Scripts, Plans, Goals and Understanding
The Artificial Intelligence Series

Roger C Schank
Consulting Editor
In the summer of 1971, there was a workshop in an ill-defined field at the intersection of psychology, artificial intelligence, and linguistics. The fifteen participants were in various ways interested in the representation of large systems of knowledge (or beliefs) based upon an understanding process operating upon information expressed in natural language. The two of us first came to appreciate each other’s work at that workshop.

There was a self-conscious sense at that workshop that maybe we were defining a new field, crossing previously rigid interdisciplinary boundaries. There were self-mocking toasts to the ‘proclamation from Mount Quissett’ (actually a small hill overlooking Quissett Harbor, Massachusetts) that henceforth this new discipline would exist and be called some name that we had not the foresight to anticipate.
The Quissett proclamation was not far from the mark— in part because it was self-fulfilling. Other conferences, some new books, and even a new journal have come about in this new field that has come to be called Cognitive Science. In addition, the two of us began to collaborate after that summer. That collaboration was facilitated when Schank moved to Yale in 1974.

A major reason it is possible for the two of us to work together on problems in human and computer understanding is that we both believe that we need computers as the metaphor in terms of which we create our theories and as the arbiter of the plausibility of our theories. There is such a range of problems and procedures involved in the understanding process that to not use a computer is simply not to know whether what you are theorizing about could ever possibly work, let alone be right.

From time to time our different backgrounds (Schank in artificial intelligence and Abelson in social psychology) caused us, in developing this book and the ideas behind it, to differ in approaches to certain problems. Abelson needed constantly to be restrained from wandering into abstract psychologizing beyond the scope of this book. (This restraint was not always effective; several Abelsonian meanders have survived.) Schank needed to be dissuaded from too much reliance on argument by cutesy example and from giving too many ad hoc lists of conceptual entities. (Such dissuasion had its limits, too. The reader will find many Schankian examples and an occasional ad hoc entity.) The two of us disagreed somewhat on the potential importance of validating experimental psychological data, but this disagreement never reached serious proportions because both of us view the present status of the experimental literature as not as helpful as we would like.

The book we have written is unusual in many ways. It is not a sum-up of things we have proven or know to be true. There are loose ends, even unnoticed ends, abounding. We had to choose between continuing on indefinitely until we were sure that what we had was right and complete, or stopping somewhat arbitrarily. We chose the latter because we realize that most research is never really finished.

The book advances four main theoretical entities: scripts, plans, goals, and themes. Each of the four is somewhat less well defined than its immediate predecessor. We feel we really understand scripts, are pretty sure about plans, somewhat less certain about goals, fuzzy about themes and completely uncertain what lies beyond that. Nonetheless, we feel strongly that our ideas are significant enough to warrant publication. We hope that the reader will allow for the imperfections of work that is still in its infancy.
This book is unusual in another way, namely that it is not a book that lies clearly in any academic discipline. It does not conform to standard conceptions of a psychology book because it does not report experiments. It does meet normal expectations for a report on artificial intelligence research because its description of computer programs is only cursory. It is not a book about linguistics because it deals with issues that exist apart from whatever language is being spoken. Nonetheless we feel that it is in fact a book about all three fields. But as we were not certain exactly what audience we were writing to, the book at times has the flavor of a mass-oriented work, aiming squarely at the middle and leaving the technical aside.

Although this book was written by the two of us, the research we report here is also the product of many seminars and discussions that took place over a two year period. The following Yale students and research staff participated in those discussions and often contributed key insights that helped us to carry on: Joshua Auerbach, Jaime Carbonell, Richard Cullingford, Gerald DeJong, Anatole Gershman, Richard Granger, Gregory Harris, Wendy Lehnert, James Meehan, Richard Proudfoot, Christopher Riesbeck, Mallory Selfridge, Walter Stutzman and Robert Wilensky.

In particular, James Meehan, Robert Wilensky, Wendy Lehnert, and Richard Cullingford contributed written material which was included either directly or indirectly in the context of this book. Richard Cullingford wrote small portions of Chapter 3 and prepared all of section 8.3. The SAM program was put together by him. He wrote the script applier part of that program and oversaw the rest of the project. Robert Wilensky wrote a great part of sections 5.6 and 7.2 and also prepared section 8.6. Since he has been working on plans and goals in PAM, many other ideas presented here may also be indirectly attributable to him. Wendy Lehnert and Robert Wilensky contributed to the ideas which germinated section 7.4. James Meehan contributed to the ideas in Chapter 4 and prepared section 8.5. Gerald DeJong prepared section 8.4 and was primarily responsible for the FRUMP program. The pieces of section 8.2 that describe different parts of SAM were written by the people who programmed those parts.

Many people have been responsible in various ways for the production of this book. Ann Clementino designed the graphics in the book and prepared the book to be typeset by the Yale Mergenthaler Printing Device. Walter Stutzman ran the typesetting programs as well as doing every other chore imaginable in getting the book to physically exist. Without their effort the book would have cost more, been available much later, and probably been a lot less attractive. Diane Schank edited the final draft and cleaned up some of the unwieldy prose. Hana Schank provided food for thought in Chapter 9.
Most of the work reported here was supported by the Advanced Research Projects Agency of the Department of Defense and monitored by the Office of Naval Research under contract No. N00014-75-C-1111. In addition, the second author received support from the National Science Foundation under grant No. BNS 76-02960.

January 1977
New Haven, Connecticut
## Contents

### Preface

### 1 Introduction

1.1 What this book is about 1  
1.2 Knowledge: Form and Content 3  
1.3 Traditional Points of View 5  
1.4 Conceptual Dependency Theory 11  
1.5 Memory 17  
1.6 The Methodology of AI 20

### 2 Causal Chains

2.1 Understanding Text 22  
2.2 Causal Types 24  
2.3 Representation of Causation 30  
2.4 Causal Propensity 32
### 3 Scripts
- 3.1 Introduction
- 3.2 The Restaurant Script
- 3.3 Script Application
- 3.4 Interferences and Distractions
- 3.5 Script Interactions
- 3.6 Types of Scripts

### 4 Plans
- 4.1 Introduction
- 4.2 The Elements of Planning
- 4.3 Named Plans
- 4.4 D-Goals
- 4.5 Planboxes
- 4.6 The Relationship Between Plans and Scripts

### 5 Goals
- 5.1 Goal Fate Graphs
- 5.2 Goal Substitutions
- 5.3 Goal Forms
- 5.4 Goals and Beliefs
- 5.5 Goal Initiation
- 5.6 Assorted Goal Issues
- 5.7 The Meaning of Words

### 6 Themes
- 6.1 Introduction
- 6.2 Role Themes
- 6.3 Interpersonal Themes
- 6.4 Life Themes

### 7 Representation of Stories
- 7.1 Representation of Scripts
- 7.2 Representation of Plans
- 7.3 Macroscopic vs. Microscopic Event Description
- 7.4 A Story

### 8 Computer Programs
- 8.1 Introduction
- 8.2 SAM
- 8.3 A Computer Run
- 8.4 Skimming Stories
- 8.5 TALESPIN
- 8.6 PAM
9 A Case Study in The Development of Knowledge Structures 222

9.1 Learning of Scripts 222
9.2 Early Episode Generalization 225
9.3 Storytelling 227
9.4 Understanding 231
9.5 Plans 234

Bibliography 239
Author Index 244
Subject Index 246
To our fathers
Maxwell Schank
and
Miles Abelson
Scripts, Plans, Goals and Understanding
1 Introduction

1.1 What this book is about

This book reflects a convergence of interests at the intersection of psychology and artificial intelligence. What is the nature of knowledge and how is this knowledge used? These questions lie at the core of both psychology and artificial intelligence. The psychologist who studies 'knowledge systems' wants to know how concepts are structured in the human mind, how such concepts develop, and how they are used in understanding and behavior. The artificial intelligence researcher wants to know how to program a computer so that it can understand and interact with the outside world. The two orientations intersect when the psychologist and the computer scientist agree that the best way to approach the problem of building an intelligent machine is to emulate the human conceptual mechanisms that deal with language. There is no way to develop adequate
computer 'understanding' without providing the computer with extensive knowledge of the particular world with which it must deal. Mechanistic approaches based on tight logical systems are inadequate when extended to real-world tasks. The real world is messy and often illogical. Therefore artificial intelligence (henceforth AI) has had to leave such approaches behind and become much more psychological (cf. Schank and Colby, 1973; Bobrow and Collins, 1975; Boden, 1976). At the same time, researchers in psychology have found it helpful to view people as 'information processors' actively trying to extract sense from the continual flow of information in the complicated world around them. Thus psychologists have become more interested in machine models of real-world knowledge systems. The name 'cognitive science' has been used to refer to this convergence of interests in psychology and artificial intelligence (Collins, 1976).

This working partnership in 'cognitive science' does not mean that psychologists and computer scientists are developing a single comprehensive theory in which people are no different from machines. Psychology and artificial intelligence have many points of difference in methods and goals. Intellectual history, like political history, is full of shifting alliances between different interest groups. We mention this because for many commentators, the blood quickens when computers and human beings are associated in any way. Strong claims for similarity (e.g., Newell and Simon, 1972) are countered by extravagant alarms (e.g., Weizenbaum, 1976). Enthusiasts and horrified skeptics rush to debate such questions as whether a computer could ever be in love. We are not interested in trying to get computers to have feelings (whatever that might turn out to mean philosophically), nor are we interested in pretending that feelings don't exist. We simply want to work on an important area of overlapping interest, namely a theory of knowledge systems. As it turns out, this overlap is substantial. For both people and machines, each in their own way, there is a serious problem in common of making sense out of what they hear, see, or are told about the world. The conceptual apparatus necessary to perform even a partial feat of understanding is formidable and fascinating. Our analysis of this apparatus is what this book is about.
1.2 Knowledge: Form and Content

A staggering amount of knowledge about the world is available to human beings individually and collectively. Before we set out on a theory of knowledge systems, we ought to ask ourselves: knowledge about what? We must be wary of the possibility that knowledge in one domain may be organized according to principles different from knowledge in another. Perhaps there is no single set of rules and relations for constructing all potential knowledge bases at will. A desire for generality and elegance might inspire a theorist to seek a 'universal' knowledge system. But if you try to imagine the simultaneous storage of knowledge about how to solve partial differential equations, how to smuggle marijuana from Mexico, how to outmaneuer your opponent in a squash game, how to prepare a legal brief, how to write song lyrics, and how to get fed when you are hungry, you will begin to glimpse the nature of the problems.

Procedures for intelligently applying past knowledge to new experience often seem to require common sense and practical rules of thumb in addition to, or instead of, formal analysis (Abelson, 1975). The prospects for the general theorist to cope with all the varied applications of common sense are especially dismal. Nevertheless, many artificial intelligence researchers take a generalist point of view. It is in the best tradition of mathematics (in which computer scientists are generally well trained) that great power is gained by separating form and content: the same system of equations may account for a great many apparently disparate phenomena. It is also a central tenet in computer science that generality is highly desirable. Turing's (1936) original principle of the general purpose machine has often been embraced as though the computer were (or soon would be) in practice a general purpose machine. The field of artificial intelligence is full of intellectual optimists who love powerful abstractions and who strive to develop all-embracing formalisms.

It is possible to be somewhat more pragmatic about knowledge, however. The five-year-old child learning to tie shoelaces need not in the process be learning anything whatsoever about mathematical topology. There is a range of psychological views on the nature of knowledge, and we shall say a little more about this in the next section. For now, we simply note that we will take a pragmatic view. We believe that the form of knowledge representation should not be separated too far from its content. When the content changes drastically, the form should change, too. The reader will encounter plenty of abstractions in this book, but each set of them will be
pegged specifically to a particular type of real-world content. Where generalizing is possible, we will attempt to take advantage of it, but we will not try to force generality where it seems unnatural.

In order to adopt this attitude, we have set some boundaries on the type of knowledge we will to consider. Our focus will be upon the world of psychological and physical events occupying the mental life of ordinary individuals, which can be understood and expressed in ordinary language. Our knowledge systems will embody what has been called ‘naive psychology’ (Heider, 1958) – the common sense (though perhaps wrong) assumptions which people make about the motives and behavior of themselves and others – and also a kind of ‘naive physics’, or primitive intuition about physical reality, as is captured in Conceptual Dependency (CD) theory (Schank, 1972, 1975). This book goes well beyond CD theory, however. That theory provides a meaning representation for events. Here we are concerned with the intentional and contextual connections between events, especially as they occur in human purposive action sequences. This new stratum of conceptual entities we call the Knowledge Structure (KS) level. It deals with human intentions, dispositions, and relationships. While it is possible computers cannot actually experience such intentions and relationships, they can perfectly well be programmed to have some understanding of their occurrence and significance, thus functioning as smart observers. If our theory is apt, it will provide a model of the human observer of the human scene; it will also explain how to construct a computer observer of the human scene, and lead to the eventual building of a computer participant in the human world.

Often our emphasis will be on the nature of potential understanding of two or three sentences, story fragments, or longer stories. These provide a straightforward and helpful way to pose the major issues. Lurking beneath the surface, however, is an interest in the ingredients of personal belief systems about the world, which dispose people toward alternative social, religious, or political actions. One of us has a major interest in belief systems and ideologies (Abelson, 1973). This book is not directly addressed to that interest, but the concepts developed are a major part of that total effort.

What we will not present in this book is a general apparatus for attempting to represent any and all knowledge. We give no information retrieval methods of interest to library scientists. The reader with a passion for mathematics and/or logic will be disappointed. Likewise, anyone wondering, for example, whether we could get a computer to play squash or roll pasta dough should not wait with
bated breath. The geometry of bouncing balls, the 'feel' of dough texture, and many other aspects of human activities involve knowledge falling outside of our present boundaries. This is because (among other reasons) visual and kinesthetic processes cannot readily be represented in verbal form. However, a great deal of the human scene can be represented verbally, and we have no lack of things to work on.

1.3 Traditional Points of View

We have mentioned that our task lies at the intersection of psychology (more specifically, cognitive psychology and cognitive social psychology) and artificial intelligence. Since we are concerned with verbally expressible knowledge, there is also an overlap with linguistics. When one tries to work in a disciplinary intersection, one inevitably comes into conflict with the traditional standards, habits, and orientations of the parent disciplines. This is especially true when the disciplines correspond to university departments, breeding suspicion of out-groups (cf. Campbell, 1969). Here we briefly sketch some of these conflicts, which we have resolved somewhat differently from others working at the same intersection.

Psychology is a heterogeneous discipline. The major subdivisions are developmental, clinical, cognitive and social psychology, and psychobiology. It is surprising to the non-psychologist but familiar to all but the youngest generation of psychologists that cognitive psychology is a relatively new branch of study. American experimental psychology was dominated for so long by behaviorism—roughly, from 1935 to 1960—that the study of mental processes lay almost entirely dormant while other branches of psychology were developing rapidly. Since mental events could not be observed directly, there was scientific resistance toward relying on them to explain anything, whatever the scientist's common sense might tell him. Introspective evidence was not regarded as objectively trustworthy.

Since 1960, there has been an enormous surge of careful experimental work on mental phenomena. Skinner notwithstanding, hu-
man psychology could not seem to do without cognitive processes. Nevertheless, the methodological caution of the behaviorists was carried over into this resurgence. Acceptable scientific procedure called for quantitative response measurements such as accuracy of recall or choice reaction time when subjects were confronted with well-controlled stimulus tasks. In the verbal domain, stimulus control usually entailed repetitive trials on isolated verbal materials, deliberately avoiding meaningful connotations in the experimental situation. While recent experimental materials have not been as trivial as the old-fashioned nonsense syllables, neither have they been genuinely meaningful or even necessarily plausible. Experimental tasks are often unusual and/or unnatural in relation to tasks encountered daily by people in using language. For example, in a well-known experiment by Foss and Jenkins (1973), subjects listened to 48 sentences such as 'The farmer placed the straw beside the wagon', with instructions to press a key the instant they first heard the phoneme 'b'. In another well-known series of experiments by Anderson and Bower (1973), subjects heard 32 unrelated sentences such as 'In the park, the hippie kissed the debutante', 'In the bank, the tailor tackled the lawyer', etc., and an hour later were asked to recall as many of them as they could. The artificiality of tasks such as the latter led Spiro (1975) to remark tartly, *Why should a research subject integrate the to-be-remembered information with his or her other knowledge? The role the information will play in his or her life can be summarized as follows: take in the information, hold it for some period of time, give it back to the experimenter in as close to the original form as possible, and then forget it forever. The information cannot be perceived as anything but useless to the subject in his or her life (given the common employment of esoteric or clearly fictional topics as stimulus materials). The information, even when not clearly fictional, is probably not true. In any case, the subject knows that the relative truth of the information has nothing to do with the purpose of the experiment.* (p.11)

In complaining about the lack of meaningful context in experiments such as these, it is no doubt unfair to present them out of their context. The experimenters had serious purposes, and the data were of some interest. But since our needs are for a set of interrelated constructs to explain the process of natural understanding of connected discourse, this style of experimentation is both too unnatural and too slow. There has been a gradual increase in research with connected discourse as stimulus material (e.g., Bransford and Johnson, 1972; Kintsch, 1974; Frederiksen, 1975; Thorndyke, 1977)
but the field is still marked with a very cautious theoretical attitude. We are willing to theorize far in advance of the usual kind of experimental validation because we need a large theory whereas experimental validation comes by tiny bits and pieces. Our approach, in the artificial intelligence tradition, is discussed in Section 1.6.

If the research properties of experimental cognitive psychology are often unduly restrictive, the traditions in the field of linguistics are even more restrictive. Linguistics has concerned itself with the problem of how to map deep representations into surface representations (see Chomsky, 1965). After a long obsession with syntactically dominated deep representations, recent work in linguistics has oriented deep representations much more towards considerations of meaning (Lakoff, 1971; Clark, 1974). Despite this reorientation linguists have managed to miss the central problems.

Two fundamental problems stand out: How do people map natural language strings into a representation of their meaning? How do people encode thoughts into natural language strings? Because of a purported interest in the purely formal properties of language, linguists have consciously avoided both of these naturalistic problems. The second question seems, on the surface, to be closer to a linguist’s heart. But linguists treat generation as a problem of determining whether a string is grammatical, i.e., whether it can be generated by the grammar they have set up. A grammar that generates natural language strings would be interesting and useful of course, if, and this is a big ‘if’, it started at the right place. Linguists tend to start their grammars at the node S (for sentence). People, on the other hand, start with an already well-formed idea (or the beginnings of an idea) that they want to express. Linguists thus wind up concerning themselves with considerations of semantics at the level of ‘Can I say this string? Will it mean something’? People already know what they want to say and that it is meaningful.

Two remedies for this linguistic notion of semantics come to mind. For the generation problem the obvious solution is to start the process earlier. How do people get thoughts to express? Linguists explicitly consign this question to other disciplines; yet it is an important part of the generation process, and one which when treated as a linguistic question completely changes the process under investigation. The other remedy is to apply such semantic considerations as ‘Does this string mean something?’ to the problem of understanding what someone else has said. Questions of how strings can be meaningfully interpreted belong to the domain of understanding, not generation, where Chomsky (1965, 1971) has repeatedly
Introduction

put them. (Actually Chomsky would deny that he works on generation. Transformationalists prefer to think of themselves as working on an abstract formalism with no process notions present at all.)

Linguists have almost totally ignored the question of how human understanding works. Since human understanding is dependent on the ability to decode language this seems odd at best. Some 'computational linguists', (e.g., Friedman, 1969 and Kay, 1973) have attacked the problem. However, they have followed linguistic tradition and consequently have maintained one of the fundamental flaws of linguistics in their work. They have divided the problem into linguistic and non-linguistic parts, a division that holds up no better for understanding than it does for generation.

Artificial intelligence has a somewhat more congenial recent history. The field is relatively new, and its early efforts were predominantly oriented toward getting computers to solve logical and mathematical problems (e.g., Newell, Shaw and Simon, 1957; Minsky, 1961; Feigenbaum and Feldman, 1963; Nilsson, 1971), and to play games such as checkers (Samuel, 1963) and chess (Bernstein et al, 1958; Newell, Shaw and Simon, 1958) intelligently. Early efforts to have computers deal with natural language were marked either by drastic failure (as in the case of mechanical translation from one language to another) or drastic oversimplification in the admissible vocabulary (Green et al, 1961) and grammar (Abelson, 1963; Colby and Gilbert, 1964), or by programming tricks producing smooth locutions which made the computer seem smarter than it actually was (Weizenbaum, 1966).

It has nevertheless been consistently regarded as important that computers deal well with natural language. In practical terms, such a development would mean that anyone could interact with a computer without learning a programming language or some special code to communicate about a special problem, whether it be library or consumer information, travel and ticket reservations, suggestions about home repairs, crop protection, first aid, etc. Computerized teaching programs would not have to be restricted to giving multiple-choice tests of the student's knowledge, but could interpret and respond intelligently to free-form answers and questions from the student. None of these high-sounding things are possible, of course, unless the computer really 'understands' the input. And that is the theoretical significance of these practical questions — to solve them requires no less than articulating the detailed nature of 'understanding'. If we understood how a human understands, then we might know how to make a computer understand, and vice versa.
In the last several years there have been two clusters of developments in artificial intelligence which are miles ahead of previous efforts. First, there is a new generation of programs for 'parsing' sentences (in English and other languages) — that is, for deciding the proper features (such as what part of speech) to assign to each word in a sentence. The approaches of Woods (1970), Winograd (1972), Riesbeck (1975) and Marcus (1975) differ in the relative priority they give to syntactic or semantic features in parsing, but all agree that semantic features are considerably more important than linguists had generally been willing to acknowledge. Second, there has been increasing recognition that context is of overwhelming importance in the interpretation of text. Implicit real-world knowledge is very often applied by the understander, and this knowledge can be very highly structured. The appropriate ingredients for extracting the meaning of a sentence, therefore, are often nowhere to be found within the sentence.

There are several famous illustrations of this latter point. Collins and Quillian's (1972) is:

1 The policeman held up his hand and stopped the car.
   
   Somehow in understanding this sentence we effortlessly create a driver who steps on a brake in response to seeing the policeman's hand. None of these intermediate links are mentioned in sentence (1). Another example, (from Abelson, 1969) is:

2 I went to three drugstores this morning.
   
   Very innocently, the concept that the person must not have found what he wanted in the first two drugstores is implied, otherwise why would he have gone to three? This kind of implicit inference is very common — and of course can be wrong, but it is intrinsic to natural understanding that useful, fallible presumptions creep in.

   Perhaps the simplest example of implicit inferences can be seen in a simple sentence such as (from Schank, 1972):

3 I like apples.
   
   The speaker is talking about 'eating' but this is not explicitly mentioned. And why should it be? The speaker, unless he is deliberately trying to fool his listener, knows that the listener knows what action is being implicitly referenced. These examples were constructed with a point in mind, but are not really unusual. In all of them, and in many, many other examples to be found in this book, more is at issue than 'semantics'. It is 'pragmatics', the way things usually work — not how they might conceivably work — which most often im-
pels the reader toward an interpretation. The reader brings a large repertoire of knowledge structures to the understanding task. Elsewhere these structures have been called 'frames' (Minsky, 1975) and 'schemata' (Rumelhart, 1976). Rumelhart puts the matter very well when he says, 'The process of understanding a passage consists in finding a schema which will account for it.'

Interestingly, the idea of the schema in the interpretation of human events has a long tradition in social psychology. American social psychology had its roots in Gestalt psychology, and therefore did not succumb to the excesses of behaviorism the way human experimental psychology did. The phenomenology of mental life maintained a central role, largely through the towering influence of Kurt Lewin in the 1940's. Lewin (1936) wrote about human goal strivings in terms of internal images people had of their 'life spaces'. Since then a long succession of social psychologists have appealed to structured ideational kernels of the way people supposed the world to be organized: Heider's (1946, 1958) 'balance principle' and 'naive psychology'; Festinger's (1957) 'cognitive dissonance theory'; Abelson and Rosenberg's (1958) 'psycho-logic'; Kelley's (1967) and Jones and Davis' (1966) 'attribution theory', and many more. The terminology of the 'schema' is very much active in the 1970's (cf. Kelley, 1971; Tesser, 1977), even in areas well beyond social psychology (Rumelhart, 1975; Bobrow and Norman, 1975; Rumelhart and Ortony, 1976). The second author's orientations in the present book can be traced back to earlier excursions into 'hot cognition' (Abelson, 1963), 'individual belief systems' (Abelson and Carroll, 1965), and 'implicational molecules' (Abelson and Reich, 1969).

There is a very long theoretical stride, however, from the idea that highly structured knowledge dominates the understanding process, to the specification of the details of the most appropriate structures. It does not take one very far to say that schemas are important: one must know the content of the schemas. To be eclectic here is to say nothing. If one falls back on the abstract position that only form is important, that the human mind is capable of developing knowledge structures of infinitely varied content, then one sacrifices the essence of the structure concept, namely the strong expectations which make reality understandable. In other words, a knowledge structure theory must make a commitment to particular content schemas.

The commitment to particular content is a policy we follow consistently throughout the book. Whether we are talking of scripts, plans,
goals, themes, etc., we try whenever feasible to lay out the particulars of members of these conceptual categories. This is the same policy as was followed by the first author in developing Conceptual Dependency theory (Schank, 1972) to describe individual actions.

There has been much debate over whether the conceptual primitives of CD theory are the 'right' primitives, and some criticism that the theory is ad hoc. For many purposes, however, the important criterion is whether the theory is useful. Further, we would argue that any theory proposed as a replacement will have to come to grips with the same content issues as CD theory, and will more than likely end up with much the same primitives (as did Norman and Rumelhart (1975) for example). Indeed, the systematic linguistic exploration by Jackendoff (1976) of candidates for primitives seems to point in this direction.

We anticipate that there will be similar debate about the primitives we will propose in this book for higher-level knowledge structures. We will not be dogmatic about particular primitives, however, knowing that revisions in our scheme will no doubt be necessary as psychological validations and unanticipated theoretical considerations come along.

1.4 Conceptual Dependency Theory

In order to understand what follows in this book it is helpful to have a rudimentary exposure to Conceptual Dependency Theory. The theory has been described at length elsewhere (see especially Schank, 1975); we need not go into it in much detail here.

Conceptual Dependency (henceforth CD) is a theory of the representation of the meaning of sentences. The basic axiom of the theory is:

A For any two sentences that are identical in meaning, regardless of language, there should be only one representation.

The above axiom has an important corollary that derives from it.

B Any information in a sentence that is implicit must be made explicit in the representation of the meaning of that sentence.
These two rules have forced us to look for one economical form for representing meaning. In doing so, we have invented the initial framework:

C The meaning propositions underlying language are called conceptualizations. A conceptualization can be active or stative.

D An active conceptualization has the form: Actor Action Object Direction (Instrument)

E A stative conceptualization has the form: Object (is in) State (with Value)

The form that we postulate for conceptualizations has led us to the principle of primitive actions. That is, because a conceptualization is defined as an actor doing something to an object in a direction, we have had to determine just what an actor can do. Clearly, Principle A forces us to look closely at actions that seem similar to see if we can extract the essence of their similarity. Principle B forces us to make explicit whatever differences there might be between two actions and to express them accordingly. For example, two verbs in a language may share a similar primitive element (as 'give' and 'take' share the primitive element TRANSFER of POSSESSION) but also have differences. The best representation for our purposes for a given verb then, will be the primitive element it shares with other verbs, plus the explicitly stated concepts that make it unique. As it happens, these explicitly stated concepts also turn out to share similar elements with other verbs, so that often a verb is represented as a particular combination of primitive actions and states none of which are unique to that verb, but whose combination is entirely unique. (Many verbs are represented entirely by states with no primitive act used at all.)

The primitive acts of Conceptual Dependency are:

| ATRANS | The transfer of an abstract relationship such as possession, ownership or control. Thus, one sense of 'give' is: ATRANS something to someone else; a sense of 'take' is: ATRANS something to oneself. 'Buy' is made up of two conceptualizations that cause each other, one an ATRANS of money, the other an ATRANS of the object being bought. |
**PTRANS** The transfer of the physical location of an object. Thus, 'go' is **PTRANS** oneself to a place; 'put' is **PTRANS** of an object to a place.

**PROPEL** The application of a physical force to an object. **PROPEL** is used whenever any force is applied regardless of whether a movement (**PTRANS**) took place. In English, 'push', 'pull', 'throw', 'kick', have **PROPEL** as part of them. 'John pushed the table to the wall' is a **PROPEL** that causes a **PTRANS**. 'John threw the ball' is **PROPEL** that involves an ending of a **GRASP** ACT at the same time. Often words that do not necessarily mean **PROPEL** can probably infer **PROPEL**. Thus, 'break' means to **DO** something that causes a change in physical state of a specific sort (where **DO** indicates an unknown ACT). Most of the time the ACT that fills in the **DO** is **PROPEL** although this is certainly not necessarily the case.

**MOVE** The movement of a body part of an animal by that animal. **MOVE** is nearly always the ACT in an instrumental conceptualization for other ACTs. That is, in order to throw, it is necessary to **MOVE** one's arm. Likewise **MOVE** foot is the instrument of 'kick' and **MOVE** hand is often the instrument of the verb 'hand'. **MOVE** is less frequently used noninstrumentally, but 'kiss', 'raise your hand', 'scratch' are examples.

**GRASP** The grasping of an object by an actor. The verbs 'hold', 'grab', 'let go', and 'throw' involve **GRASP** or the ending of a **GRASP**.

**INGEST** The taking in of an object by an animal to the inside of that animal. Most commonly the semantics for the objects of **INGEST** (that is, what is usually **INGEST**ed) are food, liquid, and gas. Thus, 'eat', 'drink', 'smoke', 'breathe', are common examples in **INGEST**.

**EXPEL** The expulsion of an object from the body of an animal into the physical world. Whatever is **EXPEL**ed is very likely to have been previously **INGEST**ed. Words for excretion and secretion are described by **EXPEL**, among
Introduction

**MTRANS** The transfer of mental information between animals or within an animal. We partition memory into two pieces: The CP (conscious processor where something is thought of), and the LTM (long term memory where things are stored). The various sense organs can also serve as the originators of an MTRANS. Thus, 'tell' is MTRANS between people, 'see' is MTRANS from eyes to CP, 'remember' is MTRANS from LTM to CP, 'forget' is the inability to do that, 'learn' is the MTRANSing of new information to LTM.

**MBUILD** The construction by an animal of new information from old information. Thus, 'decide', 'conclude', 'imagine', 'consider', are common examples of MBUILD.

**SPEAK** The actions of producing sounds. Many objects can SPEAK, but human ones usually are SPEAKing as an instrument of MTRANSing. The words 'say', 'play music', 'purr', 'scream' involve SPEAK.

**ATTEND** The action of attending or focusing a sense organ towards a stimulus. ATTEND ear is 'listen', ATTEND eye is 'see' and so on. ATTEND is nearly always referred to in English as the instrument of MTRANS. Thus, in Conceptual Dependency, 'see' is treated as MTRANS to CP from eye by instrument of ATTEND eye to object.

Some set of primitive ACTs is essential for representing meanings, especially if sentences that have the same meaning are going to be be represented in only one way. The ACTs presented here are not category names for verbs. They are the elements of action. An analogous situation is the formation of compounds from the elements in chemistry.

The use of such primitives severely reduces the inference problem (see Schank, 1975), since inference rules need only be written once for any ACT rather than many times for each verb that references that ACT. For example, one rule is that if you MTRANS something to your LTM, then it is present there (i.e., you know it). This is true whether the verb of MTRANSing was 'see', 'hear', 'inform', 'memorize', or whatever. The inference comes from the ACT rather than the verb.
Conceptualizations that are attribute-value statements make use of a large number of SCALES. These scales run between boundaries which by convention are labeled -10 to 10. Scales are useful for indicating changes in state. Some of the scales we use, with their boundaries and some steps in between, are indicated below. In current applications of Conceptual Dependency Theory, it has not been necessary to undertake a serious quantitative scaling of relative points along the -10 to 10 continuum. At present, the occasional numerical references are only used suggestively.

**HEALTH** (dead, diseased, under the weather, tolerable, in the pink)

**ANTICIPATION** (terrified, nervous, hoping, confident)

**MENTAL STATE** (broken, depressed, all right, happy, ecstatic)

**PHYSICAL STATE** (end of existence, damaged, OK, perfect)

**AWARENESS** (dead, unconscious, asleep, awake, keen)

The symbol $\rhd$ denotes causality. Some example sentences and their representations are:

John killed Mary.

John **DO**

Mary **HEALTH**(-10)

John kicked Mary.

John **PROPEL** foot **to** Mary

foot(John) **BE PHYSICAL CONTACT**(Mary)

John told Mary that Bill was happy.

John **MTRANS**(Bill **BE MENT.ST**(5)) **to** Mary

John read a book.

John **MTRANS**(Information) **to LTM**(John) **from** book

inst(John **ATTEND** eyes **to** book)
In the original development of Conceptual Dependency theory, we spent most of our effort on representation of verbs and states. The bulk of Chapter 3 is one answer to the question of how to represent nouns. How does one represent a restaurant? Is it 'a place where people eat'? Or 'a place you go to eat where someone serves you and you pay'? How far do you go in such a representation? Scripts, although invented to handle a different but related problem, form the basis of the answer to the representation of certain complex nouns as well. How to represent concrete nouns is discussed briefly when we deal with memory in the next section.

Other researchers in artificial intelligence have much discussed the primitive actions that we have developed. Many of them seem to adopt one or more of them for their purposes, while usually rejecting either the rest of the set or the principle that it is necessary to represent sentences at the level of primitive actions each and every time. The most often heard suggestion is that one should only 'break down words into primitives when necessary'.

When is it necessary to break down a sentence into its minimal meaning units? The answer is simple enough: only when you need to exploit the 'meaning' itself. It is not necessary for word association tasks, for microworlds where there is little or no ambiguity or overlap in meaning, or for simple retrieval tasks where the meaning of the elements dealt with is not needed.

If you need to know the meaning of what you are dealing with, then it is necessary to look at the elements that make up that meaning. The only argument to this can be an argument based upon when you break down a sentence, not if you break down a sentence.

The 'when' question seems clear enough to us, although others differ with our position. Since memory ideally stores information in only one way, any pattern matching that needs to be done against information stored in memory requires a canonical form for the information. That is, information in memory must be stored in something like the primitive terms of Conceptual Dependency, and likewise the inference processes that are part of memory must be in those terms.

Should the breakdown into primitives occur after parsing ('when necessary'), or during parsing (assuming it is always necessary)? A good parser should exploit the meaning of a sentence. In understanding it seems doubtful that people first do a syntactic analysis without recourse to meaning and then look at the meaning. People understand as they go. Our parser (Riesbeck, 1975) has been quite
successful using predictions that it generates based upon the kinds of meanings that it expects. Since it is hard to find a case when such breakdown is not necessary (in a real and complex system), we see little choice but to 'break down the words' every time.

One exception to this has occurred as a result of this book. In Chapters 4-7, various Knowledge Structures are introduced as an adjunct to Conceptual Dependency. We are beginning to find that it is sometimes better to parse directly into our Knowledge Structure representation rather than going by way of Conceptual Dependency. Thus, for example, the word 'want', which seemed primitive enough but was not so treated in Conceptual Dependency, is primitive in Knowledge Structures. It is reasonable with such words to go directly to where we want to be, thus bypassing Conceptual Dependency. This is, in fact, a complaint sometimes made about our work, namely that at the highest memory levels it will be necessary to reorganize information at places other than the primitive actions and thus we will have to 'unbreak down' again. The Knowledge Structure representation that we develop should answer this complaint.

1.5 Memory

Before we get into the substance of this book, it is worthwhile to introduce one more issue, namely memory. For a long time, the problems of natural language processing seemed to be separate from the problems of memory. Recently, Quillian (1968), Anderson and Bower (1973), Rieger (1975), Norman and Rumelhart (1975), and others have made it quite clear that memory and language are inextricably bound together. However, while the importance of dealing with memory has been generally agreed upon, the form that memory takes is still at issue. This book is, in a sense, entirely about memory. We are arguing here for certain theoretical entities that must form the basis of human memory organization.

The form of memory organization upon which our arguments are based is the notion of episodic memory. An episodic view of memory claims that memory is organized around personal experiences or episodes rather than around abstract semantic categories. If
Introduction

memory is organized around personal experiences then one of the
principal components of memory must be a procedure for recogniz­
ing repeated or similar sequences. When a standard repeated se­
quence is recognized, it is helpful in ‘filling in the blanks’ in under­
standing. Furthermore much of the language generation behavior
of people can be explained in this stereotyped way.

Other proposals for memory organization have stressed the more
scholastic notion of semantic memory. Briefly, semantic memory is
a memory for words that is organized in a hierarchical fashion using
class membership as the basic link. For example, ‘canary’ is linked
to ‘bird’ and ‘bird’ to ‘animal’ in a hierarchical tree.

We can see at once that such an organization will not work for
verbs, nor for nouns that are abstract nor for nouns that do not sub­
mit easily to standard categories (such as ‘teletype’). Even if other
semantic links besides class membership are used, such an organi­
zation implies that propositions are stored by linking them to the
words with which they are expressed. This is not possible in the
conceptual, non-word-oriented system that we have described. We
could overcome this difficulty by organizing concepts in networks
but the complexity of the possible combination of elemental con­
cepts makes this extremely cumbersome. There are other difficul­
ties as well.

An episodic memory, on the other hand, is organized around propo­
sitions linked together by their occurrence in the same event or
time span. Objects are most commonly defined by their place in a
sequence of propositions describing the events associated with an
object for an individual. A trip is stored in memory as a sequence of
the conceptualizations describing what happened on the trip. Some
of the conceptualizations will be marked as salient and some will
have been forgotten altogether.

Nominal concepts (concrete nouns) fit in this view with a two-part
definition. The first and primary part is a functional definition that
attempts to generalize the salient events over particular episodes
in which the noun has occurred. The complete functional definition
of a given noun lists all distinguishable occurrences of that noun
present in memory. The second part is a physical description of one
particular member of the class that is being defined.

For a ‘spoon,’ for example, the definition in memory lists the gen­
eral usage for a spoon first (e.g., a thing that you PTRANS into mushy
or liquid objects in order to PTRANS that object to your mouth so as
to INGEST it). All interesting specific instances would also be stored
Memory

(including, for example, 'The time I was camping and washed my spoon in the sand'). Last, we would have a physical description of a particular spoon (most likely the kind that you have at home). The over-all organization of memory is a sequence of episodes organized roughly along the time line of one's life. If we ask a man, 'Who was your girlfriend in 1968?' and ask him to report his strategy for the answer, his reply is roughly: 'First I thought about where I was and what I was doing in 1968. Then I remembered who I used to go out with then.' In other words, it really isn't possible to answer such a question by a direct look-up. Lists of 'past girlfriends' do not exist in memory. Such a list must be constructed. The process by which that list is constructed is a search through episodes organized around times and locations in memory.

Of course if we ask someone not about past girlfriends but about past history learned from books, say, 'Who ruled England in 1668?'; then the memory search mechanism might not turn out to be episodic. The respondent might conceivably remember when he learned this fact, but it is more likely that such scholastic memories could get divorced from their episodic origins and become organized more 'semantically', as in Collins' (1976) model of book knowledge. The whole question of episodic vs. semantic memory is controversial (cf. Loftus and Loftus, 1976), and our clear preference for the episodic mode is partly a function of the non-scholastic character of the knowledge we are interested in.

Some episodes are reminiscent of others. As an economy measure in the storage of episodes, when enough of them are alike they are remembered in terms of a standardized generalized episode which we will call a script. Thus, rather than list the details of what happened in a restaurant for each visit to a restaurant, memory simply lists a pointer (link) to what we call the restaurant script and stores the items in this particular episode that were significantly different from the standard script as the only items specifically in the description of that episode. This economy of storage has a side effect of poor memory for detail. But such a side effect, we shall argue, is the price of having people able to remember anything at all. Script-based memory is what will enable computers to understand without having their memories filled up so much that search time is horrendously long.
1.6 The Methodology of AI

Although the work we describe in this book is intended to lead towards the eventual computer understanding of natural language, it is not necessary to have much familiarity with computers in order to understand what we are saying. This fact is, or ought to be, true of nearly all clearly written work in artificial intelligence (AI). The computer is used in AI research as an omnipotent, but very dull and plodding, god. Under this view, it sometimes seems unnecessary to actually write the program that embodies the theory. One only need show the process in convincing enough detail. This is what one imagines. However, the reality is somewhat different – researchers actually do write programs.

Whenever an AI researcher feels he understands the process he is theorizing about in enough detail, he then begins to program it to find out where he was incomplete or wrong. It is the rare researcher who can detail a theory, program it, and have the program work right away. The time between the completion of the theory and the completion of the program that embodies the theory is usually extremely long. In modelling such complex processes as comprehension of language, there are more things to keep track of than a human trying to be conscious of each variable can manage. Understanding at such a level of complexity is a relatively subconscious process in everyday life.

What AI has to contribute to psychology is exactly this experience with modelling processes. An AI researcher asks what the input is and what the output is for every subprocess he deals with. In asking these questions he recognizes, at the very least, the nature and number of the subprocesses that must make up the entire process he wishes to model.

An analogy can be seen in asking directions from one place to another. If, while in New York, one asks how to get to Coney Island, and is told to take the ‘N’ train to the last stop, these directions will be adequate only if this improperly specified algorithm can be filled out with a great deal of knowledge about how to walk, pay for sub­ways, get in the train and so on. We call this information a ‘script’ (detailed in Chapter 3). The point here is that a computer that does not have any prior information would make no sense of this response. It must be given information about: parsing sentences, finding meanings, filling in substeps in a plan, recognizing trains, paying for subways, walking, and so on. An AI researcher is forced to specify each and every detail in a theory that accounts for the abil-
ity to understand such a simple response to a question. We cannot be satisfied by an answer such as ‘well, you use your knowledge about subways.’ To put it on a computer we must know what form that knowledge takes. How are subways represented in memory? What pieces are where? How are they accessed? When and why are they accessed? What happens before they are accessed? What happens afterwards?

It is the asking and answering of such questions, and then the testing of those answers on a computer, that constitutes AI research. We use those methods in this book and thus our arguments lose some of the traditional psychological flavor of theories. That is, we are not oriented toward finding out which pieces of our theory are quantifiable and testable in isolation. We feel that such questions can wait. First we need to know if we have a viable theory. Viable here means: Will it work on a computer? Can we properly specify each subpart?

Our attitude may be somewhat unsettling to psychologists accustomed to piecemeal experimental testing of theoretical propositions. To them we urge the same patience in judging our work that they use in tolerating the very slow accumulation of knowledge in the experimental tradition. The AI style of research is much more disciplined than it may look. Although running computer programs provides the ultimate test, there are also strong criteria of intuitive necessity and internal consistency in theory formulation. Throughout this book we will often appeal to examples where the human understander readily makes inferences not explicitly available in the text of the example, or perceives something as odd or ridiculous. We persistently ask: what does an understander have to know in order to fill in missing inferences or perceive oddities? Addressing this question leads us to an inductive, rather than experimental, style of psychology, and we feel that this is the more appropriate style for this stage of development in our problem area.
Bibliography

Abelson, R. P. 1963
Computer Simulation of 'hot' Cognition.

Abelson, R. P. 1969
Psychological implication.

Abelson, R. P. 1973
The structure of belief sys-tems.
in Schank and Colby.

Abelson, R. P. 1975
Concepts for representing mundane reality in plans. in Bobrow and Collins.

Abelson, R. P.
Carroll, J. 1965

Abelson, R. P.
Reich, C. M. 1969

Abelson, R. P.
Rosenberg, M. J. 1958

Allport, G.W.
Vernon, P.
Lindzey, G. 1951

Anderson, J.
Bower, G. 1973
Human Associative Memory. Winston-Wiley, Washington, D. C.

Anderson, R. C.
Spiro, R. J.
Montague, W. E. (eds.) 1976
Schooling and the acquisition of knowledge. Lawrence Erlbaum Associates, Hillsdale, N.J.

Atkinson, J. W. 1964
An introduction to motivation. Van Nostrand, Princeton, N.J.

Bar-Hillel, M. 1975
The base-rate fallacy in sub-jective judgments of probabil-ity.

Becker, J. 1973
A Model for Encoding Experi-mental Information. in Schank and Colby.

Bernstein, A. et al. 1958

Bobrow, D. 1975
Dimensions of representation. in Bobrow and Collins.

Bobrow, D.
Collins, A. 1976

Bobrow, D. G.
Norman, D. A. 1975
Some principles of memory schemata. in Bobrow and Collins.
Boden, M. 1977
Artificial intelligence and natural man.

Bransford, J. D.

Johnson, M. K. 1972
Contextual prerequisites for understanding: Some investigations of comprehension and recall.

Campbell, D. T. 1969
Ethnocentrism of disciplines and the fish-scale model of omniscience.
in M. Sherif and C. W. Sherif (eds.) Interdisciplinary relationships in the social science. Aldine, Chicago.

Carroll, J. D.

Chang, J. J. 1970
Analysis of individual differences in multidimensional scaling via an N-way generalization of Eckart-Young's decomposition.

Charniak, E. 1972
Towards a model of children's story comprehension.
AI TR-266, MIT.

Chomsky, N. 1965

Chomsky, N. 1971
Deep structure, surface structure, and semantic interpretation.

Clark, H. H. 1974
Semantics and Comprehension.
Mouton, the Hague.

Colby, K. M.

Gilbert, J. P. 1964

Collins, A. 1976
Processes in acquiring knowledge.
in Anderson, Spiro and Montague.

Collins, A. 1977

Collins, A. M.

Quillian, M. R. 1972

Cullingford, R. E. 1976
The application of script-based knowledge in an integrated story-understanding system.
COLING-76 Proceedings.

Feigenbaum, E.

Feldman, J. 1963
Computers and Thought.

Festinger, L. 1957
A Theory of Cognitive Dissonance.
Harper Row, Peterson, Evanston, IL.

Fikes, R. E.

Hart, R. E.

Nilsson, N. J. 1972
Learning and executing generalized robot plans.

Foss, D. J.

Jenkins, C. M. 1973
Some effects of context on the interpretation of lexically ambiguous sentences. Jour-
Bibliography

Frederiksen, C. H. 1975
Effects of context-induced processing operations on semantic information acquired from discourse.
Cognitive Psychology 7:139-166.

Freidman, J. 1969
A computer system for transformational grammar.
Comm. ACM 12(4).

Goffman, E. 1959
The presentation of self in everyday life.
Doubleday, New York.

Goldman, N. 1975
Conceptual generation.
in Schank (1975).

Green, B. F., et al. 1961
Baseball: an automatic question-answerer.

Hartigan, J. A. 1975

Heider, F. 1946
Attitudes and cognitive organization.

Heider, F. 1958
The psychology of interpersonal relations.
Wiley, New York.

Hemphill, L. 1973
The relationship of language and belief: With special emphasis on English 'for' constructions.

Henle, M. 1944
The influence of valence on substitution.
J. Psychology 17 11-19.

Jackendoff, R. 1976
Toward an explanatory semantic representation.
Linguistic Inquiry 7:1.

Joncas, E. 1977
Action expectation in social situation.

Jones, E. E.

Davis, K. E.
From acts to dispositions: the attribution process in person perception.

Katz, E.

Danet, B. 1966
Petitions and persuasive appeals: a study of official-client relations.

The MIND system.

Attribution theory in social psychology
In D. Levine (ed). Nebraska Symposium on Motivation, University of Nebraska Press, Lincoln, Nebraska.

Casual schemata and the attribution process.

The representation of meaning in memory.
Wiley, New York.

Kosslyn, S.M.
Pomerantz, J. P. 1977
Bibliography

Imagery, propositions, and the form of internal representations.
Cognitive Psychology 9: 52-76.

Lakoff, G. 1972.
Linguistics and natural logic.

Lasswell, H. D.
Kaplan, A. 1950
Power and society: A framework for political inquiry.
Yale University Press, New Haven.

Lehnert, W. 1975.
What makes SAM run? Script-based techniques for question answering.
in Schank and Nash-Webber.

Human and computational question answering.
Cognitive Science 1.

Lewin, K. 1936.

Loftus, G.
Loftus, E. 1976
Human memory: the processing of information.
Lawrence Erlbaum Associates, Hillsdale, N.J.

Marcus, M. 1975.
Diagnosis as a notion of grammar.
in Schank and Nash-Webber

McDougall, W. 1923
Outline of psychology.
Scribner, New York.


Michotte, A. 1963.
The perception of causality.

Minsky, M. 1961.
Steps toward artificial intelligence.
in Feigenbaum and Feldman.

Minsky, M. 1975.
A framework for representing knowledge.

Moore, J.
Newell, A. 1973
How can MERLIN understand?

Morris, C. W. 1956
Varieties of human value.
University of Chicago Press.

Newell, A.
Shaw, J. C.
Simon, H. A. 1957
Problem solving in humans and computers.

Newell, A.
Shaw, J. C.
Simon, H. A. 1958
Chess-playing programs and the problem of complexity.

Newell, A.
Simon, H. A. 1961
GPS, a program that simulates human thought.

Newell, A.
Simon, H. A. 1972
Human Problem Solving.
Prentice-Hall

Problem solving methods in artificial intelligence.
Norman, D.
Rumelhart, D. 1975
Explorations in cognition.
W. H. Freeman, San Francisco.

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

Quillian, M. R. 1968
Semantic memory.
in M. Minsky, ed. Semantic In-
formation Processing. MIT
Press, Cambridge, MA.

Rieger, C. 1975.
Conceptual memory.
in Schank (1975).

Riesbeck, C. 1975.
Conceptual analysis.
in Schank (1975).

Rosenberg, S.
Nelson, C.
Vivekenanathan, P. 1968
A multidimensional approach
to the structure of personal impressions.

Ross, L., et al. 1976. The effects of real and hypothetical expla-
nation upon future expectations.
Unpublished manuscript.
Stanford University.

Notes on a schema for stories.
in Bobrow and Collins.

Understanding and summarizing brief stories.
in D. LaBerge and S. J. Sa-
muels (eds). Basic processes in reading: Perception and
comprehension. Lawrence Erl-
baum Associates, Hillsdale, N.J.

Rumelhart, D. E.
Ortony, A. 1976
The representation of knowl-
edge in memory. in Anderson,
Spiro and Montague.

Planning in a hierarchy of ab-
straction spaces.
Artificial Intelligence
5:115-135.

Sacerdoti, E. D. 1975.
A structure for plans and be-
havior.
Technical note 109, AI Center,
Stanford Research Institute.

Samuel, A. L. 1963. Some studies in machine learning using the
game of checkers.
in Feigenbaum and Feldman.

Schank, R. C. 1972. Conceptual
dependency: A theory of natu-
ral language understanding.
Cognitive Psychology

Schank, R. C. 1975.
Conceptual Information Pro-
cessing.
North Holland, Amsterdam.

Schank, R. C. 1975b.
The structure of episodes in
memory.
in Bobrow and Collins.

Schank, R. C.
Colby, K. (eds.) 1973
Computer Models of Thought
and Language. W.H. Freeman,
San Francisco.

Schank, R. C.
Nash-Webber, B. L. (eds) 1975
Theoretical issues in natural
language processing.
Bolt, Beranek and Newman,
Cambridge, MA.

Shepard, R. N.
Romney, A. K.
Nerlove, S. B. (eds.) 1972
Multidimensional scaling:
theory and applications in the behavioral sciences.