph series on languages and linguistics, 1971, 24, 35-56.
Fitts, P. M. Cognitive aspects of information processing: III. Set for speed versus accuracy. Journal of Experimental Psychology, 1966, 71, 849-857.
Fitts, P. M. , & Seeger, C. M. S-R compatibility: Spatial characteristics of stimulus and response codes. Journal of Experimental Psychology, 1953, 46, 199-210.
Fitts, P. M. , & Switzer, G. Cognitive aspects of information processing: The familiarity of S-R sets and subsets. Journal of Experimental Psychology, 1962, 63, 321 -329.
Fodor, J. A. Could meaning be an *r* m? Journal of Verbal Learning and Verbal Behavior, 1965, 4, 73-81. [Also In R. C. Oldfield & J. C. Marshal (Eds.), Language: Selected readings. Baltimore: Penguin Books, 1968.]
Fodor, J. A. , & Bever, T. G. The psychological reality of linguistic segments. Journal of Verbal Learning and Verbal Behavior, 1965, 4, 414-420.
Fodor, J. A. , Bever, T. G. , & Garrett, M. F. The psychology of language. New York: McGraw-Hill, 1974.
Franks, J. J. , & Bransford, J. D. The acquisition of abstract ideas. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 311-315.

Frederiksen, C. H. Representing logical and semantic structure of knowledge acquired from discourse. Cognitive Psychology, 1975, 7, 371-458.
Frege, G. On sense and reference. Zeitschrift fụr philosophie unciphilosophische kritik. 1892, 100, 25-50.
Frijda, N. H. Simulation of human long-term memory. Psychological Bulletin, 1972, 77, 1-31.
Gardner, H. The naming of objects and symbols by children and aphasic patients. Journal of Psycholinguistic Research, 1974, 3, 133-149.
Gardner, R. A. , & Gardner, B. T. Teaching sign language to a chimpanzee. Science, 1969, 165, 664-672.
Gardner, R. A. , & Gardner, B. T. Two-way communication with an infant chimpanzee. In A. M. Schrier & F. Stollnitz (Eds.), Behavior of nonhumanprimates (Vol. 4). New York: Academic Press, 1971.
Gardner, R. A. , & Gardner, B. T. Early signs of language in child and chimpanzee. Science, 1975, 187, 752-754.
Garner, W. R. Uncertainty and structure as psychological concepts. New York: Wiley, 1962.
Garner, W. R. The stimulus in information processing. American Psychologist, 1970, 25, 350-358.
Garner, W. R. Information integration and form of encoding. In A. W. Melton & E. Martin (Eds.), Coding processes in human memory. Washington, D.C.: Winston, 1972.
Garner, W. R. The processing of information and structure. Potomac, Md.: Lawrence Erlbaum Associates, 1974.
Garner, W. R. , & Clement, D. E. Goodness of pattern and pattern uncertainty. Journal of Verbal Learning and Verbal Behavior, 1963, 2, 446-452.
Garner, W. R. , & Felfoldy, G. Integrality and separability of stimulus dimensions in information processing. Cognitive Psychology, 1970, 1, 225-241.
Garner, W. R. , Hake, H. W. , & Eriksen, C. W. Operationism and the concept of perception. Psychological Review, 1956, 63, 149-159.
Garrett, M. F. , Bever, T. G. , & Fodor, J. A. The active use of grammar in speech perception. Perception and Psychophysics, 1966, 1, 30-32.
Gibson, E. J. A systematic application of the concepts of generalization and differentiation to verbal learning. Psychological Review. 1940, 47, 196-229.
Gibson, E. J. , Pick, A. , Osser, H. , & Hammond, M. The role of grapheme-phoneme correspondence in the perception of words. American Journal of Psychology, 1962, 75, 554-570.
Gibson, J. J. The senses considered as perceptual systems. Boston: Houghton-Mifflin, 1966.
Glanzer, M. Storage mechanisms in recall. In G. H. Bower & J. T. Spence (Eds.), The psychology of learning and motivation. Vol. 5. New York: Academic Press, 1972.
Glanzer, M. ,& Clark, W. H. Accuracy of perceptual recall: An analysis of organization. Journal of Verbal Learning and Verbal Behavior, 1962, 1, 289-299,
Glanzer, M. , & Clark, W. H. The verbal loop hypothesis: Binary numbers. Journal of Verbal Learning and Verbal Behavior, 1963,2, 301-309.
Glanzer, M. , & Cunitz, A. R. Two storage mechanisms in free recall. Journal of Verbal Learning and Verbal Behavior, 1966, 5, 351-360.
Glass, A. L. , & Holyoak, K. J. Alternative conceptions of semantic memory. Cognition, 1975, 3, 313-339.
Glucksberg, S. , & Cowen, G. N. Memory for nonattended auditory material. Cognitive Psychology, 1970, 1, 149-156.
Glucksberg, S. , Trabasso, T. , & Wald, J. Linguistic structures and mental operations. Cognitive Psychology, 1973, 5, 338-370.
Godel, K. Uber formal unentscheidbare Satze der *Principia Mathematica* und verwandter Systeme. Monatschefte der Mathematik und Physik, 1931, 38, 173-198.[Translated in: Davis, M. (Ed.). The undecidable: Basic papers on undecidable propositions, unsolvable problems and computable functions. Hewlitt, N.Y.: Raven Press, 1956.]
Goldman-Eisler, F. Psycholinguistics: Experiments in spontaneous speech. New York: Academic Press, 1968.

Gough, P. B. , Grammatical transformations and speed of understanding. Journal of Verbal Learning and Verbal Behavior, 1965, 4, 107-111.
Gough, P. B. The verification of sentences: The effects of delay of evidence and sentence length. Journal of Verbal Learning and Verbal Behavior, 1966, 5, 492-496.
Gray, J. A. , & Wedderburn, A. A. I. Grouping strategies with simultaneous stimuli. Quarterly Journal of Experimental Psychology, 1960, 12, 180-184.
Green, D. W. The effects of task on the representation of sentences. Journal of Verbal Learning and Verbal Behavior, 1975, 14, 275-283.
Griffith, D. The attentional demands of mnemonic control processes. Memory and Cognition, 1976, 4, 103-108.
Haber, R. N. Information-processing approaches to visual perception. New York: Holt, Rinehart & Winston, 1969.
Haber, R. N. , & Standing, L. G. Direct measures of short-term visual storage. Quarterly Journal of Experimental Psychology, 1969, 21, 43-54,
Hanson, N. R. Patterns of discovery. Cambridge, Mass.: Harvard University Press, 1958.
Harris, R. J. Memory and comprehension of implications and inferences of complex sentences. Journal of Verbal Learning and Verbal Behavior, 1974, 13, 626-637.
Harris, R. J. , & Brewer, W. F. Deixis in memory for verb tense. Journal of Verbal Learning and Verbal Behavior, 1973, 12, 590-597.
Hartline, H. K. , & Ratliff, F. Inhibitory interaction of receptor units in the eye of *Limulus* . Journal of General Physiology, 1957, 40, 357-376.
Hartline, H. K. , & Ratliff, F. Spatial summation of inhibitory influence in the eye of the *Limulus,* and the mutual interaction of receptor units. Journal of General Physiology, 1958, 41, 1049-1066.
Hartline, H. , Wagner, H. , & Ratliff, F. Inhibition in the eye *Limulus* . Journal of General Physiology, 1956, 39, 651-673.
Haviland, S. E. , & Clark, H. H. What's new? Acquiring new information as a process in comprehension. Journal of Verbal Learning and Verbal Behavior, 1974, 13, 512-521.
Hayes, C. The ape in our house. New York: Harper & Row, 1951.
Hays, D. G. Introduction to computational linguistics. New York: American Elsevier, 1967.
Hebb, D. O. The organization of behavior. New York: Wiley, 1949.
Hecht, S. , Schlaer, A. , & Pirenne, M. H. Energy quanta and vision. Journal of General Physiology, 1942, 25, 819-840.
Henderson, L. Word recognition. In N. S. Sutherland (Ed.), Tutorial essays in psychology. Hillsdale, N.J,: Lawrence Erlbaum Associates, 1977.
Hendrick, C. (Ed.). Perspectives on social psychology. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1977.
Hick, W. E. On the rate of gain of information. Quarterly Journal of Experimental Psychology, 1952, 4, 11-26.
Holding, D. H. Guessing behavior and the Sperling store. Quarterly Journal of Experimental Psychology, 1970, 22, 248-256.
Holmes, V. M. , & Langford, J. Comprehension and recall of abstract and concrete sentences. Journal of Verbal Learning and Verbal Behavior, 1976, 5, 559-566.
Holton, G. Thematic origins of scientific thought: Kepler to Einstein. Cambridge: Harvard University Press, 1973.
Holton, G. On the role of themata in scientific thought. Science, 1975, 188, 328-334.
Holyoak, K. J. , & Glass, A. L. The role of contradictions and counterexamples in the rejection of false sentences. Journal of Verbal Learning and Verbal Behavior, 1975, 14, 215-239.
Hornby, P. A. Surface structure and presupposition. Journal of Verbal Learning and Verbal Behavior, 1974, 13, 530-538.
Hubel, D. H. , & Wiesel, T. N. Receptive fields, binocular interaction and functional architecture in the cat's visual cortex. Journal of Physiology (London), 1962, 160, 106-154.
Hubel, D. H. , & Wiesel, T. N. Shape and arangement of columns in cat's striate cortex. Journal of Physiology (London), 1963, 165, 559-568.
Hubel, D. H. , & Wiesel, T. N. Receptive fields and functional architecture in two non-striate visual areas (18 & 19) of the cat. Journal of Neurophysiology, 1965, 28, 229-289.

Hubel, D. H. , & Wiesel, T. N. Receptive fields and functional architecture of monkey striate cortex. Journal of Physiology (London), 1968, 195, 215-243.

Huey, E. B. The psychology and pedagogy of reading. Cambridge, Mass.: MIT Press, 1968.

Hull, C. L. Principles of behavior. New York: D. Appieton-Century, 1943.

Hyman, R. Stimulus information as a determinant of reaction time. Journal of Experimental Psychology, 1953, 45, 188-196.

Jacoby, L. L. , & Craik, F. I. M. Effects of elaboration of processing at encoding and retrieval: trace distinctiveness and recovery of initial context. In L. S. Cermak & F. I. M. Craik (Eds.), Levels of processing and human memory. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1978.

Jakobson, R. , Fant, G. , & Halle, M. Preliminaries to speech analysis: The distinctive features and their correlates. Cambridge, Mass.: MIT Press, 1963.

Jakobson, R. , & Halle, M. Fundamentals of language. The Hague: Mouton, 1956.

James, W. The principles of psychology. New York: Holt, 1890. [Reprinted by Dover, New York, 1950.]

Jenkins, J. J. Recognition memory for picture sequences. Colloquium presented at the University of Houston, 1977.

Jennings, J. R. Wood, C. C. , & Lawrence, B. E. Alcohol and speed/accuracy trade-off. Perception and Psychophysics, 1976, 9, 85-91.

Johnson, M. K. , Bransford, J. D. , Nyberg, S. E. „ & Cleary, J. J. Comprehension factors in interpreting memory for abstract and concrete sentences. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 451-454.

Johnson, M. K. , Bransford, J. D. ,& Solomon, S. K. Memory for tacit implications of sentences. Journal of Experimental Psychology, 1973, 98, 203-205.

Johnson, M. K. , Doll, T. J. , Bransford, J. D. , & Lapinski, R. H. Context effects in sentence memory. Journal of Experimental Psychology, 1974, 103, 358-360.

Johnson, N. The psychological reality of phrase-structure rules. Journal of Verbal Learning and Verbal Behavior, 1965, 4, 469-475.

Johnson, W. A. , Greenberg, S. N. , Fisher, R. P. , & Martin, D. W. Divided attention: A vehicle for monitoring memory processes. Journal of Experimental Psychology, 1970, 83, 164-171.

Johnson-Laird, P. N. Procedural semantics. Cognition, 1977, 5, 189-214.

Jorgensen, C. C. , & Kintsch, W. The role of imagery in the evaluation of sentences. Cognitive Psychology, 1973, 4, 110-116.

Jung, J. Verbal learning. Toronto: Holt, Rinehart & Winston, 1968.

Juola, J. F. Repetition and laterality effects on recognition memory for words and pictures. Memory & Cognition, 1973, 1, 183-192.

Juola, J. F. , & Atkinson, R. C. Memory scanning for words vs. categories. Journal of Verbal Learning and Verbal Behavior, 1971, 10, 522-527.

Juola, J. F. , Choe, C. S. , & Leavitt, D. D. A reanalysis of the word superiority effect. Paper presented at the Psychonomic Society meeting, Boston, 1974.

Juola, J. F. , Fischler, L. , Wood, C. T. & Atkinson, R. C. Recognition time for information stored in long-term memory. Perception and Psychophysics, 1971, 10, 8-14.

Juola, J. F. , Leavitt, D. D. , & Choe, C. S. Letter identification in word, nonword, and single-letter displays. Bulletin of the Psychonomic Society, 1974, 4, 278-280.

Juola, J. F. , Schadler, M. , Chabot, R. , McCaughey, M. , & Wait, J. What do children learn when they learn to read? In L. Resnick & P. Weaver (Eds.), Theory and practice of beginning reading (Vol. 2). Hillsdale, N.J.: Lawrence Erlbaum Associates, in press.

Kahneman, D. Remarks on attention control. Acta Psychologica. In A. F. Sanders (Ed.), Attention and performance III. 1970, 118-131.

Kahneman, D. Attention and effort. Englewood Cliffs, N.J,: Prentice-Hall, 1973.

Katz, J. J. , & Fodor, J. A The structure of a semantic theory. Language, 1963, 39, 170-210.

Keele, S. W. Attention and human performance. Pacific Palisades, Calif.: Goodyear, 1973.

Kellogg, W. N. , & Kellogg, L. A. The ape and the child. New York: McGraw-Hill, 1933.

Kessel, F. S. The philosophy of science as proclaimed and science as practiced. American Psychologist, 1969, 24, 999-1005.

King, D. R. W. , & Anderson, J. R. Long-term memory search: An intersecting activation process. Journal of Verbal Learning and Verbal Behavior, 1976, 15, 587-605.
Kintsch, W. The representation of meaning in memory. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1974.
Kintsch, W. Memory for prose. In C. N. Cofer (Ed.), The structure of human memory. San Francisco: Freeman, 1976.
Kintsch, W. On comprehending stories, In M. A. Just & P. A. Carpenter (Eds.), Cognitive processes in comprehension. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1977.
Kintsch, W. , & Keenan, J. Reading rate and retention as a function of the number of propositions in the base structure of sentences. Cognitive Psychology, 1973, 5, 257-274.
Kintsch, W. , Kozminsky, E. , Streby, W. J. , McKoon, G. , & Keenan, J. M. Comprehension and recall of text as a function of content variables. Journal of Verbal Learning and Verbal Behavior, 1975, 74, 196-214.
Klahr, D. , & Wallace, J. C. Cognitive development: An information-processingview. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1976.
Klee, H. , & Eysenck, M. W. Comprehension of abstract and concrete sentences. Journal of Verbal Learning and Verbal Behavior, 1973, 12, 522-529.
Koch, S. (Ed.). Psychology: A study of a science. New York: McGraw-Hill, 1959.
Kochen, M. , MacKay, D. M. , Maron, M. E. , Scriven, M. , & Uhr, L. Computers and comprehension. Rand Corporation Memorandum RM-4065-PR, April 1964.
Kolers, P. A. , Some psychological aspects of pattern recognition. In P. A. Kolers & M. Eden (Eds.), Recognizing patterns, Cambridge, Mass.: MIT Press, 5968.
Kolers, P. A. A pattern analyzing basis of recognition. In L. S. Cermak & F. I. M. Craik (Eds.), Levels of processing and human memory. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1978.
Kosslyn, S. M. , & Pomerantz, J. R. , Imagery, propositions, and the form of internal representations. Cognitive Psychology, 1977, 9, 52-76.
Kroll, N. E. A. Short-term memory and the nature of interference from concurrent shadowing. Quarterly Journal of Experimental Psychology, 1972, 24, 414-419.
Kroll, N. E. A. Visual short-term memory. In J. A. Deutsch (Ed.), Short-term memory. New York: Academic Press, 1975.
Kroll, N. E. A. , & Kellicutt, M. H. Short-term recall as a function of covert rehearsal and of intervening task. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 196-204.
Kroll, N. E. A. , Parks, T. , Parkinson, S. R. , Bieber, S. L. , & Johnson, A. L. Short-term memory while shadowing: Recall of visually and of aurally presented letters. Journal of Experimental Psychology, 1970, 85, 220-224.
Kucera, H. , & Francis, W. N. Computational analysis of present-day American English. Providence, R.I.: Brown University Press, 1967.
Kuffler, S. W. Neurons in the retina: Organization, inhibition, and excitation problems. Cold Spring Harbor Symposium on Quantitative Biology, 1952, 17, 281-292.
Kuffler, S. W. Discharge patterns and functional organization of mammalian retina. Journal of Neurophysiology, 1953, 16, 37-68.
Kuhn, T. S. The structure of scientific revolutions. Chicago: University of Chicago Press, 1962.
Kuhn, T. S. The structure of scientific revolutions (2nd ed.). Chicago: University of Chicago Press, 1970. (a)
Kuhn, T. S. Logic of discovery or psychology of research? In I. Lakatos & A. Musgrave (Eds.), Criticism and the growth of knowledge. London: Cambridge University Press, 1970. (b)
Kuhn, T. S. Reflections on my critics. In I. Lakatos & A. Musgrave (Eds.), Criticism and the growth of knowledge. London: Cambridge University Press, 1970. (c)
Kuhn, T. S. Second thoughts on paradigms. In F. Suppe (Ed.), The structure of scientific theories. Urbana: University of Illinois Press, 1974.
Lachman, R. Uncertainty effects on time to access the internal lexicon. Journal of Experimental Psychology, 1973, 99, 199-208.
Lachman, R. , Shaffer, J. P. , & Hennrikus, D. Language and cognition: Effects of stimulus codability, name-word frequency, and age of acquisition on lexical reaction time. Journal of

VerbaI Learning and Verbal Behavior, 1974, 13, 613-625.
Lakatos, I. Falsification and the methodology of science research programs. In I. Lakatos & A. Musgrave (Eds.), Criticism and the growth of knowledge. London: Cambridge University Press, 1970.
Lakoff, G. Presupposition and relative well-formedness. In D. D. Steinberg & L. A. Jakobovits (Eds.), Semantics. Cambridge: Cambridge University Press, 1971.
Lakoff, R. Some reasons why there isn't any some-any rule. Language, 1969, 45, 608-615.
Landauer, T. K. , & Freedman, J. L. Information retrieval from long-term memory: Category size and recognition time. Journal of Verbal Learning and Verbal Behavior, 1968, 7, 291-295.
Landauer, T. K. , & Meyer, D. E. Category size and semantic memory retrieval. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 539-549.
Lantz, D. , & Stefflre, V. Language and cognition revisited. Journal of Abnormal and Social Psychology, 1964, 69, 472-481.
Layton, P. , & Simpson, A. J. Surface and deep structure in sentence comprehension. Journal of Verbal Learning and Verbal Behavior, 1975, 14, 658-664.
Lenneberg, E. H. Biological foundations of language. New York: Wiley, 1967.
Leonard, J. A. Partial advance information in a choice reaction task. British Journal of Psychology, 1958, 49, 89-96.
Lesgold, A. M. Pronominalization: A device for unifying sentences in memory. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 316-323.
Lettvin, J. Y. , Maturana, H. R. , McCulloch, W. S. , & Pitts, W. H. What the frog's eye tells the frog's brain. Proceedings of the IRE, 1959, 47 *(* 11 *),* 1940-1951.
Levy, B. A. Role of articulation in auditory and visual short-term memory. Journal of Verbal Learning and Verbal Behavior, 1971, 10, 123-132.
Lewis, J. L. Semantic processing of unattended messages using dichotic listening. Journal of Experimental Psychology, 1970, 85, 225-229.
Liberman, A.M. , Cooper, F. S. , Shankweiler, D. P. , & Studdert-Kennedy, M. Perception of the speech code. Psychological Review, 1967, 74, 431-461.
Liberman, A. M. , Harris, K. S. , Kinney, J. A. , & Lane, H. L. The discrimination of relative onset time of the components of certain speech and nonspeech patterns. Journal of Experimental Psychology, 1961, 61, 379-388.
Lieberman, P. On the origins of language. New York: Macmillan, 1975.
Lieberman, P. , Crelin, E. S. , & Klatt, D. H. Phonetic ability and related anatomy of the newborn, adult human, Neanderthal man and the chimpanzee. American Anthropology, 1972, 74, 287-307.
Lindsay, P. H. , & Norman, D. A. Human information processing; An introduction to psychology. New York: Academic Press, 1972.
Lindsay, P. H. , & Norman, D. A. Human information processing. New York: Academic Press, 1977.
Loftus, E. F. Leading questions and the eyewitness report. Cognitive Psychology, 1975, 7, 560-572.
Loftus, E. F. Organization and retrieval of attribute and name information. In S. Ehrlich and E. Tulving (Eds.), La Memoire Semantique. Paris: Bulletin de Psychologie, 1976.
Loftus, E. F. How to catch a zebra in semantic memory. In R. Shaw & J. Bransford (Eds.), Perceiving, acting and knowing. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1977.
Loftus, E. F. , & Palmer, J. C. Reconstruction of automobile destruction: An example of the interaction between language and memory. Journal of Verbal Learning and Verbal Behavior, 1974, 13, 585-589.
Loftus, E. F. , & Zanni, G. Eyewitness testimony: The influence of the wording of a question. Bulletin of the Psychonomic Society, 1975, 5, 86-88.
MacCorquodale, K. . On Chomsky's review of Skinner's *Verbal Behavior* . Journal of the Experimental Analysis of Behavior, 1970, 13, 83-99.
Mahoney, M. J. Cognition and behavior modification. Cambridge, Mass.: Ballinger, 1974.
Malmberg, B. Structural linguistics and human communication (2nd ed.). Heidelberg: Springer, 1963.

Mandler, G. Organization ill memory. In K. W. Spence & J. T. Spence (Eds.), Psychology of learning and motivation (Vol. I). New York: Academic Press, 1967.
Mandler, G. Consciousness: Respectable, useful, and probably necessary. In R. L. Solso (Ed.), Information processing and cognition: The Loyola Symposium. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1975.
Manelis, L. The effect of meaningfulness in tachistoscopic word perception. Perception and Psychophysics, 1974, 16, 182-192.
Marks, L. E. Some structural and sequential factors in the processing of sentences. Journal of Verbal Learning and Verbal Behavior, 1967, 6, 707-713.
Marks, L. E. , & Miller, G. A. The role of semantic and syntactic constraints in the memorization of English sentences. Journal of Verbal Learning and Verbal Behavior, 1964, 3, 1-5.
Mascall, E. L. Christian theology and natural science. New York: Longmans, Green, 1956.
Massaro, D. W. Preperceptual auditory images. Journal of Experimental Psychology, 1970, 85, 411-417.
Massaro, D. W. Preperceptual images, processing time, and perceptual units in auditory perception. Psychological Review, 1972, 79, 124-145.
Massaro, D. W. Experimental psychology and information processing. Chicago: Rand McNally, 1975.
Masterman, M. The nature of a paradigm. In I. Lakatos & A. Musgrave (Eds.), Criticism and the growth of knowledge. Cambridge: Cambridge University Press, 1970.
McCrary, J. W., Jr. , & Hunter, W. S. Serial position curves in verbal learning. Science, 1953, 117, 131-134.
McGeoch, J. A. The psychology of human learning: An introduction. New York: Van Rees Press, 1942.
McMahon, L. E. Grammatical analysis as part of understanding a sentence. Unpublished doctoral dissertation, Harvard University, 1963.
McNeill, D. The acquisition of language. New York: Harper & Row, 1970.
Mehler, J. , & Carey, P. Role of surface and base structure in the perception of sentences. Journal of Verbal Learning and Verbal Behavior, 1967, 6, 335-338.
Meier, N. Deutsche Sprachstatistik (Vols. 1 and 2). Hildesheim: G. Olms, 1964.
Melton, A. W. , & Martin, E. Coding processes in human memory. Washington, D.C.: Winston & Sons, 1972.
Merkel, J. Die zeitlichen Verhaltnisse der Willensthatigkeit. Philosophische Studien, 1885, 2, 73-127.
Meyer, D. E. On the representation and retrieval of stored semantic information. Cognitive Psychology, 1970, 1, 242-300.
Meyer, D. E. Verifying affirmative and negative propositions: Effects of negation on memory retrieval. In S. Kornblum (Ed.), A ttention and Performance IV. New York: Academic Press, 1973.
Meyer, D. E. , & Ellis, G. B. Parallel processes in word recognition. Paper presented at the meeting of the Psychonomic Society, San Antonio, November 1970.
Meyer, D. E. , & Schvaneveldt, R. W. Meaning, memory structure, and mental processes. In C. N. Cofer (Ed.), The structure of human memory. San Francisco: Freeman, 1976.
Milgram, N. A. Microgenetic analysis of word associations in schizophrenic and brain damaged patients. Journal of Abnormal and Social Psychology, 1961, 62, 364-366.
Miller, G. A. What is information measurement? American Psychologist, 1953, 8, 3-11.
Miller, G. A. The magical number seven, plus or minus two: Some limits on our capacity for processing information. Psychological Review, 1956, 63, 81-97.
Miller, G. A. Some psychological studies of grammar. American Psychologist, 1962, 17, 748-762.
Miller, G. A. Toward a third metaphor for psycholinguistics. In W. B. Weimer & D. S. Palermo (Eds.), Cognition and the symbolic processes. Hillsdale, N J.: Lawrence Erlbaum Associates, 1974.
Miller, G. A. , Bruner, J. S. , & Postman, L. Familiarity of letter sequences and tachistoscopic identification. Journal of Genetic Psychology, 1954, 50, 129-139.

Miller, G. A. , Galanter, E. , & Pribram, K. H. Plans and the structure of behavior. New York: Henry Holt & Co., Inc., 1960.
Miller, G. A. , Heise, G. A. , & Lichten, W. The intelligibility of speech as a function of the text of the test materials. Journal of Experimental Psychology, 1951, 41, 329-335.
Miller, G. , & Isard, S. Some perceptual consequences of linguistic rules. Journal of Verbal Learning and Verbal Behavior, 1963, 2, 217-228.
Miller, G. A. , & Johnson-Laird, P. N. Language and perception. Cambridge, Mass.: Harvard University Press, 1976.
Miller, G. A. , & Selfridge, J. A. Verbal context and the recall of meaningful material. American Journal of Psychology, 1950, 63, 176-185.
Milne, E. A. Modern cosmology and the christian idea of god. Oxford: Oxford University Press, 1952.
Milner, B. The memory defect in bilateral hippocampal lesions. Psychiatric Research Reports, 1959, 11, 43-52.
Milner, B. Neuropsychological evidence for differing memory processes. Abstract for the symposium on short-term and long-term memory. Proceedings of the 18th International Congress of Psychology, Moscow, 1966.
Milner, B. Amnesia following operation on the temporal lobes. In C. W. M. Whitty & O. L. Zangwill (Eds.), Amnesia. London: Butterworths, 1967.
Minsky, M. L. Computation: Finite and infinite machines. Englewood Cliffs, N.J.: Prentice-Hall, 1967.
Minsky, M. L. A framework for representing knowledge. In P. Winston (Ed.), The psychology of computer vision. New York: McGraw-Hill, 1975.
Mistler-Lachman, J. Levels of comprehension in processing of normal and ambiguous sentences. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 614-623.
Mistler-Lachman, J. Levels of comprehension and sentence memory. Journal of Verbal Learning and Verbal Behavior, 1974, 13, 98-106.
Moeser, S. D. Memory for meaning and wording in concrete and abstract sentences. Journal of Verbal Learning and Verbal Behavior, 1974, 13, 682-697.
Moray, N. Attention in dichotic listening: Affective cues and the influence of instructions. Quarterly Journal of Experimental Psychology, 1959, 11, 56-60.
Moray, N. Listening and attention. Baltimore: Penguin, 1969,
Moray, N. Attention: Selective processes in vision and hearing. New York: Academic Press, 1970.
Moray, N. , Bates, A. , & Barnett, T. Experiments on the four-eared man. Journal of Acoustical Society of America, 1965, 38, 196-201.
Morris, C. D. , Bransford, J. D. ,& Franks, J. J. Levels of processing versus transfer appropriate processing. Journal of Verbal Learning and Verbal Behavior, 1977,16, 519-534.
Mowbray, G. H. , & Rhoades, M. V. On the reduction of choice reaction times with practice. Quarterly Journal of Experimental Psychology, 1959, 11, 16-23.
Mowrer, O. H. The psychologist looks at language. American Psychologist, 1954, 9, 600-694.
Murdock, B. B. The immediate retention of unrelated words. Journal of Experimental Psychology, 1960, 60, 222-234.
Murdock, B. B., Jr. The retention of individual items. Journal of Experimental Psychology, 1961, 62, 618-625.
Murdock, B. B., Jr. Four channel effects in short-term memory. Psychonomic Science, 1971, 24, 197-198.
Naus, M. J. , Glucksberg, S. , & Ornstein, P. A. Taxonomic word categories and memory search. Cognitive Psychology, 1972, 3, 643-654.
Neisser, U. Decision-time without reaction time: Experiments in visual scanning. American Journal of Psychology, 1963, 76, 376-385.
Neisser, U. Visual search. Scientific American, 1964, 210, 94-102.
Neisser, U. Cognitive psychology. New York: Appleton-Century-Crofts, 1967.
Neisser, U. *Selective reading. A method for the study of visual attention.* Nineteenth International Congress of Psychology, London, 1969.

Neisser, U. Cognition and reality. San Francisco: Freeman, 1976,
Neisser, U. , & Becklen, R. Selective looking: Attending to visually specified events. Cognitive Psychology, 1975, 7, 480-494.
Nelson, D. L. Remembering pictures and words: Significance and appearance. In L. S. Cermak & F. I. M. Craik (Eds.), Levels of processing and human memory. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1978.
Newell, A. You can't play 20 questions with nature and win: Projective comments on the papers of this symposium. In W. G. Chase (Ed.), Visual information processing. New York: Academic Press, 1973.
Newell, A. , Shaw, J. C. , & Simon, H. A. Elements of a theory of human problem solving. Psychological Review, 1958, 65, 151-166.
Newell, A. , & Simon, H. A. The simulation of human thought. In Current trends in psychological theory. Pittsburgh: University of Pittsburgh Press, 1961.
Newell, A. , & Simon, H. Human problem solving. Englewood Cliffs, N. J.: Prentice-Hall, 1972.
Newell, A. , & Simon, H. A. Computer science as empirical inquiry: Symbols and search. Communications of the ACM, 1976, 19, 113-126.
Nickerson, R. S. Binary classification reaction time: A review of some studies of human information processing capabilities. Psychonomics Monograph Supplement, 1972, 4(Whole No. 65), 275-318.
Norman, D. A. Toward a theory of memory and attention. Psychological Review, 1968, 75, 522-536.
Norman, D. A. Models of human memory. New York: Academic Press, 1970.
Norman, D. A. Memory, knowledge, and the answering of questions. In R. L. Solso (Ed.), Contemporary issues in cognitive psychology: The Loyola Symposium. Washington, D. C.: Winston, 1973.
Norman, D. A. , & Bobrow, D. G. On data limited and resource limited processes. Cognitive Psychology, 1975, 7, 44-64.
Norman, D. A. , & Bobrow, D. G. On the role of active memory processes in perception and cognition. In C. Cofer (Ed.), The structure of human memory. San Francisco: Freeman, 1976.
Norman, D. A. , & Rumelhart, D. E. A system for perception and memory. In D. A. Norman (Ed.), Models of human memory. New York: Academic Press, 1970.
Norman, D. A. , Rumelhart, D. E. , & the LNR Research Group. Explorations in cognition. San Francisco: Freeman, 1975.
Oldfield, R. C. Individual vocabulary and semantic currency. British Journal of Social and Clinical Psychology, 1963, 2, 122-130.
Oldfield, R. C. Things, words and the brain. Quarterly Journal of Experimental Psychology, 1966, 18, 340-353.
Oldfield, R. C. , & Wingfieid, A. The time it takes to name an object. Nature, 1964, 202, 1031-1032.
Oldfield, R. C. , & Wingfieid, A. , Response latencies in naming objects. Quarterly Journal of Experimental Psychology, 1965, 17, 273-281.
Olson, D. R. , & Filby, N. On the comprehension of active and passive sentences. Cognitive Psychology, 1972, 3, 361-381.
Osgood, C. E. Method and theory in experimental psychology. New York: Oxford University Press, 1953.
Ostry, D. , Moray, N. , & Marks, G. Attention, practice, and semantic targets. Journal of Experimental Psychology: Human Perception and Performance, 1976, 2, 326-336.
Pachella, R. G. The interpretation of reaction time in information processing research. In B. Kantowitz (Ed.), Human information processing: Tutorials in performance and cognition, Hillsdale, N.J.: Lawrence Erlbaum Associates, 1974.
Paivio, A. Mental imagery in associative learning and memory. Psychological Review, 1969, 76, 241-263.
Paivio, A. Imagery and verbal processes. New York: Holt, Rinehart & Winston, 1971.
Paivio, A. , & Csapo, K. , Concrete-image and verbal memory codes. Journal of Experimental Psychology, 1969, 80, 279-285.

Palmer, S. E. Visual perception and world knowledge. In D. A. Norman , D. E. Rumelhart , & the LNR Research Group (Eds.), Explorations in cognition. San Francisco: Freeman, 1975.
Palmer, S. E. Fundamental aspects of cognitive representation. In E. Rosch & B. B. Lloyd (Eds.), Cognition and categorization. Hillsdale, N. J.: Lawrence Erlbaum Associates, 1978.
Parker, E. S. , Birnbaum, I. M. , & Noble, E. P. Alcohol and memory: Storage and state dependency. Journal of Verbal Learning and Verbal Behavior, 1976, 15, 691-702.
Parkinson, S. R. Short-term memory while shadowing: Multiple-item recall of visually and of aurally presented letters. Journal of Experimental Psychology, 1972, 92, 256-265.
Parkinson, S. R. , Parks, T. E. , & Kroll, N. E. A. Visual and auditory short-term memory: Effects of phonemically similar auditory shadow material during the retention interval. Journal of Experimental Psychology, 1971, 87, 274-280.
Patterson, F. G. The gestures of a gorilla: Language acquisition in another pongid. Brain and Language, 1978, 5, 72-97.
Pavlov. I. P. Conditioned reflexes. London: Oxford University Press, 1927.
Perrin, M. Brownian movement and molecular reality. London: Taylor and Francis, 1910.
Peirce, J. R. Symbols, signals, and noise: The nature and process of communication. New York: Harper & Row, 1961.
Peterson, L. R. Verbal learning and memory. Annual Review of Psycyhology, 1977, 28, 393-415.
Peterson, L. R. , & Johnson, S. T. Some effects of minimizing articulation on short-term retention. Journal of Verbal Learning and Verbal Behavior, 1971, 10, 346-354.
Peterson, L. R. , & Peterson, M. J. Short-term retention of individual verbal items. Journal of Experimental Psychology, 1959, 58, 193-198.
Pew, R. W. The speed accuracy operating characteristic. ACTA Psychologica, 1969, 30, 16-26.
Phillips, W. A. & Baddeley, A. D. Reaction time and short-term visual memory. Psychonomic Science, 1971, 22, 73-74.
Polanyi, M. Personal knowledge: Towards a post-critical philosophy. Chicago: University of Chicago Press, 1962.
Pollack, I. Speed of classification of words into superordinate categories. Journal of Verbal Learning and Verbal Behavior, 1963, 2, 159-165.
Pollatsek, A. , & Battencourt, H. O. The spaced-practice effect in the distractor paradigm is related to proactive interference but not to short-term store. Journal of Experimental Psychology: Human Learning and Memory, 1976, 2, 128-141.
Polyak, S. L. The vertebrate visual system. Chicago: University of Chicago Press, 1957.
Pompi, K. F. , & Lachman, R. Surrogate processes in the short-term retention of connected discourse. Journal of Experimental Psychology, 1967, 75, 143-150.
Popper, K. R. The logic of scientific discovery. New York: Basic Books, 1959.
Popper, K. R. Normal science and its dangers. In I. Lakatos & A. Musgrave (Eds.), Criticism and the growth of knowledge. London: Cambridge University Press, 1970.
Posner, M. I. Abstraction and the process of recognition. In G. H. Bower & J. T. Spence (Eds.), The psychology of learning and motivation: Advances in research and theory (Vol. 3). New York: McGraw-Hill, 1969.
Posner, M. I. Coordination of internal codes. In W. G. Chase (Ed.), Visual information processing. New York: Academic Press, 1973.
Posner, M. I. , & Boies, S. J. Components of attention. Psychological Review, 1971, 78, 391-408.
Posner, M. I. , & Klein, R. M. On the functions of consciousness. In S. Kornbium (Ed.), Attention and performance IV. New York: Academic Press, 1973.
Posner, M. I. , Klein, R. M. , Summers, J. , & Buggie, S. On the selection of signals. Memory and Cognition, 1973, 1, 2-12.
Posner, M. I. , & McLean, J. P. Cognition: Forwards or backwards? Contemporary Psychology, 1977, 7, 481-482.
Posner, M. I. , & Rogers, M. G. K. Chronometric Analysis of Abstraction and Recognition. In W. K. Estes (Ed.), Handbook of learning and cognitive processes (Vol. 6). Hillsdale, N. J.: Lawrence Erlbaum Associates, 1978.

Posner, M. I. , & Snyder, C. R. R. Attention and cognitive control. In R. L. Solso (Ed.), Information processing and cognition: The Loyola Symposium. Potomac, Md.: Lawrence Erlbaum Associates, 1974.

Post, E. L. Finite combinatory processes—Formulation I. Journal of Symbolic Logic, 1936, 1, 103-105.

Postman, L. The present status of interference theory. In C. N. Cofer (Ed,), Verbal learning and verbal behavior. New York: McGraw-Hill, 1961.

Postman, L. Verbal learning and memory. Annual Review of Psychology, 1975, 26, 291-335.

Premack, D. A. A functional analysis of language. Journal of Experimental Analysis of Behavior, 1970, 14, 107-125.

Premack, D. A. Language in chimpanzee? Science, 1971, 172, 808-822.

Pribram, K. H. Why a neuropsychologist must know the literature in memory, perception and cognition as well as physiological psychology. (To be published by Lawrence Erlbaum Associates.)

Pylyshyn, Z. W. What the mind's eye tells the mind's brain: A critique of mental imagery *Psychological Bulletin* , 1973, 80, 1-24.

Quillian, M. R. Semantic memory. In M. Minsky (Ed.), Semantic information processing. Cambridge, Mass.: MIT Press, 1968.

Quillian, M. R. The teachable language comprehender: A stimulation program and theory of language. Communications of the ACM, 1969, 12, 459-476.

Radtke, R. C. , & Grove, E. K. Proactive inhibition in short-term memory: Availability or accessibility? Journal of Experimental Psychology: Human Learning and Memory, 1977, 3, 78-91.

Raphael, B. The thinking computer: Mind inside matter. San Francisco: Freeman, 1976.

Ratliff, F. Mach bands. San Francisco: Hoiden Day, 1965.

Ratliff, F. , & Hartline, H. K. The responses of *Limulus* optic nerve fibers to patterns of illumination on the receptor mosaic. Journal of General Physiology, 1959, 42, 1241-1255.

Reed, S. K, Psychological processes in pattern recognition. New York: Academic Press, 1973.

Reicher, G. M. Perceptual recognition as a function of meaningfulness of stimulus material. Journal of Experimental Psychology, 1969, 81, 274-280.

Reitman, J. S. Mechanisms of forgetting in short-term memory. Cognitive Psychology, 1971, 2, 185-195.

Reitman, J. S. Without surreptitious rehearsal: Information and short-term memory decays. Journal of Verbal Learning and Verbal Behavior, 1974, 13, 365-377.

Restle, F. Critique of pure memory. In R. L. Solso (Ed.), Theories in cognitive psychology: The Loyola Symposium. Potomac, Md.: Lawrence Erlbaum Associates, 1974.

Restle, F. Answering questions from cognitive structures. In F. Restle , R. M. Shiffrin , N. J. Castellan , H. R. Lindman , & D. B. Pisoni (Eds.), Cognitive theory (Vol. 1). Hillsdale, N.J.: Lawrence Erlbaum Associates, 1975.

Rips, L. J. Quantification and semantic memory. Cognitive Psychology, 1975, 7, 307-340.

Rips, L. J. , Shoben, E. J. , & Smith, E. , E Semantic distance and the verification of semantic relations. Journal of Verbal Learning and Verbal Behavior, 1973, 12, 1-20.

Rosch, E. On the internal structure of perceputal and semantic categories. In T. M. Moore (Ed.), Cognitive development and the acquisition of language. New York: Academic Press, 1973.

Rosch,E. Cognitive representations of semantic categories. Journal of Experimental Psychology: General, 1975, 104 *(* 3 *),* 192-233.

Rosch, E. , & Mervis, C. B. Family resemblances: Studies in the internal structure of categories. Cognitive Psychology, 1975, 7, 573-605.

Rosch, E. , Mervis, C. B. , Gray, W. , Johnson, D. , & Boyes-Braem, P. Basic objects in natural categories. Cognitive Psychology, 1976, 8, 382-439.

Rothstein, L. D. Recognition reaction time: Searching for search. Unpublished doctoral dissertation, Kent State University, 1973.

Rothstein, L. D. , & Morin, R. E. The effects of size of stimulus ensemble and the method of set size manipulation on recognition reaction time. Paper presented at the meeting of the

Midwestern Psychological Association, Cleveland, May 1972.
Rumelhart, D. E. Notes on a schema for stories. In D. G. Bobrow & A. M. Collins (Eds.), Representations and understanding: Studies in cognitive science. New York: Academic Press, 1975.
Rumelhart, D. E. An introduction to human information processing. New York: Wiley, 1977.
Rumelhart, D. E. , Lindsay, P. H. , & Norman, D. A. A process model for long-term memory. In E. Tulving & W. Donaldson (Eds.), Organization of memory. New York: Academic Press, 1972.
Sachs, J. S. Recognition memory for syntactic and semantic aspects of connected discourse. Perception and Psychophysics, 1967, 2, 437-442.
Salzberg, P.M. On the generality of encoding specificity. Journal of Experimental Psychology: Human Learning and Memory, 1976, 2, 586-596.
Salzberg, P. M. , Parks, T. E. , Kroll, N. E. A. , & Parkinson, S. R. Retroactive effects of phonemic similarity on short-term recall of visual and auditory stimuli. Journal of Experimental Psychology, 1971, 91, 43-46.
Savin, H. B. , & Bever, T. G. The nonperceptual reality of the phoneme. Journal of Verbal Learning and Verbal Behavior, 1970, 9, 295-302.
Savin, H. B. , & Perchonock, E. Grammatical structure and the immediate recall of English sentences. Journal of Verbal Learning and Verbal Behavior, 1965, 4, 348-353.
Schaeffer, B. , & Wallace, R. Semantic similarity and the comparison of word meanings. Journal of Experimental Psychology, 1969, 82, 343-346.
Schaeffer, B. , & Wallace, R. The comparison of word meanings. Journal of Experimental Psychology, 1970, 86, 144-152.
Schallert, D. L. improving memory for prose: The relationship between depth of processing and context. Journal of Verbal Learning and Verbal Behavior, 1976, 15, 621-632.
Schank, R. C. Conceptual dependency: A theory of natural language understanding. Cognitive Psychology, 1972, 3, 552-631.
Schank, R. C. Conceptual information processing. New York: American Elsevier, 1975.
Schank, R. C. The role of memory in language processing. In C. N. Cofer (Ed.), The structure of human memory. San Francisco: Freeman, 1976.
Schank, R. , & Abelson, R. Scripts, plans, goals and understanding. Hillsdale, N. J.: Lawrence Erlbaum Associates, 1977.
Scheffler, I. Vision and revolution: A postscript on Kuhn. Philosophy of Science, 1972, 39, 366-374.
Schendel, J. D. Analysis of the rehearsal processes in the release from proactive interference. Journal of Experimental Psychology: Human Learning and Memory, 1976, 2, 76-82.
Schneider, W. , & Shiffrin, R. M. Controlled and automatic human information processing: I. Detection, search, and attention. Psychological Review: 1977, 84, 1-66.
Schweller, D. G. , Brewer, W. F. , & Dahl, D. Memory for illocutionary forces and perlocutionary effects of utterances. Journal of Verbal Learning and Verbal Behavior, 1976, 15, 325-337.
Segal, E. M. , & Lachman, R. Complex behavior or higher mental process: Is there a paradigm shift? American Psychologist, 1972, 27, 46-55.
Segal, S. J. , & Fusella, V. Influence of imaged pictures and sounds on detection of visual and auditory signals. Journal of Experimental Psychology, 1970, 83, 458-464.
Selfridge, O. G. Pandemonium: A paradigm for learning. In Symposium on the mechanization of thought processes. London: HM Stationery Office, 1959.
Selfridge, O. G. , & Neisser, U. Pattern recognition by machine. Scientific American, 1960, 203, 60-68.
Seymour, P. H. K. Judgments of verticality and response availability. Bulletin of the Psychonomic Society, 1973, 1, 196-198.
Shafto, M. The space for case. Journal of Verbal Learning and Verbal Behavior, 1973, 12, 551-562.
Shallice, T. Dual functions of consciousness. Psychologica! Review, 1972, 79, 383-393.

Shallice, T. , & Warrington, E. K. Independent functioning of verbal memory stores: A neuropsychological study. Quarterly Journal of Experimental Psychology, 1970, 22, 261-273.
Shannon, C. E. A mathematical theory of communication. Bell System Technical Journal, 1948, 27, 379-423, 623-656.
Shapere, D. Critique of the paradigm concept. Science, 1971, 172, 706-709.
Shapere, D. Scientific theories and their domains. In F. Suppe (Ed.), The structure of scientific theories (2nd ed.). Urbana: University of Illinois Press, 1977
Shaw, R. , & Bransford, J. Approaches to the problem of knowledge. In R. Shaw & J. Bransford (Eds.), Perceiving, acting, and knowing. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1977.
Shepard, R. N. Recognition memory for words, sentences, and pictures. Journal of Verbal Learning and Verbal Behavior, 1967, 6, 156-163.
Shepard, R. N. , & Metzler, J. Mental rotation of three-dimensional objects. Science, 1971, 171, 701-703.
Shiffrin, R. M. Information persistence in short-term memory. Journal of Experimental Psychology, 1973, 100, 39-49.
Shiffrin, R. M. The locus and role of attention in memory systems. In P. M. A. Rabbit & S. Dornic (Eds.), Attention and performance V. New York: Academic Press, 1975.
Shiffrin, R. M. Introduction to "Human memory: A proposed system and its control processes." In G. H. Bower (Ed.), The psychology of learning and motivation (Vol. 11). New York: Academic Press, 1978.
Shiffrin, R. M. , & Atkinson, R. C. Storage and retrieval processes in long-term memory. Psychological Review, 1969, 76, 179-193.
Shiffrin, R. M. , & Gardner, G. T. Visual processing capacity and attentional control. Journal of Experimental Psychology, 1972, 93, 73-82.
Shiffrin, R. M. , & Grantham, D. W. Can attention be allocated to sensory modalities? Perception and Psychophysics, 1974, 15, 460-474.
Shiffrin, R. M. , KcKay, D. P. , & Shaffer, W. O. Attending to forty-nine spatial positions at once. Journal of Experimental Psychology: Human Perception and Performance, 1976, 2, 14-22.
Shiffrin, R. M. , & Schneider, W. Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. Psychological Review, 1977, 84, 127-190.
Shoben, E. J. , Rips, L. J. , & Smith, E. E. Issues in semantic memory: A response to Glass and Holyoak (Tech. Rep. No. 101). Urbana, Ill.: Center for the Study of Reading, University of Illinois, 1978 (in press).
Shulman, H. G. Encoding and retention of semantic and phonemic information in short-term memory. Journal of Verbal Learning and Verbal Behavior, 1970, 9, 499-508.
Shulman, H. G. Semantic confusion errors in short-term memory. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 221-227.
Simon, H. A. Information processing theory of human problem solving (C.I.P. Working Paper No. 324). Carnegie-Mellon University, May 28, 1976.
Simon, H. A. , & Feigenbaum, E. A. An information-processing theory of some effects of similarity, familiarization, and meaningfuiness in verbal learning. Journal of Verbal Learning and Verbal Behavior, 1964, 3, 385-396.
Simon, H. A. , & Newell, A. Information processing in computer and man. American Scientist, 1964, 53, 281-300.
Skinner, B. F. Verbal behavior. New York: Appleton-Century-Crofts, 1957.
Slobin, D. I. Grammatical transformations in childhood and adulthood. Journal of Verbal Learning and Verbal Behavior, 1966, 5, 219-227.
Smith, E. E. Effects of familiarity on stimulus recognition and categorization. Journal of Experimental Psychology, 1967, 74, 324-332.
Smith, E. E. Choice reaction time: An analysis of the major theoretical positions. Psychological Bulletin, 1968, 69, 77-110.
Smith, E. E. Theories of semantic memory. In W. K. Estes (Ed.), Handbook of learning and cognitive processes (Vol. 5). Hillsdale, N.J.: Lawrence Erlbaum Associates, 1978.

Smith, E. E. , Shoben, E. J. , & Rips, L. J. Structure and process in semantic memory: A featural model for semantic decision. Psychological Review, 1974, 81, 214-241.
Smith, E. E. , & Spoehr, D. T. The perception of printed English: A theoretical perspective. In B. H. Kantowitz (Ed.), Human information processing: Tutorials in performance and cognition. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1974.
Smith, M. C. , & Schiller, P. H. Forward and backward masking: A comparison. Canadian Journal of Psychology, 1966, 20, 191-197.
Somjen, G. Sensory coding in the mammalian nervous system. New York: Plenum Press, 1972.
Spelke, E. , Hirst, W. , & Neisser, U. Skills of divided attention. Cognition, 1976, 4, 215-230.
Spence, K. W. Behavior theory and conditioning. New Haven, Conn.: Yale University Press, 1956.
Spencer, T. J. Some effects of different masking stimuli on iconic storage. Journal of Experimental Psychology, 1969, 81, 132-140.
Spencer, T. J. , & Shuntich, R. Evidence for an interruption theory of backward masking. Journal of Experimental Psychology, 1970, 85, 198- 203.
Sperling, G. The information available in brief visual presentations. Psychological Monographs, 1960, 74(Whole No. 11).
Spyropoulos, T. , & Ceraso, J. Categorized and uncategorized attributes as recall cues: The phenomenon of limited access. Cognitive Psychology, 1977, 9, 384-402.
Staats, A. W. , & Staats, C. K. Complex human behavior. New York: Holt, Rinehart & Winston, 1963.
Standing, L. Learning 10,000 pictures. Quarterly Journal of Experimental Psychology, 1973, 25, 207-222.
Stanners, R. F. , Headley, D. B. , & Clark, W. R. The pupillary response to sentences: Influences of listening set and deep structure. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 257-263.
Stegmuller, W. The structure and dynamics of theories. New York: Springer-Verlag, 1976.
Stein, B. The effects of cue-target uniqueness on cued recall performance. Memory and Cognition, 1977, 5, 319-322.
Sternberg, S. Retrieval from recent memory: Some reaction time experiments and a search theory. Paper presented at the meeting of the Psychonomic Society, Bryn Mawr, August 1963.
Sternberg, S. High-speed scanning in human memory. Science, 1966, 153, 652-654.
Sternberg, S. Two operations in character recognition: Some evidence from reaction-time measurements. Perception and Psychophysics, 1967, 2, 45-53.
Sternberg, S. The discovery of processing stages: Extensions of Donders' method. Acta Psychologica, 1969, 30, 276-315. (a)
Sternberg, S. Memory-scanning: Mental processes revealed by reaction-time experiments. American Scientist, 1969, 57, 421-457. (b)
Sternberg, S. Decomposing menial processes with reaction-time data. Invited address, Midwestern Psychological Association , Detroit, May 1971.
Sternberg, S. Memory scanning: New findings and current controversies. Quarterly Journal of Experimental Psychology, 1975, 27, 1-32.
Stevens, K. N. Segments, features, and analysis by synthesis. In J. F. Kavanagh & I. G. Mattingly (Eds.), Language by ear and by eye: The relationship between speech and reading. Cambridge, Mass.: MIT Press, 1972.
Stevens, K. N. , & Halle, M. Remarks on analysis by synthesis and distinctive features. In W. Wathen-Dunn (Ed.), Models for perception of speech and visual form. Cambridge, Mass.: MIT Press, 1967.
Stevens, S. S. Psychology and the science of science. Psychological Bulletin, 1939, 36, 221-262.
Stolz, W. A study of the ability to decode grammatically novel sentences. Journal of Verbal Learning and Verbal Behavior, 1967, 6, 867-873.
Suppe, F. The structure of scientific theories (2nd ed.). Urbana: University of Illinois Press, 1977.

Tanenhaus, M. K. , Carroll, J. M. , & Bever, T. G. Sentence-picture verification models as theories of sentence comprehension: A critique of Carpenter and Just. Psychological Review, 1976, 83, 310-317.

Taylor, D. A. Stage analysis of reaction time. *P* sychological Bulletin, 1976, 83, 161- 191

Teichner, W. H. , & Krebs, M. J. Laws of visual choice reaction time. Psychological Review, 1974, 81, 75-98.

Theios, J. Reaction-time measurements in the study of memory processes: Theory and data. In G. H. Bower (Ed.), The psychology of learning and motivation (Vol. 7). New York: Academic Press, 1973.

Theios, J. , Smith, P.G. , Haviland, S. E. , Traupmann, J. , & Moy, M. C. Memory scanning as a serial self-terminating process. Journal of Experimental Psychology, 1973, 97, 323-336.

Thomson, D. M. , & Tulving, E. Associative encoding and retrieval: Weak and strong cues. Journal of Experimental Psychology, 1970, 86, 255-262.

Thorndike. E. L. , & Lorge, I. The teacher's work book of 30,000 words. New York: Teachers College of Columbia University, 1944.

Thorndyke, P. W. Conceptual complexity and imagery in comprehension and memory. Journal of Verbal Learning and Verbal Behavior, 1975, 14, 359-369.

Toulmin, S. Human understanding (Vol. 1). Princeton, N.J.: Princeton University Press, 1972.

Townsend, J. T. Some results on the identifiability of parallel and serial processes. British Journal of Mathematical and Statistical Psychology, 1972, 25, 168-199.

Townsend, J. T. Issues and models concerning the processing of a finite number of inputs. In B. H. Kantowitz (Ed.), Human information processing: Tutorials in performance and cognition. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1974.

Treisman, A. M. Contextual cues in selective listening. Quarterly Journal of Experimental Psychology, 1960, 12, 242-248.

Treisman, A. M. Selective attention in man. British Medical Bulletin, 1964, 20, 12-16. (a)

Treisman, A.M. Monitoring and storage of irrelevant messages in selective attention. Journal of Verbal Learning and Verbal Behavior, 1964, 3, 449-459. (b)

Treisman, A. M. Strategies and models of selective attention. Psychological Review, 1969, 7*6* , 282-292.

Treisman, A. M. , & Davies, A. Divided attention to ear and eye. In S. Kornblum (Ed.), Attention and performance IV. New York: Academic Press, 1973.

Treisman, A. , Squire, R. , & Green, J. Semantic processing in dichotic listening: A replication. Memory and Cognition, 1974, 2, 641-646.

Tulving, E. Subjective organization in free recall of "unrelated" words. Psychological Review, 1962, 69, 344-354.

Tulving, E. Intratrial and intertrial retention: Notes towards a theory of free recall verbal learning. Psychology Review, 1964, 71, 219-237.

Tulving, E. Theoretical issues in free recall. In T. R. Dixon & D. L. Horton (Eds.), Verbal behavior and general behavior theory. Englewood Cliffs, N.J.: Prentice-Hall, 1968.

Tulving, E. Episodic and semantic memory. In E. Tulving & W. Donaldson (Eds.), Organization of memory. New York: Academic Press, 1972.

Tulving, E. Memory research: What kind of progress? Paper presented at the memory conference in Uppsala, Sweden, June 1977. [To be published in: Nilsson, L. G.. (Ed.). Perspectives on memory research: Essays in honor of Uppsala University's 500th anniversary. Hillsdale, N.J.:Lawrence Erlbaum Associates, 1979.]

Tulving, E. Relation between encoding specificity and levels of processing. In L. S. Cermak & F. I. M. Craik (Eds.), Levels of processing and human memory. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1978.

Tulving, E. , & Gold, C. Stimulus information and contextual information as determinants of tachistoscopic recognition of words. Journal of Experimental Psychology, 1963, 66, 319-327.

Tulving, E. , Mandler, G. , & Baumel, R. Interaction of two sources of information in tachistoscopic word recognition. Canadian Journal of Psychology, 1964, 18, 62-71.

Tulving, E. , & Osier, S. Effectiveness of retrieval cues in memory for words. Journal of Experimental Psychology, 1968, 77, 593-601.

Turing, A. M. On computable numbers, with an application to the Entscheidungsproblem. Proceedings of the London Mathematics Society (Series 2), 1936, 42, 230-265.
Turvey, M. T. , & Shaw, R. E. Memory (or, knowing) as a matter of specification not representation: Notes toward a different class of machines. In L. S. Cermak & F. I. M. Craik (Eds.), Levels of processing and human memory. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1978.
Tversky, A. Features of similarity. Psychological Review, 1977, 84, 327-352.
Underwood, B. J. , & Schulz, R. W. Meaningfulness and verbal learning. Philadelphia: Lippincott, 1960.
Underwood, G. Moray vs. the rest: The effects of extended practice on shadowing. Quarterly Journal of Experimental Psychology, 1974, 26, 368-373.
Uttal, W. R. The psychobiology of sensory coding. New York: Harper & Row, 1973.
van Dijk, T. A. , & Kintsch, W. Cognitive psychology and discourse. In W. Dressier (Ed.), Text linguistics. Berlin: deGruyeter, 1977.
Volkova, V. D. On certain characteristics of the formation of conditioned reflexes to speech stimuli in children. Fiziol. Zh. SSSR, 1953, 39, 540-548. Cited In G. Razran , The observable unconscious and the inferable conscious in current Soviet psychophysiology: Interoceptive conditioning, semantic conditioning, and the orienting reflexPsychological Review, 1961, 63(2), 81-147.
von Frisch, K. Dialects in the language of the bees. Scientific American, 1962, 207, 79-87.
von Frisch, K. Honeybees: Do they use direction and distance information provided by their dancers? Science, 1967, 158, 1072-1076.
von Neumann, J. The computer and the brain. New Haven: Yale University Press, 1958
Von Wright, J. M. , Anderson, K. , & Stenman, U. Generalization of conditioned GSR's in dichotic listening. In P. M. A. Rabbitt & S. Dornic (Eds.), Attention and performance V. New York: Academic Press, 1975.
Wanner, E. On remembering, forgetting, and understanding sentences. The Hague: Mouton, 1974.
Warren, R. E. , & Warren, N. T. Dual semantic encoding of homographs and homophones embedded in context. Memory & Cognition, 1976, 4, 586-592.
Warren, R. M. Perceptual restoration of missing speech sounds. Science, 1970, 167, 392-393.
Warren, R. M. Identification times for phonemic components of graded complexity and for spelling of speech. Perception & Psychophysics, 1971, 9(4), 345-349.
Wason, P. C. The contexts of plausible denial. Journal of Verbal Learning and Verbal Behavior, 1965, 4, 7-11.
Watkins, M. J. , Ho, E. , & Tulving, E. Context effects in recognition memory for faces. Journal of Verbal Learning and Verbal Behavior, 1976, 15, 505-517.
Watson, J. B. Behaviorism (rev. ed.). New York: Norton, 1930.
Watzlawick, P. , Beavin, J. H. , & Jackson, D. D. Pragmatics of human communication. New York: Norton, 1967.
Waugh, N. C. Free versus serial recall. Journal of Experimental Psychology, 1961, 62, 496-502.
Waugh, N. C. , & Norman, D. A. Primary memory. Psychological Review, 1965, 72, 89-104.
Waugh, N. C. , & Norman, D. A. The measure of interference in primary memory. Journal of Verbal Learning and Verbal Behavior, 1968, 7, 617 -626.
Weimer, W. B. Overview of a cognitive conspiracy: Reflections on the volume. In W. B. Weimer & D. S. Palermo (Eds.), Cognition and the symbolic processes. Potomac, Md.: Lawrence Erlbaum Associates, 1974.
Weimer, W. B. Cognition: Forwards or backwards? Contemporary Psychology, 1977, 7, 483-484.
Weimer, W. B. , & Palermo, D. S. Paradigms and normal science in psychology. Science Studies, 1973, 3, 211-244.
Weimer, W. B. , & Palermo, D. S. (Eds.). Cognition and the symbolic processes. Potomac, Md.: Lawrence Erlbaum Associates, 1974.

Weingartner, H. , Adefris, W. , Eich, J. E. & Murphy, D. L. Encoding-imagery specificity in alcohol state-dependent learning. Journal of Experimental Psychology: Human Learning and Memory, 1976, 2, 83-87.

Weisstein, N. , & Harris, C. S. Visual detection of line segments: An object-superiority effect. Science, 1974, 186, 752-755.

Weizenbaum, J. Computer power and human reason: From judgment to calculation. San Francisco; Freeman, 1976.

Welford, A. T. Fundamentals of skill. London: Methuen, 1968.

Welford, A. T. Skilled performance: Perceptual and motor skills. Glenview, Ill.: Scott, Foresman, 1976.

Wertheimer, M. Untersuchungen zur Lehre von der Gestait. II. *Psychologische Forschung* , 1923, 4, 301-305.

Whitehead, A. N. , & Russell, B. A. W. Principia mathematica (Vols. 1-3). Cambridge: 1910-1913; 2nd ed., 1925-1927.

Whitfield, I. C. , & Evans, E. F. Responses of auditory cortical neurons to stimuli of changing frequency. Journal of Neurophysiology, 1965, 28, 655-672.

Wickelgren, W. A. Speed-accuracy tradeoff and information processing dynamics. Acta Psychologica, 1977, 41, 67-85.

Wickens, D. D. Encoding categories of words: An empirical approach to meaning. Psychological Review, 1970, 77, 1-15.

Wickens, D. D. , Moody, M. , & Shearer, P. W. Lack of memory for nonattended items in dichotic listening. Journal of Experimental Psychology: Human Learning and Memory, 1976, 2, 712-719.

Wilder, L. Articulation and acoustic characteristics of speech sounds. In D. W. Massaro (Ed.), Understanding language: An information-processing analysis of speech perception, reading and psycholinguistics. New York: Academic Press, 1975.

Wilkins, A. J. Conjoint frequency, category size, and categorization time. Journal of Verbal Learning and Verbal Behavior, 1971, 10, 382-385.

Winograd, E. , & Rivers-Bulkeley, N. T. Effects of changing context on remembering faces. Journal of Experimental Psychology: Human Learning and Memory, 1977, 3, 397-405.

Winograd, T. Understanding natural language. Cognitive Psychology, 1972, 3, 1—191.

Winograd, T. Frame representations and the declarative-procedural controversy. In D. Bobrow & A. Collins (Ed.), Representations and understanding. New York: Academic Press, 1975.

Wiseman, S. , & Tulving, E. Encoding specificity: Relation between recall superiority and recognition failure. Journal of Experimental Psychology: Human Learning and Memory, 1976, 2, 349-361.

Woods, W. Transition network grammars for natural language analysis. Communications of the ACM, 1970, 13, 591-606.

Woods, W. An experimental parsing system for transition network grammars. In R. Rustin (Ed.), Natural language processing. New York: Algorithmics Press, 1973.

Woodworth, R. S. Experimental Psychology. New York: Henry Holt, 1938,

Wright, P. Some observations on how people answer questions about sentences. Journal of Verbal Learning and Verbal Behavior, 1972, 11, 188-195.

Wright, M. J. , & Ikeda, H. Processing of spatial and temporal information in the visual system. In F. O. Schmitt , F. G. Worden , & G. Adelman (Eds.), The neurosciences: Third study program. Cambridge, Mass.: MIT Press, 1974.

Wundt, W. Zur Kritik tachistosckopischer Versuche. Philosophische Studien, 1899, 15, 287-317.

Zelniker, T. Perceptual attenuation of an irrelevant auditory verbal input as measured by an involuntary verbal response in a selective attention task. Journal of Experimental Psychology, 1971, 87, 52-56.

Zipf, G. K. Human behavior and the principle of least effort. Cambridge, Mass.: Addison-Wesley, 1949.